Program and Book of Abstracts

Greetings

When people meet at a conference, magic things may happen. Not only will they learn about the latest developments in their field, but they will also get to know their peers on a more personal level, initiate new collaborations and make new friendships.

This is why the Swiss Vacuum Society decided to organize the 15th European Vacuum Conference (EVC-15) on behalf of the International Union for Vacuum Science, Technique and Applications (IUVSTA). Together with CERN, the premier organization for particle physics research with the largest vacuum installation in the world, we invite you to participate at EVC-15 on the premises of the International Conference Centre (CICG) in Geneva from 17 to 22 June 2018.

EVC-15 is a special conference: not only is it 30 years since John Colligon founded the European Vacuum Conference series, we will also celebrate the 60th anniversary of IUVSTA with a dedicated session in the afternoon of Monday 18th. Plenary lectures will be given by Joe Greene (US) on the History of Materials Science since the Big Bang, by Anne L'Huillier (SE) on Exploring Matter at Ultrashort Time Scales, by Cristoforo Benvenuti (IT) on Getter Pumping for Accelerators and finally by astronaut Claude Nicollier (CH) on his experience of Extravehicular Activities in Low Earth Orbit.

At the conference over 140 oral contributions as Plenary, Invited and Contributed presentations will illustrate the most recent advancement in vacuum science and technology as well as materials technologies they enable. In addition two poster sessions will trigger open and fruitful discussions between participants on novelties in the domain.

A trade show on technologies related to vacuum products in the main hall of the conference centre complements the conference. On Thursday afternoon a tour through the CERN facilities is planned, followed by the conference banquet at the beautifully located Château de Penthes.

Geneva, located at the foot of the Alps and the Jura, on the banks of Lake Léman, at the border of Switzerland and France, has a long history of diversity and tolerance. It is the well-known seat of several International Organizations (among them the European headquarters of UN, WHO, WTO, UNHCR, ICRC, WIPO, ITO, ISO and CERN). Geneva is also a unique city of culture with a 2000 years long history and the perfect home base for exploring wonderful surroundings in Switzerland and France.

On behalf of the EVC-15 Organising Committee we welcome you to the conference in Geneva

Martin Wüest, Chair Organising Committee

Mauro Taborelli, Vice-Chair Organising Committee

Jörg Patscheider, Chair Scientific Committee

Pierre Strubin, Chair Local Organising Committee

Addresses

Conference Address

Centre International de Conférences Genève (CICG)
17 rue de Varembé
CH - 1211 Genève 20
T +41 22 791 91 11
F +41 22 791 90 64

Organiser's Address

Schweizerische Vakuumgesellschaft / Société Suisse du Vide (Swiss Vacuum Society)
c/o PreOffice GmbH
Rebgasse 14
CH-2540 Grenchen
The Swiss Vacuum Society also uses the acronym ***swissvacuum***, which will be used in this document.

Society Seat:
Schweizerische Vakuumgesellschaft (Société Suisse du Vide) (Swiss Vacuum Society)
c/o Pfeiffer Vacuum (Schweiz) AG
Förrlibuckstrasse 30
8005 Zürich
www.swissvacuum.org

Conference Registration Hours

The registration and Information Desk is open on:

Sunday	17:00-20:00
Monday-Wednesday	08:00-18:00
Thursday- Friday	08:00-12:00

Conference Registration Fees

Regular Attendees full week

If registered and paid

• before May 4, 2018	CHF 650
• from May 4 to June 3, 2018	CHF 850
• after June 3, 2018 or at the conference desk	CHF 980

Day Pass

• Monday, Tuesday or Wednesday	CHF 300/day
• Thursday or Friday	CHF 200/day

Students (with student ID)	CHF 300
Companion Program	CHF 200
Exhibits only	Free

The registration fees for full week participants and students include the access to all talks and poster sessions in the International Conference Centre, Geneva (CICG). Also included are the lunches and coffee breaks from Monday to Thursday, the Welcome Party on Sunday evening, the visit to CERN on Thursday afternoon and the Conference Dinner on Thursday evening.

The registration fees for single day participants include the access to all talks and poster sessions for the chosen day. Also included are the lunch and coffee breaks for Monday, Tuesday or Wednesday, the coffee breaks for Thursday or Friday. The visit to CERN on Thursday afternoon and the Conference Dinner on Thursday evening are not included and cannot be booked separately.

The registration fees for companions include the Welcome Party on Sunday evening, the visit to CERN on Thursday afternoon and the Conference Dinner on Thursday evening.

All presenters are required to register for the full conference duration.

Congress Registration Cancellation Policy

In case of cancellation of a registration, all or part of the fees will be reimbursed under following conditions:

- 100% will be reimbursed if cancellation is notified before February 28, 2018;
- 50% will be reimbursed if cancellation is notified before May 20, 2018;
- No reimbursement will be made if cancellation is notified after May 20, 2018.

All refunds requests must be in writing by mail to the Conference Secretary (conference@evc15.org) as soon as possible.

In case of "no-show" at the Conference, no claims for reimbursement will be accepted.

Withdrawal of contributions should be announced as soon as possible to the Scientific Committee (scientific@evc15.org). There are no financial aspects associated with contributions. Contributors must have registered and paid their fees to be allowed to present their work.

Locations

Registration Desk
CICG Ground floor, entrance area

Session Rooms
CICG, Rooms 2, 3, 4 on ground floor

Poster Session
CICG, Ground floor, main hall

Lunch at MIP
CICG, Restaurant, 1st floor

Industrial Exhibition
CICG, Ground floor, main hall

Speaker Preparation Room
CICG, Next to bar “Léman” on ground floor

Coffee Breaks
CICG Ground floor, main hall

Please note that food and drinks **are not allowed** in the session rooms.

Welcome Reception (Sunday 17th June 2018)

A Welcome Cocktail will take place on from 18:00 to 19:30 at CICG, on the first floor, either inside or on the terrace, if weather permits.

The registration desk, located right at the entrance of CICG, will be open from 16:00 to 20:00, allowing picking up the conference bag and the admission badge, required to take part at the Cocktail.

Technical Tour (Thursday 21st June 2018)

A CERN visit will be organized on Thursday afternoon June 21, 2018, according to the following schedule:

- Departure by bus from CICG to CERN at 13:00;
- Introductory talk, followed by the visit of several points of interest by groups of 48 persons;
- Return by bus to either Hotel des Nations or Hotel IBIS Nations Centre at 17:30

Because of a limit of participants, the visit to CERN will only be possible for persons having announced their participation when they registered. Participants who have paid their registration fees will receive an email asking them to fill in some additional information required by the CERN Visitors Service. An ad-hoc badge will be included in the conference bag. Only persons wearing their badge will be allowed to enter CERN. Please look at the CERN Instructions for Visits.

Banquet (Thursday 21st June 2018)

The banquet will take place at

Domaine de Penthes
Chemin de l'Impératrice 18, 1292 Pregny-Chambésy, Switzerland

The Penthes estate is located in one of the most beautiful parks of Geneva's neighbourhood. It benefits from an exceptional environment with a view over Lake Geneva and the Mont Blanc.

There will be an aperitif served in the Château with the Museum of the Swiss Abroad, followed by dinner in the Espace Gallatin (300 m walk)

Because of a limit of seats, the participation to the dinner will only be possible for persons having announced their participation when they registered.

Buses will pick-up participants at Hotel des Nations or Hotel IBIS Centre Nations at 19:00. Domaine de Penthes can be reached from the Cornavin railway station by bus (bus V and Z, not very frequent), or after a 15 minutes walk from Place des Nations with its many bus and tramway lines. After the dinner, buses will return participants to either Hotel des Nations or Hotel IBIS Centre Nations from 21:45 (first departure) until 22:15 (last departure). For those wanting to appreciate the calm area of the embassy quarter, again it is possible to walk back to Place des Nations and have public transportation until after midnight.

Important Notice:

On 21st of June Pope Francis will come to Geneva and a mass will be celebrated at Palexpo. As more than 40'000 persons are expected to attend the mass, the Geneva Police foresees severe perturbations to the traffic. We therefore might have to **suppress the stops at the hotels after the CERN Tour** and go directly from CERN to the Domaine de Penthes for the aperitif and the dinner. Further information will be announced on Thursday.

Committees

Scientific Committee

- Jörg Patscheider, Evatec AG, Trübbach, Switzerland (Chairman)
- Paolo Chiggiato, CERN, Geneva, Switzerland
- Diederik Depla, University Ghent, Ghent, Belgium
- Anouk Galtayries, IRCP-CNRS, Paris, France
- Ana Gomes Silva, New University of Lisbon, Lisbon, Portugal
- Ulf Helmersson, Linköping University, Linköping, Sweden
- Jay Hendricks, NIST, Gaithersburg, MD, USA
- Janez Setina, IMT, Ljubljana, Slovenia
- Jacek Szuber, Silesian University of Technology, Gliwice, Poland
- Andrej Vincze, International Laser Centre, Bratislava, Slovakia

Organising Committee

- Martin Wüest, INFICON, Balzers, Liechtenstein (Chairman)
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- Barbara Hirsiger, PreOffice, Grenchen, Switzerland
- Maria Llorente Herraiz, CERN, Geneva, Switzerland
- Christian Muser, BUSCH, Magden, Switzerland
- Jörg Patscheider, Evatec AG, Trübbach, Switzerland
- Pierre Strubin, CERN, Geneva, Switzerland
- Mauro Taborelli, CERN, Geneva, Switzerland
- Urs Wälchli, INFICON, Balzers, Liechtenstein

Future IUVSTA Events

- VASSCAA-9, 13-16 August 2018, Sydney, Australia
- ECOSS 34, 26-31 August 2018, Aarhus, Denmark
- International Vacuum Conference (IVC-21), 1-5 July 2019, Malmö, Sweden

IUVSTA Workshops and Schools

- 9th International Workshop on Surface Physics, 24-28 June 2019, Trzebnica, Poland
- Nanoscale Oxides System in Physics and Chemistry, 1-5 July 2018, Avila, Spain
- Surface Micro-Spectroscopy and Spectro-Microscopy of Electrical Phenomena, 2-5 September 2018, Weizmann Institute of Science, Rehovot, Israel
- New Horizons in Boron-Containing Coatings: Modelling, Synthesis and Applications, 2–6 September 2018, Vadstena, Sweden
- Nanoporous Materials for Green Energy Conversion and Storage, 14-18 October 2018, Seggau, Austria
- Nano-Optics, 18-22 February 2019, Braga, Portugal

Applications from analytics and physics laboratories require reliable vacuum components with outstanding product features.

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Plenary Speakers

- **Ludvik Martinu, École Polytechnique Montréal (CA)**
  Tomorrow's optical coatings: From passive interference filters and multifunctional systems towards smart meta-structures - Change of paradigm?
- **Christian Teichert, Montanuniversität Leoben (A)**
  The fascinating world of organic nanocrystals on 2D materials
- **Maria Ascensio, Soleil Synchrotron (F)**
  Chemical and electronic imaging of energy and electronics materials important for basic science and industrial applications
- **Kai Nordlund, University of Helsinki (FI)**
  Fundamental mechanisms of accelerated and plasma ion interactions with materials: insights from atomistic simulations
- **Philippe Walter, University Paris 6 (F)**
  Nanostructures and layer stacking in artistic materials: the origin of colors in paintings

Special Sessions

IUVSTA 60

We will celebrate the 60th anniversary of the International Union for Vacuum Science, Technology and Applications (IUVSTA) with a special session on Monday afternoon.

Invited speakers for this event are:

- **Joe Greene**, University of Illinois (US), Linköping University (SE), Taiwan Tech (TW)
  History of Materials Science since the Big Bang
- **Anne L'Huillier**, Lund University (SE)
  Exploring Matter at Ultrashort Time Scales
- **Cristoforo Benvenuti**, CERN (CH) ret.
  Getter Pumping for Accelerators
- **Claude Nicollier**, ESA (CH) ret.
  Working in Vacuum - Extravehicular Activities in Low Earth Orbit

Everyone is invited to attend the lectures (entry is free)

Workshop

Elsevier Author and Reviewer Workshop
"How to get publish and how to review a paper in a scientific journal"

This includes structure of the paper, quality of figures, plagiarism, reviewing and publishing process, scientific ethics, open access

Tuesday June19, 2018 12:00, CICG, Room 4

The workshop will be given by:

Oleg Malyshev, Associate Editor Vacuum, STFC Daresbury Laboratory, Warrington, Cheshire, UK

General Information

Health and Safety

There is no medical assistance on site. In case of medical emergency dial **144** for the ambulance and inform the registration desk.

In case of fire alarm, leave the building through the emergency exits and follow the instructions of the staff from CICG.

For other issues, please contact the registration desk.

Conference Badge Policy

Participants must have their badge clearly visible to obtain admission to the technical sessions and to be served during the coffee breaks. Visiting the exhibition is free, as is access to all common parts of CICG.

Conference Language

The official language of the conference is English.

Internet

CICG provides free WLAN Internet in the conference area.

Recording/Photo Policy

Recording of Presentations

Recording of presentations is prohibited. No individual or entity - including a presenting author - may electronically record or broadcast any portion of the EVC-15 Meeting without prior written consent of *swissvacuum* and the presenter. Press representatives must receive a Press Pass and photo/recording permission from EVC-15. *swissvacuum* reserves the rights to any approved audio and video production of presentations at all Swiss Vacuum events.

Taking pictures of participants

Attendees or exhibitors are encouraged to network and enjoy the meeting experience. As such, capturing memories of casual meeting activities and networking is permitted with the permission of those being prominently photographed. Photographing formal meeting presentations, posters, or displays is forbidden without permission of *swissvacuum* and the presenter.

Videos and Photos for EVC-15 use

EVC-15 Meeting attendance implies your consent to be photographed, filmed and/or otherwise recorded for use on the *swissvacuum*, EVC-15 or IUVSTA websites or news publications. Please note that no technical presentations will be recorded without prior consent the authors.

Photography during the CERN tour

Photographing is allowed during the tour of the CERN facilities

Data Privacy Protection Statement

The data you have provided EVC-15 with during the registration process or the submission of an abstract is strictly used for the purpose of the Conference. Only authorized members of the Organising Committee can modify this data, e.g. to acknowledge that the conference fees have been paid. We do not share this data with others.

The data you entered to ask access for the CERN visit is subject to the CERN Data Privacy Protection Policy.

Notes for Presenters

Oral presentation guidelines

A computer, a projector, a microphone and a pointer will be available in the session rooms. All the hardware elements will be provided by the organisers to ensure consistency in technical quality and allow for quick and smooth transition between the speakers. The available computers support MS Office and Adobe PDF for presentations. If the presentation contains very special characters or needs specific fonts, they have to be provided by the speaker and embedded into the presentation. If not embedded, the video files attached to the presentation must be located in the same folder as the presentation files.

The presentations must be uploaded to INDICO. This can be done by the presenters before the conference, or on the conference site (speakers room). Indication on how to upload a contribution can be found on the Presentation Guidelines of our website. Help will be provided when required by CERN students and fellows. The electronic access to the presentations will be restricted to the authors and the staff of EVC-15. Presentations will be deleted from INDICO after the conference.

There will be technical assistance in every lecture room before and during the sessions.

Poster presentation guidelines

General Information

The poster exhibition will be held on the ground level of the conference site. Your poster board will be marked with the same marker as listed in the Programme Book (for example - Tue-PS1-22 or Wed-PS2-17) and which has been given in your personal e-mail notification. Poster presenters must ensure that their poster is fixed to the corresponding numbered board on the relevant days according to the Scientific Programme.

Poster format

Panels for individual posters will be A0 (1189 mm wide and 841 mm high, *Portrait* orientation).

Suitable tape or pins will be provided at the welcome desk.

Poster placarding

The posters will be displayed in two groups: the first group on Tuesday (Poster Session-1 or PS1) and the second group on Wednesday (Poster Session-2 or PS2). The presenting authors are asked to placard their posters at the beginning of their poster day (Tuesday or Wednesday morning). They should be present at the poster during the appropriate sessions listed below and remove their posters at the latest the next day early morning.

PS1 - POSTER SESSION-1
Tuesday 19 June 17:00 – 18:20
and
PS2 - POSTER SESSION-2
Wednesday 20 June 17:00 – 18:20

Publication

The abstract book and the program can be downloaded at www.evc15.org or its site on INDICO.

There will be no conference proceedings. However, authors are encouraged to submit a write-up of their presentation, which will be stored in INDICO and remain accessible after the conference.

Sponsors

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Other Sponsors

The European Organization for Nuclear Research (CERN)

Geneva Convention Bureau

Swiss Vacuum Society (*swissvacuum*)

Canton of Geneva

Exhibition

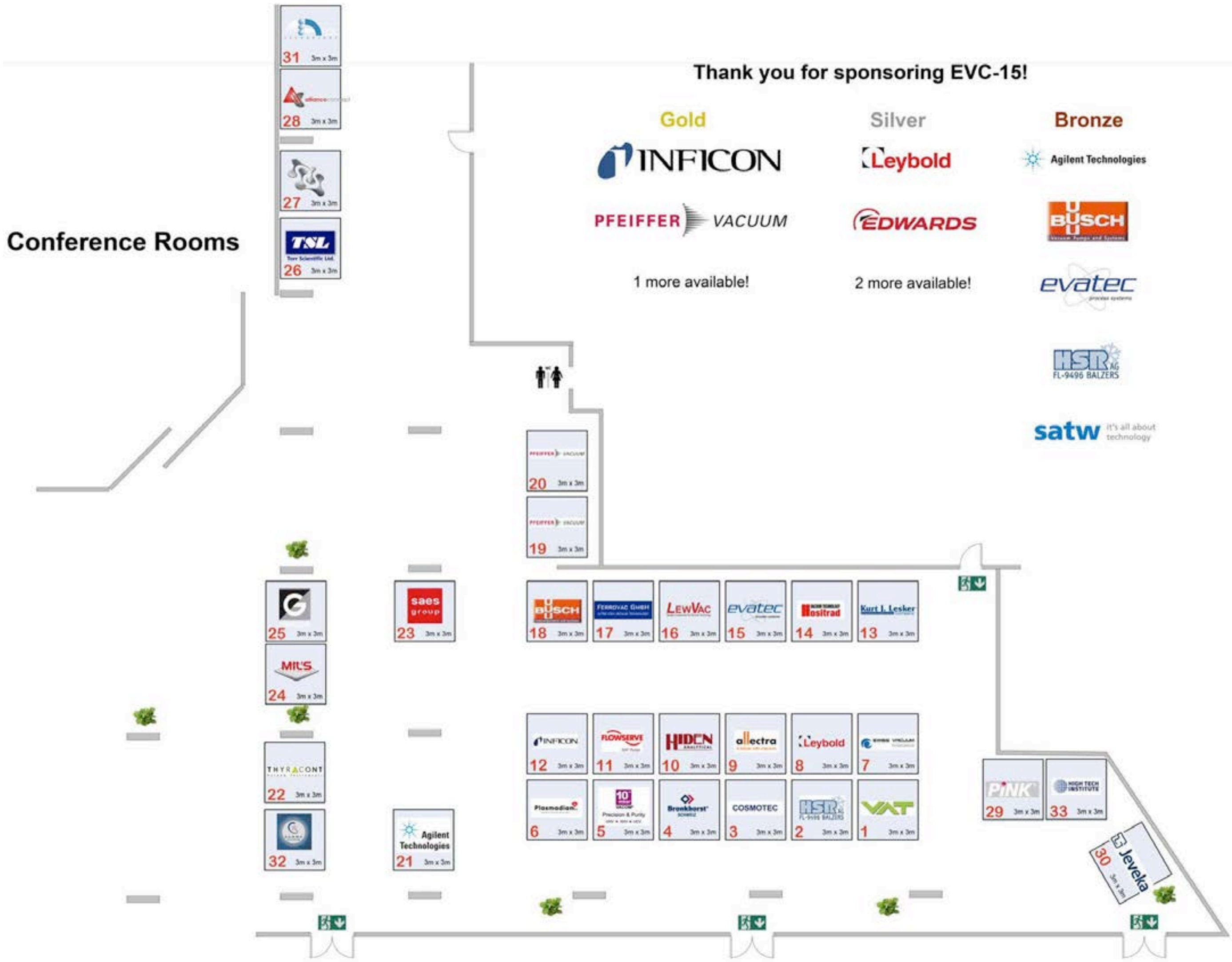
Special Exhibition

The University of Geneva showcases physics experiments on the ground floor as well as behind the bar “Léman”.

Exhibition Opening Hours

Monday	12:00 to 18:00
Tuesday	09:00 to 18:00
Wednesday	09:00 to 15:40

Exhibition Floor Plan



Exhibiting Companies

Company	Webaddress	Booth
Agilent	**www.agilent.com**	21
Alca Technology	**www.alcatechnology.com**	31
Allectra	**www.allectra.eu**	9
Alliance Concept	**www.alliance-concept.com**	28
Bronkhorst Schweiz	**www.bronkhorst.ch**	4
Busch	**www.buschag.ch**	18
Cosmotec	**www.cosmotec.us**	3
Evatec	**www.evatecnet.com**	15
Ferrovac	**www.ferrovac.com**	17
Flowserve	**www.flowserve.com**	11
Gamma	**www.gammavacuum.com**	32
Gencoa	**www.gencoa.com**	25
Hiden	**www.hiden.co.uk**	10
High Tech Institute	**www.hightechinstitute.nl**	33
Hositrad	**www.hositrad.nl**	14
HSR	**www.hsr.li**	2
INFICON	**www.inficon.com**	12
Interface Precision Engineering	**www.interface-precision.com**	27
Jeveka	**www.jeveka.nl**	30
Kurt J. Lesker	**www.lesker.com**	13
LewVac	**www.lewvac.co.uk**	16
Leybold Vacuum	**www.leybold.com**	8
MILS Lyon	**www.mils.fr**	24
Pfeiffer Vacuum	**www.pfeiffer-vacuum.ch**	19, 20
PINK	**www.pink-vak.de**	29
Plasmadiam	**www.plasmadiam.com**	6
SAES Getter	**www.saesgetters.com**	23
Swiss Vacuum Technologies	**www.swissvacuum.com**	7
Thyracont	**www.thyracont-vacuum.com**	22
Torr Scientific	**www.torrscientific.co.uk**	26
Vacom	**www.vacom.de**	5
VAT	**www.vatvalve.com**	1

Technical Sessions

Bio	Biointerfaces
EMP	Electronic Materials and Processing
NSN	Nanometer Structures and Nanotechnology 1-2
PST	Plasma Science and Technique
SS & ASS	Surface Science and Applied Surface Science 1-3
TF & SE	Thin Films and Surface Engineering 1-5
ViA	Vacuum in Accelerators 1-6
VST	Vacuum Science and Technology 1-6

Session Overview

Day	**Room 2**	**Room 3**	**Room 4**
Monday Morning	TF & SE 1	VST 1	NMN 1
Monday Afternoon	60 Years IUVSTA		
Tuesday Morning	TF & SE 2	VST 2	NMN 2
Tuesday Afternoon	TF & SE 3	VST 3	SS & ASS 1
Wednesday Morning	TF & SE 4	VST 4	SS & ASS 2
Wednesday Afternoon	TF & SE 5 / ViA 1	VST 5	SS & ASS 3
Thursday Morning	ViA 2	VST 6	Bio
Thursday Afternoon			
Friday Morning	ViA 3	PST	EMP

Detailed Timetable

The detailed timetable can be found on our website. By default, it opens with the session overview. Click the button Detailed view to see the individual talks. Click on a specific talk to access its abstract.

15th European Vacuum Conference (EVC-15)

Sunday 17 June 2018 - Friday 22 June 2018

Book of Abstracts

Contents

Opening / 416

European Vacuum Conference: The First 30 Years

John Colligon; Series Founder, Materials Group, Huddersfield University

Corresponding Auhor(s): j.colligon@hud.ac.uk

This short overview looks at the origins of EVC in the IUVSTA committees, the first conference in Salford, Manchester UK 1988 and the subsequent venues throughout its 30 year history. There are also a few details of associated events, such as IUVSTA Executive Council Meetings. Fuller details will be presented on a poster board and delegates are asked to take a look and help me identify the names of people on some of the pictures.

Plenary session / 380

Optical coatings of tomorrow: From passive interference filters and multifunctional systems towards smart meta-structures - Change of paradigm?

Ludvik Martinu[1]

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Optical coating (OC) applications represent a multibillion dollar market worldwide; they range from antireflective (AR) coatings found in most optical components and low emissivity windows in build-ings and automobiles to narrowband optical interference filters used in telecommunications. As the range of applications of OCs continuously broadens and extremely attractive market opportunities arise, it is becoming increasingly important to develop new nanostructured thin film materials with specific multifunctional properties. Further progress in this fast evolving field is strongly stimulated by a simultaneous action of two forces: a) the “pulling force” represented by the economic, technological and societal needs, including sustainable development, and b) the “pushing force” related to the curiosity-driven nanotechnology combining new design concepts of materials and devices, fabri-cation processes and innovative characterization tools, where the only limitation frequently appears to be our imagination.

This presentation will describe a holistic approach to OCs based on a broad and in depth knowledge of the interplay between the design, material, process and performance assessment with respect to specific applications and coating system durability in demanding environments. It will review the progress and future opportunities for the use of discrete, graded, and nanostructurally-controlled architectures benefiting from the nanomaterials’ meta-structures, advanced deposition techniques including high power impulse magnetron sputtering (HiPIMS) and tailored plasma- and ion-surface interactions, as well as complex systems implementing active (smart, tunable) materials.

Tomorrow’s trends will be illustrated by examples from different fields of applications ranging from passive hybrid elastic OC for ophthalmic lenses, hard protective OC for displays, and optical interfer-ence filters for gravitational waves detection to active OC and advanced glazings for energy saving using smart windows, active color-shifting security and authentication devices, and smart radiators with self-tuned emissivity for thermal management in satellites.

Nanometer Structures and Nanotechnology / 377

Nanotechnology the next decade:

A Key Enabler for Disruptive Innovations.

Lars Montelius[1]

1 INL

Corresponding Author(s): lars.montelius@inl.int

The digital economy will transform the science and innovation landscape allowing participatory rapid diffusion of knowledge, competencies and capabilities paving the way for effective and mean-ingful deployment of knowledge never before being witnessed. Nanotechnology is a Key Enabling Technology with promises for making solid contributions to the grand challenges of today, such as sufficient sustainable energy supply on demand, clean water to everyone, novel e-health solutions with impact on the growing ageing population multi-sickness panorama and life-styles diseases etc. Solutions to these challenges demands increased transversal interdisciplinary participation. Not only transversal within the Sciences but also transversal in all kind of societal dimensions including an increased empowered participation of people.

The explosion of IoT-products, massive data and sharing economy services are mega-trends of today´s society and the immense interconnectivity change modern society in a pace never before being witnessed. These major societal developments challenge society. But the needed changes also foster disruptive innovations. A key for such changes is the increased and participatory dialogue in society. This trend is clearly seen in the European funding policies becoming more aligned to mission driven perspectives. In order to fully tap all possibilities offered within the Key Enabling Technologies there is a continued need to put emphasis on transversal funding support schemes. If not, there is a risk that the enabling character of inventions will either disappear or take very long time to diffuse into other verticals, effectively hampering the innovation capital to be fully exploited.

The Higher Educational Systems are key for addressing large societal challenges. Hence, these societal changes will in turn challenge present higher education systems. Systems that still to large extents are "analogue" although several novel concepts have lately been introduced in the discussions, e.g. massive on-line courses. But there are needs for novel solutions and incentives in order to recruit needed trans-disciplinary engagements.

Nanotechnology, being a major key enabling technology, in combination with AI, VR and uantum Computation, will in the next decade be a major driver for disruptive innovations in various verticals as well as an effective tool for fostering the meaningful utilization of knowledge for a meaningful and sustainable global development.

Vacuum Science & Technology / 346

Development of 30 and 1000 Torr Full-Scale Optical Diaphragm Gauges

Author(s): Janos Marki[1]

Co-author(s): Gaétan Duplain [2] ; Oskar Untermarzoner [3] ; Ansou Traoré [2]

[1] *Inficon*

[2] *OpSens Inc.*

[3] *In icon AG*

Corresponding Author(s): janos.marki@gmail.com

Presently, for high accuracy near-atmosphere vacuum measurements, capacitive diaphragm gauges (CDGs) are the norm. However, for a number of demanding applications involving high temperatures, strong electromagnetic fields or high-energy radiation, optical diaphragm gauges (ODGs, [1] & [2]) would be much better suited alternatives.

In these ODGs, the sensor head incorporates a Fabry-Pérot interferometer, of which the cavity distance is pressure-dependent. As the cavity distance changes, the gap in time between the wave packages reflected from the planar surfaces on each side of the cavity changes as well. The light reflected from the sensor head is transported to the detector by means of an optical fibre. The detector's output signal is used to infer the cavity distance, which in turn serves as the basis for a pressure vs cavity distance calibration. By making use of such fibre optic technology to transport the measurement signal, it can propagate with minimal losses, so that even kilometer-scale sensor-detector unit distances become viable without additional signal amplification.

This inherently passive measurement arrangement provides major advantages over capacitive sensors, where for harsh environments, the electronics has to be placed at a distance adequately far away from the sensor head. For any real-life distances, the resulting electric signal quality degradation poses a major problem, as for these capacitive sensors, very low signal levels need to be measured with high accuracy.
At INFICON AG, Balzers, Liechtenstein, a feasibility study has been carried out on two sets of sen-sors with deflection ranges designed for 1000 and 30 Torr full-scale pressure readings, respectively. The ODGs' housings are composed from Al2O3 and sapphire, and the membrane is sapphire as well. The sensors were encased in housings regulated to a stable 100 °C temperature and operated using a CoreSens CSC-M multi-channel WLPI interferometer. The experimental evaluation of the sensors included the determination of the diaphragm cavity distance vs pressure characteristics, medium-term high vacuum drift behaviour, influence of atmospheric pressure and heater block temperature as well as signal recovery following atmospheric pressure exposure. The first results indicate ODG sensor performance on par with CDGs of equivalent full scale ranges.

[1]J.M.López-Higuera et al, "High-temperature optical fiber transducer for a smart structure on iron-steel production industry". Proceedings of SPIE - The International Society for Optical Engineering, Vol. 4328. http://dx.doi.org/10.1117/12.435541

[2]K. Totsu et al, "Vacuum sealed ultra miniature fiber-optic pressure sensor using white light in-terferometry", 12th International Conference on Transducers, solid-state sensors, actuators and mi-crosystems, 2003, Boston, USA, pp. 931-934 vol.1., doi: 10.1109/SENSOR.2003.1215628

Thin Films & Surface Engineering / 356

Semiconductor Thin Films by Hybrid Pulsed Laser Deposition Methods

Author(s): Reinhard Schwarz[1]

Co-author(s): Rachid Ayouchi [1] ; Pedro Sanguino [1]

[1] *Instituto Superior Técnico*

Corresponding Author(s): rschwarz@fisica.ist.utl.pt

Pulsed Laser Deposition, PLD, is a flexible and low-cost thin film deposition method, widely used for the preparation of insulating, semiconducting and metallic thin films with thickness ranging from a few nanometers up to tens of microns.

In the present contribution we will describe our work during the past 15 years employing this method at IST, Lisbon. Straight-forward PLD was combined in some cases with presence of inert background gas, or with simultaneous addition of a plasma-enhanced chemical vapour deposition, CVD, of oxygen or nitrogen gas. In special cases we employed a cyclic hybrid process. Nanostructures like nanospheres and nanowires have been studied.

The films were characterized by different structural and optical methods including X-ray diffraction, atomic force microscopy (AFM), dark and photoconductivity, steady-state and time-resolved photoluminescence (PL), optical transmission spectroscopy and time resolved microwave conductivity (TMWC). Surface morphology and chemical composition was analysed with X-ray Photoelectron Spectroscopy (XPS).

We will highlight three examples of our experience and the advantages of PLD deposition of (a) semiconductors like thin films of GaN, (b) nanowires of ZnO, and (c) insulators like ferroelectric sodium-potassium-niobate (NKN).

Vacuum Science & Technology / 290

Conceptual consequences of the NewSI to the unit of pressure

Dominik Prazak[1]

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The New SI (which will very probably be adopted this autumn) will no longer be a mere set of the definitions of the units, but an organic system binding the units and the invariant constants of Nature. The approaching redefinition will become a complete turn to the system of units being interdependent by the defining constants and at the same time it will cause a dissolution of the border between the basic and the derived SI units. Hence, it will require an increased attention to its educational aspects, highlighting a need of a correct usage of the quantity calculus. Without it, the users would not be able to appreciate the New SI. The presentation will focus on the unit of pressure as an illustrative example of a unit derived from the physical invariants. It will show its position in the system in a synoptic way and emphasize its wider relations to the existing concepts of the systems of units for the theoretical physics (like the Planck system).

Thin Films & Surface Engineering / **313**

Structure, thermal stability and oxidation resistance of TiBN PVD hard coatings

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TiBN ternary coatings are of great industrial value, considering their prominent mechanical and tribological properties, such as super hardness, low intrinsic stress and high wear resistance. These coatings have been successfully applied to cutting tools, die-casting moulds, forging dies, aluminium extrusion dies, etc. Therefore, for these applications, the thermal stability and oxidation resistance of TiBN coatings will have a profound influence on the performance of the coated tools, moulds and dies during service. The TiBN coatings were deposited onto HSS substrates. The coatings were prepared by cathodic arc evaporation using the LARC® technology. The impact of various boron content on TiBN structure, thermal stability, oxidation resistance and presence of residual stresses inside the layers will be studied. With X-ray diffraction, TEM and SEM microscopy, the morphology, structure and phase composition of coatings were evaluated. XRD analysis was also employed for detection of phase changes in deposited TiBN coatings and residual stresses measurements as well.

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Growth of obliquely deposited nanostructured Ti thin films

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Highly porous, nanostructured metallic thin films are interesting for numerous applications such as electrodes in fuel cells and Li-ion batteries as well as for surface enhanced Raman sensors and implants. Combining electron beam evaporation and oblique angle deposition (OAD) represents an elegant and powerful technique to sculpture manifold surface morphologies on the nanometer scale. Thereby, the substrates normal is tilted to a highly oblique angle θ with respect to the incoming par-ticle flux. Due to the oblique deposition geometry, shadowing is induced during the growth process so that a thin film consisting of separated tilted nano-sized columns is formed. Rotating the substrate changes the growth direction of these columns, which allows the creation of nano-sized screws, spi-rals or chevron structures, for instance. The precise control of surface morphology plays a key role for tailoring many film properties. During the last decades, mainly insulating and semi-conducting OAD structures have been in the focus of research activities, but the knowledge about the growth process of metallic OAD structures still remains incomplete. However, the angle of the incoming particle flux θ and the substrate temperature TSub have already been identified as parameters that influence the growth of such columns significantly. The experimental setup allows varying the inci-dence angle θ between $0° \leq \theta \leq 90°$ and the substrate temperature TSub between 77 K ≤ TSub ≤ 1000 K. The presentation concentrates on the microstructure, texture and morphology of nano-sized Ti columns depending on these parameters. Natively and thermally oxidized Si(100) pieces were used as substrates. During deposition, the working pressure in the vacuum chamber was constant at 10-7 Pa. Analysis was carried out using X-ray diffraction in-plane pole figure measurements, scanning electron microscopy and high-resolution transmission electron microscopy.

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The End of Mercury Manometers with the Quantum-Based Pascal

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At NIST, new methods of pressure and vacuum realization that are based on quantum calculations are currently under development. This is exciting in that it fits with the current redefinition, that if a new technique relies upon a quantum property, measurement, calculation, or invariant of nature, then this technique can have served as a primary standard. Standards built this way are then directly tractable to the SI and will not itself require re-calibration. for the Pascal, NIST has developed a Fixed Length Optical Cavity (FLOC) and a Variable Length Optical Cavity (VLOC) that operate by measur-ing the gas pressure thought the interaction of light with the atomic or molecular properties of the gas. Combined, these standards enable the elimination of mercury manometers, a standard that has been in use for four centuries. The talk will cover the current status of the project that was started over 5 years ago with an NIST Innovations in Measurement Science project, and will connect this effort to the boarder context of SI-Redefinition. The talk will also briefly update activates on the Cold Atom Vacuum Standard (CAVS) project, and the NIST Thermodynamic Metrology Group.

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Microstructure, Stress Gradients, and Mechanical Properties in Diamond Films Revealed by Cross-sectional X-ray Nanodiffraction and Microcantilever Testing

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Ultrananocrystalline diamond (UNCD) films consist of small randomly oriented diamond grains em-bedded in an amorphous C:H matrix. Usually, the grain size is determined by X-ray diffraction or transmission electron microscopy, revealing information only from the total UNCD film or only locally from selected areas with low statistics, respectively. In this work, we present the first cross-sectional X-ray nanodiffraction study of diamond multi-layers with varying grain size from micro-crystalline diamond to UNCD. X-ray nanodiffraction was performed in transmission geometry at ESRF in Grenoble, using a beam diameter of 30 nm oriented parallel to the diamond-Si interface. The sample was scanned in equidistant steps from interface to substrate, revealing depth gradients of texture, grain size and residual stress across the film. Micro cantilevers fabricated by focused ion beam milling were used to access Young's modulus and fracture stess in both UNCD and microcrys-talline sublayers. In addition, a nanoindenter-based mapping of Young's modulus was carried out on a cross section of the layer system prepared by FIB. The results show complex cross-sectional gradients of microstructure and stress state.

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Hybrid metal/inorganic/organic nanotubes

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Hybrid nanoparticles are gaining increased recognition for their importance in many areas including catalysis, medicine, and light-harvesting. The ability to tune the properties of these hybrids is thus of great interest; furthermore, such structures can be subject to additional processing to form unique structures. This work presents the coating of gold nanoparticles (GNPs) on an inorganic nanotube (WS2-NT) template, linking of the GNPs by ligands, and finally etching away the NT to leave a ro-bust, yet hollow cylinder formed of GNPs. This preparation differs from previous attempts to coat nanostructures by nanoparticles using defect-guided processes in that our method is specific and efficient, resulting in a controlled and uniform coverage as well as the possibility to remove the orig-inal template leaving an intact nanotubule. Characterization of the mechanical, thermal, electrical and electro-optical properties of these new species was performed using x-ray diffraction, electron microscopy, Raman spectroscopy, and a variety of scanning probed microscopy (SPM) techniques.

Here, emphasis will be placed on the SPM measurements which show distinct electrical and mechanical behavior distinguishing the decorated tubes, and etched final products. These results will be compared to the other techniques applied, and used to understand the nature of the networking between the GNPs, and how it affects the mechanical integrity, electrical and optical properties of the resultant structures.

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Development of a new UHV/XHV pressure standard (Cold Atom Vacuum Standard)

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Since the earliest days of neutral atom trapping it has been known that the background gas in the vacuum limits the lifetime of atoms in the trap. We are inverting this problem to create a quantum-based standard and sensor. Because the measured loss-rate of ultra-cold atoms from the trap depends on a fundamental atomic property (the loss-rate coefficient or thermalized cross section) such atoms can be used as an absolute sensor and primary vacuum standard. Researchers have often observed that the relationship between the trap lifetime and background gas can be an indication of the vac-uum level, but a true absolute sensor of vacuum has not yet been realized. We are developing the atomic toolkit, and designing and building the apparatus to measure relevant cross sections, as well as building our first prototype vacuum sensing apparatus. In this presentation, we will discuss our progress, and present our newest measurements.

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Magnetic field sensors based on 2D materials as graphene and Bi2Se3

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Ultra-thin layered materials as graphene (Gr) and, belonging to the topological insulators, Bi2Se3 represent unique physical and chemical properties due to the reduced dimensionality (2D materials). The both materials: Gr [1] and Bi2Se3 [2] exhibit specific properties as regards surface conductiv-ity what makes them interesting for construction of the highly sensitive magneto-resistive sensors. Elaboration of the preparation procedure of the magnetic field sensors based on the ultra-thin active layers and optimization of their surface structure, and architecture were the main aims of this work. During this talk, we shall present developed by us manufacturing procedure of such flat electronic devices as magnetic field sensors with the active part based on layered materials with thickness in the sub-nm scale [3]. Manufacturing procedure uses: maskless photolithography for Gr (a process

replacing the Ar+ ions etching process), transfer of the macroscopic (but ultra-thin due to exfoliation processing) flakes of Bi_2Se_3 and deposition of metals (as electrodes) using the magnetron (DC) sputtering. In our approach the sensor active layer have been shaped by the ion sputtering (Ar+) as opposed to the previously used techniques of digestive reactive etching [4]. The proposed solu-tion prevents oxidation of the surface in the case of semiconductor substrates functionalization, and therefore it is more compatible with CMOS technology. We shall also present our original sensor architecture developed to enhance the sensor sensitivity and signal to noise ratio [5].
Authors with the PUT affiliation (1) have been supported by Polish Ministry of Science and Higher Education within the project No. 06/62/DSPB/2182.

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Simulation of an extractor ionisation gauge

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We describe the numerical simulation of an extractor gauge using SIMION 8.0 software. The de-tailed geometry was defined in SolidWorks and imported into SIMION as 5 separated electrodes. All dimensions defined by the manufacturer were strictly followed. Length distribution of calculated electron trajectories has been evaluated. This allowed determining the mean trajectory length in-side the grid volume. Its magnitude of 19.3 mm was latter used to calculate the gauge sensitivity. The ion collection efficiency was also assessed as a function of the distance to the collector, having an average of 70.5 %. From these results and the ionization cross section taken from the literature, the sensitivity was calculated as 6.1 mbar-1 for N_2 at 150 ℃, well in agreement with the sensitivity given by the manufacturer (6.25 mbar-1). The sensitivity for He and for H_2 was also calculated based on the known ionization cross sections.
A second simulation approach was done running a LUA code in parallel with the electron trajectory calculation. The trajectory was divided into segments and for each segment we checked if ioniza-tion took place using simple Monte Carlo algorithm. The ionization probability along a segment was determined from the segment length, gas concentration and the ionization cross section. Once the ionization takes place, we 'annihilate' the electron and 'create' an ion of a given mass, charge and velocity. In the LUA code we did that by transforming the fast electron into a slow ion. The initial velocity of ions is determined randomly so that it obeys Maxwell distribution for the previously de-fined gas temperature. So, we tested segments until we get an ionization event – in every segment the projectile enters as an electron. Once the ionization takes place, we follow the ion trajectory. Since the ionization probability is low, instead of a single electron we assume a bunch of electrons which amount is a function of the pressure. Further details on the algorithm will be provided. This approach was useful to calculate the sensitivity as a function of the pressure. At pressures below 10-3 mbar, we obtained the same sensitivity as by the first approach. A clear decrease was found at high pressures due to the increased probability that an ion is formed outside the grid and therefore not collected.

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In-Situ²: In-Situ High-Temperature High-Energy X-Ray Diffraction and In-Situ Micromechanical Testing of nanostructured AlCrSiN-AlCrN multilayer coating prepared by reactive arc evaporation

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Nanostructured hard coatings exhibit complicated structure-property relationships which originate from their microstructure, phase and residual stress variations at the nanoscale. In this contribution, a multi-layered coating composed of equally thick soft hexagonal (h) Al90Cr10N and metastable hard cubic (c) Al63Cr27Si10N sublayers, with a bilayer period of ~65 nm, was investigated during anneal-ing by high-temperature high-energy synchrotron X-ray diffraction (HT-HE-XRD) and complemen-tary micromechanical tests in a scanning electron microscope (SEM). HT-HE-XRD was performed by using an in-situ dilatometry setup, which has, due to size restrictions, not been established up to now in the field of hard protective coatings. A combination of high-temperature dilatometry and high-energy small- and wide-angle synchrotron X-ray diffraction (SAXD, WAXD) represents a unique tool for characterization of coatings, revealing microstructure development at high temperatures accompanied by variations of residual stresses. Both types of data analysis evidenced that the peri-odicity of the multi-layered structure changes with the onset of the cubic-to-hexagonal transition in the Al63Cr27Si10N sublayers. SEM on the coating cross-section before and after the thermal cycle indicates that the multilayer architecture remains stable, whereas the bilayer period increases to ~73 nm. Furthermore, in situ micromechanical tests on cantilevers fabricated using focused ion beam (FIB) milling from the as-deposited and annealed state were used to determine Young's modulus *E*, fracture stress σF and fracture toughness *K*Ic. The measured mechanical properties proved, that during annealing the elastic properties (*E*) change with phase transformation, whereas the fracture properties (σF, *K*Ic) remain nearly constant after the thermal cycle. This evidences that the fracture properties depend mainly on the microstructure, not as much on the elastic difference between the constituents of the system.

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Enhanced photoresponsivity of Au functionalized ZnO nanofibers

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Photodetectors have attracted great attention in various applications such as industrial and envi-ronmental monitoring [1]. One-dimensional (1D) ZnO nanostructures due to their wide band gap (~3.3 eV), large exciton binding energy (60 meV), high effective surface area as well as good charge transport are considered as proper building blocks for fabricating UV photodetectors [2]. Among different methods for synthesizing 1D nanostructures, electrospinning is an efficient and scalable technique which yields a considerable amount of long (µm size) 1D ZnO nanofibers which makes device fabrication more facile. Despite good UV photodetection of 1D ZnO nanostructures, improv-ing their performance parameters such as response and detection range is still a challenge. One of the strategies to reach these goals is incorporation of noble metal (Au, Pt, and Ag) nanoparticles (NPs) into 1D ZnO nanofibers which improves detector properties through surface modifications and Schottky junctions'' formation [3]. Moreover, it is believed that size and homogeneity of the noble metal NPs play an important role in the light sensing. Therefore, we have used sputtering technique to deposit Au thin film with different layer thicknesses to optimize functionalization of 1D ZnO nanofibers. To fabricate photodetectors, Au interdigitated electrodes (width: 200 µm and separation: 30 µm) were patterned on SiO2/Si substrates by photolithography process followed by deposition of ZnO nanofibers via electrospinning method. Then, different thicknesses of Au layer in the nanometer range (2-8 nm) were sputtered on the prepared samples, and subsequently they were annealed at 450 ℃ for 30 Min. The samples were characterized using scanning electron mi-croscopy (SEM), photoluminescence (PL) and UV-Visible spectroscopy. Measurement of higher UV photoresponse (Iphoto/Idark) of the Au decorated ZnO nanofibers as compared to the pure ones with maximum value for the sample with 4 nm Au, confirms the effective role of the Au NPs in the sensing mechanism. To achieve a wider spectral response range (UV-Vis-IR), an optimum Au film thickness of 8 nm was determined for the studied ZnO nanofibers. Furthermore, it was also found that Au NPs exhibit localized surface plasmon resonance (LSPR), leading to broaden of photodetection range into visible region.

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Vacuum Science & Technology / 276

Electron source for an improved hot cathode ion gauge

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We assume that a hot cathode ion gauge can be made more stable by using an electron source for introducing an accelerated electron beam into the ionization volume in a straight path. By doing so, the electron trajectories, kinetic energy and current inside the ionization volume could be well defined and stable.The electron beam should have an energy of about 200 eV for stable ionizing the gas. In absence of a convenient complete commercial solution for our application we started to investigate electron guns by simulation and experiment. Key parameters like electron transmission efficiency and tolerances have been investigated as a function of the source geometry and potentials. The possibility of suppressing unwanted secondary effects depends on the spacial distribution of the electrons. The simulations have been carried out using the COMSOL Multiphysics 5.0 software. The packages AC/DC>electrostatics and AC/DC>Particle Tracing>Charged Particle Tracing have been used. The work is a part of the EURAMET EMPIR project "16NRM5-ion gauge".

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Controlling the Boron-to-Titanium Ratio in Magnetron-Sputter-Deposited TiB_x Thin Films via Preferential Ionization of Sputter-Ejected Ti

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TiBx thin films grown from compound TiB2 targets by magnetron sputter deposition are typically highly over-stoichiometric, with x ranging from 2.4 to 3.5, due to differences in Ti and B preferential ejections angles and gas-phase scattering during transport between the target and the substrate. We show that the use of highly-magnetically-unbalanced magnetron sputtering of TiB2 target leads to selective ionization of sputter-ejected Ti atoms which are steered via an external magnetic field to the film, thus establishing control of the B/Ti ratio with the ability to obtain stoichiometric TiB2 films over a wide range in Ar sputtering pressures.1 We further demonstrate that stoichiometric TiB2 films can be obtained using high power impulse magnetron sputtering (HiPIMS) in Ar; the B/Ti ratio x is controllably varied from 2.08 to 1.83 by adjusting the length of HiPIMS pulses tau between 100 and 30 μs, while maintaining average power and pulse frequency constant. Energy- and time-dependent mass spectrometry analyses of ion fluxes incident at the substrate position show that the density of metal ions increases with decreasing tau, due to a dramatic increase in the peak target current density and strong gas rarefaction. With tau < 60 μs, film growth is increasingly controlled by incident ions rather than neutrals. Thus, since sputter-ejected Ti atoms have a higher probability of being ionized than B atoms due to their lower first ionization potential and larger ionization cross-section, the Ti concentration in as-deposited films increases with decreasing ton as ionized sputtered species are steered to the substrate by the plasma in order to maintain charge neutrality.

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The 14-billion Year History of the Universe Leading to Modern Materials Science

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The story begins approximately 13.8 billion years ago with the Big Bang. A brief introduction will trace the evolution of the universe to what we observe today. Many of the formative events occurred in the first tiny fractions of a second (our universe evolved from consisting entirely of a quark/gluon plasma to form the first hadrons: protons and neutrons) to minutes (free neutrons decay to electrons, neutrinos, and more protons) to a few tens of thousands of years (elementary particles react to form the first elements which leads, in turn, to the development of stars due to local density fluctuations). Planet Earth nucleated and began to accrete interstellar debris ~4.5 billion years ago. While the lighter metal elements on earth formed primarily due to stellar supernovae explosions, the primary mechanism leading to the formation of the heavier elements has only recently been demonstrated. The first known sophisticated stone tools used by hominids, found in northern Ethiopia, date to 2.6 million years ago

Gold is likely the first metal discovered by man, >11,000 years ago. However, unlike copper (Mesopotamia, ~9000 BC), bronze (Iran, ~5000 BC), and cast iron (China, ~600 BC), it was too soft for fabrication of tools and weapons. Instead, gold was used for decoration, religious artifacts, and commerce. Spec-tacular metal sculpting displaying very high levels of metallurgical and artistic craftsmanship have been found in Mesopotamia (S. Iraq). The earliest high-purity Au artifacts derive not from Egypt, as commonly thought, but from NE Bulgaria ~6500 y ago; however, the largest known concentration of ancient gold mines is in the Egyptian Eastern Desert. Metal extraction from ore, copper smelting, was already being carried out in the Balkans (E. Serbia and S. Bulgaria) ~7500 years ago.

Gold brazing of metal parts was first reported in ~3400 BC in Sumaria. The earliest documented thin metal films were gold layers, some less than 1000 Å thick, produced chemi-mechanically by Egyptians ~5000 years ago. Examples, gilded on copper and bronze statues and artifacts (requiring sophisticated compositionally-graded interfacial adhesion layers), were found in hewn-stone pyra-mids dating to ~2650 BC in Saqqara. Spectacular samples of embossed gold sheets date to at least 2600 BC. Electroless gold and silver plating was developed much later by the Moche Indians of Peru in ~100 BC.

Early biomaterials used as human prosthetics following successful amputations date to 950 BC in Egypt, while the first recorded quantum-mechanical nano-based devices, exhibiting spectacular dichroic nanophotonic effects based on ~200-Å-diameter Au alloy quantum dots, were synthesized in Rome during the early third-century AD.

Vapor-phase deposition of thin metal and ceramic films on bulk substrates (as used in manufactur-ing of today's transistors, hard discs, LED TVs, etc.) had to wait for the invention of vacuum pumps (~1650 for mechanical pumps, through ~1865 for ballistic mercury momentum-transfer pumps). The fascinating development of crystallography (Plato [Greece], 360 BC; through Kepler [Germany], 1611; Haüy [France], 1780s; and Miller [UK, 1839]), is essential for describing crystal structure in modern materials science, mineralogy, and geology.

While an historical road map tracing the progress of materials technology is interesting in itself, the stories behind these developments are even more remarkable and provide insight into the evolution of scientific reasoning.

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Exploring Matter at Ultrashort Time Scales

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High-order harmonic generation (HHG) in gases and its applications is today an active field of re-search worldwide. High-order harmonics are created when intense laser radiation interacts with a gas of atoms or molecules. In the time domain, the emission is a train of pulses in the extreme ultraviolet range, separated by half a laser cycle and with attosecond duration. The interference between attosecond pulses results in a frequency comb of high-order (odd) harmonics. This presen-tation will introduce the physics and describe the present status of high-order harmonic generation and attosecond pulses.
There is today an increased diversity of HHG sources driven by a variety of lasers ranging from high energy lasers at low repetition rate to high average power lasers, based upon optical parametric amplification or simply high-power oscillators. HHG sources can be vastly different, with parame-ters such as peak power or repetition rate varying by several orders of magnitude. There is also a growing diversity of HHG applications spanning many areas from atomic and molecular physics to condensed matter. We will focus on the use of attosecond pulses to probe photoionization dynamics in atoms.

60 years IUVSTA / 404

Getter pumping for particle accelerators

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Non-Evaporable Getters (NEG) were first adopted to provide a fast, evenly distributed pumping for the Large Electron Positron collider (LEP) at CERN. The NEG, in the form of a getter powder coated strip, was installed along about 23 Km of the LEP vacuum chamber.
A similar solution was later applied to pump the room temperature sectors of the present CERN major accelerator, the Large Hadron Collider (LHC). In this case, the NEG strip was replaced by a thin film of NEG, coated on the internal walls of the LHC chambers by a sputtering technique. More recently, a roll-to-roll coating machine has been developed to NEG coat a thin aluminium foil by sputtering. Although developed for a Solar Energy application, this technique could also be applied to particle accelerators, by shaping the coated foil in the form of a liner to be inserted inside vacuum chambers of any geometry. Such a liner would either replace or complement the chamber coating.

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Working in Vacuum - Extravehicular Activities in Low Earth Orbit

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This is not a lecture about vacuum, but about working in the quasi-vacuum of the space environment in Low Earth Orbit! During the Shuttle program and currently on the US segment of the Interna-tional Space Station, the Extravehicular Mobility Unit or EMU is used for spacewalks. The strategies, procedures and safely guidelines for the proper execution of these activities will be explained, partly based on the spacewalking experience of the lecturer during a Hubble Space Telescope servicing mission in 1999.

Plenary session / 343

The fascinating world of organic nanocrystals on 2D materials

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Crystalline films of small conjugated molecules offer attractive potential for fabricating organic so-lar cells, organic light emitting diodes (LEDs), and organic field effect transistors (OFETs) on flexible substrates. Here, the novel two-dimensional (2D) van der Waals materials like conducting graphene (Gr), insulating ultrathin hexagonal boron nitride (hBN) or semiconducting transition metal dichalco-genides come into play. Gr for instance offers potential application as transparent conductive elec-trode in organic solar cells and LEDs replacing indium tin oxide, whereas hBN can be used as ul-trathin flexible dielectric in OFETs. Since small conjugated molecules like the rod-like molecule para-hexaphenyl (6P) fit well to the hexagonal structure of 2D materials, growth of 6P can be ex-pected in a lying configuration. This has indeed been observed by low-energy electron microscopy for growth of 6P on Pt(111) supported Gr in a layer by-layer fashion [1].

Here, we report on the self-assembly of crystalline needles composed of rod-like molecules on exfo-liated, wrinkle-free Gr [2] and hBN [3], both transferred onto SiO2. The needles are several 10 nm wide and a few nm high, they can extend to several 10 µm in length. The discrete needle directions with respect to armchair and zigzag directions of the substrates were determined by atomic-force microscopy (AFM) in conjunction with density functional theory calculations.
Through in-situ measurements during molecule deposition on Gr in field-effect transistor device geometries, the charge transfer at the interface was directly probed. The amount of charge trans-ferred per adsorbed molecule is only about one thousandth of an electron transferred per molecule [4]. Further, electrostatic force microscopy (EFM) based charging and charge spreading experiments demonstrate the optoelectronic properties of the organic nanoneedles. Finally, AFM based manip-ulation is employed to probe the mechanical robustness of the 2D materials [5] as well as of the organic nanocrystals.

Work has been performed in collaboration with G. Hlawacek, M. Kratzer, A. Matković, J. Genser, G. Lin, A. Cizek, A. Vukusić (Leoben), R. van Gastel, F.S. Khokhar, B. Poelsema (University of Twente, NL), J. Vujin, B. Vasić, Stanković, R. Gajić (University of Belgrade, Serbia), Z. Chen, O. Siri, T. Léoni, C. Becker (Aix Marseille Université, France), D. Lüftner, and P. Puschnig (University of Graz, Aus-tria).

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Nanometer Structures and Nanotechnology / 359

Surface analysis of nanomaterials: needs and challenges.

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It is recognized that detailed physico-chemical characterization of nanomaterials is becoming increasingly important both from the technological and from health and safety point of view. Moreover, an incomplete characterisation may inhibit or delay the scientific and technological impact of nanoscience and nanotechnology. However, nanomaterials characterization based on individual instrumental methods is a very challenging issue because their stability, coating and environmental effects may lead to outputs that are not very easy to interpret unequivocally. For this reason multiple analysis methods are needed to understand the nature of nanomaterials, especially if we consider that surface and interfaces are critical to the behaviours of nano-sized materials [1].
Surface chemical analysis methods, such as X-ray Photoelectron Spectroscopy (XPS) and Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS), can provide an important contribution to more fully characterizing nanomaterials, so these methods should be more generally applied as part of a characterisation set of tools for nanomaterials and nanoparticles synthetized for different applica-tions [2]. Moreover, the use of advanced techniques based on synchrotron radiation and neutron scattering can also provide valuable data on nanoparticles [3-5]
In this work some examples of the use of surface analysis techniques for the characterisation of nanoparticles in complex matrices will be presented and discussed.

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The influence of post-deposition annealing on the microstructure of TiZrV non-evaporable getter coatings, their activation behaviour, and pumping speed.

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To explore the influence of activation temperatures on the operation and lifetime of non-evaporable getter coatings, films were annealed at different temperatures to monitor phase formation which was correlated with activation and pumping characteristics. TiZrV films were deposited on cylindrical stainless steel vacuum chambers, as well as oxygen-free electronic (OFE) copper and silicon substrates by magnetron sputtering of intertwisted Ti, Zr and V elemental wire cathodes with a Kr working gas. After deposition and without venting, samples were heated to temperatures of 230 ℃, 300 ℃, 350 ℃ and 380 ℃ for a total of 240 hours. The resultant films on silicon substrates were examined in the scanning electron microscope for surface and cross-section morphology, energy-dispersive X-ray spectroscopy for chemical composition, and X-ray diffraction to characterise film microstructure. To monitor activation behaviour, the evolution of surface chemistry of coated OFE copper samples was monitored during an activation cycle with X-ray photoelectron spectroscopy. Pumping speed of H2 and CO for coated stainless steel vacuum chambers was measured with a Fischer-Mommsen dome. Results indicate phase formation from higher annealing temperatures leads to delays in activation and reduced pumping speeds.

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New aluminium beam pipe upgrade for the LHC experiments during the LS2

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In 2019-2020, the LHC machine will be stopped and will enter a new phase of maintenance and consolidation called the long shutdown (LS2). During this period, all the LHC experiments will undergo significant upgrades and important modifications. One of the main objectives of the changes is to reduce the radiation dose to personnel following the ALARA (As Low As Reasonable Achievable) principle at CERN. In order to achieve this goal, new vacuum components with low-mass materials have been designed and will replace the old parts with higher material activation, induced by the interaction with the beam. In this framework, the aluminium plays a major role. The use of alu-minium in vacuum application is increasingly widespread, but the re-design of the old components with this different material is not straightforward.
This work will highlight the main issues encountered on the use of aluminium and its alloys for the ultrahigh vacuum (UHV) purposes and details the problem of the grain size for thin-walled beam pipe and its material production. Moreover, the results of the numerical mechanical calculations of the new CMS beam vacuum chamber designed with aluminium EN-AW 2219 will be also pre-sented.

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The role of oxygen in sputtering of ZnO films for ZnO nanorod-based devices

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ZnO nanorod-based devices have been of increasing interest in the field of flexible electronics, catalyst, optoelectronics and energy harvesting. These devices usually contain Zinc oxide film as a seed layer for nanorods and Indium tin oxide (ITO) film as transparent electrode. Since Indium is included in the list of critical raw materials defined by EU commission, research and development activities are required to find new Indium-free solutions. The main aims of the present work are the optimiza-tion of the electrical properties of ZnO seed layer and the replacement of the preferably-used ITO by an aluminium doped Zinc oxide (AZO) film.

The use of polymer flexible substrates usually requires the preparation of films at temperatures up to 100 ° C. Moreover, low film thickness is needed to avoid failure of the device due to forming of cracks. Thus the achievement of suitable electrical properties of AZO films deposited on flexible thermally-sensitive substrates is still difficult and therefore is subject of intense research.
In this study, all thin-film depositions were performed using a BOC Edwards TF 600 deposition system equipped with two magnetrons linked to a radio-frequency (RF) and direct current (DC) power supply. The use of this deposition system enabled the control of oxygen content in the prepared films. Electrical properties were determined by Hall measurement. The film structure and ZnO nanorods were investigated by the Scanning electron microscopy and X-Ray diffraction. The prepared films were tested on the ZnO nanorod-based piezogenerator.

It was found that the amount of oxygen fundamentally affects the electrical properties of the de-posited films. A major reason was identified as the various dominant internal defects depending on the different oxygen conditions during the processing. The control of oxygen amount allows us to achieve lower resistivity of the AZO transparent electrode and also to adjust the seed layer for different types of ZnO nanorod-based devices.

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Particle free ESS vacuum system

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The European Spallation Source (ESS) is a neutron source based on a 2GeV-5MW linear accelerator. The goal of ESS is to be the brightest neutron facility and to enable novel science in many fields such as biology research, environmental technologies and fundamental physics. The ESS Linear Acceler-ator (LINAC) is under construction, Ion source and LEBT installation is started in Q1-2018.

The protons receive the most of their acceleration in the cold LINAC, from 90 MeV out from the warm section to 2GeV into the beam delivery systems. Three types of cryomodules are used: Spoke cry-omodules (352.21 MHz, B=0.5) medium cryomodules (704.42 MHz, B=0,67) and High cryomodule (704,42 Mhz, B=0.86). These superconducting accelerating structures are sensitive to particle contam-ination and need to be protected to avoid performances loss.

At ESS three main sources of contamination are detected for the installation of the particle free ac-celerator.

1. Quantity of particle generates from active components like pumping systems, gate valves, instru-ments.
2. Particle contamination during LINAC construction from environment (dust in the tunnel or coactivity).
3. Particle contamination during assembly (human activities or tools non-adapted)

The control of particle free is based on 3 ways. Avoid the transport of particle inside the beam pipe, work in clean and classified environment and set up acceptance criteria and procedure to control them. Each part of the cold LINAC will be particle free checked before and during their installa-tion.

This contribution will discuss the tools and particle free control of the ESS cold LINAC from particle pumping cart to the quantity of particle generated by SAES NEG pump (new generation of low particle vacuum pump).

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Effect of Growth Temperature on the Structure of CoCrFeNiCu High Entropy Alloy Films

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The five component CoCrFeNiCu films were deposited by DC magnetron sputtering using spark-melted targets at background pressure of 5×10−6 Pa with a deposition rate of ~10nm/min. The working pressure was 0.3 Pa by applying 99.9 % pure argon as sputtering gas. The films were deposited onto oxidized (100) Si wafers. The growth was carried out at room temperature as well as at 380 °C.
The nanostructure of the films was analyzed by traditional transmission electron microscopy (TEM) in a Philips CM20 microscope at 200 kV accelerating voltage. High resolution TEM measurements were made in a Cs corrected 200 kV JEOL ARM 200cF microscope with atomic resolution. Samples for TEM investigation were produced in cross section views by Ar+ ion milling at grazing incidence.
The structure of the films grown at room temperature is single phase FCC and corresponds to zone T structure, with a well expressed <111> texture. The width of the columns is rather uniform, about ~25 nm, and the growth competition region is about 50 nm thick in the 500 nm thick film. The columns are rather defective, the main defects being planar defects. The film grown at high temperature possesses also the single phase FCC structure, the morphology is at transition from zone II to zone III. This is also supported by the random crystallographic orientation of the grains.
A detailed electron microscopic investigation and the possible formation mechanisms of the observed structures will be discussed.

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Optimization of noble metal nanostructured substrates for SERS.

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Surface Enhanced Raman Spectroscopy (SERS) is a very powerful technique for structural character-ization. In order to study this phenomenon nanostructured substrates are needed, and in particular those made with Cu, Ag or Au metals deposited on glass. In this work their synthesis by laser abla-tion and the characterization by UV-visible spectroscopy, Transmission Electron Microscopy (TEM) and SERS are reported. A Nd: YAG laser emitting in the third harmonic, at a wavelength of 355 nm and a pulse duration of 10 ns has been used as energy source. Nanostructures are made by varying the number of pulses typically from 200 to 20000 using about 100 mJ as output laser energy and focused in a spot of 1 mm in diameter in the corresponding target. The different morphologies were characterized and their SERS signal was measured using methylene blue as test molecule. The surface plasmon wavelength strongly depends on the nanostuctures morphology; evolving progres-sively from nanospheres to more intrincate shapes such as bean or worm-like features. It is found that the SERS signal increases monotonically with the size of the Ag, Au, Cu nanoparticles until reaching a maximum in intensity and subsequently decreases. The maximum in intensity occurs for a quasi-percolated film (worm-like features), this behavior will be analyzed in terms of the "hot spots" theoretical approach.

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Combining NEG pump and an XHV BNNT cryopump

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We have assembled a system using an array of NEG modules and a cryopump with Boron Nitride Nanotubes (BNNT) instead of the traditional charcoal. The BNNT has been mechanically attached to the cryosorption surfaces of a commerical cryopump, and the system fully baked to remove water with no adhesive present in the system. We report here on the pump speed of the BNNT cryopump, and characterize the base pressure achieved in the combined NEG/cryopump system using both an extractor gauge and a Watanabe 3BG XHV ionization gauge.

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Functional Metal-Oxide and Diamond-like Carbon Thin Films using Standard and High Power Impulse Magnetron Sputtering

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Plasma-assisted PVD processes for thin film growth allow for tailoring the film functionalities via controlling the plasma properties. Magnetron sputtering is a widely employed PVD method for preparing functional thin films that cover a wide range of applications from solar cells to hard coat-ings. An emerging magnetron sputtering based method is high power impulse magnetron sputter-ing (HiPIMS) which facilitates the generation of large ionized fluxes of film forming species. The high flux of ionized particles reaching the substrate and the possibility to tune their energy provide additional means for controlling film properties, differentiating the HiPIMS process from standard magnetron sputtering. The use of HiPIMS technology for a variety of thin film applications has ex-panded considerably in the last decade and from providing further insights into thin film growth

at atomic level to facilitating high quality coatings, HiPIMS has opened up new avenues for novel technological applications of thin films.

This presentation covers the implementation of standard magnetron sputtering and HiPIMS for two industrially relevant classes of materials namely metal-oxides and diamond-like carbon (DLC) with a focus on process-property-performance relationship. First, use of standard magnetron sputtering as an industrially relevant alternative to atomic layer deposition (ALD) of hydrogen-doped indium oxide (In_2O_3:H) transparent conductive oxide (TCO) is discussed. It is shown that high quality In_2O_3:H TCO comparable in performance to ALD can be synthesized using standard magnetron sputtering. Upon integrating into CIGS solar cells, the resulting TCO paves the way for an increase in efficiency as compared to baseline Al-doped ZnO. A range of other metal-oxide thin films that include TiO_2, yttria-stabilized zirconia (YSZ), thermochromic VO_2 are discussed where it is shown that using HiPIMS, previously unachievable performance of these thin films can be realized. For TiO_2 control over its phase formation and room temperature synthesis of anatase and rutile phases, for YSZ the implementation into solid-oxide fuel cells and for thermochromic VO_2 the potential for next-generation foil-based energy efficient smart windows is demonstrated.

In the second part, the role of HiPIMS in synthesizing high quality hydrogen free and hydrogenated DLC coatings is discussed. First, a novel strategy for synthesizing dense DLC coatings is presented. The strategy is based on electron temperature enhancement using Ne instead of Ar that facilitates an increase in carbon ionization thereby resulting in films exhibiting mass density in the order of ~ 2.8 g/cm3. It is also shown that the films exhibit a unique combination of high density, low com-pressive stress (~ 2.5 GPa) and high thermal stability. An insight into stress relaxation and recent progress with regards to mechanical behavior of these coatings is also presented. Furthermore, high rate synthesis of DLC coatings by coupling C_2H_2 with Ar- and Ne-based HiPIMS processes is also demonstrated. It is shown that by appropriate control of gas phase composition and energy of the film forming species, a ten-fold increase in the deposition rate as compared to Ar-HiPIMS process is achieved. This is obtained without significant incorporation of H (< 10 %) into the films together with high hardness (> 25 GPa) and mass density (~2.32 g/cm3). Based on the obtained results, it is con-cluded that: (i) dissociative reactions triggered by the interactions of energetic discharge electrons with hydrocarbon gas molecules is an important additional source of film forming species and (ii) film microstructure and film hydrogen content are primarily controlled by interactions of energetic plasma species with surface and sub-surface layers of the growing film.

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Distinctive Microstructures in Bitumen Evolve with Time and Composition

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The diverse microstructures that are observed by atomic force microscopy (AFM) in bitumen suggests complicated intermolecular associations. These microstructures largely contribute to bitumens' bulk mechanical properties; therefore, it is essential to understand the chemical–microstructural–mechanical relationships for optimal design of bitumen-related applications. However, the complex nature of bitumen and the various influencing factors often lead to practical challenges in investigation of bitu-mens' microstructures and their chemical origins. This study addressed some of the main concerns related to AFM characterization of bitumens' microstructures, namely the dependence of bitumens' microstructures on such factors as sample preparation methods, annealing conditions and durations, and chemical composition.

Microstructures of bitumen films of a few micrometers or thicker were comparable, regardless of their sample preparation methods. Additionally, bitumens annealed at room temperature for over 2 months showed

time-dependent microstructures, which correlate well with bitumens' room-temperature steric hardening behavior as verified by other researchers using modulated differential scanning calorimetry. Microstructures of the bitumen films stabilized after different annealing durations depending on the dimensions of the molecular structures and the complexity of the molecular interactions among the multiple phases in each bitumen. Distinctive microstructures were observed for remixed bitumens with increasing asphaltene concentrations. Consistency between our observations and other literature suggests that microstructures observed by AFM are probably not just a surface phenomenon. The above findings provide deeper insights into the establishment of the complicated chemical–mechanical relationships for bitumen that pave the path toward tuned bitumen performance.

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Pressure evolution in a 3D microcavities array

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A microcavity array is a set of volumes in the micrometer range. A 3D microcavities array is a 3D arrangement of such small cavities. It may have volumes equally spaced in an ordered pattern or not. Good examples of these materials are foams, sponges and cork. Although the motivation for this work came from the need to understand the pressure evolution in cork cells when subjected to vacuum or to pressure, the proposed approach is valid for any kind of 3D arrays or to 3D RC (resistor capacitor) networks, as it will be shown.
The purpose of this work is, first, to achieve a quantitative description of the flow from a 3D mi-crocavities' array versus time when subjected to a pressure change, and secondly, to describe the pressure evolution at any point of the inner volume.
The problem of pumping a 3D array of *n* microcavities is equivalent to discharging (or charging) of a 3D array of *n* capacitors interconnected by resistors, having all resistors at the borders shunted and connected to a power supply. The use of electrical equivalents to describe gas flow and pressure evolution is convenient because there are many options to simulate electrical circuits. Since the gas flow inside a cork is in the molecular regime, the conductance is pressure independent and the inverse of the electrical resistance is the direct equivalent to the flow conductance. This is not the case for other regimes where conductance is a function of pressure. The flow rate is the equivalent to the electrical current and pressure is the equivalent to the electrical potential. However, when the amount of cells is very large the system becomes virtually impossible of simulation. E.g. one cork stopper has about 1E9 cells. Above 1E4 nodes, the simulation performed by electrical simulators re-quires many hours on a PC. Therefore, the problem was solved by finding equivalent systems, easier and faster to simulate. Authors will show and discuss the results achieved using this approach.

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Nanotechnology Applied to Marine Polysccharides - Potential Biobased Packaging Films

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Nano-solutions for the twenty-first century - the advancement in the field of nanoscience and nanotechnology and its application to the field of food and food packaging has revoluzionized the 21st century - . Nanoencapsulation of nutraceuticals, smart delivery of nutrients, rapid sampling of biological and chemical contaminants, active and smart packaging are some of the emerging topics of nanotechnology for food sector.
The biopolymer-based packaging, although they have advantages (due to their biodegradable nature) over their petroleum-based plastic competitors, nevertheless, their use is strongly limited because of some shortcomings such as the weak mechanical and barrier properties. To overcome these limitations, and therefore to expand their applications, it is imperative that the issues related to their mechanical and barrier properties be addressed. Here we explore the water-evaporation-induced self-assembly technique approach for improvement of the Chitosan (CS) physical properties by addition of nano-additves such as unmodified clay (NaCls) and cellulose nano-whiskers (CNW). We will show that the mechanical properties of the CS films were improved by two factors: (i) slow evaporation of water is a spontaneous process, which reaches balanced states, with minimum free energy and without internal stress, leading to nacre-like structures; (ii) a synergistic effect was created between NaCls and CNW. The best mechanical properties were obtained with a weight ratio NaCls/CNW 1:2, leading to an improvement of tensile strength (+ 230%), tensile modulus (+ 448%) and elongation at break (+ 40%), compared to control chitosan films. Mixing CS with NaCls and CNW enhanced the thermal stability of CS films. This enhancement of thermal stability of the CS films seems to come from the surrounding, fixation, and stabilization of the polymer with clay platelets. The water vapor transfer rate, and oxygen transmission rate were reduced depending on the binary (NaCls/CS) or ternary (NaCls/CNW/CS) system used. This barrier may be attributed to a greater dispersion of the non-permeable inorganic unmodified clay platelets, leading to a longer and tortuous pathway for water vapor/oxygen molecules diffusion through the nacre-like layered structure formed, that was confirmed by scanning electron microscopy and X-ray analysis.

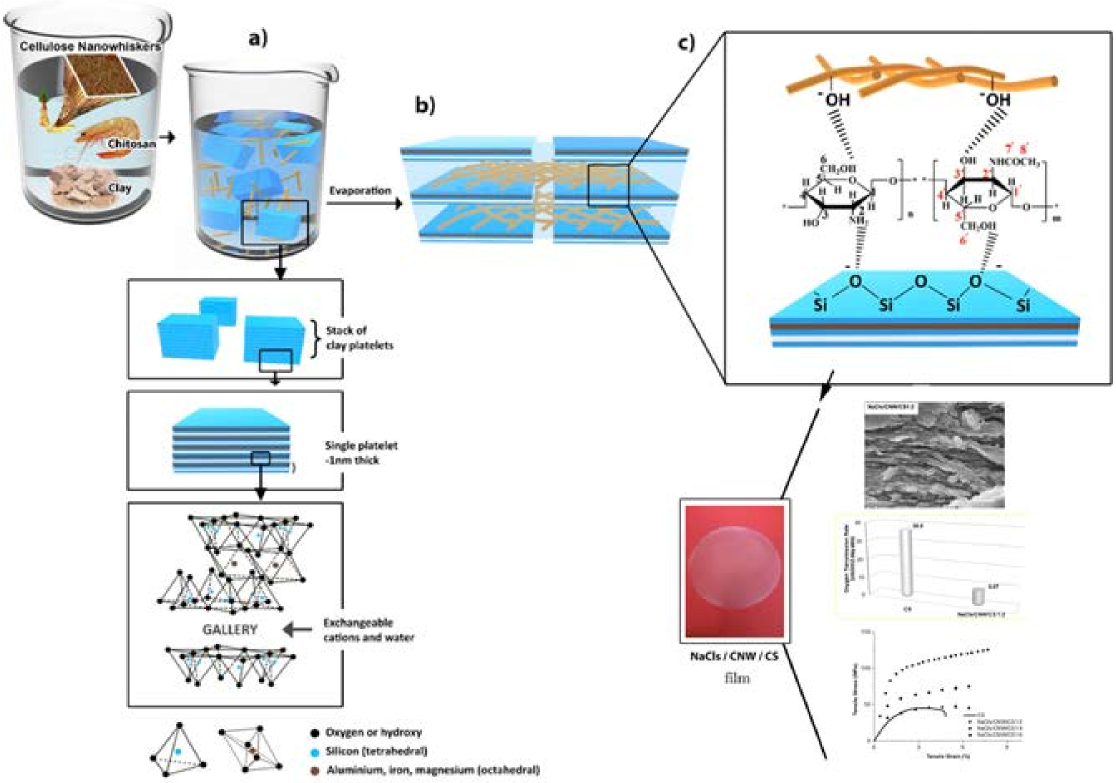

Figure 1:
a) Aqueous solutions of NaCls platelets, NWC, and CS were assembled into artificial nacre by slow evaporation.
b) Proposed structural model for the artificial nacre, in which NaCls platelet and Cellulose nano-whiskers network layers are alternately stacked into a layered structure.
c) Anionic NaCls platelets and anionic Cellulose nano-whiskers are interconnected by CS through electrostatic interaction and H bonding as confirmed by FT-IR spectroscopy.

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Measurement of the radiation tolerance of vacuum pumps

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Vacuum pumps and other components can be exposed to varying types and quantities of radiation. These include applications/apparatus in medical diagnostics and treatment, analytical instrumentation, sterilization techniques, space simulation as well as the established requirements in High Energy Physics.

This paper will present recent radiation tolerance measurements made by a DLA/ISO registered radiation test house for several scroll and other dry primary and turbomolecular secondary pumps and a range of 'active' and 'passive' gauges. Comparisons with other historic 'in-situ' measurements and an assessment of the irradiated components will be made. A program for the development of application specific radiation-compatible products will be also discussed

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Magnetron Sputter Deposition of Ti-Nb Coatings on AISI 316L Stainless Steel

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The most important criteria to develop metallic materials for manufacturing biomedical implants are the absence of toxic elements and a low modulus of elasticity. The metallic biomaterials mostly used as implants are stainless steel (SS), Co-Cr alloys, and Ti-based alloys due to their good mechanical properties, biocompatibility, high corrosion and wear resistance, and osseointegration. The compari-son of titanium and its alloys with SS and Co-Cr alloys shows that although Ti alloys are significantly more expensive than SS and Co-Cr alloys, they are more biocompatible and their elastic modulus values are more compatible with those of the human bones (10-40 GPa). The elastic modulus values for AISI 316L, Cr-Co alloys, and pure titanium are 190 GPa, 210-253 GPa, and 105 GPa, respectively. The β-Ti (body cubic centered structure) alloys can have an elastic modulus even lower than 55 GPa. Niobium has been used as a nontoxic β-stabilizing agent, and its addition to Ti causes a decrease in the elastic modulus. An interesting option to overcome the costly use of bulk β-Ti-Nb alloys would be to coat an implant with a β-Ti-Nb thin film having adequate composition and thickness so that the coating would enhance the material biocompatibility. In this work, β-Ti-Nb coatings were de-posited on AISI 316L SS substrate by magnetron sputtering, and four compositions were produced: Ti85Nb15 (Ti-26 wt. % Nb), Ti80Nb20 (Ti-33 wt.% Nb), Ti70Nb30 (Ti-45 wt. % Nb), and Ti60Nb40 (Ti-56 wt. % Nb). The coatings were characterized by atomic force microscopy (AFM), scanning electron microscopy SEM), energy-dispersive X-ray spectroscopy (EDS), transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS). The mechanical properties were assessed by nanoindentation and scratch tests. The elastic modulus and the hardness values were in the ranges of 91.8-95.4 GPa and 5.4-7.4 GPa, respectively. No detachment of the coatings was detected.

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Development and optimization of small diameter copper electro-formed getter coated vacuum chambers

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The trend in electron accelerators design consists in approaching the poles of the steering magnets close to the electron beam. This implies reducing the bore hosting the vacuum chamber and using very small diameter vacuum pipes 1. The application of functional thin films as getters by physical vapor deposition in such small diameter chambers becomes then very difficult. The aim of this project is to develop a novel procedure of coating/assembly, using a sacrificial mandrel as substrate of the thin film together with the creation of a surrounding copper chamber by electroforming [2]. The electroforming process should integrate the stainless steel vacuum flanges to the copper tube. This technology could enable to produce chambers of small diameter or complex shape, which fulfil

the necessary criteria of vacuum tightness and low outgassing rate while keeping the best getter performance for the application in ultra-high vacuum systems of particle accelerators. As low as 3 mm diameter coated vacuum chambers were successfully produced using this method. After process optimization, TiZrV getter coating showed a good H2 pumping performance with slightly delayed activation temperature compared to reference NEG coating values.

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Vacuum Science & Technology / **413**

Development of a Neutral Gas- and Ion-Mass Spectrometer for Jupiter's Moons

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The exploration of habitable environments around the gas giants in the Solar System is of major interest in upcoming planetary missions. Exactly this theme is addressed by the Jupiter Icy Moons Explorer (JUICE) mission of ESA, which will characterise the Jovian moons Ganymede, Europa and Callisto as planetary objects and potential habitats.

We developed a prototype of the Neutral gas and Ion Mass spectrometer (NIM) of the Particle Environment Package (PEP) for the JUICE mission intended for composition measurements of neutral gas and inflowing ions from thermal plasma. NIM will be used to measure the chemical composition of the exospheres of the icy Jovian moons.

Based on the ion-optical design we developed and tested the prototype NIM under realistic mission conditions and thereby successfully verified its required functionality. An important aspect of the instrument operation and thus for the testing and verification phase are of course the established vacuum conditions. An overview of the JUICE mission with special focus on the design, development and verification in vacuum of the NIM prototype will be given in this presentation.

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Grain boundary segregation in binary alloys: Prediction of thermodynamic characteristics and interaction coefficients

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Grain boundary segregation is a phenomenon studied both experimentally and theoretically for decades. The interest in this phenomenon is evoked not only by its close relationship to temper embrittlement but also by its ability to stabilize nanocrystalline structures by solute segregation in the concept of Grain Boundary Engineering.
A full description of the exact temperature and solute concentration dependence of grain boundary segregation requires reliable values of segregation enthalpy and –entropy as well as solute inter-action coefficients. However, experimental studies of all these values are rather limited, and the-oretical studies are usually restricted to segregation energy at zero Kelvin. It is obvious that such a database does not allow a full description of the grain boundary segregation in most systems of interest.
In this contribution we present a semi-empiric method enabling prediction of all required thermo-dynamic parameters – ideal enthalpy, ideal entropy and real binary interaction (Fowler) coefficient – which, in combination, describe fully the segregation of any segregant at any temperature and at individual grain boundaries. This method is based on the relationship between the segregation enthalpy and the solid solubility limit, and on the enthalpy-entropy compensation effect. The data for numerous solutes in alpha iron are predicted and they are compared to available data in the literature.

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Surface modification of a TiN coated steel by ion beam dynamic mixing

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The surface modification of a TiN coated steel was conducted by ion beam dynamic mixing (IBDM) with an ion energy of 70 keV and boron vapor deposition in order to investigate the mixing phenom-ena and to produce a mixed layer consisting of boron, titanium and nitrogen. The modified surface prepared at a boron/ion arrival ratio less than 2.2 has a convex-concave shape having a striped habit. It has been suggested that the striped convex-concave shape was developed by the "shadow effect" for the boron deposition and by the energetic ion irradiation to a initial irregularity, which may be initiated by the boron atoms acting as seeds or impurities. The mixed layer having a flat surface was not obtained except the surface layer having flat but boron-rich composition at greater boron/ion arrival ratios. From the point, where the modified layer is utilized for the under layer of the c-BN, it has been demonstrated that the roughened surface having periodically a 220 nm depth and a 200 nm separation, which may improve the adhesion of cBN thin films by the anchor effect, is produced. It has also been suggested that the boron-rich layer produced at the high boron/ion arrival ratio by IBDM possibly works well as that produced by an ion plating.

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Advancement in transient flow simulation: application to measurements of porous media permeability and tube conductance

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Investigations performed on gas flows at a microscale have become of great interest for various applications that touch almost every industrial field, such as mass flow and temperature micro sensors, micro pumps, micro-systems for mixing or separation for local gas analysis, mass spectrometers, pressure gauges, dosing valves and micro heat exchangers. Among these applications the gas flow through the low permeable membranes, which are also the flows at microscale, have also a great interest, especially in vacuum technology for filtering, separation process, protection and flow control. Recently some advancement in the transient flow simulation, based on the gas kinetic theory, was proposed in 1. Using this approach, the experimental determination of the tube conductance is realized in [2]. The very similar approach is also proposed recently to characterize the permeabilityof the porous media like the low porous membranes. Different examples of the application of the proposed methodology are shown for various type of porous media et different gases.

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”Devil’s staircase” of phase transitions in the model of dimer adsorption: computational study of thermal stability

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The term “devil’s staircase” of phase transitions is used to refer to an infinite sequence of ordered phases in a finite volume of the phase space. This phenomenon has a great potential for produc-tion of two-dimensional nanoscale objects, because one can create an infinite number of different ordered structures with different cell periods and properties using only one type of building blocks (molecules in particular case) 1. Understanding of the patterns and driving forces of self-organization in such systems can be employed for production of nanoelectronic devices (molecular electronics, sensors, functional surfaces, etc.) and of highly-selective heterogeneous catalysts.
Recently we have proposed the adsorption model for dimer molecules on hexagonal lattices [2] and have discovered the “devil’s staircase” phenomenon for the ground state of the model. In this case the key factor causing the emergence of an infinite number of ordered structures in a finite phase space volume is the presence of two concurrent types of adsorption – horizontal and vertical adsorp-tion of dimer. Lateral interactions between adsorbing species are simple and short-range – hard-wall potentials, which prohibit adsorption on nears-neighbor sites of already adsorbed molecules.
The existence of the “devil’s staircase” for the ground state of the model do not guarantee its exis-tence for non-zero temperature.
In this work we have confirmed that the sequence of ordered phases of dimers on hexagonal lattice persists at non-zero temperatures. It was shown that least five ordered phases are stable through two numerical methods in the SUSMOST code [3]: transfer-matrix and Monte Carlo (Fig.1).

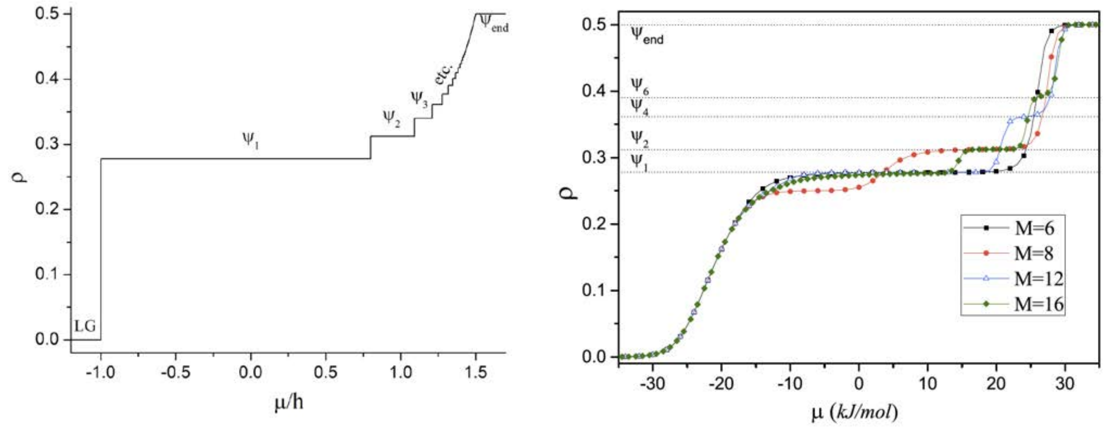

Figure 2: Adsorption isotherms as function of chemical potential in the ground state (left) and at T=200K for different lattice width M (right)

Acknowledgments: this study was supported by the Russian Science Foundation under grant 17-71-20053.
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Temperature stability of decorative electro-magnetic transparent metal-semiconductor thin-films

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Electro-magnetic transparent decorative coatings with a metallic appearance are highly desirable for military, automotive and communication applications. Inherently, a metallic film interferes with electromagnetic radiation rendering it unsuitable for these applications. Hence, metal-semiconductor alloy thin films were investigated, as their electromagnetic transparency and optical properties can be controlled.1 One challenge for these coatings is to maintain their properties during thermal events, either during manufacturing into a final device or as a result of environment conditions during use. Metal-semiconductor thin films have the inherent advantage that the optical and electrical proper-ties of the thin film can be manipulated in multiple ways. The properties of the thin films can be controlled not only by changing the alloy composition, but also by varying the deposition process parameters.
This project investigates the influence of processing parameters and thin film composition on the electro-magnetic transparency, as well as the optical properties of these coatings.
However, their suitability for high-temperature applications or processing has to be investigated. Therefore, the optical and electrical properties of these thin films have been studied for relevant process temperatures of up to 240 ℃. Their properties were analysed and compared post processing.

It was revealed that after processing the thin films at relevant temperatures, the properties changed. Possible mechanisms include oxidation, phase changes, grain formation, grain size changes and changes along grain boundaries. This information will be used to select composition and process properties so that these films can be used in a number of applications.

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Surface Science Modelling and Simulation Toolkit - bridging the gap between theory and experiment for self-assembled monolayers

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Recent advances in experimental techniques revealed a huge variety of structures that emerge in ad-sorption monolayers. For their practical application it is necessary to develop methods and tools of rational design of self-assembly processes. Drug industry experience proves that for rational design of molecular systems, computer modeling tools are invaluable. Using computer models the most promising molecules and parameter ranges can be chosen for experimental checks. Surface science routinely use methods of density functional theory (DFT) and molecular dynamics, largely due to existence of robust computer codes that allow "black box" usage. But outcomes of these methods are hard to compare with experiments. Statistical physics methods predict equilibrium properties and are much closer to experimental capabilities. In many studies such methods (Monte Carlo gener-ally) implemented in in-house codes are used for investigation of specific systems. But exploratory researches need a universal yet efficient code. We have generalized our experience in computa-tional studies of self-assembled monolayers in Surface Science Modeling and Simulation Toolkit (SuSMoST) and offer it to surface science community – http://susmost.com/ (supported by Russian Scientific Fund, project No 17-71-20053). The SuSMoST code is based on the general lattice model 1 that is able to describe a wide range of adsorption systems. Being formulated on tensor-network lan-guage it provides a common ground for several efficient algorithms with various accuracy and costs (Monte Carlo, transfer-matrix, renormalization approach). SuSMoST automates many tasks of theo-retical analysis of adsorption systems: computation of lateral interaction energies with DFT, phase diagram estimation, calculation of phase transition points, isotherms and isobars plotting.

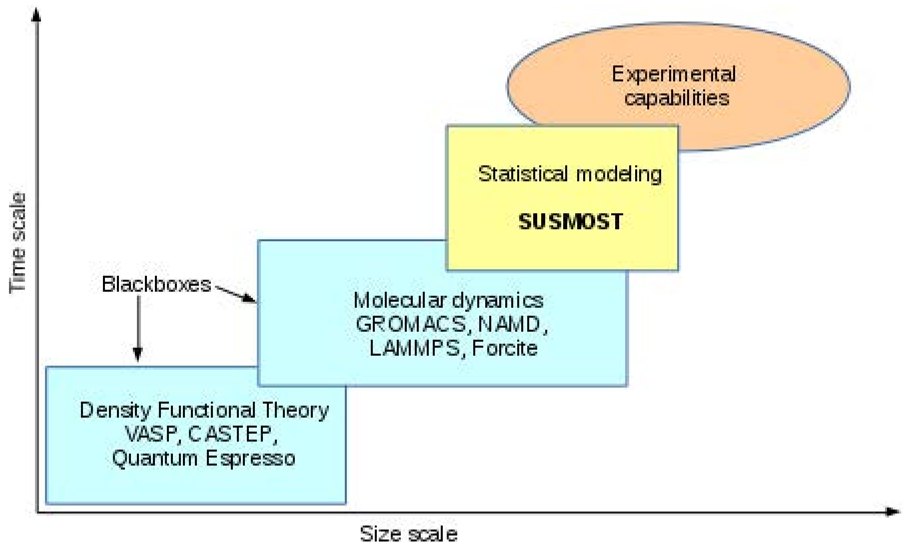

Figure 3: SuSMoST bridges the gap between theory and experiments

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Investigation of the influence of molecular and atomic nitrogen ion species during epitaxial nitride thin film growth

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Ion beam assisted deposition (IBAD) enables the engineering of thin film properties by tuning the mobility of adatoms and controlled defect generation during thin film growth. Utilizing ions of hyperthermal kinetic energy in the range of a few 1 eV up to only a few 100 eV the influence of im-pinging ions on a solid material is limited to the near surface region and hence allows the deposition of compact ultrathin epitaxial films that simultaneously exhibit high crystalline quality. Typically, ion beams in this energy regime are produced by plasma-based ion sources that feature a blend of multiple ion species at distinct, superimposed ion kinetic energy distributions.
In this work, an energy and mass selected ion beam is created, characterized and utilized to deposit epitaxial GaN nanofilms at elevated temperatures. The ion species are separated by a custom and compact quadrupole mass filter system. This well established material system is used to indepen-dently investigate the influence of hyperthermal molecular and atomic nitrogen ion species on the resulting film properties during the initial stages of the film growth. In addition, ion energies and material fluxes are varied. The crystalline quality, epitaxial relationship and defect incorporation of the resulting films are evaluated *in situ* by reflection high-energy electron diffraction (RHEED) and *ex situ* by X-ray diffraction (XRD), Raman spectroscopy and transmission electron microscopy (TEM). Film thickness and surface topography are determined by X-ray reflectometry (XRR) and atomic force microscopy (AFM). A correlation between the distinct material fluxes and the resulting growth rate as well as the nucleation process is determined and compared for each ion species. The effects of ion beam sputtering and ion beam induced defects are assessed in dependence on the ion kinetic energy and mass.

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Determination of the pressure in a TO vacuum package using a micro Pirani

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Numerous MEMS components such as acceleration sensors, gyroscope sensors, ultrasonic sensors or micro-resonators require vacuum packaging in order to reduce the gas friction of the mechanical moving parts. While these applications work already in fine vacuum, for field emission based electron or X-ray sources, high vacuum is required to avoid ion bombardment and arcing in order to achieve a long lifetime.
We developed a micro Pirani sensor with a measurement range from atmospheric pressure down to 5e-5 mbar to determine and to monitor the pressure in hermetic sealed vacuum packages. This Pirani was mounted on a TO header. Subsequently, the housing was sealed by soldering a cap on the TO header in vacuum atmosphere at 1e-6 mbar. After this sealing process, a pressure in the range of 1e-2 mbar was determined inside the vacuum package with a volume of about 4.5 cm^3. This significant increase of the pressure was attributed to outgassing of the components. For the most MEMS applications, the quality of vacuum sealing is sufficient, but not for encapsulated field emission devices. Therefore, a new TO package with a micro Pirani and an additional getter material was built. After the sealing process, the pressure inside the package was reduced to a pressure below the micro Pirani's resolution limit of 5e-5 mbar by the thermally activated getter.
For the first time, it was possible to measure such a small pressure in a hermetically sealed TO package.TO vacuum packages as well as packages on wafer-level can be further optimized by using this method of determining and monitoring the pressure. In the next step, the measurement range of Pirani sensor will be further extended in order to measure the total pressure achieved by the getter material.

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Microscopic insights on properties of morphologically complex materials using advanced synchrotron-based methods

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The invent complex nano-structured and composite materials with improved structural, chemical, electric, magnetic and optical properties has pushed the development and implementation of appropriate characterization methods exploring their structure, dynamics and function at proper spatial, temporal and energy scales. In this respect the complementary capabilities in terms of imaging, spectroscopy, spatial and time resolution of the tools operated at 3rd and 4th generation synchrotron facilities have opened unique opportunities to explore the properties of complex functional materials as a function of their size, morphology, composition and operation conditions. Ongoing developments are pushing the lateral and temporal resolution and set-ups allowing for in-situ measurements under realistic operational conditions. The most recent achievements will be illustrated by using selected results from studies of the properties of technologically relevant multicomponent materials following the effects of the chemical ambient, temperature, electomagnetic fields and radiation. The talk will include (i) properties of free-standing nanostructures as a function of composition, dimensions and ambient [1, 2]; (ii) variations in morphology and chemical state of key functional constituents

in electrochemical devices as a function of growth or operating conditions [3-5]; (iii) tracking the ultrafast dynamics triggered by external stimuli with access to elemental and/or magnetic structure of the specimen [6].

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Remote Anode Assisted Magnetron Sputtering (RAAMS) of Cr-based Hard Coatings for Tribological Applications

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In the vacuum surface engineering sector, ionized PVD and PE-CVD techniques are currently attract-ing a high degree of attention in producing high quality tribological surfaces with low friction, which exhibit high wear and corrosion resistance. Economical production for such high-quality surfaces is a significant driving factor for sustainable growth in coating manufacturing. In this direction, a cost-effective, commercially viable ionized PVD technology has been developed called RAAMS (Re-mote Anode Assisted Magnetron Sputtering) for tribological solutions.
Thick 6 µm, CrN and Cr2N coatings were deposited on hardened-high and low carbon steels with the RAAMS technology. Using this deposition method, coatings with good mechanical, tribological properties are applied to components with very high deposition rates (300 nm/min). SEM investiga-tions of coating microstructure has shown dense, non-columnar morphology throughout the coating thickness. Importance was given to understand the influence of Remote Anode Assisted Discharge (RAAD) conditions on the microstructure, stress and mechanical properties of the coating. An en-ergy resolved mass spectrometry study was carried out to monitor the energy and composition of Cr+ ions during the RAAMS deposition process. Time-averaged and time-resolved ion energy spectra for Ar+ and N+ was also recorded. Variation in the Cr+ to gas ion flux with respect to different RAAMS parameters were investigated. Tribological Ball-on-Disk testing conducted under initial Hertzian stress up to 650 MPa under dry sliding conditions against Al2O3 ball have shown low friction with COF between 0.2-0.3 and wear rate in the order of 10-6-10-7 mm3/N-m. Finally, the importance of commercial RAAMS technology in producing tribologically superior CrN, Cr2N coatings is briefly explained.

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Ion pump design to minimize particle emissions

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Ion pump design to minimize particle emissions

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Ion pumps are widely used in very sensitive applications such as Particle Accelerators and Electron Microscopes , where particles emitted from the vacuum pumps can heavily affect the performance of the machine or the resolution of the instrument .
Neutral and charged particle emission from ion pumps has been analyzed and its dependance on pressure, operating voltage and element geometry is discussed .
Optical shields are a common solution to limit particle emission , but the resulting conductance limitation is usually a major concern for the performance of the pump itself .
A specific ion pump element designed to minimize the particle emission while maintaining a high fraction of the original puming speed is described

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Outgassing and gas uptake properties of vacuum and 3D printed materials

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The outgassing rate and gas uptake properties of materials is important for a variety of applications. One example is vacuum; vacuum chambers designed for UHV or XHV (ultra-high or extreme-high vacuum) applications often require outgassing rates on the order of 10-11 Pa L/cm2/s or better, and ultra-low outgassing rates are also required for any materials used within the UHV or XHV systems. Other applications that concern outgassing and gas uptake include gas sensors and gas storage media. Recently, NIST has developed a program for studying outgassing rates and gas uptake properties of materials for the applications mentioned above. However, two specific projects are of primary concern. Firstly, NIST is interested in creating portable sensors based on ultra-cold atoms, such as the cold-atom vacuum standard (CAVS) and other sensors. Such devices will require ultra-low outgassing rates over the lifetime of the device. Outgassing concerns range from the packaging to the alkali-metal dispensers (alkalis such as Rb or Li are used as the cold-atom sensors) to fiber-optic feedthroughs. Materials considered include traditional vacuum materials such as stainless steel, as well as newer materials such as those produced by 3D printing. Second, NIST is interested in studying the gas uptake properties of composite 3D printed materials, such as MOF-ABS composites (metal-organic framework and acrylonitrile butadiene styrene). Such novel and unique materials may be used for gas storage or sensors. Resent outgassing and gas-uptake results from each of these projects will be discussed.

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In-situ electrical characterization on dipole formation on MoS2 by atomic layer deposition

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2D-TMD (transition metal dichalcogenide) materials are potential channel candidates for future semi-conducting applications. There are various challenges facing the implementation 2D TMDs into high performance transistors. Key among these issues is the development of a scalable gate dielectric formation and its influence on TMD channel performance. In this presentation four deposition pro-cesses are studied using a novel, in-situ electrical characterization system.

Exfoliated MoS2 backgated devices are loaded into an ultra-high vacuum (UHV) cluster tool which integrates a thermal ALD, a plasma enhanced ALD, and a plasma enhanced chemical vapor depo-sition with a UHV electrical probe station. Thermal ALD of Al2O3, both alone and combined with nitrogen radical surface functionalization, hollow cathode nitrogen plasma surface functionaliza-tion, and ozone surface functionalization are studied. Samples are transferred between deposition and characterization chambers under UHV conditions, allowing "half-cycle" studies to be performed. Common to all results, as well as ex-situ studies, the ALD process results in a reduction of the on-off ratio, an increase in drive current, and a large negative shift in the threshold voltage (Vth). The shift in Vth can be seen immediately after the functionalization step or from the first ALD pulse if no functionalization is performed. In the case of functionalization, the shift in Vth is attributed to the oxidation of the MoS2 surface, a result of oxygen contamination during radical functionalization. The effect of surface dipoles, precursor adsorption and coverage, and nucleation during the ALD process will be discussed as they relate to the electrical characteristics of the device.

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Argon Cluster XPS Depth Profiling of Metal Oxide Thin Films

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In XPS, argon gas cluster ion beams (GCIB) are an exciting new tool for sputter etching and depth profiling of materials. However, little is currently known of their effectiveness in reducing preferential sputtering compared to monatomic argon bombardment for many technologically important inorganic compounds. In this work, XPS depth profiles through various metal oxide thin films using monatomic and cluster beams using different GCIB parameters will be presented. Comparisons will be made between preferential sputtering and other important depth profiling parameters using argon monatomic and cluster beams. It will be shown that the response of the material and quality of the GCIB depth profiles is strongly dependent of the GCIB parameters. Using specific experimental conditions, the degree of preferential sputtering for all of the metal oxides studied could be reduced or eradicated using the argon GCIB compared to the monatomic source. Molecular dynamic simulations of cluster impacts will be employed to inform the discussion of the results.

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Plasma-based substrate modification for highly c-axis oriented growth of AlN and $Al_{1-x}S_{cx}$N thin films by reactive magnetron sputtering

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Highly piezoelectric wurtzite-type $Al_{1\ x}Sc_xN$ thin films (d_{33}=27.6 pC/N for x=0.43 1) are a promising alternative to AlN in different microelectromechanical systems (MEMS), such as surface acoustic wave (SAW) or thin film bulk acoustic wave resonators (TFBAR) used in RF filtering, sensing, and energy harvesting applications, allowing smaller and more efficient devices to be produced. How-ever, different crystal structures of binary components, i.e. wurtzite-type AlN and cubic ScN result in formation of metastable ternary $Al_{1\ x}Sc_xN$ prone to phase separation and elemental segrega-tion. It is well known, that the well-ordered microstructure and high degree of c-axis orientation in piezoelectric AlN thin films directly correlates with higher electromechanical coupling and lower acoustic losses. Achieving high material quality becomes even more challenging for metastable materials such as $Al_{1\ x}Sc_xN$. After first eliminating the misoriented grains in sputtered $Al_{1\ x}Sc_xN$ thin films by tuning Ar/N_2 gas ratio and target-to-substrate distance [2,3], we aim to furthen-hance the crystalline quality of our AlScN thin films by using plasma-based substrate modification. In this work, reactive pulsed-DC magnetron sputtering was used to grow AlScN thin films on Si(001) and Al_2O_3(0001) substrates with thicknesses up to 1000 nm. *In-situ* inductively coupled plasma (ICP) soft etch with Ar, N_2, and H_2 gasses was used to treat the substrates prior to growth and the changes in the film nucleation behavior and how the quality of subsequently grown $Al_{1\ x}Sc_xN$ thin films was affected will be shown as a function of pressure, plasma chemistry, RF bias,and ICP power based on X-ray diffraction, piezoresponse force microscopy and electrical measurements.

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Scanning helium microscopy (SHeM), contrast mechanisms, resolution and sensitivity in a new imaging technique

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Microscopy has been a major enabling technique for the development and understanding of materi-als from the bottom up. Some of the major insights in the development of modern materials have come from scanning probe, electron and ion microscopies, with advances in resolution and sensi-tivity enabling new material science. Unfortunately charged beam techniques tend to cause surface damage and scanning probe techniques are limited to relatively flat surfaces and suffer from limited scan speeds.
In the current work we present recent advances in the development of neutral beam microscopy. In collaboration with colleagues at the University of Newcastle, NSW, we have recently published some of the first reflective mode images measured with a neutral helium beam [1,2]. Using a neutral beam of helium atoms at very low energy (<100meV) and with a de Broglie wavelength of around 1Å[1,2] the aim of the project is to deliver uniquely surface sensitive images with atomic resolution and no surface damage. Helium microscopy is suitable for measuring a variety of samples includ-ing insulator, semiconductor, explosive, biological and 3D self-assembled materials and being a real space technique will not involve complicated post processing techniques.
Helium atom microscopy has been in development for some years internationally. Many of the technological barriers, for example helium focusing, sample preparation and nanoscale manipula-tion have now been addressed to enable preliminary instruments to be developed[1,2,3], however detection of neutral beams remains a challenge, particularly for helium given its high ionisation en-ergy[3]. Applications that require time sensitive measurements require a small ionisation volume; however, when high temporal resolution is not required, ionisers having a much larger volume are possible. We describe a detector developed on the basis of recent successful results[8] applied to sur-face spin-echo experiments[5,6,7] and having a sensitivity of 0.83A/mbar, the highest yet reported for helium atoms.
Finally we discuss contrast mechanisms other than topographical in origin and discuss various al-ternatives, and applications of the technique.

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Comparative Measurements of Ion Pump pumping speed according to ISO/DIS 3556 and DIN 28429

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Sputter Ion Pumps (SIP) offer an appealing strategy to efficiently maintain ultra-high and extremely-high vacuum conditions in a vacuum chamber. The pumping speed, i.e. the volume flow of gas extracted from the vacuum in a specific period of time, can be determined according to various standards. However, recorded pumping speeds may vary severely, depending on the standard chosen and the detailed procedure applied. This talk compares experimentally obtained pumping speeds of several SIPs, acquired according to the most commonly applied standards, DIN 28429:2014-05 and ISO/DIS 3556-1.2(1992).

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Deep oscillation versus direct current magnetron sputtering of AlN thin films for acoustic biosensors

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The potential to produce adequate Al/AlN films to be used in acoustic biosensors via deep oscilla-tion magnetron sputtering (DOMS) and direct current magnetron sputtering (d.c. MS) was compared. The films were deposited on 304L stainless steel substrates and extensively characterized by scan-ning electron microscopy + energy dispersive microanalysis, glancing angle x-ray diffraction, and optical profilometry. The results indicate that both methods are capable of producing the required AlN hexagonal crystal structure and (002) orientation, however, the higher ionization fraction and adatom mobility provided by DOMS, seemed to provide better microstructural features. Preliminary biofunctionalization experiments suggest that these differences in film morphology may affect the attachment of the biomarker of interest.

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One-photon and two-photon photoemission studies on hydrogenated TiO2 surfaces

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Titanium dioxide (TiO2) surfaces are of importance and interest in various aspects including photocatalytic H2 generation and hydrogen sensors. Furthermore, hydrogen-doped TiO2 has recently acquired much attention due to its excellent photocatalytic activity 1. In these regards, interaction of hydrogen with TiO2 surfaces is of particular importance. In our previous study, we have inves-tigated the interaction of hydrogen with the rutile TiO2(110) surface with nuclear reaction analysis and ultraviolet photoemission 2. The electronic excited state was, on the other hand, studied with two-photon photoemission on clean TiO2(110) [3]. In the present paper, we report one-photon and two-photon photoemission results on hydrogenated TiO2(110).

The sample was prepared by exposing clean TiO2(110) to either atomic hydrogen or a hydrogen ion beam, and one-photon and two-photon photoemission spectra were measured with the HeI source and laser light at 3.35-3.85 eV, respectively. Whereas an in-gap state was observed at about 1 eV below the Fermi level after atomic hydrogen dosage, the in-gap state intensity was considerably en-hanced after hydrogen ion irradiation. The two-photon photoemission spectra revealed a feature at about 6.5 eV above the Fermi level, which is similar to the one observed on the clean surface [3]. The intensity of the feature was also found to be dependent on the polarization. The electronic structures of the hydrogen-adsorbed and hydrogen-ion-irradiated surfaces are discussed.

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Design and Manufacturing of a wireless SAW-Pirani sensor with extended range

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Pressure is a key parameter for a large number of industrial processes. Amongst others, vacuum industry relies on accurate pressure measurement and control. Designing a single device being able to sense from very high vacuum to atmospheric pressure is a challenge to an interdisciplinary research community, leading to the development of a variety of pressure sensors using different operating principles and still handling diverging pressure ranges.
In this publication an attempt to design a compact wireless sensor handling pressures between 10-4 Pa and 105 Pa is presented. This sensor may be competitive to sensors available in the market suit-able for micro and macro applications. Operating the sensor wireless helps to prevent leakage and maintain vacuum.
The sensor is combining the well-known Pirani effect with Surface Acoustic Waves, which allows to extend the sensing range. Surface Acoustic Waves propagate on the surface of piezoelectric sub-strates. Their phase and resonance frequency are sensitive to properties of the surrounding environ-ment such as temperature and pressure.
SAW-Pirani sensors use the same operating principle as a conventional Pirani sensor since the heat losses of the substrate are proportional to the gas pressure in contact with the surface. However, the variation of the surface temperature is transduced in this case into a frequency shift that can be measured via a wireless interrogation signal.
The core of the presented sensor device consists of a 1 cm3 polymer cube crossed in its center by a microchannel. The sensing chip is located inside the crossing channel. The chip is heated via a wireless power charge receiving coil. It is interrogated via a microantenna printed on the bulk of the cube. A thermal analysis and simulation allowed to set the dimensions of the device. The manufacturing of the prototype started with the sensing chip. It consists of a Lithium Niobate substrate with an Interdigital Transducer (IDT) surrounded by a Joule heating resistance at its sur-face. The IDT is etched using electron-beam lithography.
The chip will then be integrated to the core of the sensor using bumps allowing minimum physical contact with the polymer.
The interrogation antenna is designed to fit with the needs of the sensor in terms of dimensions, reflection coefficient, power transmission distance and impedance matching. The sensor shall be interrogated from a distance of about 3 cm.
Preliminary results of the prototype testing and their comparison with the expectations of the design and the simulation will be presented.

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Photoelectron spectroscopy using high-order harmonics at megahertz repetition rates: study of correlated electron pairs in solids

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With the progressive development of femtosecond lasers, high-order harmonic generation (HHG) has become a standard technique to produce a widely tunable photon energy spectrum in the laboratory. However, the application of HHG-based light sources to electron spectroscopy and microscopy has been limited by the space-charge effects at kilohertz repetition rates of high power laser systems. With our recent development of an HHG-based light source at megahertz repetition rates using a compact fiber laser, we have demonstrated an efficient combination with time-of-flight electron spectrometer for laboratory photoelectron spectroscopy [1,2].

In this contribution we will report the advanced application of our MHz HHG-based light source to double photoemission (DPE) spectroscopy on solids, where pairs of correlated valence electrons are photoexcited and analyzed with energy- and momentum-resolution. With photon energies of 25 and 32 eV, we discover detailed structures in the energy distribution of electron pairs from Ag(001) and Cu(111) [3]. In the two-dimensional DPE energy spectra, distinct features with well-defined sum-energies of electron pairs are identified. These two-electron features can be attributed to the emission of correlated sp- and d-electrons as well as to two correlated d-electrons. The results will be compared with the self-convolution of density of states and discussed in terms of electron correlation.

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Gas Modulation Refractometry for High-Precision Assessment of Pressure under Non-Temperature-Stabilized Conditions

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We report on the realization of a novel methodology for refractometry — GAs MOdulation Refrac-tometry (GAMOR) — that decreases the influence of drifts in Fabry Perot cavity refractometry. The instrumentation is based on a dual Fabry-Perot cavity (DFPC) refractometer in which one cavity is used as the measurement cavity while the other serves as the reference. The GAMOR methodol-ogy comprises a repeatedly filling and emptying of the measurement cavity to recurrently assess the beat frequency from an empty cavity. This opens up for the use of refractometry under non-temperature-stabilized conditions. A first version of a GAMOR methodology has been realized and its basic performance has been scrutinized. It is based upon a DFPC refractometer made of Zerodur and tunable narrow linewidth fiber lasers operating around 1.55 μm, at which there are a multitude of off-the-shelves optical, electro-optic, and acousto-optic components (of which many are fiber coupled). The system is fully computer controlled, which implies it can perform unattended gas as-sessments over any foreseeable length of time. When applied to a system with no active temperature stabilization, the GAMOR methodology has demonstrated a three orders of magnitude improvement of the precision with respect to static detection. When referenced to a dead weight pressure scale the instrumentation has demonstrated assessment of pressures in the kPa range (4303 and 7226 Pa) limited by white noise with standard deviations in the 3.2 - 3.5 mPa(# of measurement cycles)^(1/2) range. This implies that for short measurement times the system exhibits a (1 sigma) total relative precision of 0.7 (0.5) ppm for assessment of pressures in the 4 kPa region and 0.5 (0.4) ppm for pres-sures around 7 kPa, where the numbers in parentheses represent the part of the total noise that has been attributed to the refractometer. The inherent properties of the GAMOR methodology open up for a variety of applications within metrology. It does not only have the potential to compete favor-ably with manometers for assessments of gas pressure, it can also be used for transfer of calibration between different pressure regions and characterization of a variety of pressure gauges, including piston gauges. Besides presenting the overall technique, its strength and limitations, we will present the latest upgrades to our system, as well as new improved results.

Poster Session Tuesday / 112

Research on the accumulation leak detection method of helium mass spectrometry based on low vacuum

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At present, non-vacuum accumulation leak detection method and vacuum leak detection method are widely used in the total leakage rate test of spacecrafts. But there are some problems of non-vacuum accumulation leak detection method, such as low leak detection sensitivity, long test period and so on. While the vacuum leak detection method has the problems of high construction cost and complicated operation. Therefore, it is necessary to study a kind of accumulation leak detection method of helium mass spectrometry based on low vacuum, in order to improve the leak detection sensitivity while reduce the construction cost as much as possible. In this paper, the feasibility of accumulation leak detection method of helium mass spectrometry based on low vacuum was studied from theoretical aspect firstly. Secondly, the optimum vacuum degree of leak detection, repeatability of experiment results and leak detection sensitivity had been tested. The results show that the accumulation leak detection method of helium mass spectrometry based on low vacuum has a higher leak detection sensitivity and good repeatability.

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The Study of Influence of Ambient Humidity on Vacuum Capacitance Diaphragm Gauges

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The capacitance diaphragm gauges play important role as the precise secondary vacuum standard in the range from atmospheric pressure down to the absolute pressure at mPa level.
One of the important factor capable to influences pressure measurements due to its effect on pressure sensors and electronics is humidity level of the ambient air. The surrounding humidity forms the equilibrium water molecules layers on all surfaces and may affect the measured capacitance.
The study concerns of new design sensors and electronics that are hermetically sealed and backfilled with nitrogen, in order to prevent humidity influencing the sensor signals. The measurement was performed using the gauges designed by INFICON LI.
CMI has tested the performance of the new sensors and electronics at variable conditions using their FPG primary absolute pressure standard as the reference. The study was done for three triads of CDG gauges in ranges of 133 Pa, 1333 Pa and 13 332 Pa at different ambient air humidity levels. The procedure, uncertainty analysis, results and discussion are presented.

Poster Session Tuesday / 368

A new calibration method and apparatus of vacuum mass spectrometer

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Abstract
The vacuum mass spectrometer is a kind of vacuum gauge for partial pressure measurement. For many vacuum applications, the partial pressure for given gas is of more interest than the total pressure of the gases in a system. If precise measurement of the partial pressure is needed, the calibration of mass spectrometer is necessary. However, the sensitivity for one gas in a mixture was changed as other gas pressure was varied. Therefore, for a specific measurement object, the specific standard sample mixture must be used to calibrate mass spectrometers. A new calibration method of vacuum mass spectrometer from 10-9 Pa to 10-5 Pa for He, N2, Ar, O2, Ne has been put forward. The exper-imental apparatus has been set up. The calibration apparatus is composed of pumping system, gas supply system, standard sample system, inlet system and calibration system. The gas flow between the inlet orifice and pumping orifice realized molecular flow in low pressure region. Two orifices were designed to be molecular flow conductance for mixture gases passing through them, which makes the gases proportion in the calibration chamber similar to that in the inlet chamber and in the standard sample chamber. Under the condition of molecular flow, the gases proportion was kept constant and sensitivities for different gas species were almost kept constant. With increasing the pressure of inlet chamber, the gas flow will deviated from the molecular flow region and sensitivi-ties changed largely from one gas to another. The sensitivity calibrated with single gas was different from that calibrated with mixed gas.
Keywords: calibration, vacuum mass spectrometer, molecular flow, standard sample gas mixture
Topic of the contribution vacuum calibration

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Development of Vacuum Calibration Apparatus for Planetary Exploration

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The growing numbers of missions for exploration of deep space environment has put forward complicated challenges for the field of vacuum metrology. Some suggests that to use 'shield' for protection of the vacuum gauges from external environment, especially temperature which affect the vacuum manometer reading significantly. However, the shield leads to increased mass, volume, power consumption at the expense of reduced reliability of the gauge. To develop less complicated gauges with stable performance, it is necessary to calibrate the vacuum gauges according to predicted working conditions rather than solely rely on laboratory parameters such as room temperature and single gas species. This study reports on a newly developed vacuum calibration apparatus for simulation of space environment. It is composed of gas supply system, pump system, temperature control system, pressure measurement, calibration system, bake system, data acquisition and control system. Through two years of experimentation, it can meet the requirements for calibration of vacuum gauges intended for planetary exploration. This work is beneficial for space technology but also industrial production. Our group is working on improving the design for greater accuracy.

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Flow Field Calculation and Optimization of Spiral Groove Dry Seal for Screw Vacuum Pump

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Screw vacuum pump, with a fully enclosed vacuum pumping process, integrates the latest achievements of mechanical, electronic control, thermodynamics and other disciplines. It has wide application prospects in raw materials chemical, chemical synthesis, drying, concentration and other fields. Dry gas seal is a new type of non-contact shaft seal on the basis of gas-lubricated bearing seal. The most used type of dry gas seal is the spiral groove seal. This study focused on the flow field calculation and the geometric parameters optimization of a single end face spiral groove dry gas seal for screw vacuum pumps. CFD method based on the coupled thermo-mechanical deformation was performed to simulate the flow field of spiral groove dry gas seal. Orthogonal method was carried out to optimize the structural parameters of spiral groove dry gas seal face. The dry gas sealing performance is further clarified by detecting and comparing the leakage rate of screw vacuum pump equipped with the optimized dry gas seal structure and the conventional seal structure. Theoretical analysis results proved the feasibility of dry gas seal for screw vacuum pump. The dry gas seal could realize the zero leakage and zero escape of the sealed medium to ensure the long-term safe and effective operation of screw vacuum pump.

Key words: dry gas seal; single end face spiral groove; screw vacuum pump; flow field; chemical industry

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Pressure evolution studies in the LHC beam pipe vacuum system at room temperature

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With the increased beam energy and the upcoming high luminosity, electron cloud and synchrotron radiation could have an important impact on the LHC residual gas density and beam parameters. An innovative room temperature Vacuum Pilot Sector (VPS) is installed in a straight section of the LHC to investigate these phenomena *in situ*.
The Large Hadron Collider (LHC) is affected by electron cloud that reduces the quality of the beam, provokes instabilities, and increases the residual-gas pressure and heat load in the vacuum chambers. Synchrotron radiation, via photoelectron emission, plays also an important role on the electron cloud build-up.
This work focuses on the comparison of pressure profiles measure in the VPS with surfaces of different nature, such as mild baked copper, non-evaporable getter coating (NEG) and amorphous carbon coating.
In addition, the VPS enables to disentangle the residual gas sources, including: surface outgassing, residual gas ionisation followed by electron stimulated desorption, as well as photon stimulated desorption. The resulting pressure distribution will be presented and analysed considering surface properties and the LHC beam parameters.
The preliminary outcomes confirm that amorphous carbon coating is compatible with future LHC's vacuum requirements.

Poster Session Tuesday / 128

Comparative Vacuum Simulations for a DLSR Upgrade of PETRA III

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"PETRA III is a third generation, 2.3 km long synchrotron radiation source. While initial studies for a conversion of PETRA III towards a diffraction-limited storage ring are ongoing, first ideas on the vacuum performance are assessed in this paper. Comparative simulations between preliminary magnetic lattice upgrades and MAX IV are performed using simplified geometries and ray-tracing, transfer-matrix as well as Monte-Carlo methods, respectively. Future ideas including test setups and facilities are outlined.

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Pentacene on Au(111) and Cu(111) studied by UPS, MAES, and first-principles calculation

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The electronic properties of organic semiconductors in bulk and at interface play an essential role in characteristic charge transport in soft matter, and eventually result in performance in organic-based devices such as organic field-effect transistors, organic thin film solar cells, organic light-emitting diodes, and single molecular junctions.1 Pentacene (C22H14) is regarded as a prototype in the -conjugated organic molecules due to high field-effect hole mobility in the crystal phase. In the conference, we report following two topics investigated by ultraviolet photoemission spectroscopy (UPS), metastable atom electron spectroscopy (MAES), and first-principles calculation using the density functional theory (DFT).
I. Local electronic states at pentacene-Au(111) and Cu(111) interfaces in the static (or equilibrium) condition. Pentacene is weakly bound on Au(111), while it chemisorbs on Cu(111) forming an induced state just below the Fermi level. The He*(23S) MAES spectrum, which provides selective information on the topmost layer,2 shows that the deexcitation channel of He*(23S) (resonance ionization or Penning ionization) is governed by the electronic properties of adsorbed pentacene.
II. Local electronic states at pentacene–Au interface under bias voltage. A bottom-contact FET structure was used for the UPS and MAES measurements. Our data indicate that the transport properties of pentacene film on Au are strongly affected by the organic–metal interface (especially hole-injecting Schottky contact).3

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Poster Session Tuesday / 136

Microscopic Mechanism of Mg-Al Alloy Coating Damping Properties: A Molecular Dynamics study

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With the rapidly development of science and technology in modern industry, the failure of mechan-ical parts caused by mechanical vibration become one of the main factors of affecting mechanical performance. Hard coatings, such as metallic and ceramic coatings, were reported the outstanding damping potential by the experience. Among them, Mg-Al alloy coating was widely used due to excellent corrosion resistance and damping property. Although, it is observed that microstructures can lead to complex damping characteristics through microscopic characterization and damping tests, the mechanism of their damping mechanisms is not understood clearly, especially the effect of various microstructures on their damping properties.
Studies showed that the coating's damping characteristics are closely related on its internal microstructure, especially within the coating of micro-defects. However, the methods of experimental

research will inevitably introduce other variables result in affecting the experimental results. In ad-dition, Mg-Al alloy coating will form dislocations due to the crystal structure, preparation methods and process technology and other reasons. It has effect on the damping and mechanical proper-ties. The use of computer simulation method avoid the above problems effectively .Meanwhile, the microscopic defect scale is the nanometer level, which is difficult studied by the experience. The molecular dynamics simulation method is used to explore the effect of microscopic defects on the damping performance of the coating, which lays the foundation for the study of coating deformation and failure mechanism.
In this paper, molecular dynamics simulation method is used to analyze the mechanical properties and damping mechanism of Mg-Al alloy coating. The molecular dynamics model of different types of Mg-Al alloy coating are obtained by modeling and simulating a variety of microscopic defects such as dislocation .The stress - strain curve, the total strain energy(W), the distortion energy(△W) and the damping factor (Q-1) under different conditions can be obtained by applying the impact and cyclic stress respectively. The microstructure of the coating is analyzed by Ovito visualization soft-ware. Changing the temperature condition and applying a fixed impact to the model. The results are analyzed by curves, energy and damping parameters of the model at different temperatures. Explor-ing the factors of influencing the mechanical properties of the Mg-Al alloy coating and microscopic mechanism of damping.

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RF power conditioning of the Elettra’s cavities with UHV NEG technology.

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Elettra is a third generation synchrotron radiation light source in operation at Trieste (Italy). This light is produced by the interaction of high energy, high intensity electron beam with dedicated magnetic fields. The electron beam gains its high energy thanks to the electromagnetic field built and stored into the Radio Frequency (RF) cavities. The typical accelerating electric field of the RF cavities is in the MV/meter range and in the tens of kW RF power range. Ultra-High Vacuum (UHV) is the mandatory prerequisite to accommodate and sustain the accelerating electric field in the resonant structure like the Elettra’s cavities together with the proper choice of the manufacturing materials, high purity oxygen free copper, and the UHV cleaning procedure. The evacuation procedure of the RF cavity from atmospheric pressure to UHV is the crucial factor to obtain the full high power Radio Frequency (RF) conditioning and, therefore, full operability of the accelerating structure. Until recently, the sputter-ion pump was the best choice to reach and operate in the E-10 mbar range, while nowadays the optimized combination of a compact ion element with the Non Evaporable Getter (NEG) technology represents a valid alternative. The two technologies have been tested on the Elettra’s cavities during the RF power conditioning procedures and the results are presented here.

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Electronic properties of pristine and potassium-doped dibenzopentacene on Au(111) studied by UPS, MAES, and first-principles calculation

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Considerable attention has been paid to elucidate the electronic properties of organic semiconductors in bulk and at interface for the basic understanding and the potential application to organic-based devices such as organic field-effect transistors, organic light emitting diodes, etc. The -conjugated hydrocarbons composed of fused benzene rings are typical organic semiconductors with high hole mobility, e.g., high-purity pentacene (C22H14) crystal reveals 35 cm2 V−1 s−1 at 290 K.1 Such a high hole mobility indicates that the band-like transport is dominant, reflecting the itinerant character of electrons in the highest-occupied molecular orbital (HOMO) derived band. Another novel interest is superconductivity in potassium-doped -conjugated hydrocarbon with high transition tempera-ture (Tc), which was realized first by K3picene (Tc = 18 K)2 followed by Kxdibenzopentacene (3 ≤ x ≤ 3.5, Tc = 33 K).3 In the conference, we report following two topics investigated by ultraviolet pho-toemission spectroscopy (UPS), metastable atom electron spectroscopy (MAES), and first-principles calculation using the density functional theory (DFT).

I. Local electronic states of dibenzopentacene (C30H18, DBP) on Au(111). DBP is weakly bound on Au(111) as in the case of pentacene on Au(111). In the He I UPS spectrum, the HOMO-derived band shows the vibrational satellite due to the hole-vibration coupling. Furthermore, the He*(23S) MAES spectrum, which provides selective information on the topmost layer,4 shows that the deexcitation chan-nel of He*(23S) (resonance ionization or Penning ionization) is governed by the electronic properties of adsorbed DBP.
II. Formation of Mott-Hubbard states in K-doped DBP. For K1DBP, K2DBP, and K3DBP, two gap states due to charge transfer were observed by the UPS and MAES spectra5 and are discussed on the basis of the Mott-Hubbard model.

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The primary flow jet core in the steam-jet vacuum pump and its influence on the pumping performance at different operating conditions

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In this paper, an experimental steam ejector refrigeration system was built to measure the ejector performance at various operating conditions. The computational fluid dynamics (CFD) approach was also used to further analyse the experimental results where the internal flow behaviour cannot be fully accessed. The influence of operating pressure on the primary jet core variation and the axial jet flow velocity distribution were numerically investigated. The simulation results revealed a suitable pattern of primary fluid expansion core is essential for the ejector to be operated on critical mode

with a high entrainment ratio. When the working steam pressure is higher than the critical value, or the suction pressure is lower, the primary flow jet core over-expands and simultaneously reduces the effective area for the secondary fluid flow. Consequently, the entrainment ratio of the ejector is decreased significantly, and the normal shock is disturbed and reverse flow occurs. Eventually the ejector will completely lost its pumping capacity if the back pressure exceeded the critical back pressure excessively.

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Study of the thermal transpiration applied to a CDG with an adjustable temperature

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The so-called thermal transpiration is a phenomenon well known to users of the thermostated ca-pacitance diaphragm gauges (CDGs) at low absolute pressures below 100 Pa. It leads to a pressure difference between the internal chamber of the CDG with respect to the vacuum chamber to which it is connected. The associated correction ratio has been studied over several decades, for CDGs thermo-regulated around 45 ℃. In the framework of the EMPIR project JRP 14IND06, the company INFICON AG has built a special model of CDG in which the temperature can be adjusted up to 90 ℃. It has been calibrated at three different temperatures, including 45 ℃, in the pressure range from 0.1 Pa to 100 Pa. The data have been analysed using existing empiric correction functions of the thermal transpiration, and the results will be discussed.

This work was supported by the European Metrology Programme for Innovation and Research (EM-PIR). EMPIR is jointly funded by the EMPIR participating countries within EURAMET and the Euro-pean Union.

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Compressibility measurements of working liquid of the primary absolute pressure standard of Russia

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Primary absolute pressure standard of Russia in the range of 0,1-1000 Pa is a laser interferometric oil manometer. In the higher part of the range the oil's density uncertainty gives the main contribution to the standard's uncertainty. The oil's density is measured at normal conditions (atmospheric pressure), but the real density value at the working pressure is less due to the liquid compressibility. Laser interferometric piezometer was developed in VNIIM to investigate the liquids compressibility

at the working pressures of the absolute pressure standard.
The construction of the piezometer and it's operation principal are follows. The steel cylindrical vessel filled with the test liquid is mounted in a vacuum chamber. The flat mirror is installed under the liquid surface at the depth of 2-3 mm. The laser beam from He-Ne laser is directed by the mirror to the center of the liquid surface where it is split in two. One of the beams is reflected from the liquid surface while the other is reflected from the mirror. Then these two beams are directed to the screen. The resulting interference pattern is recorded by the web camera on the computer. The outer vessel filled with the investigating liquid surrounds the measurement vessel to provide the additional temperature stabilization during the measurement process. When the pressure in the chamber raises the oil level decreases and so does the order of interference. The direction of motion of the rings, toward or from the center, depends on the ratio of the curvature radii of the interfering beams. The measurement procedure consists in counting of passed interference rings in the video file.
Received compressibility value for the oil is 5,2·10-10 Pa-1. It was measured with the uncertainty of 2 %.

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Oxygen dosing systems for Diamond Optics.

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Diamond Light Source is the UK's national synchrotron light source. Carbon contamination of optics in the synchrotron's associated beamlines by the disassociation of carbon from carbon monoxide and dioxide at optics surfaces under radiation can lead to a substantial drop of beam intensities and unwanted spectral features. Diamond Light Source has developed, and deployed on several beam-lines, an oxygen dosing system to protect sensitive beamline optics from carbon contamination. The mechanism appears to involve synchrotron-light-induced re-oxidation of the newly formed surface carbon and subsequent re-desorption as carbon monoxide or dioxide. Although this technique works to stop the formation of a carbon film it does not clean already-contaminated surfaces; as such it must be used consistently from day one of operations.

This poster shows the design and development of the oxygen dosing tools as well as discussing the operation of them along with observations of the effectiveness of the technique.

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Single Metal Zirconium Non-Evaporable Getter Coating

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The non-evaporable getter (NEG) coating has been used for years in many accelerators due to its advantages such as evenly distributed pumping speed, low thermal outgassing and low photon andelectron stimulated desorption yields. Although quaternary Ti-Zr-Hf-V coating deposited from an allow wire has been found to have the lowest desorption yields, highest sticking probability and sorption capacity, it is hard to find a manufacturer for such a target. Twisted wire targets occupy more space and are not good for coating narrow chambers. Single element targets are widely available and can be produced in a form of a wire that is easy to apply for a uniform coating of various shapes of vacuum chambers. Pure Zr coating is being tested to find a more efficient and cheaper way of producing the NEG coated chamber parts. In this work, three samples coated with pure Zr (dense and columnar) were analysed and results for pumping properties and electron stimulated des-orption (ESD) obtained. Pure Zr coating has shown the results that, although not as good as the ones achieved with the quaternary NEG film, could be an economic solution in practical applications. It shows that columnar Zr coating can be activated at 160℃, the temperature close to the Ti-Zr-Hf-V activation temperature and lower than the one for the widely used ternary Ti-Zr-V alloy.

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ARIEL E-linac Vacuum System

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The new Advanced Rare Isotope Laboratory (ARIEL) is TRIUMF's flagship facility that will expand Canada's capabilities to produce and study isotopes for physics and medicine. Utilizing next-generation technology, it will showcase a made-in-Canada, high-power superconducting electron accelerator to produce exotic isotopes for research and development.
ARIEL will produce radioactive isotopes by bombarding actinide targets with high energy electron beam, generated by an electron gun (EGUN) and accelerated with an electron linear accelerator (E-linac). The E-linac is comprised of an EGUN, three main accelerators, and beam transport lines delivering the beam to a beam dump or to ARIEL targets. To minimize the collision of electrons with air molecules, the E-linac requires an evacuated volume along the electrons path. When beam is running, the pressure in the EGUN has to be at level less than 1E-9 mbar, in the three accelerators and the section between the accelerators at level less than 1E-8mbar, and in the beam transport lines which deliver beam to the targets or beam dump at level less than 1E-7mbar.
The Vacuum System of the E-linac provides an environment with reduced pressure for electron beam acceleration. To achieve this goal, the vacuum system has to comply with Ultra High (UHV) and High (HV) vacuum manufacturing and assembly standards. Careful choice of materials and purchased vacuum components, their cleanliness, assembly, and handling will assure that the requirement is met.

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Determination of pumping properties of Quaternary alloy of TiZr-VAl non evaporable getter

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In recent years, the non-evaporable getter (NEG) thin film coating technology, have been developed for LHC project in 90s, is extensively used on world's accelerator vacuum chambers, especially in ultralow emittance storage rings and in small gap insertion device vacuum chambers. The main ad-vantages of using NEG coatings are distributed pumping speed, low thermal outgassing, low photon-stimulated gas desorption and low electron-stimulated gas desorption (ESD) without any effect on machine aperture.

The ASTeC Vacuum Science Group has had an ongoing study for the improvement of the non- evaporable getter (NEG) coating technology. Alike our earlier results, a new quaternary TiZrHfV coating, demonstrates better key parameters, such as lowest activation parameters, higher sticking probability and higher pumping capacity than usual ternary TiZrV coating.
In this study, we report on the pumping properties, activation temperature, sticking probability (H, Co, CO2) of new NEG quaternary alloy of TiVZrAl as function of the film structure, morphology, and composition.
Film bulk composition was determined using Rutherford Back Scattering RBS while the surface com-position and surface chemical state as function of activation temperature was determined with X-ray photoelectron spectroscopy XPS. Surface structure and its morphology was determined by Scanning electron Microscope and X-ray diffraction.

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Vacuum measurement standards at KRISS and results of bilateral comparison between KRISS and NINVAST

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The Vacuum Measurement Lab at Korea Research Institute of Standards and Science (KRISS), Rep. of Korea, maintains primary standards as well as systems for calibration by comparison method. The KRISS primary standards can be used for the calibration purpose in the pressure range from ~ 10-7 Pa to 133 kPa.
It is mainly categorized into manometers, static (volume, series) expansion systems, and dynamic expansion (orifice) systems. For bilateral as well as key comparison of these standards, KRISS has participated in the past where its standards have good degree of equivalence and hence international recognition, with other national standards like that of NMIJ, NIST, PTB, NPL (UK), etc. We also will discuss about vacuum gauges calibration methods and uncertainty analysis using vacuum standard system as primary standards and comparison systems.
We will also discuss about results of the bilateral comparison between KRISS and NINVAST (National Institute of Vacuum Science and Technology) in Pakistan. Two Capacitance Diaphragm Gauges were used as transfer gauges. The results were good agreement within uncertainty limited between two NMIs.

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Calibration and operation of total pressure gauges and residual gas analysers for UHV beamlines at CERN.

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Calibration and operation of total pressure gauges and residual gas analysers for UHV beamlines at CERN.

The vacuum systems of CERN amount to 120 km of beam lines; half of that length needs UHV to fulfil the particle beam requirements. Along the accelerators, dedicated pressure gauges and residual gas analysers are deployed for online gas density monitoring. The calibration of such instruments is an important activity for which new set-ups have been installed and are now operated. We will describe the applied calibration procedures for both total pressure gauges and residual gas analysers. Statistical details will be given for sensitivities. In addition, the main causes of breakdown will be explained. The CERN strategy for vacuum instrumentation will be finally presented.

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Electromagnetic Characterisations of Non-Evaporable Getter Thin Films based on Waveguide Method

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Non-evaporable Getter (NEG) thin films have been widely used for ultrahigh vacuum applications, since the NEG coated vacuum chambers can function as a 'local distributed pump' after thermal activation. This is especially useful for conductance limited vacuum chambers, such as normally found at the particle accelerators. The NEG coated stainless-steel vacuum chambers have been used at the existing facility of synchrotron SIS18 at GSI to improve the vacuum performance of the synchrotron. The NEG coated chambers are also foreseen to be used for some of the vacuum chambers at the FAIR accelerator facility, such as at the synchrotron SIS100 and High Energy Storage Ring (HESR). This NEG coating was fabricated based on DC magnetron sputtering of Titanium, Zirconium, and Vanadium alloys and it was produced in-house at the Vacuum Group GSI.
It is believed that the use of NEG coating may affect the beam impedance in a particle accelerator. This work aims to characterise the electromagnetic properties of the NEG coating at broadband frequencies, which are useful to investigate the effect of the NEG coating on the beam performance for a particle accelerator.
The characterisation of the electromagnetic properties of NEG coating in this work is obtained from the combination of measurement and simulation of scattering parameters (S-parameters). The scattering parameters measurements are carried out using a vector network analyser at broadband frequencies (1-10 GHz), based on microstrip and coplanar waveguide methods.CST (Computer Simulation Technology) microwave studio is employed for simulation of the scattering parameters. The impedance as well as the conductivity of the NEG coating can then be determined from the measurement and simulation results of the S-parameters.

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NEG coating for narrow tubes: challenges in deposition and testing

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One of the main advantages of NEG coating is providing required pressure in UHV/XHV range in vacuum chamber with restricted vacuum conductivity, i.e. vacuum chambers with high aspect ratio (length to characteristic cross section size). The most challenging for NEG coating production is depositing of the tubed with diameters smaller than 20 mm. We have developed and tested a deposition facility for coating 0.5 long tubes with a diameter of 5-10 mm.
Equally challenging was to design a facility to measure pumping speed and capacity of such tubes, as a total pumping capacity is too low. A new pumping properties characterisation facility was built and tested. The results for a sample tubes with various diameters in the range of 5-40 mm will be shown.

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Effect of hydrogen bulk content on the thermal removal of copper surface oxide

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Copper is often used as thin film substrate in particle accelerators, in particular for non-evaporable getters and niobium. The native copper oxide, formed on the copper surface at room temperature in air, consists mainly of cuprous oxide Cu2O. This compound is very stable and can dissociate or sub-limate only at high temperatures. However, baking copper under ultra-high vacuum at 250C-300C is sufficient to reduce the oxide and generate a metallic surface. The influence of the hydrogen con-tent in the copper bulk on the oxide reduction process has been investigated by thermal desorption spectroscopy (TDS) monitoring the hydrogen and water vapour peak signals, and by X-ray Pho-toemission Spectroscopy (XPS). The TDS results indicate a possible relation between the measured signals of desorbed water vapour and hydrogen. The XPS analysis as a function of heating time demonstrates that a higher hydrogen content favours a faster removal of the oxide layer.

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Measurement of the adsorption isotherms and the mean residence time of hydrogen and deuterium physisorbed on a cold copper surface

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Cryopumping is one of effective methods to evacuate H_2 and has been used in various vacuum systems because of its cleanliness and high pumping speed. For development and utilization of cryopumps, it is indispensable to elucidate the physisorption characteristics of a cryosurface against H_2 in extremely high vacuum (XHV), where H_2 is the dominant residual gas. Several authors have reported unexpected outcomes in either the static or dynamic characteristics of H_2 cryopumping, such as the abnormal temperature dependence of the equilibrium pressure [1,2,3] and the deviation from the Dubinin-Radushkevich-Kaganer (DRK) equation [4,5], but their origins have not been clarified yet.
In this study, we aimed to obtain the adsorption isotherms and the mean residence time of H_2 and D_2 on a copper surface using the electron stimulated desorption (ESD) technique [6]. Since H^+ (D^+) ions are mainly generated by dissociative ionization of H_2 (D_2), the ESD yield of H^+ (D^+) is assumed to be proportional to the density of H_2 (D_2) physisorbed on the surface in the submonolayer range. We measured the adsorption isotherms at the equilibrium pressures between 10^{-10} and 10^{-6} Pa in the temperature range of 4.0 - 7.0 K and clearly observed the two-dimensional condensation. Whereas the adsorption isotherms of H_2 at pressures below 10^{-8} Pa were affected by H^+ originating from surface impurities of hydrocarbons, those of D_2 were able to be obtained without their influences in the whole pressure range. We also measured the mean residence time by monitoring the ESD yields of H_2 and D_2 in transitional states.

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Measuring the Change of Gas Flow Conductance Due to Altered Surface Conditions of a Tube

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Gas flow conductance of a tube can be measured with the pressure decay method. Here, a vacuum chamber of volume V is pumped through the tube, which allows for conductance C to be determined from the slope of the logarithm of the pressure decay curve $C = V \times \mathrm{d}(\ln(p))/\mathrm{d}t$, if upstream pressure p is measured with sufficient precision. In our case, estimated uncertainty of the measured conductance is 0.3%, and reproducibility is below 0.2%. Conductance was measured for an electropolished stainless steel tube with inner diameter 7.76 mm and length 776 mm, using various pure gases. Conductance was then measured after several surface treatment steps, including heating with exposure to either O2 and H2, and vacuum baking the tube surface. The tube was then etched in *aqua regia* in order to produce macroscopic roughness of the inner surface, and the previous process was repeated. For He gas the maximum difference of tube conductance of different treatments was as high as 19 %.
The observed difference in values of conductance in molecular regime was attributed to changes of effective tangential momentum accommodation coefficient. Results were compared with published research on tangential momentum accommodation coefficient of spinning rotor vacuum gauge.

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Design and commissioning of the Cryogenic SEY measurement facility at Daresbury

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Electron cloud mitigation will be critical for the Future Circular Collider (FCC) and it has been speci-fied that the wall material needs to have a Secondary Electron Yield (SEY) < 1. The baseline material for electron cloud mitigation will be Laser Ablated Surface Engineering (LASE) of Copper on the beam screen. The FCC will have a beam screen with T between 20 and 60 K therefore the behaviour of the LASE surfaces is critical at these temperatures. In this work we will report the first results from the cryogenic SEY measurement facility at Daresbury Laboratory of LASE samples at these temperatures with and without cryosorbed gasses on the surface.

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From vacuum acceptance test to vacuum simulation: ELENA case study

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The Extra-Low Energy Anti-proton ring (ELENA) is a decelerator at CERN with the aim to slow down the antiprotons from the Antiproton Decelerator (AD) to a kinetic energy of 100 keV, improving the antimatter experiments trapping efficiency. ELENA operates in the Ultra High Vacuum (UHV) regime to assure a sufficiently long pbar lifetime and reduced beam blow-up. As the ring is under commission, there is an interest to assess its achievable vacuum quality with a simulation study. The vacuum system is baked and in addition to lumped ion pumps, makes extensive use of non-evaporable getter (NEG) coating for increased distributed pumping. The simulation study uses the open-source software MolFlow+ to integrate data from vacuum tests of individual components done in the vacuum laboratory with the mechanical design of the complete machine. The objective of this work is to provide pressure profiles along the beam trajectory, based on measured outgassing of components combined with the available pumping speed in the system. Moreover, the model is used to simulate several scenarios e.g. the pumping speed of the NEG for different gas species and the potential effect of NEG saturation.

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Uniform Magnetic Fields Effects on Secondary Electron Emission of Polycrystalline Copper

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The quest for high intensity proton circular accelerators calls for efficient electron cloud mitigation. Of particular interest is the electron cloud build-up in the steering dipole magnets necessary for the bending of particle trajectories in circular colliders. The electron cloud formation relates directly to the secondary electron yield of the accelerator's vacuum chambers surrounding the proton beams. Even though data on secondary electron yield in presence of a magnetic field are scarce, simula-tions show that magnetic field can influence the secondary electron yield. To better understand the dynamic of the electron cloud build-up, we designed a new experimental setup for measuring the secondary electron yield in presence of a DC weak magnetic field (few tens of Gauss). We report on preliminary results on the effect of a magnetic field – perpendicular to the surface – on the secondary electron yield of a polycrystalline copper surface.

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The LIU Project: Vacuum performance simulation of the upgraded SPS accelerator

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The LHC injectors Upgrade (LIU) project has the goal to prepare the injector chain to reliably deliver the beams required by the High Luminosity LHC (HL-LHC) era, aiming at doubling beam intensity while reducing the beam emittance. At the last stage of the injector chain, the Super Proton Synchrotron (SPS) will be extensively modified in the scope of LIU, starting in 2019. It will feature a new dumping system, upgraded RF system, upgraded extraction channels and carbon coated vacuum chambers.

The vacuum performance is one of the key factors of the project: the analysis of the challenging upgrades to the vacuum layouts is presented, mainly focusing on the modifications taking place in Long Straight Sections 1 and 5, triggered by the relocation of the new beam dumping system. The evaluation of the vacuum performance of the new layouts has been carried out through the electri-cal network analogy: the expected time-dependent profiles are shown together with the predicted pressure at 24h of pump down.

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The LIU Project: Vacuum performance simulation of the upgraded PS complex

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The injector chain of LHC is being upgraded to achieve the beam quality required for the High-Luminosity LHC (5e34 cm^-2s^-1). To achieve that performance the injectors have to provide beams of double intensity and 2.5 times the present brightness.
The LHC Injectors Upgrade project (LIU) requires the connection of the new proton source (LINAC4) that will provide negative hydrogen ions at 160 MeV instead of protons at 50 MeV. This new injection will require the complete refurbishment of the injection line to PSB synchrotron to strip the nega-tive ions and accelerate the beam to 2 GeV instead of actual 1.4GeV. This increase also requires the rearrangement of the PS synchrotron injection. All this modifications will have a significant impact on the vacuum layout and performance. This contribution illustrates these modifications and the expected vacuum performance after their implementation.

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Investigations by simulation for ionization type gauges suitable as vacuum transfer standard

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The EURAMET EMPIR project "16NRM5-ion gauge" aims to develop a standardised ionization gauge that is suitable as a transfer standard. In such a gauge the electron trajectories, kinetic energy and current inside the ionization volume needs to be well defined and stable. In the search for a most suitable design, CERN, amongst the other consortium partners, carried out a series of simulation on different ionization gauge concepts that have the potential to meet the stringent requirements. Parameters, such as ion gauge sensitivities, ion collection efficiency and electron transmission efficiency have been simulated as a function of emission current, pressure, electron source alignment and potential. The possibility of suppressing ESD electrons and protecting the ion collector from direct X-rays from the electron impinging area have also been addressed. In ionization gauges space charge may be an important limitation that need to be considered. The simulations have been car-ried out using the Vector Fields Opera software. Within this software the Scala analysing module is specialised in charged particle trajectories and solving space charge problems.

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Radio frequency surface resistance measurement of metals for accelerator vacuum chamber

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Vacuum chamber RF surface resistance may play a significant role in beam instabilities of charge particle accelerators. Several dedicated choked TE010-mode resonators with 2 and 3 chokes were designed and built in ASTeC for surface resistance measurements of planar samples.
In this paper we report our study on improving the accuracy of surface resistance measurements and possible sources of errors. Three 7.8 GHz cavities made of copper, aluminium and niobium and ten (?) different well known samples (copper, aluminium, tin, please add others) were employed to prove this method and demonstrate the errors. Good agreement between measured surface resistance values and those predicted by the employed theoretical model demonstrated the suitability of the described technique for RF surface resistance measurements.

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Electron stimulated desorption yield of technical materials used in the LHC vacuum system

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In 2017, LHC overcame the target for integrated luminosity achieving the goal of 125 fb-1 since the start of its operation. All along this period LHC vacuum system successfully faced the challenge ofthe pressure instabilities generated by electron clouds. In this framework Electron Stimulated Des-orption (ESD) studies revealed to be fundamental for dynamic pressure prediction and limitation. This article presents a summary of laboratory investigations performed in support of beam vacuum operation team on electron stimulated desorption for technical materials. The phenomenon of loss of conditioning was deeply analysed in different operation conditions: static vacuum effect was consid-ered together with the effect of different venting techniques according to standard and non-standard vacuum operation procedures. In case of NEG-coated sample, the effects of partial activation and different saturation effects were analysed, too.

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Electron impact on the cryosorbed gas of selected accelerator materials.

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The vacuum chambers of the LHC's arcs operate in a temperature range between 1.9 K, i.e. the tem-perature of the superconducting magnets, and 20 K. At such low temperatures, most of the residual gas species are efficiently adsorbed on the cold surface.

LHC's beam emits synchrotron radiation inside its bending magnets and, consequently, electrons are extracted from the surrounding walls by photoelectric effect. The bunched proton beam accelerates the photoelectrons, building-up an "electron cloud" which generates gas desorption and heat load on the cryogenic vacuum system. This phenomenon might become a limiting factor for the operation of the High Luminosity LHC upgrade, where more intense beams will circulates.

In order to study the electron interaction with gas adsorbed at cryogenic temperature, a new facility has been designed and built at CERN. It reproduces in the laboratory the typical conditions of a cryo-genic ultra-high vacuum surface, present in the accelerator. A sample representing the inner surface of the accelerator is mounted on a 4-axis manipulator able to regulate the temperature between 10K and 250K, in a fully conditioned vessel. Known quantities of gas are adsorbed on the sample sur-face that can be bombarded by an electron beam at different energies. In this paper, we present the results obtained with selected accelerator materials at different surface gas coverages.

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Experiments on exhaust performance by NEG applied pumping system

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Vacuum system of the RAON heavy ion accelerator has been designed to meet local vacuum requirements based on the pressure rise due to the stimulated desorption by scattered ions interacting with residual gases. Main pumps of warm section, of which the target pressure is 5x10-9 mbar, between cryomodules will be of NEG type which has merits such as a large effective pumping speed if installed inside, no limit in mechanical life time, continuous pumping even in the case of power break, and robustness in the aspect of vacuum break accident. However NEG pumps have apparent demerits of finite pumping capacity, periodic activation, above all, disability for pumping inert gases (Ar, He) and hydrocarbons (CH4). Limited pumping capacity of NEG pumps can be overcome easily in UHV conditions, while a solution to overcome the handicap is using small supplement pumps like sputter ion pump to pump the inactive gases. In simulation results of MolFlow, the size of SIP is not that important for sustaining the required vacuum pressure at warm section chamber because NEG pump alone can accomplish the goal when neglecting inactive gas sources through real and/or virtual leaks and permeations. In real situation there must be finite sources of inactive gases regardless of magnitude, which put a question to us about the practical limit in size of the SIP. A vacuum system with integrated getter pump using an NEXTorr Z300-5 pump has been established and vacuum performance was tested. Vacuum properties of the NEG materal ZAO and vacuum characteristics of various pump combinations including even NEG pump alone were investigated. We could reach the 10-11 mbar range using a NEXTorr pump after minor activation, and the pressure was maintained at low 10-10 mbar range when operating Z300 only.

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Field-emission investigations of micro-structured stainless steel ASTM 304

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Highly-alloyed chrome-nickel stainless steel is the most important material in vacuum technology. Especially in high and ultra-high vacuum technology it is used for vacuum chambers and components. One of the main research focuses before 2005 1 was the study of parasitic field emission (FE) of specially treated stainless-steel surfaces for applications in accelerator technology. The measured threshold field strength is about 25…30 V/µm for 1 nA 2. An important cause of field emission enhancement is the grain boundary structure. Therefore, stainless steel (ASTM 304 or 1.4301) was wet-chemical micro-structured and investigated with respect to field-emission properties. Some selected results are:
1. Threshold field strengths of micro-structured stainless steel are in the range of 7 V/µm for 1 mA (is better than [3], but CNT field emitter has 1…2 V/µm [4]).
2. For application as FE cathodes in vacuum components (cylindrical surfaces 1), very large cathode arrays of a few cm² can be produced cost efficiently.
3. Very large cathode arrays with lower current density (≤ 30µA/cm²) are field emitter with long-term stability.
However, the main objective is the substitution of thermionic cathodes in vacuum electronic applications.

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Outgassing Measurements of Laser Engineered Copper Surfaces

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Laser Engineered Surface Structures (LESS) is a novel technology for reducing the Secondary Elec-tron Yield (SEY) of metal surfaces, and has recently been investigated for mitigating the electron-cloud phenomenon in high-intensity particle accelerators such as the HL-LHC and the FCC at CERN. Treatment with LESS increases the surface roughness, thus the outgassing of treated surfaces can be different compared to untreated ones. Pumpdown curves have been measured for copper samples with LESS in order to characterize water outgassing and estimating the effective surface area. The gas accumulation technique has then been used to identify whether LESS might trap ambient air, and to measure hydrogen outgassing. We report the results of these measurements, for different LESS treatment conditions.

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Liquids in vacuum. Atomic Layer Injection for studying the origin of life.

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Liquids and vacuum are opposite concepts. We have developed a new technique for making possi-ble the coexistence and the emergence of liquid solutions inside a vacuum chamber. We call this technique «Atomic Layer Injection», ALI 1 and it allows to deposit sub monolayers of biomolecules, as Adenosine triphosphate (ATP), or gold nanoparticles from a liquid solution at room temperature. With this technique the molecule to be deposited or nanostructure stays in its original solution (out-side of vacuum), and it is introduced inside the vacuum vessel as micro droplets.
The second application of the technique is related to space simulation [2,3]. In the Mars polar re-gions, cyanobacteria could survive in specific areas where ice coexists with water, or alternatively form in cycles. This process occurs at low temperature, few minibars of pressure in an environment mainly form of carbon dioxide. In a vacuum chamber it is very difficult to maintain a constant wa-ter pressure in the mbar range where the pumps are constantly working. The combination of low temperature, relatively high pressure and the correct design of pumping of the chamber with the control of water injection over a cyanobacteria registry, allow the study of the emergence of the microorganism in this extreme environments and learning about the possibility of habitability in Polar Regions of Mars.

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Outgassing of differently gold-coated copper samples

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Heavy ion ring accelerators suffer from dynamic vacuum increase due to ion-induced desorption. Lost beam ions collide with the vacuum vessel, trigger the release of gas and the resulting pressure rise leads to more beam loss. This self-amplifying effect is a severe intensity limitation and affects the design and operation of next generation heavy ion accelerators.
A common mitigation of the dynamic vacuum deterioration is the installation of ion-catcher systems in the loss regions. These so-called collimators ensure beam loss in a controlled manner. First, the impact angle of the lost ion is perpendicular, what leads to way lower induced desorption yields compared to grazing incidence loss. Second, the pumping speed in this area is increased. Finally, the collimator block on which the loss occurs can be made out of low-desorbing material. After years of research, gold-coated copper established as material with the lowest desorption yield amongst different irradiation beam parameters. The low stimulated desorption can be explained by the high thermal conductivity of copper. The gold coating prevents the surface from oxidation. As gold and copper diffuse into each other, a blocking layer out of chromium, nickel or silver is applied. Presently it is still under investigation, which of these materials is the best choice for diffusion prevention.
Technically there are three coating methods available for the application of the layers on top of the copper block. Coating by thermal evaporation and sputter coating both employ high vacuum environments, with an applied process gas pressure in case of sputtering. From that, the risk of process gas inclusions in sputter coatings exists. Sputter coatings have higher sticking forces to the substrate as compared to evaporation-coated layers. Electro-deposition on the other hand uses the most undefined environment with a high probability of impurity inclusions. The aim of this work is to investigate the content of volatile species such as C, N and O inside of the deposited layers for different coating methods and layer thickness. The volatile species are suspected to contribute to the desorbed gas and therefore have to be minimized. A measurement campaign has been started to determine the amount of volatile species in the layers by thermal desorption spectroscopy in a new dedicated setup. First results will be presented with the focus on layer thickness, material of the blocking layer and comparison of the coating techniques.

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The flow through a long rectangular channel and the angular distribution of the emitted molecules

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In order to realize a non-destructive and fast 2D profile monitor for an accelerator, we are now de-veloping a dense gas sheet target in a vacuum, applying the beaming effect as used in the field of vacuum technology.
Test-particle Monte Carlo simulations revealed that the long rectangular channel with the very small ratio of the gap to the width is effectual to form the thin gas sheet.
For example, the fraction of outgoing molecules within the azimuth of 0.01 rad becomes 25% of all molecules with the parameter set of L : a : b = 100 : 50 :0.1. Here, the letters a, b, and L represent the length of the long and short sides, and the length of the channel, respectively.
By the way, when the flow through the rectangular channel is increased to obtain a dense gas target, the intermolecular collisions in the channel will increase and change the characteristics of the flow. Actually, many authors simulated the long channels as well as a capillary, and discussed about the influences of the intermolecular collisions in the channels. However, there are not so many experi-ments.
Thus, we have examined the flow through the long rectangular channel, especially to survey the influences on the performances of the gas sheet.

1) In the relation of the flow rate and the inlet pressure, the conductance decreases from the value for the perfect molecular flow and reaches at the Knudsen minimum as the pressure increases. The value at the Knudsen minimum is about a half of the molecular-flow conductance.
2) Angular distributions of the emitted molecules from the rectangular channel have been examined as a function of the inlet pressure. The distribution, which has an influence on the thickness, changes synchronizing with change of conductance.
The experimental details of the rectangular channel will be shown in the conference.

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The Vacuum System of the Photon Transport Beamlines at the European XFEL Facility.

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The European XFEL is a 3.4 km long underground facility that generates extremely intense X-ray flashes to be used by researchers from all over the world. It officially began operation in September 2017. In full operation it produces coherent femtosecond pulses with unprecedented brilliance in the energy range from 250 eV to 25 keV at MHz repetition rate. The facility comprises a linear accelerator and initially three branched beamlines: SASE1 and SASE2 that operate in the hard X-ray regime, and SASE3 that covers the soft X-ray range up to 3,5 keV.

One of the main challenges faced during the installation has been the fact that a large proportion of the almost 2.8 km long photon vacuum system had to be assembled under ISO5 cleanroom class to guard the optical properties of the high quality X-Ray mirrors.

The UHV specifications were developed not only to fulfil the mentioned issue, but also to harmonize the different contributions from the involved industry partners and/or the various in-kind component contributions from the rest of participating institutions.

In general, the overall static pressure is in the 10-9 mbar range. Since most of the system is unbaked, this is achieved using a combination of proper cleaning processes, surface treatments and a lumped distribution of triode ion pumps with additional specific configurations at critical components (mirrors, gratings, etc.) where NEG cartridges are also used.

For all the existing windowless gas based devices (diagnostics and beam intensity attenuation) a distribution of TMP differential pumping schemes has been systematically deployed.

The activities of the Vacuum Team are being progressively extended to the coordination and support of the six experimental end-stations to optimize the performance of any subsystem dealing with vacuum, including experimental chambers, centralized forevacuum distribution lines, operational consolidation of vacuum equipment and installation or upgrade activities.

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Mimicking cosmic dust in the laboratory. The STARDUST machine

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Cosmic dust grains are believed to play an essential role in the emergency of chemical complexity in the universe. In particular, it may catalyze new chemical reactions with the circumstellar and interstellar gases. In addition, accretion of volatiles on dust grain surfaces leads to the formation of icy mantles, whose processing in the interstellar medium (ISM) also contributes to the large variety of molecular species found in the ISM. Albeit its importance, much remains unknown on the cosmic dust formation processes and laboratory astrochemistry using ultra-high-vacuum (UHV) technolo-gies and characterization techniques, may provide an excellent workbench for these studies.

Here, we present the STARDUST machine, an innovative experimental station devoted to the engi-neering, production, manipulation, processing and in-situ analysis of a wide variety of clusters and nanoparticles, particularly designed to mimic the travel of cosmic dust seeds towards the interstel-lar medium. Its original design offers unique possibilities for nanoparticle growth, namely a very high throughput with controlled size, control of the composition and structure in a clean ultra-high vacuum environment, by using a scaled-up multiple ion cluster source with an implemented design. The nanoparticles generated can be processed in-flight by annealing, acceleration, or interaction with background gasses and the resulting nanoparticles can be further analyzed in-situ by means of different surface science techniques.

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A theoretical study of Ni segregation through NiTi /TiO2-x

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The Nitinol (acronyms for NiTi Naval Ordnance Laboratory) is quasi equiatomic alloy of Ni-Ti known for its properties of shape memory, superplasticity, strength and biocompatibility. It is the most widely used form memory alloy in the production of biomedical devices. However, the presence of Ni in metallic or oxidized form on its surface or the release of it from the core of the alloy is a serious problem because of its allergenic properties and toxicity to human tissue. The most usual procedure is the modification of the surface by a coating that resists corrosion and is biocompatible. The simplest of the procedures consists of a surface oxidation that manages to grow an oxide film on the NiTi, the Ti being oxidized preferentially. For this reason we performed a DFT study of Ni segregation for different oxide coverage. Our results show that Ni diffusion is strongly dependent of the presence of Ti and o vacancies and the nature of an intermediary oxidation layer. We also analyzed the changes in the electronic structure and bonding at the interface.

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Development of radiation hard and magnetic field compatible vacuum gauges for the ITER project

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The ITER Tokamak, designed to study deuterium-tritium fusion reactions and to demonstrate its viability as a sustainable and clean energy source, is currently being built in South France, on Cadarache site. Its vacuum system, one of the largest and most complex vacuum systems ever to be built, requires several hundred of vacuum sensors for the pressure monitoring of its high vacuum systems.

High vacuum gauges operating under magnetic fields as high as 300mT, with gamma radiation in excess of 1MGy and significant neutron fluency, will be necessary in order to fulfill the pressure measurements of the torus vessel, neutral beam injectors, cryostat vessel, diagnostics, cryogenic distribution and heating systems of the ITER Tokamak.
Following an international call for tender and the signature of a Strategic agreement between ITER and the company INFICON, specific pirani and cold cathode gauges with remote controller have been developed and qualified to operate under the difficult ITER environment. Other sensors of novel technologies are also being developed to overcome the ITER vacuum instrumentation challenges.

In this paper the ITER specific environmental conditions and requirements for pressure measurements are reminded. The standardization process for ITER passive vacuum gauges and controllers is then described and emphasis is given toward the products development and qualification testing. Final gauges performances are then detailed and successfully commercialized ITER standard products are lastly exposed.

To complete the picture, highlight is given on additional vacuum sensing development required to complete the ITER vacuum instrumentation portfolio and achieve an operationally safe design.

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Vacuum leak testing system for the propulsion system of large spacecraft

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A gas leak on orbit is a fatal fault for spacecraft, so a series of leak tests are carried out during the process of manufacturing and assembling. Helium leak testing method has much higher sensitivity than other methods. In order to gain high leak testing sensitivity, a spacecraft should undergo a helium leak test in large vacuum chamber. A vacuum leak testing system was built for the measurement of the global leakage of the large spacecraft. The vacuum chamber of the system is a cubic vacuum chamber with 4.5m in length, 4.5m in width, and 6.5m in high. The vacuum system has a DN1250 cryopump and 8 DN320 turbo molecular pumps as high vacuum system and 3 roots-screw pumps units as low vacuum system. The ultimate vacuum of the system is 5×10-4Pa, and the minimum detectable leak rate of the system is 1×10-7Pa.m3/s.

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The finite element analysis of vacuum leak detection container

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According to the requirement of vacuum leak detection container for small satellite, a set of vacuum leak detection container is developed. This paper discuss the design of model and the finite element analysis of different models. Through calculating the variation of the displacement X, Y, Z of different parts of the door and the cabinet, the stress distribution of different parts and the rotation Z of the door flange and casing flange, we determine whether the deflection of flange under internal vacuum will cause the fall of the sealing effect of the sealing ring.
Introduction

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The leak detection methods of the electric propulsion spacecraft researched after xenon filled

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In order to test the leakage of the electric propulsion spacecraft after the xenon filling, it was studied which were the leak detection of methods and key technologies. A leak detection system has been developed by basing on the gas chromatography(GC). It was reliable which was verified by the experiments. The result proved that the leak detection system of the electric propulsion spacecraft could satisfy the task requirements.

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Study on the helium permeability of graphene oxide membranes for leak testing

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As the development of electronic technique and miniaturization of vacuum electronic devices, it has higher demands for their lifetime and reliability.In order to meet the sealing performance requirements, extra-high sensitive mass spectrometer leak detection method is developed. So the leak rate of 10-15Pa•m3 / s on the order of the standard leakage is demanded. Increasing the number of holes in the graphene on the artificial control, the leak rate of grapheme would be improved. Based on this idea, a certain defective graphene as a penetrating element, using in the ultra-sensitive leak detection can be made. In this paper the relationship among the permeability of helium and the pressure difference and the thickness of the GO membrane were studied. The permeation mechanism of GO membrane of the minimal leak rate was discussed, which provides a reference for the study of ultra-sensitive leak detection technology.

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Process optimization of AZO thin films with Al2O3 buffer layers prepared by RF magnetron sputtering

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The AZO (aluminum-doped zinc oxide) thin film, produced by coating on the flexible substrate, has many advantages such as light quality, rich resource, flexible and mass production. This paper presents an effective method for the parameters optimization for the deposition process for AZO thin films, using the Taguchi method, combined with grey relational analysis, and an L-9 orthogonal array was chosen for the experiments. The dependence of the structural, electrical and optical properties of transparent conducting AZO thin films with or without buffer layers deposited onto flexible polyethylene terephthalate (PET) substrates was compared. AZO thin films were prepared by radio frequency magnetron sputtering with an AZO ceramic target (2wt% Al2O3), by ranging sputtering power from 40 to 120W, working pressure from 0.5 to 3.0 Pa, sputtering time from 10 to 90 min, substrate temperature from 25 to 125℃. The results indicate that the thickness values of Al2O3 buffer layers have a large influence on the crystalline structures and photoelectric properties of AZO thin films. As the buffer thickness increased, the resistivity of AZO thin film decreased and the corresponding mobility increased, resulting from crystallinity improvement. The only (002) diffraction peak for the film is observed at 2 theta similar to 34.35 degrees, which shows that the films had a hexagonal ZnO wurtzite structure. The intensity of (002) peak decrease with increasing thickness of the Al2O3 buffer layer. The results show that compared with the sample without buffer layer, residual stress in samples with buffer layer of appropriate thickness reduced and the grain size increased. SEM images show that the surface is smooth and dense. The average transmittance of all AZO films in the visible range is about 80%. Four-point probe results show that the sheet resistance of AZO film with Al2O3 buffer layer has a significant decrease when compared with that of the single AZO film. All the results suggest that the insertion of Al2O3 buffer layer effectively improved the quality of AZO film on the PET substrate.

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Research on the Optical-Electrical Characteristic of Amorphous Silicon Thin Film

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Amorphous silicon thin film solar cells have excellent photoelectric properties including simple preparation process, low production cost, easy to manufacture in large area. In this paper, we studied the influence of each layer parameters on performance of a-Si solar cells by wxAMPS simulation software such as the thickness, optical band gap, the doping concentration of the window layer and the defect density of intrinsic layer on the solar cells. Results show that when the thickness of the window layer increases from 5nm to 30nm, the conversion efficiency of solar cell decreases, and the conversion efficiency improves when the optical band gap of the window layer increases from 1.6eV to 1.9eV. The doping concentration in window layer and the defect density in the intrinsic absorption layer are the key factors that influence the performance of solar cell, the performance deteriorate rapidly when the doping concentration in window layer is lower than 1019 cm-3, or the defect density of intrinsic absorption is higher than 1017cm-3eV-1. The best performance of solar cell is obtained with the conversion efficiency of 7.82% when the thickness of the window layer is 5nm. Considering much defect in thin film in actual production in factories if the thickness of window layers is too thin, we choose 10nm as the optimal value with the conversion efficiency of 7.55%. The optimal value of optical band gap of window layer is 1.9eV. Though the band gap of a-Si thin film is about 1.72eV, we can increase it by other processions, such as the incorporation of Ge and C element in window layer. The theoretical study on various factors on the open-circuit voltage (Voc), short-circuit current (Joc), fill factor (FF) and the conversion efficiency of solar cells will provide theoretical guidance to experiment and production.

Poster Session Tuesday / 214

Determination of pumping properties and surface resistance of quaternary alloy of non-evaporable getter of TiZrVCu

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Non Evaporable Getter (NEG) has been employed extensively in the particle accelerator especially where the conductance of the vessel is severely restricted and ultra-high vacuum condition is required. NEG coating will significantly reduce the rate of outgassing and at the same time provides active pumping surface for H2, CO and CO2. In addition, it has been proven that NEG coated surfaces have a very low secondary electron yield, as well as low photon stimulated desorption and electron stimulated desorption yields. However the existing NEG film increases the impedance of the beam pipe by an order of magnitude which can the beam pipe wakefield impedance.
In order to increase NEG conductivity, at ASTeC we have commenced to study alternative NEG composition by adding more conductive element such as copper. In this study, we report on the pumping

properties, activation temperature, sticking probability (H, Co, CO2) and surface resistance Deterof new NEG quaternary alloy of TiVZrCu as function of the film structure, morphology, and composition.
Film bulk composition was determined using Rutherford Back Scattering RBS while the surface composition and surface chemical state as function of activation temperature was determined with X-ray photoelectron spectroscopy XPS. Surface structure and its morphology was determined by Scanning electron Microscope and X-ray driffraction.

Poster Session Tuesday / 119

Alumina ceramics vacuum chambers for injection magnets and their support configuration in the J-PARC RCS

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Alumina ceramics vacuum chambers are used in half the area of the whole ring in the J-PARC RCS to reduce eddy current effects due to rapidly varying magnetic field. The cross sections of these chamber are race track and circular used in dipole magnets, in quadrupole magnets, respectively and the chambers which are installed in injection magnets have several kinds of cross section which are ellipse, rectangular and racket-shape. A TiN film of 15 nm thick is formed inside the chambers for suppressing secondary electron emission, and copper stripes are mounted by epoxy adhesive outside the chambers for lowering the beam impedance.
All ceramics chambers of RCS are placed on the holding jig which is made by epoxy resin and alumina fiber mat for avoiding eddy current effect due to a rapid-cycling magnetic field. It was found that the radiation damage of epoxy resin used for the holding jig was small, because the tensile strength of the epoxy resin was still kept more than 300 MPa after gamma ray irradiation of 30 MGy.
These alumina ceramics vacuum chambers and also their support have worked very well and the RCS has been operated stably for ten years.

Poster Session Tuesday / 120

The gas migration in cryogenic tubes

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In superconductive linear accelerator, the performance and stability can be adversely impacted by gas adsorbed on cryogenic surfaces. The cryogenic devices usually work at liquid 4.2 K or 1.9 K, at such low temperature, the phenomena of gas adsorption on cryogenic surface will affect the gas migrating process along vacuum tubes obviously, so the gas migration process will be much different from the process at room temperature. In order to study the character of gas migration in cryogenic tubes, adsorbed probability and sojourn time at 4.2 K are measured by experimental study. whereafter, a model is established associated with experimental study results to depict gas migration process in cryogenic tubes. The model established in this article can be applied not only for hydrogen or helium migration in cryogenic tubes but also for other gas migration in tubes with

strong adsorbed probability. By the experimental study, model established and analyzed, it is indicated that at cryogenic temperature (4.2 K), adsorbed probability for hydrogen is very close to 1, which is several orders higher than the adsorbed probability at room temperature. The distribution of pressure in cryogenic tubes is also different from room temperature tubes.

Poster Session Tuesday / 121

Facile fabrication of amine-functionalized g-C3N4 nanosheets for enhanced nitrogen photofixation

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1.Introduction
The fabrication of g-C3N4 nanosheets is considered to be an effective method for improving its photocatalytic activity. Unfortunately, the time consuming multi-step synthesis and low yields of common approaches limit practical applications of both top-down and bottom-up synthesis methods.1 Herein, we used a one-pot approach to obtain amine-functionalized ultrathin g-C3N4 nanosheets by collecting the gaseous products from thermal polymerization of urea at 550 ℃.
2.Results and Discussion
As a product of urea decomposition, cyanic acid can spontaneously and rapid polymerize to generate cyanuric acid.2 The cyanuric acid then reacts with NH3 to produce ammelide, and melamine is obtained by the further reaction of ammelide and NH3. Finally, ultrathin g-C3N4 nanosheets were obtained in the larger porcelain crucible by the copolymerization process of melamine in the gaseous phase (shown in Fig. 1).

Fig.1 The different formation processes of g-C3N4 in gaseous and solid phase.
As shown in Fig. 2, the ultrathin and uniform g-C3N4 nanosheets could be easily achieved and the thickness was about 2.0 nm.

Fig.2 TEM and AFM images of g-C3N4 nanosheets.
As shown in Fig. 3a, the g-C3N4 nanosheets exhibited superior photocatalytic activity compared with bulk g-C3N4. However, the production of NH4+ decreased in the presence of N2, indicating that O2 played a dominant role in the photocatalytic N2 fixation by the g-C3N4 nanosheets (shown in Fig. 3b).

Fig.3 (a) Visible-light nitrogen fixation over bulk g-C3N4 and g-C3N4 nanosheets. (b) Visible-light nitrogen fixation under different atmospheres over g-C3N4 nanosheets.
3.Conclusion
The obtained g-C3N4 nanosheets have large surface area, high reduction potential and enhanced charge-carrier separation rate, thus promoting its activity for photocatalytic nitrogen fixation.

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Poster Session Tuesday / 123

The multistage differential pumping system in CIADS

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CIADS is short for China Initiative Accelerator Driven System, consists of intense-beam proton accelerator,spallation target and subcritical core.The multistage differential pumping system is a part of the large and complex vacuum system of CIADS which is between intense-beam proton accelerator and spallation target. The working pressure of spallation target is 5.0E4Pa for He,however, the pressure of beam line which links the accelerator is 1.0E-6Pa.So ensuring the proton bean to bombard the spallation target and obtaining the pressure vary from 5.0E4Pa to1.0E-6Pa is an important research task.
The multistage differential pumping system with ten orders of magnitude pressure differential is obtained, of which working pressure spans all areas of vacuum, including viscous, transition and molecular flows. Based on the principle of differential vacuum system, this poster introduces the choices of materials, vacuum measurement elements and pumping system.In a few days, the availability of pumping system will be tested. The calculation and the design of ten-stage differential vacuum system has been finished already.

Plenary session / 379

Chemical and electronic imaging of energy and electronics materials important for basic science and industrial applications

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Recently, remarkable progress has been achieved in modern microscopies. However, even if they have attained exceptional lateral resolution, the problem of providing powerful spectroscopic characterization at the nano- and mesoscopic-scale still remains. This gap is particularly filled by an innovative and powerful technique named k-space nanoscope or NanoARPES (Nano Angle Resolved Photoelectron Spectroscopy). This cutting-edge nanoscope is able to determine the momentum and spatial resolved electronic structure, disclosing the implications of heterogeneities and confinement on the valence band electronic states typically present close to the Fermi level. The k-space nanoscope can be effectively combined with chemical imaging based on high energy resolution core level scanning photoemission and X-ray absorption able to detect even very tiny different chemical environments.

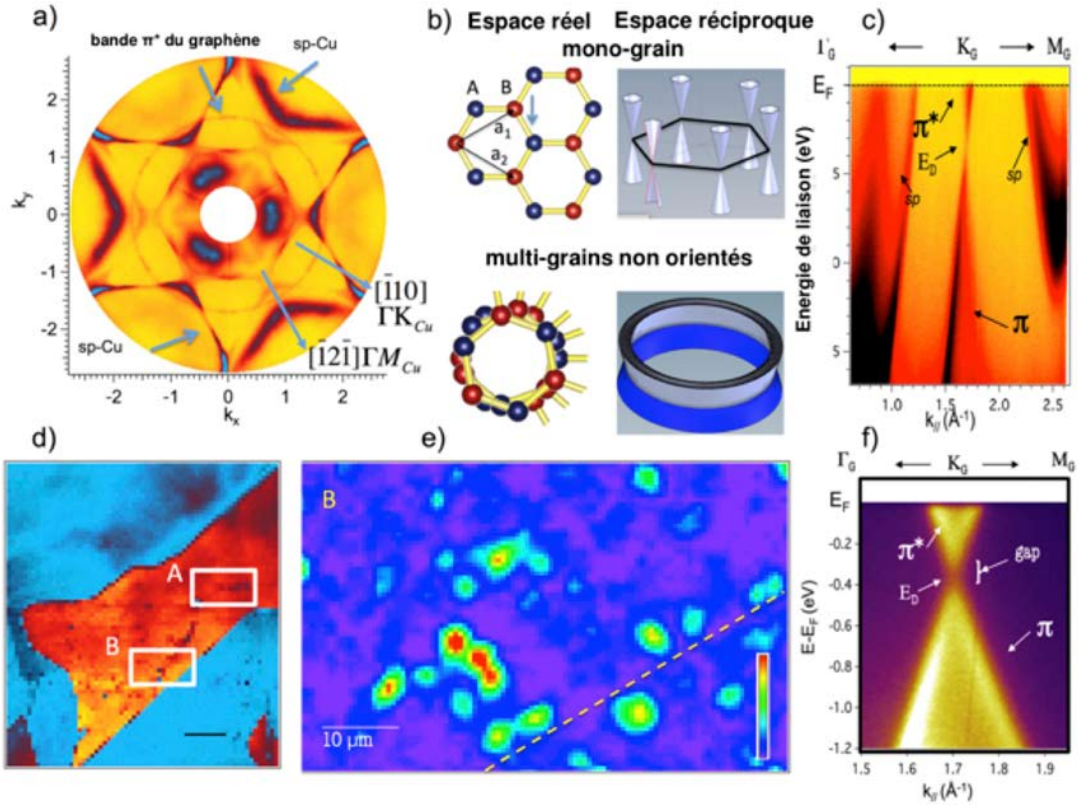

Figure 4: Electronic imaging by NanoARPES. of graphene films grown on copper foils by CVD, (a) The Fermi surface of the films (b) the symmetry of the real and reciprocal space of the graphene. (c) Dispersion of electronic states (E vs k // curves) (d) and (e) images of copper and graphene grains, respectively. (f) Zoom on the Dirac cone of a particular graphene grain.

In this presentation, the more relevant innovations in the field of chemical and electronic imaging of 2D materials will be disclosed, highlighting the basic principles, associated instrumental and appealing scientific cases. In particular, our findings describing the electronic properties of mono-atomic exfoliated graphene films as well as mono- and poly-crystalline monolayer of graphene grown on copper and SiC 2 will be presented. Outstanding Graphene/hBN and Graphene/MoS2 heterostrustures will be also described together with our latest results from electronic and chemical mapping of other complex 2D materials, beyond graphene [3-5]. Finally, special mention will be devoted the spin-charge separation in metallic MoSe2 grain boundary [6].

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Thin Films & Surface Engineering / 371

Specific features of thin film metallic glasses and their elastic properties relationship

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The bulk metallic glasses BMGs discovered in 1960, are very promising for structural and other applications. The searches for the mechanisms formation, thermal stability, origins of their ductility/brittleness and relationship between density, elastic/plastic properties, local chemical ordering and glass forming ability (GFA) are the hottest topics in the undergoing research of amorphous alloys. Many simple systems such as binary alloys either BMGs or thin film metallic glasses (TFMGs) are conveniently elaborated since a few ten years. Immiscible TE-TL (early transition-late transition metals) is an important category, which has already a good GFA and is used in combination with many other elements. The tremendous problem of BMGs is how to avoid the precipitation of the immiscible elements in the melts or the supercooled liquid. In case of thin films, via the sputtering, a vapor-to-solid, process, it is possible to avoid the precipitation of the immiscible elements, and an over-saturated amount of these elements could be added into the amorphous-alloy matrix. In this search, a systematic study of the properties of representative TE-TL binary alloys is a good starting point and can be extended to multicomponent alloys such as amorphous high entropy alloys, increasing their complexity. This presentation will recall specific features of amorphous materials compared to crystalline ones, conditions of appearance, and discuss their relationship with their elastic properties. Several examples of TFMGs elaborated in collaboration with different groups either by magnetron sputtering or pulsed laser deposition will be discussed, taking advantage of a unique combination of two complementary non-destructive techniques to measure film's thermomechanical properties. The non-conventional Surface Brillouin light Scattering (SBS) and Picosecond Ultrasonics (PU) are used to accurately measure sound velocities from which Debye temperature (θ_D) and isotropic elastic properties (C_{ij}) are calculated. Other mechanical parameter such as the Pugh's shear modulus over bulk modulus ratio (G/B), the Cauchy pressure ($C_{12} - C_{44}$), the cooperative parameter or Poisson ratio and the fragility index can also be used to infer the plastic behavior of these TFMGs. When possible, the usefulness of theoretical tools such as the molecular dynamics in the study of such disordered materials will be recall.

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Coordination self-assembly of terephthalic acid molecules and Fe on Cu(100) surface: phase diagram from statistical simulation

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Molecular self-assembly is the most promising approach for the direct preparation of functional nanomaterials. Recently, the coordination-driven self-assembly are increasingly being used to create metal-organic structures of varying complexity on the solid surface: discrete polygons, cages, one-dimensional polymers, two-dimensional porous networks [1,2]. In comparison with other non-covalent interactions, the metal-ligand coordination is superior. Despite the high binding energy, it is reversible and characterized by high directionality and selectivity. In addition, surface-confined metal-organic networks have greater thermal stability than other 2D supramolecular structures based, for example, on hydrogen bonds motifs.
In this contribution, we propose a detailed lattice gas model of contact monolayer of terephtalic acid molecules and Fe atoms on Cu(100) surface under ultra-high vacuum conditions, taking into account the surface mediation effects. The model was investigated with Monte Carlo methods and tensor-network approach as implemented in the SUSMOST code [3]. We have explored the effect of metal-ligand partial pressures ratio and temperature on the structure of adsorption layer. The simple lattice model allows us to determine not only the possible structures of the adlayer, but also the thermodynamic conditions of the phase existence in terms of partial pressures (chemical potentials

in gas phase) of the components. Our results are in good agreement with the experimental data [4,5]. The insights from this study can be helpful in design of 2D metal-organic architectures consisted of linear rod-like organic ligands on solid surfaces.

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Vacuum Science & Technology / 207

Adhesive bonding: applications and perspectives in UHV

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In the field of vacuum physics in industry as well as at research institutes the number of applications using optical signals for simple observation tasks, sample illumination or process monitoring increased dramatically in the last decades. As a result of the enhanced interest the demands on optical properties, the vacuum seals and the material properties of the vacuum optic components increase as well. As a consequence the joining technology between the optical material and the metallic surrounding becomes more important. In relation to the joining technology, the material choice and parameters of material processing have to be suitable for UHV applications concerning the cleanliness, outgassing and bakeout specifications and have to maintain the required high optical quality.

The present contribution focusses on the rapidly developing technology of adhesive bonding. Therefore, the benefits of adhesive bonding compared to the well-established techniques like brazing and thermal fusion are discussed using two examples: vacuum viewports and optical fiber feedthroughs. In terms of brazing or thermal fusion the choice of the optical material and the metallic surrounding is strictly limited, whereas adhesive bonding allows a flexible choice depending on the purpose of the application. In addition, in case of adhesive bonding the talk addresses the well-established concern of UHV compatibility and proves with experimental investigations the UHV suitability. In the contribution, the different joining technologies are characterized concerning technical and commercial aspects. Simulations and experimental data will be presented regarding mechanical stress, thermal cycling and outgassing rates.

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Surface properties of TiO2(011) and Mg:TiO2(011)

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Titanium dioxide is a metal oxide with many relevant technological properties for photocatalysis, chemical reactivity, electrical conductivity and solar energy harvesting. TiO2 is an inert insulator in stoichiometric form and it can be easily reduced into a n-type semiconductor TiO2-x with the transformation of Ti4+ to Ti3+ ions. This reduction is also characterized by the excess electrons populating localized Ti3d states in the band gap 1. These electrons can be well characterized by the presence of a defect state at about 0.8 eV below the Fermi level 2. Moreover, in the case of very low defect content, Ti3d states signal can be increased through resonant valence-band photoemission process where, at resonance, the direct photoemission of a valence-band electron interferes with the two-step autoionization process leading to the same final state. The angular distribution and the corresponding PhotoElectron Diffraction (PED) pattern of the defect state in resonant conditions have been measured for the rutile TiO2(110) surface and its distribution mapped in the case of a non-stochiometric surface [3] and after deposition of Na on a stoichiometric surface [4]. The main finding was the demonstration that charge distribution of the band gap state is essentially an intrinsic property of the TiO2 (110) surface, because largely independent of the way excess electrons are created. Within this framework we studied another rutile surface – the (011) - in the presence of Mg. Mg is a common contaminant of TiO2 and, by thermal annealing of the sample, it is possible to make it segregate from the bulk of the sample up to the surface. Both core level and valence band photoemission experiments were performed and the spectra show a decrease of the defect state linked to Mg presence. PhotoElectron Diffraction (PED) patterns were also recorded in order to study the localization of magnesium in the TiO2 surface layers. The experimental data set allows to exclude the formation of metallic Mg clusters on the surface and, rather, to point to the substitution of Mg into the Ti lattice sites. The decrease of the defect state intensity in the band gap observed in the presence of Mg is due to the formation of MgO which takes the role of "metal oxide dopant" for the TiO2 , since doping with a metal oxide (i.e. ionic doping) does not induce electron excess. In the case of stoichiometric and contaminant-free TiO2(011), the comparison of the experimental PED patterns with the simulation of the different models proposed so far [5] permits us to indicate the microfacet model as the reconstruction able to explain the specific observed features [6].

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New design flexibility for non-magnetic UHV chambers by using AluVaC®-Technology

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Aluminum is one of the preferable materials for reaching the UHV/XHV level. Comparable outgassing rates in the 1E-14 mbar*l/s/cm² regime using stainless steel components are only achievable by vacuum firing. Furthermore, stainless steel chambers for UHV/XHV applications are typically welded using different parts of tubes and CF weld flanges. After the welding and vacuum firing

it is almost impossible to reach defined geometric dimensions and tolerances in the range of some micron.

The talk covers non-monolithic and monolithic UHV vacuum chambers made from aluminum by using AluVaC®-technology. Combining the advantages of a well machinable material with the extremely low outgassing rates, in unbaked and in-situ baked condition, UHV vacuum chamber design can be rethought. Monolithic chambers can be machined rapidly, avoiding weldseams and ensuring a more compact chamber design, with minimum space requirements for maximal amount of ports.

In the talk, the new chamber design flexibility is discussed in detail, examples are given and experimental results are presented for stress tests, outgassing rate measurements and thermo-cycles.

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Comprehensive Thin Film Analysis by Cross-sectional X-ray Nanodiffraction

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All thin films and engineered surface layers inherently exhibit marked through-thickness property gradients. The complexity of these gradients varies greatly, ranging from the simplest case of a nucleation layer at a substrate interface, to intricately taylored multilayer architectures comprising many different materials, phases and microstructures at multiple levels of hierarchy. In order to understand the overall functional properties of these structures it is of paramount importance to characterize these through-thickness gradients, ultimately making it possible to properly attribute certain aspects of application performance to the time-dependent deposition parameters.
It is the aim of this contribution to demonstrate the comprehensive analytical capabilities of cross-sectional X-ray nanodiffraction (CS-nXRD) for this purpose. Using recent advances in X-ray focussing optics and 2D X-ray detector equipment, it has become possible to scan thin film cross-sections with sub-30nm spatial resolution, while recording the corresponding film thickness-dependent diffraction patterns. Contained within this combination of high resolution real space scanning and extensive reciprocal space analysis is the possibility to access a vast amount of information during each growth stage of a thin film.
Using the example of a $\mathrm{TiN}-\mathrm{SiO}_x$ multilayered thin film, the various parameters accessible through CS-nXRD will be presented. The film was deposited using magnetically unbalanced reactive pulsed direct current magnetron sputtering from one Si and two oblique Ti targets, alternately switching between them, resulting in a zigzag-like film morphology. The evolution of (I) phase composition, (II) crystallographic texture, (III) grain size, (IV) micro-stress/defect concentration and (V) macro-stress *within each of the sublayers* was characterized and could be attributed to various and time-dependent growth mechanisms, as well as the corresponding deposition conditions.
Further, complementary analysis by electron microscopy and CS-nXRD using *in-situ* sample environments for mechanical and/or thermal loading can provide an even more complete picture, where the nano-scale behavior of thin films during critical application conditions comes into reach of real

experimental characterization. For this purpose mechanical testing devices dedicated to *in-situ* CS-nXRD have been devloped and various examples will be presented, illustrating the potential of this approach.

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Oxygen Reduction Reaction Activity for Surface-strain-controlled Pt-M(111) Model Catalyst Surfaces Prepared in UHV

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Comprehensive understanding of oxygen reduction reaction (ORR) activity enhancement mechanisms for Pt-based alloy (Pt-M) catalysts is a key for developing highly-efficient cathode catalysts for polymer electrolyte fuel cell. To clarify the effects of the alloy surface atomic structures (e.g., atomic arrangements of surface Pt atoms, Pt/M atomic ratio etc.,) on ORR activity, well-defined model catalyst study should be required. We have investigated ORR properties for the well-defined Pt-based bimetallic single crystal surface alloys prepared in ultra-high vacuum (UHV) 1. In this study, ORR activities are investigated for Pt/M (M=Co and Zr) model catalysts prepared on Pt(111) substrate through alternative arc-plasma depositions (APDs) of Pt and M nano-layers.
The UHV-APD-EC apparatus is described elsewhere 2. Pt and M layers were alternately deposited onto a clean Pt(111) substrate by the APDs in UHV. Total thickness of the Pt/M and thickness of the topmost-surface Pt and bottom M layers are fixed to be 6 nm, 1.6nm, and 0.4nm, respectively, and the underlying M thickness are changed. Structural analysis for the prepared PtMxnm/Pt3.6nm/M0.4nm/Pt(111) (denoted hereafter as M_xnm) samples are performed by using in-plane XRD, cross-sectional STEM. For the ORR activity evaluation, the UHV-prepared samples were transferred to an N2-purged glove box without air exposure. Cyclic voltammetry (CV) and linear sweep voltammetry (LSV) were conducted in N2-purged and O2-saturated 0.1M HClO4 in the glove-box. To discuss EC stability, square-wave potential cycling between 0.6(3s) ~ 1.0(3s) V vs. RHE was applied.
Surface strain estimated by in-plane XRD showed that compressive and tensile strain worked on Pt-Co(111) and Pt-Zr(111) bimetallic surfaces, respectively. ORR activity enhancement well corresponds to in-plane lattice distance of the topmost Pt(111) layers estimated by the XRD. For example, the activity enhancement factor for the Co_1.6nm having ca. 2 % compressive strain is highest (13-fold vs. Pt(111)) for the Pt-Co(111) series. The results suggest that the ORR enhancements closely correlate with surface strain of the topmost Pt(111) layers induced by underlying M layers.
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High Vacuum set-up for permeability and diffusivity measurements of vacuum materials

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Vacuum materials require precise knowledge of their permeability *P* and diffusivity *D*, e.g. for sealing or outgassing. Agreement with the methods to measure *P* and *D*, mainly infusion/outgassing or membrane techinques1, is sometimes poor and material dependent2.
The paper reports an experimental apparatus for gas flux measurements suitable for membrane techniques. It allows to measure transient fluxes and consequently simultaneously *P* and *D*3. A novel membrane assembly and the insertion of a Spinning Rotor Gauge (SRG) allow accurate results respect to a similar system described in ref. 4. A non-permeable material supports the permeation cell, composed by a freestanding membrane. Freestanding configuration avoids miscalculations of permeation area and unwanted lateral diffusion, artefacts often observed in membrane permeability measurements. A turbo pump maintains high vacuum conditions at the membrane downstream side. The system is equipped with a Residual Gas Analyzer (RGA), an Ion Gauge, a SRG, and a leak of known conductance. Upstream side of the membrane is equipped with diaphragm gauge. The measure of the stationary gas flow *Jss* generated by a known differential pressure of pure gas across the membrane allows to determine the permeability. The diffusion *D* is calculated by means of eq. (5) of ref. 4 integrating *J(t)* with respect to time. Because of fast response time of the RGA and taking into account that it is calibrated against SRG, the relative error on *D* is < 10%.

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Bottom-up fabrication of atomically precise graphene nanoribbons

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The bottom-up fabrication strategy 1 has introduced the possibility to grow carbon nanostructures with atomic precision and hence allows to controllably tune their electronic properties. The approach building on the predefined colligation and dehydrogenation of specifically designed precursor monomers has been successfully applied for the synthesis of various types of graphene nanoribbons (GNRs), including armchair GNRs with width-controlled electronic band gaps [2-5] as well as zigzag GNRs with their characteristic edge states [6]. Here, I will review the basic mechanisms of the bottom-up fabrication of GNRs and describe recent advances in the fabrication of prototypical devices with GNRs as active material 7. An even wider range of properties can be accessed by creating GNR heterostructures where segments of different width and hence bandgaps are seamlessly stacked along the GNR axis. We have recently shown that highly tunable intraribbon quantum dots can be fabricated on the basis of seven atom wide (N=7) armchair GNRs [8]. By controlled overheating of the pristine 7-AGNRs, segments of multiple widths can be achieved through edge fusion, which results in low-bandgap segments embedded in the large bandgap 7-AGNR. Most importantly, the interfaces between the segments are atomically defined and give rise to characteristic interface states. The energy splitting of these interface states has a different dependence on the quantum dot length, as compared to the confined quantum dot states, which introduces an additional degree of

freedom for controlling the electronic structure of the GNR quantum dot. Finally, concepts for the synthesis of GNR heterostructures exhibiting such localised states at predefined positions will be discussed in view of further extending the range of electronic properties of GNRs.

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Calibration of helium leak rate down to 10-14 Pa m3/s for leak testing of MEMS

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Vacuum sealing devices with a small inner volume like micro-electro-mechanical system (MEMS) require a strict helium leak test to ensure the lifetime because the inner pressure rapidly increase even if a fine leak is occurred. However, it is difficult to measure the helium leak rate less than 10-11 Pa m3/s reliably because the range of commercially available helium standard leak is limited down to 10-11 Pa m3/s in typical. In this study, we have developed a helium leak testing devise including a calibration system whose calibration range is less than 10-11 Pa m3/s. The principle of the calibration is a constant conductance method where the leak rate is obtained by the product of the molecular conductance of a leak element and its upstream pressure. A porous plug made of a sintered stainless-steel with a molecular conductance of 3.04×10-9 m3/s for He was used as the leak element. The upstream pressure was set by using a static expansion method down to 10-5 Pa. The generated helium leak down to 10-14 Pa m3/s was measured by an accumulation method with a quadrupole mass spectrometer (QMS) and non-evaporated getter (NEG) pump. The increase of partial pressure of helium was measured by QMS. The NEG pump was used to maintain the operational pressure of QMS by evacuating outgases from the inner wall of the vacuum chamber and QMS except for helium. The increase ratio of helium partial pressure was proportional to the generated helium leak rate down to 10-14 Pa m3/s. ‘

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Generation of an energy and mass selective hyperthermal ion beam for investigation of ion-assisted thin film growth processes

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Apart from the widely applied chemical vapor phase epitaxy and conventional molecular-beam epitaxy (MBE) there exist other methods to prepare thin epitaxial compound (nitride) films or nanostructures like the ion-beam assisted deposition (IBAD) technique. IBAD is a hybrid physical thin film deposition technique which on the one hand offers the opportunity to investigate fundamental processes involved in ion-assisted film growth and on the other hand provides manifold possibilities to intentionally modify the properties of the prepared thin films. The technique is characterized by simultaneous irradiation of the growing thin film with energetic ions during deposition. By this, a ballistic enhancement of the adatom mobility can be achieved, leading to an enhanced crystalline quality even for thin and ultra-thin films. Additionally, the technique is defined by the separability of the material fluxes that are directed towards the sample, as well as by the accurately adjustable parameters vapor flux and ion flux, the latter generated in form of a broad ion beam. In the case of nitrogen ion beams however, nitrogen plasma based ion-beam sources counteract the demand to chose the ion-beam parameters as freely as possible, because the resulting ion beam consists of a blend of both molecular and atomic nitrogen ions. Particularly in the case of hyperthermal ion energies ranging from several 1 eV to a few 100 eV this creates great difficulties in assessing the dissemination of the ion energy to the growing film surface. In this contribution, a custom setup is presented which allows generating a hyperthermal nitrogen ion beam with variable ion energy and selectable ion mass. This was realized by combining a plasma based ion source with a quadrupole mass filter system, equipped with entry and exit ion optics, ion-beam deflection, as well as ion-beam current monitoring. The key features of this setup are demonstrated and discussed regarding ion-assisted thin film growth.

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Brittle film-induced cracking of ductile substrates

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Film and substrate mechanical integrity is essential for the whole system's performance. In the present study, cracking of brass ductile substrate induced by brittle TiN film fracture was observed. Counter-intuitively, instead of protecting the ductile substrate, a brittle film can cause its premature fracture, as demonstrated here experimentally. Brittle film fracture could induce cracking of ductile substrate at considerably low strain level. Analytical calculation based on energy conservation during crack propagation is presented to explain this phenomenon of film-induced cracking. It is shown that crack depth penetrated into the substrate is a function of both crack velocity and the number of dislocations emitted from the crack tip. Relatively thick brittle films and fast propagating cracks favor fracture of the ductile substrates. The critical crack velocity, which can induce the cracking of brass substrate, is 61 m/s. The presence of brittle film could not only prevent dislocations escaping from the surface of the crystal and inhibit dislocations emitting from surface dislocation sources, but also initiate a channel crack with high velocity due to brittle fracture. Both of them contribute to crack propagation in soft brass substrate. This study provides an alternative view to the notion that a brittle film can protect the ductile substrate from damage.

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A Novel vacuum gauge: Applications for Pressure Measurement, He-Leak detection and Residual Gas Analysis

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A pressure gauge with an integrated He-leak detector based on a novel ion source was presented to the vacuum community at the EVC-14 in 2016. The recent progress in the development of a vacuum gauge based on this ion source will be presented.

The fundamental idea of the vacuum gauge is the novel measuring principle: Instead of directly measuring the ion current, ions are accumulated inside an electron space charge region. The total pressure in the chamber is determined by the accumulation time that is necessary to collect a certain amount of ions. Thereby the capacity of the ion trap is independent from the prevailing pressure and is exclusively determined by the space charge density.

Regarding the pressure measurement, this measuring principle has some advantages compared to the conventional hot cathode: At high pressures the accumulation times are very short. This allows high repetition rates in the range of only a few milliseconds. In the low pressure range (XHV, UHV), the accumulation time is long, however it is possible to measure these pressures reliably since the ions signal remains constant.

Furthermore, a short time-of-flight (TOF) path is connected to the ion source. On this route, the collected ions are separated according to their masses and measured at the Faraday Cup detector in a time separated manner. This enables the gauge to measure the residual gas composition simultaneously to the total pressure. In particular a Helium leakage test can be carried out without the usage of a cost-intensive electron multiplier.

In the talk the underlying physical principles of the novel ion source are presented along with numerous experimental results. Next to total pressure and low mass spectrum measurements, the capability of analyzing the gas composition up to 50 m/z at high repetition rates is evaluated. Use cases for different final applications will be discussed.

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Highly selective covalent organic functionalization of epitaxial graphene: a platform nano-bio-hybrid composites

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Graphene functionalization is an important step for the development of graphene-based materials with tailored electronic properties. However, its high chemical inertness makes difficult a selective covalent functionalization, and most of the works performed up to the date report electrostatic molecular adsorption or unruly functionalization. We show a new mechanism for promoting highly specific covalent bonding of any amino-terminated molecule and a description of the operating processes. We show, by different experimental techniques and theoretical methods, that the excess of charge at carbon dangling-bonds formed on single-atomic vacancies at the graphene surface induces enhanced reactivity towards a selective oxidation of the amino group and subsequent integration of the N within the graphene network. Functionalized surfaces retain the electronic properties of pristine graphene as unaltered.

Thus, we use this strategy to link to graphene a molecule with a robust thiol-terminated moiety derived from a p-aminothiophenol (p-ATP) molecules. We use this facile strategy to covalently link gold nanoparticles, which remain firmly anchored to the surface after many washing and annealing cycles. In parallel, we also couple in vitro a thiol-modified ssDNA aptamer to the p-ATP-functionalized graphene surface, and successfully obtain atomic force microscopy images both in air and in a liquid environment, and demonstrate that the anchored aptamer retains the functionality required to recognize its target protein, PCBP-2. This work opens the door to the integration of high-quality graphene layers in technological platforms for plasmonics, biosensing or advanced field-effect transistor devices.
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Catalytic Performance of Coated Hollow Glass Microspheres

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Hydrogen can be stored in a hybrid system consisting of hydrogen pressurized hollow glass microspheres (HGMS) and a hydride, e.g. $NaBH_4$. Storage involves heating and pressurizing the spheres at approx. 85 MPa, forcing the gas into the them. Hydrogen is released by heating again to approx. 250°C. To reach this temperature the exothermal chemical reaction of $NaBH_4$ with water, which produces hydrogen as a welcome by-product, is used. To promote the reaction the HGMS (diameter approx. 20 µm) have to be coated with a catalyst. The catalyst coating on the HGMS is deposited using a special coating device based on non-reactive (for metals) and reactive (for non-metals) magnetron sputtering. It provides continuous intermixing of the fragile spheres in a container by a combination of rotation and concussion. It is possible to produce extremely homogenous coatings on single spheres as well as on ensembles with volumes up to 100 ml.
The catalytic reaction is tested in a set-up which measures the released heat and amount of hydrogen. For a two layer film architecture which consists of an adhesion promoting film of reactively sputtered TiO_2 and a reactively co-deposited film of Ru and TiO_2 the theoretical maxima of released heat and hydrogen could be achieved in a first run. This special film architecture was chosen because pure Ru, despite also exhibiting excellent catalytic properties, delaminated from the microspheres after performing the catalytic reaction. To test the durability of the two layer system, more catalytic runs were performed on the same sample. It could be shown that catalytic activity was still present at the fourth re-use, if the catalyst coated spheres were cleaned properly from reaction products by exposure to an acidic environment. The coatings sustained all cleaning steps and only showed minor signs of delamination, so that they can be considered to be usable also for even more catalytic cycles.

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Measurement of permeability of low permeable membranes

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The determination of the permeability of low porous media like the micro and nanoporous membrane is still a challenge up to now. The low permeable membranes have several applications in vacuum technology, filtering, separation process, protection from shock waves and flow control. It can combine high mass flow rate and a high level of rarefaction. This property makes it particularly suitable as a leak element, by taking advantage of the constancy of conductance in free molecular regime, for example for calibration of ionization gauges or mass spectrometer 1. Gas permeability is an important parameter to understand the transport characteristics of the porous media. This characteristic can be obtained from the mass or volume flow rate through a media. The proposed experimental methodology is based on the constant volume technique, which was initially developed for the isothermal and non-isothermal measurements of the mass flow rate through the microchannels 2. In this work, we present an experimental technique allowing for step by step verification which allows for higher accuracy and shorter experiment time than the similar and commonly used method such as "pulse-decay" techniques [3]. We investigate permeability for a wide range of pressure and several gases, from continuum to free molecular regime.

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Secondary Electron Emission Study of Nanometric Carbon Coatings

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An investigation on the secondary electron emission (SEE) properties and stability of nanometric carbon coatings is reported. The key to creating an ideal material to avoid avoiding multipactor effect or electron cloud in large particle accelerators, is to modify its SEE properties to obtain SEY<1 in all primary energy range. The SEE coefficient (SEY) was measured by single-pulse electron beams with a pulse dose of 80 fC. To study the modifications on the optical and chemical properties of these coatings under heat-treatments and corrosive and/or oxidative agents, complementary techniques were used: x-ray photoelectron spectroscopy, field-emission scanning electron microscopy, and UV-VIS spectroscopy. We have achieved nanometric rough carbon coatings with SEY<1 for all primary energies. The photoemission quantum yield and the building up of surface charge under VUV pulsed irradiation were compared with a reference gold foil. Also Ni, Ag and Cr (< 20 nm) coated with carbon show a shift of their SEY curves (SEY versus primary energy) towards higher energies, in the 0-200 eV region of the first crossover energy for SEY = 1.

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A novel wide-range apparatus developed for performance testing of molecular pump

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As an effective tool to acquire ultra-high vacuum (UHV), molecular pump is widely used in scientific research and advanced manufacturing, and the performance testing of molecular pump is of great importance to its quality evaluation and the design for UHV system. This presentation will not only give a thorough introduction of a novel wide-range testing apparatus of molecular pump developed by Beijing Engineering Technology Research Center for Vacuum Metrology and Testing, but also show the results of the testing program organized by Chinese Vacuum Society (CVS) in 2017 to evaluate all kings of the molecular pumps used in China.
Comparing with other testing apparatuses of molecular pump based on dynamic conductance method or flowmeter method, the newly-developed testing apparatus extends the measurement ranges of pumping speed, compression ratio, as well as ultimate vacuum in the following ways: I) the apparatus is designed by well-modularized method and composed of three modules, that is, gas flowmeter module, test chamber module and calibration module; II) a newly-developed combining standard gas flowmeter providing a fine control of gas flow in the range of 10~10-12 Pam3/s is applied in the gas flowmeter module, and only by this method, the pressure in the test chamber can approach the range of 1~10-8 Pa in the testing process; III) the test chamber module consists of a series of test chambers with different sizes to meet the needs of various molecular pumps; IV) to improve the accuracy of measurement, the pressure of test chamber is measured by a combination of a capacitance diaphragm gauge (CDG), a spinning rotor gauge and an extractor gauge, in which the spinning rotor gauge is used as a reference standard to in situ calibrate the extractor gauge in the range of 10-2⊠10-4 Pa; V) the outlet pressure of the molecular pump is measured by a combination of gauges with range of 1×10-2~1×105 Pa, which can extend the range of the compression ratio.
The experimental results show that the newly-developed apparatus can reach the pumping speed range of 1~6000 L/s with a combined standard uncertainty of 1.6%~2.6%, the ultimate pressure range of 10-3~2×10-10 Pa with a combined standard uncertainty of 1.2% ~3.0% and a compression ratio range of 10~1012 with a combined standard uncertainty of 1.3% ~ 3.2%.

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Structure and properties of ion-assisted and co-sputtered Ti-Zr-B hard and superhard coatings

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Ti-Zr-B films including TiB2-Zr composite, TiZrB2 solid solution, and TiB2/ZrB2 multilayer films were deposited by co-sputtering targets of TiB2 and Zr as well as TiB2 and ZrB2 under various substrate bias voltages. Zr and Ti are in the same group in the periodic table. Zr/Ti atoms may occupy either substitutional or interstitial positions in the lattice forming (TixZr1-x)B2 solid solution. The range of substrate voltage explored is from 0 to -200 V. The bias voltage between -90 and -120 V is appropriate for optimal film mechanical properties. For example, under a substrate bias of -95 V, the films of ~3 at% of Zr in TiB2 exhibit (TixZr1-x)B2 solid solution phase with strong (0001) preferred orientation and achieved the highest hardness of 52 GPa with ~ 2 GPa of compressive stress and a surface roughness of 0.3 nm. In contrast, the film prepared without substrate bias is randomly oriented and not a solid solution and possesses only 19 GPa in hardness, 0.25 GPa of tensile stress and a surface roughness of 3.0 nm. The results show that the crystal preferred orientation, crystallinity, composition, grain size, surface roughness, stress, toughness, and hardness of the Ti-Zr-B films are greatly affected by the ion bombardment on the growing film.

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Ensuring well defined quality of vacuum components – a combined user and manufacturer perspective

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While planning vacuum experiments in particle accelerators and other research facilities, many technical conditions have to be considered. Especially to achieve vacuum in the UHV/XHV range, components like vacuum chambers need to fulfill well defined, vacuum-specific requirements. For that reason, it is important to specify grantable and binding quality characteristics when vacuum components are manufactured by a vacuum industry company. "Leak rate", "residual outgassing rates", "cleanliness", "suitable for UHV applications" - these are just technical buzzwords when not everybody means the same whilst using them. A general technical language is necessary for the accurate definition of Quality and according acceptance inspection rules.
The present talk will give suggestions from a manufacturers point of view for the unmistakable declaration of quantified and verifiable, vacuum-specific characteristics for vacuum chambers and components. Systematic investigations in several manufacturing steps and their impact, especially on outgassing characteristics, are presented. From the research results, engineering and manufacturing principles are derived for the production of UHV/XHV-components with residual outgassing rates down to the measuring limit of commonly used analyzing equipment. Elaborated measurement and test methods for verifying the correlation between required specifications and the real component characteristics will be reviewed.
Framed in an overview of the complete planning, construction and manufacturing chain of vacuum chambers and components in an industrial scale, the talk will contribute into an improved cooperative work between vacuum component manufacturers and particle accelerator users. Finally it is shown: tough requirements in UHV/XHV-components can be guaranteed and achieved on an economically reasonable way.

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Anomalous behavior of the magnetization at the surface of Fe3O4(100)

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Magnetite (Fe_3O_4) is attracting attention as a potential material for spintronic devices due to the predicted half-metallic behavior with a high Curie temperature of 858 K 1. The recent trend toward high densification of devices increases the importance of the surfaces. In our previous work, non-collinear magnetic structures are revealed at the Fe/MgO(001) interface 2 and on the Fe_3O_4(111) surface [3]. On the other hand, it is theoretically pointed out that the critical behavior at the surface is different from that in the bulk if the surface exchange interaction is different from the bulk one [4].
In this work, we investigated the magnetic phase transition and the magnetization direction of the Fe_3O_4(100) surface by means of the conversion electron Mössbauer spectroscopy (CEMS). The sample is $^{57}Fe_3O_4$(100) with a thickness of 20 nm deposited on the Fe_3O_4(100) to raise the surface sensitivity of CEMS. The temperature dependence of CEMS was measured in helium and the internal

magnetic field was obtained from the spectral analysis. The Curie temperature is estimated at 861 K. The critical exponents of the tetrahedral (A) and octahedral (B) sites of Fe are respectively estimated at 0.237±0.010 and 0.277±0.006. These are close to the value of 0.23 of the 2D XY-model in contrast to the bulk values which are described by the 3D Heisenberg model [5]. The magnetization directions of the A and B sites are in-plane up to 680 K, which is different from the easy magnetization axis of 111 of magnetite. Furthermore, it was found that the magnetization directions gradually cant from in-plane to out-of-plane above 720 K. Considering the probing depth of CEMS, these characteristics have a depth of larger than 50 nm.

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Trapped aqueous films lubricate a highly-hydrophobic surface.

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Friction at hydrophobic surfaces in aqueous media is ubiquitous (e.g. prosthetic implants, contact lenses), but is not well understood. Here we measure directly both normal forces and sliding friction in an aqueous environment between a hydrophilic surface (single-crystal mica) and a stable, smooth, strongly hydrophobic surface (a spin-cast fluoropolymer film), using a surface force balance. Normal-force vs. surface-separation profiles indicate a high negative charge density on the hydrophobic surface, in line with previous studies where it is commonly attributed to adsorbed –OH- ions. Sliding of the compressed surfaces under water or in salt solution (0.1M NaCl) reveals remarkably low friction (friction coefficient � ≈ 0.003 – 0.009) up to contact pressures of at least 50 atm (ca. 5 MPa). This is attributed to hydration lubrication mediated by hydrated counterions trapped between the surfaces: hydronium ions in the case of water or Na+ ions in the salt solution. Our results show that lubrication at a hydrophobic surface under water can occur via mechanisms hitherto associated only with hydrophilic surfaces.

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Monitoring of volatile vacuum species using remote optical emission spectroscopy

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Conventional residual gas analysers, such as quadrupole RGAs, have difficulty directly monitoring certain processes due to the high process pressures (typically above 1E-4 mbar) and the presence of volatile species such as hydrocarbons. These hydrocarbons often contaminate the RGA filaments, rendering the sensor unusable.
An alternative gas monitoring sensor that operates directly at pressures above 1E-4 mbar has been

built around plasma emission monitoring. A small "remote" plasma can be generated inside a vacuum sensor. Consequently, species that are present within the vacuum become excited in the sensor's plasma, emitting a spectrum of light, which can then be used to identify and monitor the emitting species. Crucially, this sensing method has been shown to be robust when exposed to the CVD and ALD processing environments.
This presentation will describe the principle of this sensing method and results that can be achieved in areas that cannot be addressed easily by conventional RGA technology. Detailed information will be presented of its use in monitoring both thermal and plasma ALD processes that use precursors such as water vapour, ammonia and aluminium and niobium based hydrocarbons.

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Laser–SARPES study of spin-texture of Sn atomic layer at graphene/SiC(0001) interface

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Tin (Sn) atomic layers attract considerable interest owing to their spin-dependent physical properties caused by their strong spin–orbit interaction. We have studied the spin-dependent band structure in a Sn atomic layer that is intercalated into the graphene/SiC(0001) interface 1 using laser-based spin- and angle-resolved photoemission spectroscopy (laser-SARPES) . We can not only obtain high energy-resolution spectra but also observe spin-dependent quantum interference in the photoemission process 2 with the use of the newly-developed laser-SARPES[3]. In the atomic layer, the Sn atoms occupy on-top sites of the Si-terminated SiC(0001) surface with in-plane Sn–Sn bonding. The graphene overlayer ensures little oxidation upon exposure to air in the Sn atomic layer at the interface. This is useful for *ex situ* characterization and device fabrication. We find spin-split Sn bands due to the spin-orbit interaction. At K point, two kinds of spin splitting, Rashba and Zeemann types, appear while the crystal symmetry indicates only the Zeemann type [4]. The experimental results are attributed to a novel symmetry of the Sn wave function on the basis of first-principles calculations.

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One-dimensional phosphorus chain and two-dimensional blue phosphorene grown on Au(111) by molecular-beam epitaxy

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Single layer (SL) phosphorus (phosphorene) has drawn considerable research attention recently. It is a semiconductor showing superior transport and optical properties. In the past several years, few-layer or SL black phosphorus has been successfully isolated by exfoliation and extensively studied. Recently, an allotrope of black phosphorus, blue phosphorus (blueP), is predicted to stabilize in SL form on several substrates. In this work, we report a unique growth sequence of blueP by molecular-beam epitaxy during its growth on Au(111) substrate. One-dimensional (1D) atomic chains of phosphorus are observed at low coverage, which develop into more compact patches of the $(\sqrt{3} \times \sqrt{3})R30^\circ$ structure and finally blueP with increasing coverage. In particular, over a large coverage range, a composite surface consisted of locally high-P coverage blueP islands and locally low-coverage 1D chains or loose $(\sqrt{3} \times \sqrt{3})R30^\circ$ patches prevails owing to the minimization of the overall system energy. First-principle calculations are carried out to explain this growth phenomenon.

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Development and first investigations of a new static expansion system based on aluminum technology

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The static expansion method is a well established method for realizing the pressure scale in medium and high vacuum by a fundamental method. The main component of uncertainty of the generated pressure in such a system is due to the temperature uncertainty of the vessels involved during an expansion. Stainless steel is a relative poor heat conductor so that considerable gradients of temperature can develop across a larger vessel. For this reason, PTB is developing a new static expansion system based on aluminum. First results indicate that the temperature uniformity of the vessel is greatly improved compared to stainless vessel under the same conditions. This justifies the expectation that the total uncertainty of the realized pressures will be considerably reduced. First results of temperature measurements and expansion ratio determinations will be presented.
In addition, the new system shall be completely automated. The concept of this automation will also be presented.

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Novel Superhydrophobic Celllulose Coating and Its Multifunctional Applications

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Recently, an increasing trend has been noticed towards synthesizing superhydrophobic surface with a water contact angle (WCA) higher than 150° due to its many potential applications including water repellency, oil spill recovery, self-cleaning, antifouling, anti-icing-deicing and so on. Unfortunately, most of the cases the superhydrophobic surface was achieved utilizing either fluorinated materials or organic-inorganic nanoparticles as the water−solid contact angle varies with the surface chemistry and roughness of the solid surface. Herein, we presented a novel approach for preparation of superhydrophobic coating without involving any such hazardous chemicals with the oath to create sustainable world. The superhydrophobic coating was prepared using cellulose nanofibers (CNFs) via a new surface modification chemistry. The as-synthesized cellulose surface shows water contact angle (WCA) value of 161°(±2°). When used this material to coat other substrates such as paper, sponge, fabrics, aluminium, etc., to test the water repellent capacity, the WCA values were found to be between 136-147°(±3°) for the above surfaces. Moreover, the excellent durability of the coating made it very promising for efficient oil/water separation process to self-cleaning textile.

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Thin Films of Trimeric Surfactant as Boundary Lubricants

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Surfactants are widely used to modify surfaces and interfaces properties. Unique cationic trimeric surfactant was found to form liposome-like aggregates in solution (1, 2). The surface structure of the trimeric surfactant tri(dodecyldimethylammonioacetoxy)-diethyltriamine trichloride (DTAD) on mica, and the interactions between two such DTAD-coated surfaces were determined using atomic force microscopy and a surface force balance. In an aqueous solution of 3 mM, five times the critical aggregation concentration (CAC), the surfaces are coated with worm-like micelles or hemi-micelles and larger (ca. 80 nm) bilayer vesicles (3). This surface coating is strongly lubricating up to some tens of atmospheres, attributed to the hydration-lubrication mechanism acting at the exposed, highly hydrated surfactant headgroups. Moreover, on replacing the DTAD solution by surfactant-free water, the surface structures have changed to a smooth and hydrophobic monolayer. Surprisingly, this trimeric surfactant monolayer, which is highly hydrophobic, is at the same time positively charged under water. These monolayers are stable over days even under salt solution (3). The stability is attributed to the several stabilization pathways available to DTAD on the mica surface.

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Vacuum Science & Technology / 115

Simulation and measurement of the deuterium retention in the cryogenic beamline of the KATRIN experiment

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The KATRIN neutrino experiment aims to measure the effective mass of electron anti-neutrinos with an unprecedented sensitivity of 0.2 eV/c^2 by measuring the energy spectrum of beta-electrons from tritium decays close to the endpoint of the spectrum. The decays take place in a high-intensity windowless gaseous tritium source (WGTS). The electrons are guided by strong magnetic fields through a beamline with super-conducting solenoids to the huge main spectrometer (10^{-11} mbar) for energy measurement. Since only a fraction of $2 \cdot 10^{-13}$ of all electrons have a kinetic energy within 1 eV below the spectral endpoint, the sensitivity of the measurement depends on a low background rate in the spectrometer. Therefore the tritium flow from the source (10^{-3} mbar) has to be reduced by at least 14 orders of magnitude before it reaches the spectrometer section. This large reduction in the 90-mm-diameter beamline is achieved with a combination of differential pumping, using turbomolecular pumps (TMP) and a cryogenic pumping section (CPS) with an argon frost layer at around 3 K.
This talk describes the Test Particle Monte Carlo (TPMC) simulation of the beamline of the CPS for the non-radioactive gas deuterium with MolFlow+. Since the gas flow through the CPS is reduced by far more than 7 orders of magnitude, the simulation is done in several consecutive steps. The results are combined in the post processing of the TPMC results. In the post processing algorithm we also investigate the time dependence of the reduction factor by considering a finite sojourn time of the deuterium on the cryogenic argon layer. This leads to a slow migration of deuterium in downstream direction. In a final step the half-life and migration of tritium is taken into account by a reduced sojourn time.
After finishing the construction of the KATRIN setup, the commissioning of the experiment started in October 2016. The results of the commissioning measurements with deuterium will be compared with the TMPC simulations. First traces of tritium are planned to be admitted into the beamline in May 2018.

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Fine Analysis of Surface Structure by using Kikuchi Envelope of Reflection High-Energy Electron Diffraction

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Fine Analysis of Surface Structure by using Kikuchi Envelope of Reflection High-Energy Electron Diffraction

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The Kikuchi pattern, which is created by the result of inelastic scattering and dynamical diffraction of electrons, includes structural and elemental information about the surface. The Kikuchi envelope related to the surface wave resonance (SWR) is considered to include detailed information about the topmost surface. The Kikuchi pattern has been simulated based on dynamical diffraction theory 1. It was also shown that the simulated pattern agrees with the observed pattern very well. Comparison between the simulated and observed patterns confirms that Kikuchi envelope under the SWR for the reconstructed surface shows the influence of the local surface potential formed by the adsorbate, where the surface wave propagates within the surface reconstructed layer with a thickness of 0.2 nm 1.
The intensity profile of the Kikuchi envelope is very sensitive to the surface structure. In this paper, we show that the intensity profile of the Kikuchi Envelope changes with the position of surface atom in the simulation of the Si(111) $\sqrt{3}\mathbf{x}\sqrt{3}$-Ag surface structure, where the contrast of the Kikuchi Envelope shows clear change when the height of Ag layer sifts to 0.01 nm. The intensity profile of Kikuchi Envelope is very useful to determine the fine analysis of the surface structure.

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Vacuum Science & Technology / 238

An analysing tool for analogue residual gas spectra in UHV implying machine-learning applications

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We present an algorithm that helps identifying components and contaminants in a residual gas spectrum. At first the possible weighted contribution to the measured spectrum for each reference out of a library is determined and ranked. A residual gas spectrum, in logarithmic scale, is then reconstructed by simulation based on partial pressures and fragmentation patterns of the most likely components and compared with the measured spectrum. The algorithm takes into account analyser specific parameters such as noise, electronic offset and sensitivity.
Residual gas analysis is also to a great part pattern recognition. This is a typical application for machine-learning tools. Such tools, however, need to be trained with a large number of spectra. The fact that residual gas spectra can be simulated in a rather realistic way with the upper mentioned method gives the possibility to train such tools with thousands of simulated randomised gas mixtures. The outcome of a feasibility study about the usefulness of using machine-learning applications for the recognition of residual gas components is presented. Such a tool may then be a complementary and faster approach of identification of residual gas components.

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Tribological and electrical characterization of Ag/Rh coating pair for sliding RF contact application for ITER

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Radio-Frequency (RF) contacts are key components on the International Thermonuclear Experimental Reactor (ITER) Ion Cyclotron Resonance Heating (ICRH) antenna, and these components are facing big challenges such as 2kA operation current load and severe wear at around 200 °C in high vacuum. Stainless steel 316L and CuCrZr are proper candidates to be applied as the base materials for the conductor and the RF contacts louvers respectively. Functional coatings are planned to be applied both on the surfaces of CuCrZr and 316L for the purposes of wear prevention, oxidation protection and contact resistance optimization. Owing to their excellent thermal and electrical conductivities, Rh and Ag were selected and electroplated on the 316L and CuCrZr substrates as functional coatings. As a high vacuum machine that reaches to 10-6Pa, before operation, ITER vacuum chamber is mandatory to be baked at around 250 °C for vacuum conditioning. In order to study the effects of long time thermal ageing on the Ag/Rh coating pairs, 500h baking at 250 °C under 10-6Pa vacuum condition was performed and the materials properties change as well as the diffusion phenomenon between Ag/Rh were characterized. In addition, the electrical and tribological performance of Ag/Rh contacting pair have been carefully studied on a dedicated test bed, which was developed by integrating ITER ICRH RF contacts' realistic working conditions such as high vacuum and high temperature. The results obtained can be helpful for ITER to choose the optimal RF contact coating material and can be referred by other RF contacts development which are working at high temperature under vacuum.

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Plasma electrolytic oxidation of niobium in silicate electrolyte

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Porous structures in anodic coatings, such as those formed by plasma electrolytic oxidation (PEO), are potentially favourable for the addition of material that improves the surface properties. The PEO process results in relatively thick ceramic coatings, which are formed in aqueous electrolytes under high voltages that cause formation of microdischarges on the coating due to dielectric breakdown. In this study coatings have been formed on niobium. The coatings are being developed with the purpose of providing coated niobium substrates that can support a magnesium diboride superconducting layer, with several methods of layer production being considered. The present work focuses on the processing conditions required for formation of the PEO coatings, the kinetics of coating formation, and the composition, morphology and structure of the resulting oxide layers. The study employed a silicate electrolyte, a constant rms current density, with a frequency of 50 Hz and a square waveform. A range of negative-to-positive current ratios was used to form the coatings. Voltage-time curves were recorded to monitor the coating growth. The coatings were examined by field emission analytical scanning microscopy and X-ray diffraction. The coatings, which were of thickness in the range 40 to 60 μm, are shown to be highly porous, with a relatively thick, silica-rich outer region and a thinner, niobium-rich inner region. The coatings contained Nb2O5 and silicon-rich amorphous material. The rate of coating growth decreased with increasing processing time, associated with a relatively drop in the voltage, and a reduction in the intensity of sparking.

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The role of Ga in the acetylene hydrogenation on PdGa intermetallic

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Density functional theory calculations were performed, studying the acetylene hydrogenation reaction over the PdGa(110) surface. The reaction C2H2+H2⟶ C2H4 was simulated and characterized in terms of the change in the chemical bonding. Also we analyze the changes in the electronic structure in the different steps of the reaction, what allowed us to understand more the role of Pd, Ga, and C2H2 during the reaction. This analysis, together with the determination of the bond order in each step of the reaction, revealed that Ga is a part of the active site and not a single spacer.

Vacuum in Accelerators / 242

Technological challenges and solutions for vacuum systems of modern particle accelerators

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Modern particle accelerators introduced have more and more demanding specifications to the beam vacuum chambers. From one side, the specified vacuum level is often not only UHV but even XHV, from another side, the cross sectional sizes of beam vacuum chamber are getting smaller and smaller, down to as little as 5 mm. In addition, this can also be complicated by another specification: short bunch machines are very sensitive to a vacuum chamber surface resistance coupled with beam longitudinal impedance which, in turn, affects the beam emittance, thus the acceptable level of surface resistance should be specified for each application and met in beam vacuum chamber design. Other challenges are the ion induced pressure instability and the beam induced electron mutipacting (BIEM) in positively charged machines. ASTeC vacuum science group is working on various solutions for the listed problems. Among them, the non-evaporable getter (NEG) coating as one of the most preferable solutions to provide UHV/XHV especially in conductance limited vacuum chambers), the laser ablation surface engineering (LASE) as a very efficient method to suppress BIEM, and others. The overview of ASTeC progress will be given in this talk.

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The effect of gold particle size on the activity of Au/TiO2 catalyst in the hydrogenation of CO2

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Triggered by environmental protection concerns, CO2 chemistry and the usage of CO2 as an industrial feedstock have become popular topics recently. It also turned out the nanosized gold particles

show considerable catalytic activity.
The thermal activation of CO_2 on Au nanoparticles supported on TiO_2 and titanate nanotubes was studied. The catalysts were prepared by the incipient wetness method using $HAuCl_4$. The reduction step was carried out either by H_2 at 523 K or by $NaBH_4$ at 298 K. The catalysts were characterized by HRTEM, XPS and DRIFTS. TEM images showed that the size of the Au particles was around 9 nm on the H_2 reduced sample, and only 4 nm on the $NaBH_4$ reduced catalysts irrespective of the support. XP spectra revealed the existence of a metallic and a positively shifted gold state.
The hydrogenation of CO_2 was followed to test the catalytic activity of the samples. Partially reduced CO_2 formed on the gold particles in reverse water-gas shift reaction. IR spectra did not justify the presence of Au-CO complexes, but showed the presence of formate on the support. The samples reduced by $NaBH_4$ were more active, since the metal particle size was smaller, even when their total amount was less. The nature of the support can also modify the reaction routes of the reactants.

Vacuum in Accelerators / 241

Computer simulation of pressure distribution and ion beam efficiency in accelerator vacuum chambers for designing vacuum system of cyclotron complexes

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The main parameters of vacuum systems for heavy ion cyclotron complexes are determined by means of computer programs GENAP and VACLOS that were developed and tested on the basis of experiments on four heavy ion cyclotrons of the FLNR. They estimate ion beam losses based on both the numerical simulation of pressure distribution in vacuum chambers practically of any arbitrary geometry and calculation of cross sections for a recharge of ions on the residual gases and were used for design of the vacuum systems of accelerators, such as the DC-72 (Slovak Republic), CYTREC cyclotron complex (Dubna), the DC-60 (Astana University in the Republic of Kazakhstan), the DC-110 (Dubna Centre of Nano & Nuclear Technology) and the DC-280 heavy ion cyclotron complex, which is now being launched at the FLNR, JINR.

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Exotic behaviour of topological semimetal SB (111)

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Due to a strong spin-orbit interaction, the surface states of Sb (111) are similar to those for topological insulators. The surface states are protected by time-reversal symmetry and have linear energy-momentum dispersion relation. Surface modification (for example, defects in surface structure) leads

to a local break of the surface translational symmetry and can change surface states. It is the primary reason to study the defects of Sb crystal structure and their effect on the surface states dispersion. Etching of the Sb (111) surface using Ar+ ions is a standard way to create defects both in bulk and on the surface of the crystal. For qualitative interpretation of the photoelectron features, we have provided the comparative experiments on at (111) surface and after ion etching.
Sb (111) ion etching at room temperature reveals the anomalous exotic behavior of a surface crystal structure. It results in the formation of flat terraces with a size of 2nm. Investigation of the electronic structure of the etched Sb (111) surface has demonstrated an increase of density of states at the Fermi level that was confirmed by DFT simulations. The results are discussed in terms of local break of the Peierls transition conditions.
The authors thank Russian-German laboratory at BESSY II and the Resource Center of Saint Petersburg State University "Physical Methods of Surface Investigation''.

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Development of a coating setup for in-situ deployment of an amorphous carbon thin film in the beam screens of the High Luminosity Large Hadron Collider.

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Amorphous carbon(a-C) thin films with low Secondary Electron Yield (SEY) are the baseline solution to mitigate the electron multipacting phenomenon in the beam screens of some critical superconducting magnets of the High Luminosity Large Hadron Collider (HL-LHC). Many of these magnets are already installed in the accelerator ring and the a-C coating has to be done 'in-situ'. We present the development of a coating system consisting of a carriage with two cylindrical magnetron sputtering targets, one of titanium and another of graphite, that is displaced along the 15 meter beam screen by pulling cables. Optimization of the coating parameters is discussed, with emphasis on the double role of the titanium to enhance adhesion and as a getter to reduce the partial pressure of hydrogen during the deposition, in order to achieve SEY < 1.1. The coating is characterized in terms of SEY along the 15 metres, the vacuum outgassing, morphology, adhesion and resistance to ionizing radiation. A strategy for the large-scale coating campaign in the LHC tunnel is proposed (hundreds of meters).

Surface Science & Applied Surface Science / **326**

Strain relaxation and epitaxial relationship of perylene overlayer on Ag(110).

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We present a room temperature STM and HREEL study of perylene self-assembly on Ag(110) beyond the monolayer coverage regime.
Coupling of the perylene aromatic boards yields π-π bonded stacks. The perylene stacks self-assemble into a continuous three dimensional (3D) epitaxial overlayer of (3x5) symmetry. The self-assembly was driven by thermodynamic balance of the three factors: (i) the site recognition effect, (ii) the intermolecular interaction and (iii) the thermal motion of the perylene molecules. The balance bestows to the overlayer the unique ability to accommodate the underlying substrate morphology. The overlayer is able to spread over the surface steps as a single structure preserving its lateral order and keeping epitaxial relationship with every surface terrace. The complete epitaxy is driven by (i) anchoring of half of the perylene stacks into define adsorption sites on each terrace, (ii) interlacing of the perylene stacks across the steps within the entire H-bonded network and (iii) relaxation of the overlayer strain, stemming from the interplay of the molecule-substrate and molecule-molecule interaction, via short-range thermal motion of the molecules.
This complete epitaxy phenomenon is described via (i) structural and statistical analysis of the molecularly resolved STM topographies (ii) detection and analysis of particular vibration modes enhanced by electron-phonon coupling (iii) monitoring of the short-range molecular displacements under the strain relaxation and (iv) parametrization of the intermolecular interaction via pair potential calculation.

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Investigation of copper conditioning and deconditioning processes for particle accelerators

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The electron cloud phenomenon is currently one of the main limitations to the operation of high intensity positively charged particle accelerators as the LHC. The Secondary Electron Yield (SEY) of the inner surface of the beam vacuum chamber steers the multiplication of primary electrons produced by both synchrotron radiation and ionization of residual gases. For several materials used in accelerator vacuum systems, the SEY decreases under electron bombardment and accelerators rely on this effect, called conditioning, to operate the beam in stable conditions. The understanding of the conditioning and deconditioning processes is essential to interpret the present LHC heat load to the cryogenic system and predict the LHC operation for future more intense beams.
To investigate these phenomena, chemically cleaned Cu OFE samples (material of the inner beam screen surface in the LHC arcs) were conditioned down to different SEY values in the lab, using an electron gun. The surface modifications induced by the electron bombardment were followed by X-Ray photoelectron spectroscopy. The results show Cu(OH)2 removal, vanishing of high binding energy components of the C1s line, and carbon graphitization. These samples were then stored in different atmospheres to study the impact of the environment on the deconditioning process: vacuum, desiccator, saturated vapour pressure of water. The results of SEY and surface chemistry evolution for different deconditioning atmospheres will be presented. In parallel, the fundamental mechanisms of the conditioning process are investigated on well characterized model surfaces of copper and the related results will be presented.

Poster Session Wednesday / 366

High performance organic single-crystal nanowire electronics via modulate the intermolecular center-to-center distance

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Controlling the charge transport by varying the molecular packing and understanding their structure–property correlations are essential for developing high-performance organic electronic devices.[1-3] Here, we demonstrate that the charge carrier mobility in organic single-crystal nanowires can be modulated with respect to the intermolecular center-to-center distance by applying uniaxial strain to the cofacially stacked crystals. Monotonic changes in charge carrier mobility (from 0.0196 to 19.6 cm2V−1s−1 for 6,13-bis(triisopropylsilylethylnyl) pentacene (TIPS-PEN)) were observed under a wide range of strains from −16.7% (compressive) to 16.7% (tensile). Furthermore, the measured values of charge carrier mobility were in good agreement with theoretical calculations based on charge localized hopping theory. These results provide a definitive relationship between intermolecular packing arrangement and charge transports, which enables a huge improvement in charge carrier mobility for organic single-crystal materials.

Poster Session Wednesday / 365

Controlled electronic properties of graphene via atomic layer deposition

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As a source material for numerous electrical applications, graphene has received great attention in two-dimensional (2D) materials field. For applications of graphene, it is critical to fine control of the Fermi level and the carrier concentration through a nondestructive doping method. Here, we develop an effective way to fabricate conformal ZnO thin films on graphene via atomic layer deposition through a reactive functional material layer and analysis its electrical behavior. This non-destructive and precise n-doping method provides a finely tunable result in thickness with 1 Å resolution. More importantly, the n-doped graphenes with ZnO thin films have a uniform and conformal morphology and good quality with a low density of pinholes. The electrical properties of graphene transistor including carrier density and doping state are controlled as a function of the thin film thickness. In addition, ZnO thin film barrier characteristics are observed by the extraordinary stability of graphene devices in air condition against air-borne water and oxygen which are an effect on the graphene. To other 2D materials such as MoS2 and WSe2, ZnO thin film ALD was successfully applied and shown enhanced electron mobility.

Poster Session Wednesday / 342

In-situ TEM investigation of amorphous Cu-Mn/C films for interconnect application

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Cu-Mn films are perspective contact and interconnect material 1. However, their application on low-κ dielectrics (carbon doped oxides) is difficult since Mn can react with carbon extracting it from the dielectric and complicates interface chemistry. In this study we report in-situ TEM results obtained on thermal stability of metastable amorphous Cu-Mn films and solid phase reaction between the films and carbon substrates. The amorphous Cu-Mn films (with 50 and 70 at% Mn content) were deposited by DC magnetron sputtering at room temperature. Evaporated carbon foils were used as substrates to model low-κ carbon doped oxides in their reaction with Cu-Mn films. In-situ TEM investigations revealed that the amorphous state is stable below 300℃, where the films crystallize into Cu(Mn) and α-Mn-based solid solutions. While Cu-based solid solution remains stable up to 600oC, Mn-based phases alter. Mn carbide phases appear at 400℃ accompanied with the disappearance of α-Mn phase and the decrease of Mn content of Cu(Mn) phase. In the temperature range of 400-500℃ Mn23C6 and Mn5C2 carbide phases are present. As temperature increases, more carbon diffuses into the film and hence the compound of lower C:Mn ratio (Mn23C6) disappears and a new phase of higher C:Mn ratio, the Mn7C3 appears. Mn5C2 carbides have lamellar structure and show Arrhenius-type grain growth in the temperature range of 400-600oC. The activation energy of Mn5C2 growth is 101±20 and 88±22 kJ/mol respectively in the film containing 50 and 70 at% Mn, indicating that carbide growth is facilitated with increasing Mn content. In addition to carbide formation, surface oxidation occurs as well in the system. Thermodynamic considerations indicate that Mn carbide formation can only occur in the Cu-Mn-C-O system when the Mn is not fully oxidized and there are free metallic Mn atoms left.

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Field emission induced lower switching power of TiO2 memristor using CNT-array as bottom electrode

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Field emission induced lower switching power of TiO2 memristor using CNT-array as bottom electrode

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Memristors are the most promising candidate for next generation of memory devices and also for mimicking the synapses of the human brain 1. The mostly accepted switching mechanism for oxide-based memristors is rely on formation/rupture of conductive filaments of oxygen vacancies and also changing the Schottky-barrier height at the interface of layers by applying a suitable bias voltage 2. Therefore, controlling the electric field distribution in an active layer (i.e. TiO2) is a fundamental requirement for optimizing the performance of a memristor device [3].
In this research, we have used an array of carbon nanotubes (CNT) as bottom electrode (BE) of TiO2 based memristor device to apply its local field effect for reducing the working voltage. To grow the layer of CNT's arrays, we have employed plasma enhanced chemical vapor deposition (PECVD) by using a pre-patterned Ni thin film as a catalyst through applying sputter deposition

and photolithography patterning in a 50 µm line width. In the next step, we have used both radio frequency (RF) sputtering and CVD methods (for comparison) to deposit TiO_2 thin film as the active layer with an optimized thickness of about 60 nm. In the final step, DC sputtering technique was utilized to deposit Au thin film as top electrode (TE) and finally it patterned with a line width of 30 µm. Surface morphology of the device was analyzed by scanning electron microscopy (SEM) and its electrical property was investigated by I-V measurements. Moreover, we investigated the field emission of CNT array as an excellent emitter.
Based on our data analysis, it was found that the surface morphology and nanostructure of the TiO_2 film deposited by CVD is more uniform and compact as compared to TiO_2 film prepared by sputtering method. Thus, we have patterned Au thin film with a crossbar structure on top of the CVD deposited TiO_2 thin film. In addition, I-V measurements also showed a low required working voltage of 0.89 V for the prepared CNT array as bottom electrode of the device that leads to a lower required switching power from high to low resistance state. The reduction in switching power is due to enhance local electric field intensity of the field emission generated from the surface of the CNT array at the BE/active layer interface.

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Effect of Growth Temperature on the Structure of CoCrFeNiCu High Entropy Alloy Films

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The five component CoCrFeNiCu films were deposited by DC magnetron sputtering using spark-melted targets at background pressure of 5×10^{-6} Pa with a deposition rate of ~10nm/min. The working pressure was 0.3 Pa by applying 99.9 % pure argon as sputtering gas. The films were deposited onto oxidized (100) Si wafers. The growth was carried out at room temperature as well as at 380 oC. The nanostructure of the films was analyzed by traditional transmission electron microscopy (TEM) in a Philips CM20 microscope at 200 kV accelerating voltage. High resolution TEM measurements were made in a Cs corrected 200 kV JEOL ARM 200cF microscope with atomic resolution. Samples for TEM investigation were produced in cross section views by Ar+ ion milling at grazing incidence. The structure of the films grown at room temperature is single phase FCC and corresponds to zone T structure, with a well expressed <111> texture. The width of the columns is rather uniform, about ~25 nm, and the growth competition region is about 50 nm thick in the 500 nm thick film. The columns are rather defective, the main defects being planar defects.
The film grown at high temperature possesses also the single phase FCC structure, the morphology is at transition from zone II to zone III. This is also supported by the random crystallographic orientation of the grains.
A detailed electron microscopic investigation and the possible formation mechanisms of the observed structures will be discussed.

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Monte Carlo study on magnetic properties in ferrimagnetic Ising thin films

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In the present work, we have studied the magnetic properties of a ferrimagnetic mixed spins S=2 and S'=3/2 Ising thin film using Monte Carlo simulations. The ground state phase diagrams of mixed spins-Ising thin film are given. The different magnetic phases are found in different planes. The critical temperatures have been found for different values of thin films. The thermal magnetization with reduced exchange interactions and crystal-fields of mixed spins are obtained with different thins films, temperatures and exchanges interactions. The multiples hysteresis and the superparamagnetic behaviour were established around the transition temperature.

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Cobaltosic oxide nanocrystals with exposed low-surface-energy planes anchored on chemically integrated graphitic carbon nitride-modified nitrogen-doped graphene: a high-performance anode material for lithium-ion batteries

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A facile strategy to synthesize a composite composed of cubic Co3O4 nanocrystals anchored on chemically integrated g-C3N4-modified N-graphene (CN-NG) as an advanced anode material for high-performance lithium-ion batteries is reported. It is found that the morphology of the Co3O4 nanocrystals contains blunt-edge nanocubes with well-demarcated boundaries and numerous exposed low-index (111) crystallographic facets. These planes can be directly involved in the electrochemical reactions, providing rapid Li-ion transport channels for charging and discharging and thus enhancing the round-trip diffusion efficiency. On the other hand, the CN-NG support displays unusual textural features, such as superior structural stability, accessible active sites, and good electrical conductivity. The experimental results reveal that the chemical and electronic coupling of graphitic carbon nitride and nitrogen-doped graphene synergistically facilitate the anchoring of Co3O4 nanocrystals and prevents their migration. The resulting Co3O4/CN-NG composite exhibits a high specific reversible capacity of up to 1096 mAh g-1 with excellent cycling stability and rate capability. We believe that such a hybrid carbon support could open a new path for applications in electrocatalysis, sensors, supercapacitors, etc., in the near future.

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Ultrathin molybdenum disulfide/carbon nitride nanosheets with abundant active sites for enhanced hydrogen evolution

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The exploration of highly active catalysts for hydrogen evolution reaction (HER) is beneficial to realize high catalytic activity and enhance kinetics for water splitting. Herein, the flower-like molybdenum disulfide/carbon nitride (MoS2/CN) nanosheets with thickness of 4.6 nm and enlarged interlayer spacing of 0.64 nm were synthesized via a facile hydrothermal method. As expected, the ultrathin thickness endowed MoS2/CN with abundant active sites, ensuring an outstanding catalytic activity and excellent stability for HER in alkaline electrolyte. The MoS2/CN nanocomposite can offer onset overpotential of 153 mV versus reversible hydrogen electrode (RHE). Notably, the Tafel slope is only 43 mV dec-1, which is significantly better than those of reported MoS2-based hydrogen evolution catalysts, revealing the superior HER performance particularly in catalytic kinetics. More significantly, the density functional theory (DFT) calculation further verifies that rich active sites confined in ultrathin nanostructure of g-C3N4 nanolayers could increase the activity of MoS2/CN and result in enhanced HER efficiency. This study indicates that rational interaction between two different 2D materials can significantly facilitate H2 generation, which endows extraordinary HER activity.

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The Bamboo Leaf-like NiCo2O4 nanobelts with Surface Pore Defects Supported on rGO as Advanced Anode Material for Lithium Ion Batteries

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The rGO-supported NiCo2O4 nanobelts (SPD-NiCo2O4/rGO) with surface pore defects and preferred orientation growth of the (311) plane are successfully constructed by a low-temperature hydrothermal method combined with a subsequent calcination treatment. The results show that as-obtained SPD-NiCo2O4/rGO nanoarchitectures possess abundant pore defects on the surface of NiCo2O4 nanobelts with an average diameter of 3.5 nm. Moreover, NiCo2O4 nanobelts loaded on the surface of rGO has a preferred orientation with exposed (311) plane. It is found that the SPD-NiCo2O4/rGO nanoarchitectures as a LIBs anode material exhibit a high specific capacity (1393 mAh g−1 at a current density of 0.1 A g−1), excellent rate capability (1132, 1066, 993 and 869 mAh g-1 at 200, 300, 500 and 1000 mA g-1, respectively.), and a superior cycling stability (only 0.4% capacity decay after 50 cycles). The remarkable Li storage performance of the SPD-NiCo2O4/rGO nanoarchitectures can be mainly attributed to the unique NiCo2O4 nanobelts morphology with surface pore defects and preferred orientation growth of the (311) plane, and the synergistic effect between the NiCo2O4 nanobelts and rGO.

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Self-supporting Porous Pt-Ag Aerogel as Highly Bifunctional Active Electrocatalysts for Oxygen reduction and Methanol oxidation

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Three-dimensional (3D) porous metal aerogels as a self-supporting proton structure show excellent ability to transmit protons. However, the reported metal porous aerogels are still in the field of electro-catalysis need to be further improved. In this study, we designed a simple method of hydrothermal reduction to prepare the hydrogel of 3D assembled metal nanowires, which obtain the metal aerogels by freeze drying for high surface area and porosity. Under the electron microscope, the aerogels exhibit a high density nanowire structure with a particle size of 7.6 nm, which contributes to excellent electro-catalytic activity. Specifically, the specific/mass activities of the resultant Pt0.6Ag1 aerogel for oxygen reduction reaction (ORR) are 2.7/3.3 times higher than commercial Pt/C catalyst, respectively. Which are 4.1/5.5-fold compared with those of Pt/C catalyst for methanol oxidation reaction (MOR), respectively. At the same time, the sample also has excellent electro-catalytic stability because the introduction of Ag to produce oxygen-enriched effect, coordination of Pt to improve the ability of anti-intermediate poisoning. The successful synthesis of metal aerogels by this green method has a very broad prospect.

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Solid Solution Hardening of Reactively Sputtered Nanolaminate ZrN-TiN Coatings

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The development of nanocomposite coatings has opened new possibilities for the fabrication of functional and protective coatings with unusual combinations of mechanical, tribological and chemical properties such as stability at elevated temperatures, high hardness and toughness, wear and corrosion resistance. In this study, nanolaminate structures consisting of ZrN and TiN layers were prepared using various modulation periods during pulse-dc magnetron sputtering. The coatings were deposited on nitrided Ti-6Al-4V alloys (duplex treatment) and simultaneously on (100) silicon wafers. The Zr and Ti targets (both 51 mm diameter), were pulsed in asynchronous mode at 300 kHz and 1.1 µs reverse time (duty cycle ~70%). Two types of coatings of a total thickness of approximately 1 µm and 4 µm were prepared by adjusting the deposition time. The structure of the coatings was studied by X-ray diffraction and High-Resolution Scanning Electron Microscopy, and the hardness (H) and the reduced Young's modulus (E), were determined by depth-sensing indentation (Hysitron Inc.) using a Berkovich pyramidal tip. In the case of the nanolaminate coatings, various individual modulation periodes, L, were explored. The nanolaminate coatings with L ranging from 1 to 10 nm displayed a single phase of solid solution with a Zr-rich composition, Ti0.35Zr0.65N. This finding indicates mixing or diffusion between the two phases which occurred during the growth. The grain size was found to vary with the value of L. The grain size of the solid solution Ti0.35Zr0.65N was ~8-12 nm, while that of the laminate structure was ~10-25 nm. The solid solution structure was found to be the main cause of the hardening of the nanolaminate structure; H values of the solid solution coatings were between 32 and 35 GPa, significantly higher than those of the single-layer coatings (21 GPa for TiN and 18 GPa for ZrN). The hardness and the grain size varied with the modulation period of the multilayer coating, which was also found to affect the wear resistance and other tribological characteristics related to the friction coefficient, µ, to the resistance to plastic deformation, H3/E2, and to toughness, H/E.

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Synthesis of ZnFe2O4/BiOBr nanocomposites immobilized on Palygorskite with enhanced photocatalytic activity under solar light irradiation

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Abstract
Visible-light-driven photocatalyst is an attractive research topic in the fields of pollution removal and fuel production. BiOBr has recently stimulated intensive interest in photocatalytic degradation because of its high photocatalytic activity and stability under UV and visible light irradiation. However, it is difficult to separate from liquid solution and its BET surface is needed to be improved. Thus, incorporating magnetic component into photocatalyst and introducing the hybrid photocatalyst onto a carrier (with high surface) can overcome these two problems. In this article, Attapulgite (a kind of natural clay) was used as the carrier of hybrid photocatalyst ZnFe2O4-BiOBr (presented as magnetic and photocatalytic component respectively). A magnetically recoverable nanocomposite photocatalyst (marked as ATT-ZnFe2O4-BiOBr) was successfully obtained by introducing ZnFe2O4 and BiOBr onto the surface of Attapulgite via hydrothermal method and in-situ precipitation method, respectively. It was found that ZnFe2O4 and BiOBr composite particles were successfully introduced onto the Attapulgite fibers' surface without obvious aggregation. Compared with P25 and BiOBr, ATT-ZnFe2O4-BiOBr exhibits exceptional photocatalytic activity in visible-light degradation of 10 mg•L-1 methyl orange. The highest degradation ratio of methyl orange reached to 98.81 % for ATT-ZnFe2O4-BiOBr. Moreover, ATT-ZnFe2O4-BiOBr could be readily recovered and the degradation ratio maintains more than 95.00 % after 5 cycles.

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Properties of CdZnTe films deposited on polyimide substrates by close-spaced sublimation

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As an II-VI semiconductor material, Cadmium zinc telluride (CdZnTe) compound which has wider band-gap and higher atomic number than Si, Ge and GaAs, is excellent for radiation application. CdZnTe-based devices are widely used in healthcare field, nuclear detection system, security checks and space science. Because of high cost and the difficulties of high quality CdZnTe single crystal growth, CdZnTe films are a promising choice for large-area radiation detector application [1, 2].
Polyimide (PI) materials are lightweight, flexible, resistant to heat and chemicals. It's the ideal substrate for flexible electronic devices and optoelectronic devices. So far, there has been no report about the preparation of CdZnTe films on PI substrates. In this work, CdZnTe films were deposited on PI substrates by close-spaced sublimation. The surface morphology, structural, electrical and optical characteristics of CdZnTe films was investigated in detail.

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Effects of substrate materials on boron and gallium co-doped ZnO films by RF magnetron sputtering

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Among the dopants used for the ZnO TCO films, Ga have been one of the most potential candidates because its ionic radius is closed to Zn2+ that could cause only small ZnO lattice distortion even for high Ga concentrations. In addition, Ga is less reactive with oxygen compared with other impurities. B-doped ZnO also get widely investigation because it could perform perfect transparency and better conductivity and improved thermal stability. Therefore, B and Ga co-doped ZnO (BGZO) films are expected to achieve improvements in electrical and optical properties [1, 2].
In general, glass, sapphire, and Si are often used as substrates for epitaxially grown of ZnO-based TCO films. Nowadays, TCO films on flexible substrates have attracted more and more attention because they can meet the expanding needs of modern photoelectrical devices, due to their special merits including lightweight, non-friability, small volume and low cost. Polyimide (PI) and polyethylene terephthalate (PET) films have been the ideal flexible substrate for its physical and chemical performance. In this work, BGZO films were deposited by radio frequency (RF) magnetron sputtering on PI, PET, glass and Si substrates. The effect of substrate materials on the surface morphology, structural, electrical and optical characteristics of BGZO films was researched in detail.

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NEG coatings on small diameter vacuum chambers for Hefei Advanced Light Source

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Hefei advanced light source is the fourth generation Diffraction-Limited Storage Ring，which reduces aperture of vacuum chambers to few centimeters. General pumps cannot satisfy the ultrahigh vacuum due to conductance limitation and the intense photon bombardment. Most of the beam pipes need to be deposited with Ti-Zr-V nonevaporable getter (NEG) thin films in order to provide distributed pumping and low gas desorption, and allow to achieve low pressure in narrow and conductance limited chambers. In this paper, NEG will be deposited by DC and pulsed DC magnetron sputtering using Ti-Zr-V alloy wire sputter-targets. The optimizations of the coating properties are achieved by varying deposition parameters, such as pressure, power, magnetic field and so on. The coating properties are analyzed by different materials characterization methods. The vacuum performance related to coating properties is evaluated by the measurement of pumping speed and surface coverage in the end.

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Developement of highly repeatable and recoverable phototransistors based on multi-functional oxide channels

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Visible-to-ultraviolet photodetectors are widely used in imaging, optical communication/interconnects/switches, security, and consumer optoelectronics. In contrast to conventional resistive-type photodetectors, thin-film transistor-based photodetectors (phototransistors) enable easier control of the responsivity and selectivity, which would allow increased amplification of lower detection signals. Much research has been carried out to fabricate CdS-based thin-film transistor (TFT) devices as an alternative to a-Si. However, the versatile fundamental properties of CdS, such as its direct visible band gap, high refraction index, relatively low work function, and good chemical thermal stability, continue to make it appealing for electronic and optoelectronic applications. However, the innovative improvement of CdS-based phototransistors, due to their potential for highly repeatable and recoverable photo-sensing, has rarely been reported.
Alternatively, oxide semiconductors are considered to be the most feasible semiconducting materials for transparent/flexible optoelectronic devices. The photo-response of oxide-based photo-TFTs is largely attributed to the photo-excitation of subgap states, such as ionized oxygen vacancies, and the subsequent liberation of electrons. However, the photo-excitation of ionized oxygen vacancies in oxide-based photo-TFTs is accompanied by lattice relaxation, which subsequently results in a persistent photocurrent. Unfortunately, this usually leads to long recovery times for oxide-based photo-TFTs, as compared to those of typical II-VI semiconductors.
In this work, the channel layers of chalcogenide CdS phototransistors were composed of multi-stacked constituent layers with significantly different physical properties. These were designed to produce high photo-sensing performance by combining the various characteristics of individual layers. Our proposed channel structure is based on multi-layers consisting of Al2O3, CdS, and ZnO, etc.

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Measuring uncertainty for various types of dual-rotating-compensator spectroscopic ellipsometers

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Various multichannel rotating-element spectroscopic ellipsometers have excellent measurement capabilities, such as real-time, high-precision, non-destructive and non-contact, resulting in widespread use in semiconductor manufacturing processes. With the development of semiconductor device processing technology, thin films used in these techniques have become thinner and thinner, reaching the atomic layer level, and the shape of the nano-pattern has changed from a two-dimensional structure to a three-dimensional structure. It is becoming more and more complicated. Therefore, to continue to use the rotating-element spectroscopic ellipsometer as a measurement tool in the next-generation semiconductor industry, it is important to continually increase measurement uncertainty. Recently we have developed a universal evaluations and expressions of measuring uncertainty for all types of rotating-element spectroscopic ellipsometers 1. We also introduced a general data-reduction process to demonstrate the universal analytical function of the combined standard uncertainty of the ellipsometric sample parameters. To solve the incompleteness of the analytic expressions, we formulate the estimated covariance for the Fourier coefficient means extracted from the radiant flux waveform using a new Fourier analysis 2. Our approach provides a method for calculating theoretical model equations that can be applied to various kinds of multi-channel rotating-element spectroscopic ellipsometers and can determine the theoretical equations for the measured confidence level, i.e. combined standard uncertainty of ellipsometric sample parameter. In this presentation it is shown that the calculation data of the combined standard uncertainty for various types of rotating element spectroscopic ellipsometer is obtained using a universal representation of the combined standard uncertainty. In particular, the calculation results for the dual-rotating-compensator spectroscopic ellipsometers will be compared and evaluated with the calculated results for the common single-rotating spectroscopic ellipsometers.

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Clarification of the relationship between electrical properties and the columnar structure of sputtered Al-doped zinc oxide films

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Fabrication of inorganic transparent conductive oxides (TCOs) on polymer substrates has been of increasing interest due to their potential applications in the field of flexible electronics. Nevertheless, the brittleness of inorganic thin films often results in a failure of the flexible electronic devices caused by strains formed during stretching, folding or bending. The higher the film thickness, the lower is the strain required to initiate cracks in the film. Thus, achieving the appropriate characteristics at the lowest possible film thickness is very important.

Aluminum doped zinc oxide (AZO) has attained prominence as being a very good transparent conducting oxide for optoelectronics and photovoltaic applications. It is considered a cheap and non-toxic alternative to preferably used Indium tin oxide films. Nevertheless, the reduction in the AZO film thickness leads to a significant increase in its resistivity. The present work deals with the investigation of the thickness dependence of electrical properties of AZO films prepared at substrate temperature 100℃.

The AZO films were prepared by magnetron sputtering using deposition system BOC Edwards TF 600. The structure was characterized by electron microscopy. The film resistivity, Hall mobility and carrier concentration were measured on square samples (8 × 8 mm2) at room temperature by the Van der Pauw method. We have proposed an extended one-dimensional mathematical model based on the trapping states related to the grain boundaries. The experimentally determined parameters together with the model allow to identify electrical properties at individual thickness layers and correlate them with the film structure observed at a given distance from the substrate. The presented approach describes very well the inferior electrical conductivity of very thin films, as well as the conductivity saturation for larger film thickness.

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Solution immersed silicon (SIS)-based biosensors for the direct monitoring of small-molecular-weight analytes

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Noise from refractive index (RI) fluctuations of the liquid environment near sensor surface due to factors such as temperature, pressure, and concertation gradient is inevitable in surface plasmon resonance (SPR) sensing technology. As a result, SPR devices are unable for quantitative and qualitative detection of small molecules and low-concentration analytes. To address this issue, novel solution-immersed-silicon (SIS) sensing technology was developed 1. Near p-wave anti-reflective boundary condition, SIS shows extremely high thickness change sensitivity and inert for RI change of buffer solution. SIS sensor setup is cost effective and contains sensor cell, sample injection drive and signal detection; no sophisticated microfluidics is needed. SIS immunosensor chip is a simple silicon wafer covered with the assembled monolayer. The detection limit of 10 pg/ml of antigens for hepatitis B virus (HBV) and acute myocardial infarction (AMI) in human blood serum [2,3] was achieved with SIS sensors.
Here, we are presenting a study on the interactions of small molecule: protein tyrosine phosphatase (PTP) inhibitors with immobilized protein tyrosine phosphatase 1B(PTP1B). The PTP1B enzyme have high significance in human health, specifically in diabetes and cancer. We have achieved the detection limit of 10 nM without any amplification technique.

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Functionalization of organosilicate thin films by catalytic reaction using Microwave-exited Plasma

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Organosilcate film such as polysilsesquioxanes can be used as a low dielectric material or an optical coating due to its low electron density, low dielectric constant and low refractive index. Also, they can be used as a base bottom layer to form nano-structure patterns using block copolymers. To make an aligned line patterns using block copolymers, it need to control surface energy of organosilicate films. Previously, modification of surface energy of organosilicate films by changing curing temperature and time is reported.
In this study, we developed a new method to control surface energy of organosilicate films using microwave-exited plasma treatment. By catalytic reaction between films and exited species like radicals and ions, chemical structure was changed. By breaking chemical bonds specially Si-CH3 bonds and forming Si-OH groups, hydrophobicity of organosilicate films decreased by increasing exposure time and decreasing a distance between plasma outlet and film surface. Hydrophobicity of films was measured and compared by water contact angles. And chemical structural changes before and after plasma treatment were measured using Fourier-Transform Infrared (FT-IR) spectroscopy. Surface morphology after plasma treatment was also confirmed by using an Atomic Force Microscopy (AFM) and a Scanning Electron Microscopy (SEM).

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Low-temperature atmospheric microwave plasma using two-parallel-wires transmission line resonator

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In recent, atmospheric microwave plasmas (AMP) have attracted much attention as promising plasma sources for industrial applications such as material processing, surface treatment and biomedicine 1. The plasma sources have advantages: the AMP eliminates the need for a vacuum system and the AMP has a long operational time of the electrodes 2. However, the AMP has its limitation to treat a large area because it is hard to enlarge the plasma volume at atmospheric pressure using a single plasma device with low power. In this work, a plasma source using a two-parallel-wires transmission line resonator (TPWR) in atmospheric argon is described [3]. The E-field distribution and reflection coefficient of the resonator are calculated by COMSOL Multiphysics software based on finite elements method. Then, the TPWR is fabricated to investigate physical properties such as excitation temperature, electron temperature and rotational temperature. The TPWR-AMP can sustain with low power less than 3 watts. The electron excitation temperature was measured by the Boltzmann plot and the rotational temperature was determined by comparing the measured and simulated spectra of rotational lines of the OH band. The electron density was obtained based on Stark broadening with the measured emission spectra. The characteristics of the TPWR-AMP shows that the device has the potential to be used effectively in industry.

1 J H Kim et al., Appl. Phys. Lett. 86 (2005)
2 J Winter et al., Plasma Sources Sci. Technol. 24 (2015)
[3] J Choi et al., Phys. Plasmas 24 093516 (2017)

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A unique QLED-OLED hybrid structure for white electroluminescent devices

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For last 10 years, the performance of colloidal quantum dot-light-emitting diodes (QLEDs) has been dramatically improved. However, most of QLED work has been fulfilled in the form of monochromatic device, while white QLED still remains a long way to go. After solution-processed deposition of hole transport layer and emitting layer based on colloidal quantum dots, electron transport layer and emitting layer based on organic host-dopant system were deposited using thermal evaporation. The generation of white light was accomplished by the sequential structure of red emitting QLEDs and blue emitting OLEDs. , The unique hybrid electroluminescent devices generated a high-quality white light with a high color rendering index (CRI). The detailed I-V-L characteristics were studied to get efficient and high CRI white emission.

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Calculation of activation temperature of TiZrV getter film

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TiZrV film should be baked to make oxygen atom diffuse from the surface passivation layer into the interior of the film. Oxygen diffusion along grain boundary plays dominant role during activation. This process was simulated and the relation between activation temperature and grain size was obtained.

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A novel growth method for ZnO nanorods by hydrothermal method applied rotating precursor solution

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In the last two decades, one-dimensional (1D) nanostructures have been extensively studied due to their distinguishing features such as quantum-mechanical confinement effects and high surface-to-volume ratios, exhibiting a number of potential applications. Of these, ZnO is one of the most interesting II-VI semiconductors with a wide direct bandgap of 3.37 eV and a high exciton binding energy of 60 meV at room temperature. In particular, ZnO can be excited to generate electron-hole pairs by absorption of ultraviolet (UV) light, being therefore regarded as promising material for efficient UV sensors and blue light-emitting devices, with the former finding numerous practical applications in fields such as flame detection, environmental studies, and medical communication equipment. However, the use of 1D ZnO NRs in such sensors requires their photoresponse properties (e.g., photoresponsivity and photosensitivity) to be improved. Threfore, to use the ZnO NRs in the sensor, it is necessary to improved crystalline ZnO NRs. The high-quality ZnO NRs can be prepared under high vacuum and high energy experimental conditions, such as molcular beam epitaxy, thermal evaporation, and metal-organic chemical vapor deposition, which, however, makes them unacceptably expensive. On the other hand, hydrothermal method is a simple method for the growth of ZnO NRs with a high deposition rate, ready control of the dopant concentration, and growth at low temperature and the growth of ZnO NRs through hydrothermal method is accomplished by the combination of Zn2+ and OH- ions. In other words, the growth rate of ZnO NRs through hydrothermal method is affected by the number of the Zn2+ and OH- ions. The number of the Zn2+ ions in the precursor solution is decided the molarity of precursor reagent like zinc nitrate hexahydrate, and the number of the OH- ions can be controlled by insertion of hexamethylenetetramine (HMT), temperature of precursor solution, and insertion of ammonia solution to increase value of pH. But, the appropriate increase of value of pH increases the OH- ions, which causes the fast growth rate of hydrothermal method, whereas the excessive increase of pH accelerates the dissolution of grown ZnO NRs and it causes the degradation of structural properties of ZnO NRs. Thus, to prevent the degradation of hydrothermally grown ZnO NRs, many researchers have used the HMT as the source of OH- ions. But, the use of the HMT causes the transformation of the end of ZnO NRs sharply, which decreased the performance of ZnO NRs-based UV detectors. Therefore, it is necessary to develop the new method for the improvement of declined structural and optical properties owing to the use of HMT as OH- ions source. Surface modification is one of the widely used methods to change the physical properties of different one-dimensional nanostructures for better performances of devices. Narayanan et al. reported that the annealing of hydrothermally grown ZnO NRs leads to changes of morphology

of ZnO NRs, and it improves the optical and electrical properties of ZnO NRs. Also, Park et al. reported that the rotating cathode on the electrodeposition accelerates not only the supply of OH- ions but also modification of the morphology of ZnO NRs, which causes the improvement of UV sensing properties of ZnO NRs. However, the point defect such as interstitial zinc and oxygen vacancies can be generated by annealing of ZnO NRs, and there is little study about surface modification of the ZnO NRs using the hydrothermal method. Here we report a new and simple method to improve optical and photoresponse properties of ZnO NRs. We grew the ZnO NRs using the hydrothermal method with rotation of precursor solution and the precursor solution was rotated during the growth process. Also, we investigated the effect of rotation rate of precursor solution on the morphological, structural, and optical properties of the NRs, and fabricated the UV photodetectors based on the ZnO NRs to observe the changes in the UV photoresponse with rotation rate of precursor solution. In FE-SEM images, the ZnO NRs grown at the non-rotated precursor solution had higher density than the other ZnO NRs grown at the rotating precursor solution. Also, in case of the ZnO NRs grown at non-rotated precursor solution, the length was 1.85 µm and the diameter is 76.3 nm. Furthermore, the length of ZnO NRs grown in rotating precursor solution at 100, 150, and 200 rpm was 3.62, 2.42, and 2.11 µm, respectively, indicating the decrease of length with increasing rotation rate. Similarly, the diameter of ZnO NRs, which grown in the rotating solution at 100, 150, and 200 rpm, decreased from 91.6 to 57.2 nm with increasing rotation rate. It is due to that the appropriate rotation rate of precursor solution stimulated the generation of OH- ions, whereas the excessively fast rotation rate interrupted the formation of ZnO nuclei on the surface of ZnO seed layer although it also stimulated the generation of OH- ions, and a small quantity of ZnO nuclei caused the decrease of growth rate of ZnO NRs. Therefore, ZnO NRs grown in a solution rotating at 100 rpm which is appropriate rotation rate had the longest length and diameter, whereas ZnO NRs grown in a solution rotating at 200 rpm which was relatively fast rotation rate had the shortest length and diameter. All ZnO NRs had a strong intensity of diffraction peaks at 34.43 o corresponded to the diffraction from ZnO (002) plane and two relatively weak intensities of diffraction peak at 31.78 o and 36.27 o corresponded to the diffraction from ZnO (100) and (101) planes, respectively. The Intensity of diffraction peak from ZnO (002) plane of ZnO NRs grown in rotating precursor solution was stronger than that of ZnO NRs grown at the non-rotated precursor solution. Especially, the intensity of ZnO (002) peak of ZnO NRs grown in a solution rotating at 100 rpm is weaker than that of ZnO NRs grown in a solution rotating at 150 rpm, while the intensity of ZnO (100) peak of ZnO NRs grown in a solution rotating at 100 rpm is stronger than that of ZnO NRs grown in a solution rotating at 150 rpm. In case of the PL spectra, the ZnO NRs grown in rotating precursor solution at 200 rpm exhibited the strongest intensity of NBE emission and it was due to that the ZnO NRs grown in rotating precursor solution at 200 rpm had the shortest length and diameter of NRs, indicating a greater amount of the photon absorption owing to the large surface area. Furthermore, the intensity of broad yellow emission increased about twice as the rotation of precursor solution occurred, and it gradually increased with increasing rotation rate of precursor solution from 100 to 150 rpm and decreased with increasing rotation rate of precursor solution from 150 to 200 rpm. As mentioned above, the appropriate rotation rate of precursor solution from 100 to 150 rpm stimulated the generation of OH- ions, which increased the number of interstitial oxygen, whereas the excessively fast rotation rate like 200 rpm retrained the diffusion into the ZnO lattice in spite of a greater amount of OH- ions. As a result, the ZnO NRs grown in rotating precursor solution at 150 rpm exhibited the strongest intensity of DL emission and the ZnO NRs grown at the non-rotated precursor solution exhibited the lowest intensity of DL emission. To measure the UV photoresponse property of the ZnO NRs with rotation rate of precursor solution, metal-semiconductor-metal UV photodetectors based on the ZnO NRs were fabricated. The ZnO NRs grown in the rotating precursor solution had a greater amount of interstitial oxygen which provided the free electrons than ZnO NRs grown at the non-rotated precursor solution. Thus, a greater amount of free electrons made a greater amount of adsorbed oxygen ions and it increased the number of photo-generated electrons moved to the electrode based on the bias voltage. Therefore, the ZnO NRs grown in the rotating precursor solution, which had a greater amount of free electrons, exhibited higher value of photocurrent than ZnO NRs grown at the non-rotated precursor solution. The photosensitivity of ZnO NRs can be calculated by the following equation:
S=I_ph/I_dark
where S is the photosensitivity of the ZnO thin films, Iph is the photocurrent, and Idark is the dark current. The calculated photosensitivity of ZnO NRs was gradually increased with increasing rotation rate from 0 to 150 rpm and decreased with increasing rotation rate from 150 to 200 rpm. It indicated that ZnO NRs grown in rotating precursor solution at 150 rpm generated the greatest amount of photo-generated electrons under the same intensity of UV light and it is suitable for photodetector with high sensitivity and reproducibility.

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Growth of Ti-Zr-V non-evaporable getter films on ion-implanted substrate

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The Ti-Zr-V non-evaporable getter (NEG) films were grown on ion-implanted substrates, including aluminum, stainless steel, and CuCrZr alloy. To create buried disorder, Ar ions with an energy of 200 keV were implanted into the sample. The Ti-Zr-V getter films grown on these ion-implanted substrate were characterized using scanning electron microscopy (SEM), X-ray diffraction (XRD), electron spectroscopy for chemical analysis (ESCA), and transmission electron microscopy (TEM). Similar properties and results were observed for the surface morphology and composition of the Ti-Zr-V films on both ion-implanted and pristine substrates. Besides, crystalline structure of the NEG films was a little different and the activation of the NEG films was apparently different for the cases of ion-implanted substrates. The thermal activation temperature of the NEG films was obviously lower in the ion-implanted sample than in the original sample. Besides, the TEM images showed that some defects were observed near the surface of the substrate after ion implantation process. These created damages indeed have the effect on the reduction reaction of NEG films. The mechanism is discussed in the paper.

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Amorphous Carbon Coatings for Vacuum Chambers of Particle Accelerators and Research on Secondary Electron Yield

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Amorphous carbon (a-C) thin film applied to vacuum chambers of high-energy particle accelerators can decrease secondary electron yield⊠SEY⊠and suppress electron-cloud effectively. A dc magnetron sputtering apparatus to obtain a-C film has been designed. With the equipment, a-C thin film can be deposited on the inner face of stainless steel pipes ultimately which is uniform and high-quality. Meanwhile, it is found that a-C has a low SEY⊠1.2 measured by the secondary electron emission measurement set-up in the National Synchrotron Radiation Laboratory. The result indicates that a-C is an ideal material for modern accelerators.

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Atomic layer deposition of titanium oxide using cyclopentadienyl-type titanium precursors

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Titanium-containing thin films are widely used in microelectronic device structures such as high-permittivity capacitors, barrier metals, and metal gate structures. ALD technology has replaced PVD and CVD to provide excellent step coverage, accurate film thickness control, and high film quality. Many titanium alkylamides and titanium alkoxides such as Tetrakis(dimethylamino)titanium (TDMAT) and titanium tetraisopropoxide (TTIP) have been used as the ALD precursor, and ALD titanium oxide films were deposited at relatively low temperatures, and the maximum ALD process temperature was approximately 200℃. In general, the electrical characteristics of the dielectric film can be improved by increasing deposition temperature, because the density of the film increases and the impurity concentration decreases. In case of high-temperature deposition, however, the step coverage was poor because of the thermal decomposition of the precursor, resulting in a thicker film on the top surface. Therefore, we need titanium precursors with excellent thermal stability together with high reactivity and sufficient volatility. In the case of zirconium precursors, it was reported that thermal stability of tetrakis(ethylmethylamino)zirconium is improved by replacing an alkylamine group with cyclopentadienyl to form tris(dimethylamino)cyclopentadienyl zirconium 1. In the present study, we investigated the ALD of titanium oxide using various heteroleptic titanium compounds composed of combinations of different ligands, such as cyclopentadienyl, alkylamino, alkoxy, and linked ligands. Saturation dose and the ALD temperature window were determined by measuring growth rate with different precursor feeding times, oxidizing agent feeding times, and the process temperatures. The reaction mechanism was studied by using in-situ quartz crystal microbalance (QCM) and Fourier transform infrared (FTIR) spectroscopy. The physical and electrical properties of the deposited films were also characterized.

1 J. Niinistö et al, J. Mater. Chem., 18 (2008) 5243.

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Compact getter pump with arc evaporator of Titanium

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Liquid helium cryopumps are among the most efficient high vacuum pumps used in controlled thermonuclear fusion experiments. Cryopumps can provide exceptionally high pumping capacity for hydrogen/deuterium at high pumping speed, but have limitations on the heat load. From the other side, growing average power of the fusion experiments demands high speed pumps capable to withstand high heat load. For this type of applications, cryosorption (or getter) pumps attract more and more attention. Usually, a layer of Titanium sputtered over a cryopanel cooled by liquid nitrogen serves as a sorption surface in this type of pumps. This paper describes design of a compact getter pump based on U-shaped cell made of ribbed aluminum and equipped with arc evaporator of Titanium. Pumping properties of the pump are measured in the temperature range of 80 – 300K for both hydrogen and deuterium. Optimal modes of titanium films deposition are studied for a range of the gas load. Calculations of the sorption properties of the pumping cell are conducted based on an original method, which allows to consider directional molecular flows in the measuring volume.

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LASE surfaces for the mitigation of the Electron cloud in positively charged accelerators

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The formation of an electron cloud is an issue that effects proton accelerators. It is a phenomena caused by electrons interacting with the surface of the walls of the accelerator resulting in the production of more electrons. It has already been seen that Laser Ablation Surface Engineering (LASE) of surfaces can reduce the Secondary Electron Yield (SEY) of Copper to below unity. In this work we will report on the surface analysis for a variety of LASE surfaces with different laser parameters (wavelength, scan speed, pitch, repetition rate, power, and pulse length).

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Effect of oxidation time on ZnO nanostructures prepared from Zn films by electro-oxidation

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Transparent semiconducting oxides, such as copper oxide, tin-doped indium oxide, fluorine-doped tin oxide, and zinc oxide (ZnO) have attracted considerable scientific attention owing to their unique properties. They are used in a wide variety of applications, including solar cells, surface-acoustic wave devices, and optoelectronic devices. ZnO which has a wide band gap (3.37 eV) and a high exciton binding energy (60 meV) is one of the promising materials for applications in optoelectronic devices operating in the ultraviolet (UV) region. Although various optoelectronic devices based on ZnO have been developed, it is important to grow ZnO films with high crystallinity to obtain good electrical and photoresponse properties. Structural defects in ZnO form defect-related states, which deteriorate the electrical properties, and surface defects deteriorate the photoresponse properties because of band bending. Therefore, it is essential to develop a method for preparing ZnO films with high crystallinity.
Various fabrication techniques, such as molecular beam epitaxy, chemical vapor deposition, thermal evaporation, and oxidation have been used to prepare highly crystalline ZnO film. Among these, the oxidation method is advantageous as it is simple and inexpensive. Thermal oxidation is the most well-known oxidation method, wherein a high quality ZnO film is obtained from metallic Zn films by applying heat at a temperature of 900 ℃ or above. Another oxidation method is the hot-water treatment method in which Zn is oxidized in hot water (90 ℃) for a long time to form high quality ZnO nanostructures. The former method requires a considerably high temperature, and cracks may occur when the difference in the thermal expansion coefficient between the substrate and the Zn film is large. In the latter, the process is carried out at a relatively low temperature, but requires a long time.
The electrochemical oxidation method can overcome the disadvantages of thermal and hot-water oxidation methods. In the electrochemical oxidation method, the formation of Zn(OH)2, which is a key product of oxidation by electrolysis of OH- from water, is accelerated, and Zn is rapidly oxidized to ZnO at a relatively low temperature. This method can be used to grow ZnO in the form of films or nanostructures depending on the oxidation temperature, thickness of the Zn film, oxidation time,

current density, and pH of the solution. However, the mechanism of the oxidation process in this method has not been studied so far.
In the present work, we prepared ZnO nanostructures at various oxidation times by electrochemical oxidation and studied the growth mechanism of ZnO nanostructures based on the oxidation time. ZnO nanostructures were grown by oxidizing Zn films using the electrochemical oxidation method. According to the SEM images, the oxidation process for the formation of ZnO nanostructures consisted of three steps. First, Zn with a hexagonal columnar crystal was preferentially oxidized at the side surfaces because of the presence of relatively unstable planes, and then, Zn2+ which was ionized from the Zn (002) plane was crystallized on the ZnO crystal wall by combining with OH-. Finally, the formed ZnO crystals aggregated to form a tooth-like structure. This oxidation process was confirmed by the XRD results, which indicated a decrease in the intensity of the Zn (100) peak and a shift in the position of the Zn (002) peak to that of the ZnO (101) peak. As the oxidation time was increased, rearrangement of the crystals took place and the structural and surface defects were reduced, which decreased the non-radiative transition and increased the NBE emission. The photo responsivity and the photosensitivity of the ZnO nanostructures that were not sufficiently oxidized, i.e., at 1, 5, 10, and 20 min, were very low. However, the photoresponse properties of the ZnO nanostructures sufficiently oxidized at 30, 60, and 120 min gradually increased with increase in the oxidation time owing to rearrangement of the ZnO crystals. The enhanced photoresponse properties of the ZnO nanostructures are promising for applications in optoelectronic devices.

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Characterization of Cu nanoparticles via X-ray photoelectron spectroscopy in combination with SESSA calculations

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Copper nanoparticles (NP) have attracted great interest due to their unique properties which make them ideal candidates for applications in catalysis 1.

Within this study we have investigated the properties of nanoparticles produced in ionic liquid-aqueous micellar systems, which would provide a media for further coupling reactions.
Despite the protective stabilizing environment of the ionic liquid, several question like possible oxide/hydroxide-shell formation within the aqueous solution including parameters, e.g. coverage and thickness of these layers need to be addressed to understand NP behavior in possible applications.
Therefore, we have employed X-ray photoelectrons spectroscopy (XPS) in combination with theoretical calculations using the SESSA software package [2, 3].

Cu NP were formed via chemical reduction of $CuCl_2$ using sodium borohydride or hydrazine in ionic liquid (1-alkyl-3-methyl-imidazolium chloride)/aqueous solutions [4, 5].

Cu 2p and Cu LMM signals of the different NP were recorded and compared to signals from high-purity planar Cu and Cu-oxide reference samples.
As Cu 2p signals show no traces of Cu(II), we determined the Cu(0)/Cu(I) ratios from the Cu LMM signals.

Subsequently, different over-layer thicknesses have been calculated using SESSA. Assuming homogeneous coverage, the thickness of the oxide layer can be determined in the sub-nm range with accuracy better than one monolayer.

We could evidence the formation of few atomic layers of oxides, which exhibit varying thickness due to changes in the fabrication process. These variations can distinctly influence the NPs properties when they are used in catalytic reactions, thus proving that XPS is an essential tool for NP metrology.

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Diamond-like carbon film with excellent tribomechanical properties deposited by PACVD

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Diamond-like carbon (DLC) films have been deposited on stainless steel wafers by plasma assisted chemical vapor deposition technique. Thickness and roughness of the film were measured by a surface profilometer. Microhardness, friction coefficient and profiles of wear tracks of DLC films were investigated by microhardness tester, ball on disk tribometer and surface profilometer, separately. Results showed that DLC film prepared by plasma assisted chemical vapor deposition displayed excellent tribological and mechanical properties. Roughness Ra of the film with a thickness of beyond 2 micrometers was about 56 nm. DLC film on stainless steel showed a high microhardness (Hv) which was more than 2000. Friction coefficient of DLC was lower than 0.25 when counterpart was a steel ball. Wear rate of the film which was calculated by Archard's classical wear equation after the measurements of wear tracks' cross sectional areas belonged to the order of magnitude of 10 to -8 cubic milliliters per Nm.

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Stretchable Transparent Electrodes Based on Silver Nanowires and Conductive Polymers for Stretchable Electronics

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The development of high-performance transparent electrodes is of great importance for efficient, low-cost organic optoelectronic devices such as organic solar cells and organic light emitting diodes. Silver Nanowires (AgNWs) are regarded as promising alternative transparent electrodes to replace conventional indium tin oxide (ITO) electrode due to their low sheet resistance, high transmittance, and low-cost processing. Here, high performance stretchable transparent electrodes based on AgNWs and conductive polymer poly (3,4 ethylenedioxythiophene):poly (styrenesulfonate) PEDOT: PSS on an elastomeric polydimethylsiloxane (PDMS) has been investigated. The surface modifier introduced in this study significantly improves the hydrophilicity of the PDMS surface. The resulting hybrid transparent electrodes show a low sheet resistance of 25 Ω/sq and high transmittance of 82%, which are comparable to the performance of indium tin oxide (ITO) reference electrodes. In addition, the hybrid transparent electrodes show a remarkably small resistance change below 10 % up to the strain of 100 %. Furthermore, the hybrid electrodes are employed for stretchable heater device, resulting in good device performance.

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Highly Conductive, Stretchable, Flexible Transparent Electrodes on Bio-polymer Substrates for Stretchable Electronics

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Stretchable electronic devices have received much attention due to its novel applications including stretchable, wearable displays, sensors, solar cells, light emitting skins, bio-metric devices, and human-interface devices. The development of transparent electrode is of importance to achieve high performance stretchable opto-electronics. ITO is the most widely used transparent electrodes in conventional opto-electronic devices, however it has inherent brittleness and needs high temperature process. Here, we investigate high performance stretchable transparent electrodes based on silver nano-wires as alternative electrodes to replace ITO with chitosan stretchable substrates. While PDMS is most widely used materials as a stretchable transparent substrate, chitosan has received much attention as a promising stretchable transparent substrate which is bio-degradable, bio-compatible. The stretchable transparent electrodes on chitosan developed here show the high transmittance (88.9%), the low sheet resistance (12.2 ohm/sq), and excellent stretch-ability. The stretchable transparent electrodes are successfully adopted into AC-electroluminescence devices with ZnS: Cu phosphors.

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The Nothing On Insulator Nanotransistor with Diamond Lateral Islands for Electrons Emission in Vacuum

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Abstract: A diamond on insulator structure with a pure tunnelling conduction between source and drain, modulated by a gate bias, is investigated as alternative nano-device. The Nothing On Insulator (NOI) cavity represents the main device body. The Atlas simulations establish superior drain currents and minimum capacitances suitable for THz operation.
Introduction: The NOI nano-device and the lateral field emission devices have in common the Fowler-Nordheim tunnelling; its distinctive features are the nano-diamond islands sizes and a cavity of only 1…4nm, so suitable for co-integration with Diamond/Si-FETs. Also, the dynamic study is a novelty for this device.
Methods: In the first set of simulations the diamond islands have flat walls of 15nmx15nm on insulator of 15nm, a vacuum cavity of 2nm, p-type diamond doping concentration of NA=2E+20cm-3, oxide/diamond interface charge. In the second set, the walls roughness is considered as 3 growths.
Results: The transfer characteristics reveal better ION/IOFF >108, better subthreshold slopes than Si-NOI and prove the main distinctive feature of this nano-transistor versus the lateral diamond field emission devices - the gate control of 0.1 ÷ 10 nA/V. The output characteristics obey to the exponential shape, offering superior ON voltage than Si-NOI. Due to an extremely low area, the simulated capacitances are about 0.5 …0.06aF meaning a cutoff frequency around THz. The conductances start from 10-16S and increase toward 10-5S at 100GHz. The device with roughness improves all these features, sharp growths facilitating the tunnelling.
Discussion: In conclusions, the Diamond-NOI implementation versus Si-NOI offers better: gate

breakdown, ON drain-source voltage, ION/IOFF, sub-500mV/dec subthreshold slopes, sub-aF capacitances suitable for THz applications.
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Nanotopographic microdomains on Ti alloys by sequential ion beam irradiation and wet etching

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The multiscale topography of Ti alloys (and especially Ti6Al4V) has been studied extensively as a way of conditioning cell adhesion and biocompatibility. In the present work, we have induced the modification of Ti alloys at the micro and nanoscale by using selective ion beam irradiation with Si ions at 5 MeV and wet etching in HF solutions. The selectivity is induced by the irradiation through a microstripe micropattern, which modifies the susceptibility of the Ti to the acid solutions and gives rise to 1D microscale distributions of nanorough areas. The susceptibility can be predicted by using ellipsometry, since a thin passivation oxide layer progresses on the Ti alloy in agreement with the applied fluence within the submonolayer to monolayer range. The resulting micropatterns are also a function of the wet-etching solution and immersion time. Both field effect scanning electron microscopy and atomic force microscopy confirm that the contrast between the irradiated and non irradiated areas consists of an additional nanorough background. The consequences on the biological response of the surfaces have been studied by water contact angle measurements and incubation of serum proteins and interrogation by optical and infrared spectroscopy. At cellular level, the patterns are able to induce guidance, which sustains that the Ti alloys could be attractive substrates for the analysis of cells response to drugs under non voltaic polarization.

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Effect of Methane Addition and Process Temperature on the Hardened Case Properties by Plasma Nitrocarburizing on DIN 100Cr6 Steel

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Plasma nitrocarburizing is a thermochemical process that employs the pulsed DC luminescent discharge technology to introduce both nitrogen and carbon into the surfaces of metals and their alloys. The case formed by the treatment typically consists of two different layers: an thin outer layer, named compound layer, which presents excellent wear and tribological performances, and a thick inner diffusion layer that can improve the fatigue properties. The carbon amount in the plasma gaseous

mixture and the process temperature affect directly the morphology, microstructure, and the formation of the compound layer, and consequently affect the hardened surface layer proprieties. In a carbon-free plasma (nitriding), the predominant phase formed in the compound layer is the Fe4N phase, while for carbon-enriched plasma (nitrocarburizing), the Fe2-3N phase prevails. Excessive amount of carbon in the gaseous mixture may produce cementite (Fe3C), which can be considered hard and brittle. The diffusion zone is a supersatured interstitial solution of carbon and nitrogen in a metallic matrix. This work investigates the effects of the methane addiction in the nitrogen and hydrogen mixture, and the process temperature on the plasma modification of DIN 100Cr6 steel samples. This steel is used as raw material in the manufacture of a mechanical component applied in hermetic compressors for refrigeration. Four methane concentrations (0, 1.0, 1.5, and 2.0%) and two temperatures (550 and 600℃) were used. The samples were characterized by XRD, SEM, EDS, wear resistance, and micro-hardness tests. Micro-porosity layers were formed for all process conditions. For higher CH4 concentrations, the Fe2-3N phase was preferentially formed on the modified surface, yielding higher microhardness and wear resistance values. The samples treated at 600℃ presented larger surface layer thicknesses and also higher microhardness values.

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Improving plasma uniformity using superimposed multi-frequency of an inductively-coupled plasma source

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Die shrinks are essential for improving the productivity and performance of nanoscale semiconductor devices. Since the cost to manufacture a wafer is not proportional to the number of chips on the wafer, die shrinks reduce the manufacturing cost per chip by enabling the use of more chips on each wafer. As the chip size shrinks, it is possible to include many chips on the edge of the wafer. Thus, to achieve high profit margins, it is very important to increase the yield of the wafer edge. In current semiconductor manufacturing processes, it is very difficult to control plasma uniformity due to challenging nanoscale patterning. Recently, numerous theoretical and experimental studies have been conducted to improve plasma uniformity by investigating approaches, such as separate dual frequency excitation and very high frequency mixing.
In this study, superimposed multi-frequency operation on an inductively-coupled plasma (ICP) source was investigated as a method for controlling plasma uniformity. Toward that end, 13.56 MHz and 2 MHz radio frequency (RF) power was supplied to the same top electrode, and 12.56 MHz was applied to the bottom electrode. To examine how a low frequency source affects uniformity, single frequency and dual superimposing frequency were compared. The plasma parameters of a superimposed ICP with a biased substrate were measured under various conditions. A spatially resolved Langmuir probe with extensible bellows and linear drive was used to measure the plasma parameters across the 300 mm wafer to determine uniformity. The plasma characteristics of a superimposed dual frequency (13.56 MHz/2 MHz) ICP system were investigated and compared with a single frequency ICP system. Variations in multi-frequency source power changed the ion energy distribution profiles and plasma uniformity. It was observed that the plasma uniformity was better in the superimposed dual frequency ICP than the single source ICP.

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Epitaxial growth of CuInSe2/InSe/Si heterostructures for photovoltaic applications

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Next generation Si solar cell is heading for the use of ultra-thin Si wafers with the thickness less than 50μm. The challenge is to develop an effective light trapping technology for the PV cells in this category since crystalline Si is an indirect-gap material with a low optical absorption coefficient. In this work, we develop a novel device structure using an efficient light absorption layer of CuInSe2 (CIS) at the bottom of Si homojunction. The device under investigation possesses epitaxial structure on single-crystalline Si substrate. Since the lattice mismatch of CIS/Si is considerable large, the insertion of a thin layer of 2D compound (InSe) at the interface is employed to solve the mismatch problem (so-called van der Waals epitaxy). Device simulation using PC1D indicates that the cell efficiency of a device structure of n-Si/p-Si/InSe/p-CIS may reach 32.5% under AM 1.5 illumination as the wafer thickness down to 5μm. An additional role of InSe is to create a band alignment which is favorable to separate the electron-hole pairs produced in CIS and transport in opposite directions. It is more like a tandem-cell structure so that a decent energy conversion efficiency can be achieved. The simulation has considered the interface recombination and used the up-to-date material parameters reported in the literature. To verify the simulation results, a molecular beam epitaxy (MBE) technique is employed to grown an interfacial layer of InSe on (100)Si prior to the deposition of a CIS film. With the use of a Hg lamp to conduct the photo-assisted growth, we are able to grow epitaxial CIS films at a temperature as low as 300oC. This temperature prohibits the interdiffusion in the heterostructure as confirmed by our TEM microanalysis. The fabrication and properties of the above-mentioned device structure will also be reported in the conference.

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Stabilisation of tetragonal ZrO2 by oxygen plasma treatment of sputtered ZrCu and ZrAl thin films

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The stabilization of tetragonal zirconium dioxide (zirconia) by doping at room temperature has already been carried out with dopant materials like Y or Mg. In the present work it was investigated if stabilization is possible with alternative dopants like Al and Cu. The films were produced with a dual cathode magnetron sputtering device. Because it is expected that the stabilization depends on the dopant concentration, the Zr coatings were produced with a dopant gradient. So it was possible to investigate many different compositions with only few samples. This dopant gradient could be produced with a modification of the substrate holder in the sputtering chamber where a small wall partially shadows the vapor beam of the do-pant. After production of the ZrAl and ZrCu samples, first their chemical composition was determined by energy dispersive X-ray spectroscopy in a scanning electron microscope. Then they were treated with oxygen plasma. Depth profiles were recorded by Auger electron spectroscopy to investigate the progress of the oxidation. For crystallographic analysis X-ray diffraction was used. The surface morphology was measured with an atomic force mi-croscope.
The results show that the stabilization worked successfully with Cu while for Al no for-mation of the tetragonal phase was observed. In addition the results show that oxygen treat-ment time and power could be important parameters for the formation of tetragonal zirconia.

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Room temperature magnetron sputtering of InGaZnO and ZTO amorphous oxide semiconductors

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Amorphous oxide semiconductors (AOS) have attracted a great deal of attention as they offer a combination of interesting properties, namely high carrier mobility along with high optical transparency, mechanical flexibility as well as smooth surface. AOS are thus suitable for transparent flexible electronics such as thin-film transistors or/and flat-panel displays. Another key advantage is the fact that AOS can be prepared at low temperatures large area deposition techniques such as magnetron sputtering on the flexible substrates. Although In-Ga-Zn-O has the best performance so far, there is an interest in In-free alternatives.
The properties of AOS are extremely sensitive to the deposition conditions, stoichiometry and composition, giving rise to a wide range of tunable optical and electrical properties. In this work we examined the effect of different discharge configurations to identify the relation between growth conditions and properties of magnetron sputtered InGaZnO(IGZO) and ZnSnO(ZTO) films. IGZO films were deposited by RF sputtering from an oxide target while for ZTO, reactive sputtering from an alloy target was used. The changes of chemical composition, structure, electrical and optical properties of IGZO and ZTO films dependent on the lateral substrate position have been analysed by Hall measurements, Raman, XPS and UV-Vis spectroscopy. The a-IGZO films deposited by rf sputtering showed a large variation in resistivity, Hall mobility and carrier concentration. The best as-deposited IGZO films had resistivity of about 2·10-2 Ohm·cm and electron mobility up 10 cm2·V-1·s-1. The lateral property gradients are discussed with respect to the composition and energy of the material flux towards the substrate and major effect of oxygen and gallium ions is demonstrated.

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Synthesis of 2D MoS2 for flexible gas sensor at low temperature

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The effective synthesis two-dimensional molybdenum disulfides (2D MoS2) at low temperature is essential for their use in flexible devices. In this work, 2D MoS2 was grown directly at a low-temperature of 200 ℃ on both hard substrates (SiO2) and soft substrates (PI) using chemical vapor deposition (CVD) with Mo(CO)6 and H2S. We investigated the effect of the growth temperature and Mo concentration on layered growth by Raman spectroscopy and microscopy. The optical microscopy, Raman spectroscopy, X-ray photoemission spectroscopy, photoluminescence, and transmission electron microscopy measurements indicate that the low temperature CVD MoS2 is layered structure with good uniformity, stoichiometry and controlled layer number. Furthermore, we demonstrated the realization of 2D MoS2 based flexible gas sensor on PI substrate without any transfer process,

and the sensor shows competitive sensor performance and mechanical durability at room temperature.
This study develops a low-temperature method for the deposition of MoS2 on substrate with low plastic deformation temperatures and to characterize the gas sensing properties of the prepared materials. The utility of the prepared material for sensing NO2 and NH3 over a wide range of concentrations. The strategies presented herein will be useful in the future development of flexible sensors.

Poster Session Wednesday / 286

Microwave-excited Microplasma Arrays in Atmospheric Air by Coplanar Waveguide Resonator

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Microplasma arrays in atmospheric air for wide area have been developed. The plasma sources consist of quarter-wavelength resonators. Slot line resonators and coplanar waveguide resonators were used due to the compact size and simple structure 1. The single resonator is capable of generating microplasmas with less than 5-W input power at resonance, and specific gas supply such as argon or helium is not necessary to sustain the microplasmas 2. Therefore, the air microplasmas can last for hours without being turned off if the microwave power is continuously supplied. A comparative analysis of plasma physics including radical generation and plasma temperatures for each argon, helium and air plasmas has been conducted with optical emission spectroscopy to characterize the plasma generator. The electric field distribution and reflection coefficient have been analyzed with ANSYS HFSS to verify the possibility of plasma generation prior to the device fabrication. Two methods related to multiple microplasmas are discussed in this work. The first is about the multiple microplasmas source using a Wilkinson power divider. For stable power distribution to individual resonator, the Wilkinson power divider on printed circuit board was designed and made. Secondly, applying coupled mode theory to the multiple microplasmas for uniformity is discussed [3].

Keywords: microwave, air microplasmas, coplanar waveguide resonators, Wilkinson power divider, coupled mode theory

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Poster Session Wednesday / 301

Evaluation of Mechanical Properties of Transparent AZO(Aluminum-doped Zinc Oxide)-zincone Hybrid Multilayer Thin Films Grown on a Transparent Polyimide Substrate by Atomic and Molecular Layer Depositions

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Currently, a curved OLED(organic light-emitting diode) display is leading the smartphone market, so there is a growing interest in bendable displays. A transparent display has also attracted the attention of the smartphone market with the flexible display. To meet the required properties for the commercializing flexible and transparent display devices, the improvements of mechanical, optical and electrical properties of transparent electrodes are essential. According to previous studies, AZO-zincone hybrid layer has many advantages over conventional AZO single layer in terms of electrical properties and flexibility. In this study, the comparison of mechanical properties between conventional AZO single thin films and AZO-zincone hybrid multilayer films were performed using various characterization tools, i.e. nano-indentation, bending test and micro tensile test. Hybrid multi-layer thin films were deposited on TPI (transparent polyimide) substrate using ALD (atomic layer deposition) and MLD (molecular layer deposition) techniques. By combining these two deposition techniques, various multi-layer organic-inorganic hybrid thin film structures can be fabricated. Various layer-by-layer thin film structures were fabricated by controlling the thickness and composition of the thin films. The hybrid multi-layer thin films show great potential for future high-end bendable display technologies due to their tunable mechanical, optical and electrical properties based on multi-layer thin structures.

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Effects of Composition Ratios and Microstructure on Mechanical and Electrical Properties of AZO – Zincone Nanolaminates Using Atomic and Molecular Layer Depositions

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The combination of ALD and MLD techniques enables the fabrication of various functional organic – inorganic hybrid thin film structures. In this work, Al-doped zinc oxide (AZO) and zincone multilayers were deposited on polymer substrate using diethylzinc (DEZ) with H2O and hydroquinone (HQ) precursors. Because the nanolaminates structure of AZO - zincone is consisted with organic and inorganic layers, the mechanical and electrical advantages of those two materials may impact the final properties of hybrid thin films. The characteristics of the hybrid thin film are varied significantly with the change of composition ratios, the thin film microstructure and process conditions. Various nano-structures of hybrid thin film were fabricated by controlling composition ratio and process conditions, and their microstructure and morphology were analyzed. The mechanical properties of hybrid thin films grown on transparent polyimide substrate were characterized by the micro-tensile test. The variation of electrical resistivities of hybrid thin films were also measured during the micro-tensile test, so the reliability of hybrid thin films were analyzed under external deformations. . In addition, the optical transmittance of nanolaminates thin films was also measured with various composition ratios and compared with conventional AZO single inorganic thin film.

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XPS study of the front/back interfaces in Kesterite photovoltaic devices

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Thin film Kesterites (CZT(SSe)) are currently the most promising photovoltaics (PV) materials for new niche markets such as Building-integrated PV (BIPV) and Product-integrated PV (PIPV) due to their composition based on earth abundant elements and also to their promising photovoltaic device performance. Their tunable bandgap (between 1-1.5 eV) renders them particularly suited also for their integration in more complex devices such as in bi-facial or tandem structures using a transparent back contact. Especially in this case, the use of a transparent back contact requires the incorporation of a layer at the interface to improve the back contact band alignment. In that sense, transition metal oxides (TMO) have proved to be useful thin films for enhancing the characteristics of the solar devices, especially when used at the back/front interfaces of the absorber, since they contribute to the band alignment and thus the carrier injection. Another promising strategy for the front interface consists in changing the alkali nature and content during the deposition of the CdS buffer layer.
Therefore, in this work we present the most recent results of X-ray Photoelectron Spectroscopy (XPS) characterization of (1) the back interfaces in Kesterite-based solar using functionalized transparent conductive oxides consisting on different TMOs used onto the FTO (fluorine doped tin oxide) back contact, with/without Molybdenum on top, and (2) the front interfaces of absorbers using CdS layers with different alkali strategies. The characterization results of these interfaces will give further understanding on the mechanisms enhancing the band alignment of the back and front layers with the absorber to achieve a better performance of Kesterite devices.

Poster Session Wednesday / 325

Formation and structure of TiN/ZrN multilayer coatings deposited on tool steel

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The formation of coatings with high hardness, toughness, wear- and corrosion-resistance, suitable for applications in the area of medicine (anti-corrosion and wear-resistance coatings of different medical instruments, artificial joints and implants) and machine engineering (protective coatings on cutting, forming and petal processing instruments and bearings) are problems of great importance nowadays. TiN/ZrN multilayer coating system is a hard, wear resistant material which is widely used for cutting and forming tools and other components operating in an abrasive wear environment.
In this study TiN/ZrN multilayer coatings was deposited on tool steel by direct current magnetron sputtering. The experiments were conducted on samples of W320 (0.31 wt% C; 0.30 wt% Si; 0.35 wt% Mn; 2.9 wt% Cr; 2,8 wt% Mo; 0.5 wt% V) hot-work tool steel that were heat-treated in advance.
The structure of the coatings was observed by XRD (X-ray diffraction) with CuKα characteristic radiation (1.54 Å). The measurements were conducted in Bragg-Brentano (B-B) symmetrical mode, from 20° to 80° at 2θ scale. The step has been chosen 0.1° with counting time 10 sec. per step. The microstructure of the obtained multilayer coatings was investigated by Scanning Electron Microscopy

(SEM), as backscattered electrons have been used. The accelerated voltage was 20 kV. The chemical composition was studied by Energy-Dispersive X-ray Spectroscopy (EDX). The surface of the coatings was observed by Atomic Forced Microscopy (ATM). Nanoindenter tester (Brucker, USA) was used to measure the nanohardness and Young's modulus.
The obtained results demonstrate the possibility of formation of hard and wear resistant multilayer coating of TiN/ZrN on the tool steels. It was shown the opportunity of formation of surface coatings with good stoichiometry and great mechanical properties with the chosen technological parameters, applied during the deposition.

Poster Session Wednesday / 328

Structure and properties of TiO2/TiN deposited on EBM modified stainless steel

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It is well known that the stainless steel alloys are widely used to manufacture stainless steel (SS) implant and instruments for medical applications. However, they have low shear strength and wear resistance. The application of hard PVD coatings on properly prepared stainless steel surface could basically improve the mechanical and functional properties.
The substrate material used in the present study was stainless steel 304. Previously, the substrates have been electron-beam modified followed by deposition of bilayered TiO2/TiN coatings. This work concentrates on the nature and strength of the applied electron-beam surface modification(EBSM). X-ray diffraction (XRD), atomic force microscopy (AFM), and nanoindentation were carried out to examine the effect of the EBSM and coating deposition on the crystallographic structure, phase composition, surface topography and mechanical properties of the bilayers. The results obtained in the present study for the hardness are discussed in the context of the crystallographic principles, and significant attention has been paid to the characterization of the phase composition and preferred crystallographic orientation. This, together with comparative analyses of the surface topography, quantitatively evaluated by statistical treatment of AFM data, are expected to give new knowledge of the processes which occur during the growth of TiN/TiO2 coatings with and without electron-beam surface modification of the substrates.

Plenary session / 373

Fundamental mechanisms of accelerated and plasma ion interactions with materials: insights from atomistic simulations

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In this talk, I will overview how atomistic computer simulations carried out over the last about 30 years, have enabled a much improved understandings of how ions accelerated in a vacuum interact with materials. Molecular dynamics simulations have enabled a good understanding of heat spikes, in which damage production mechanisms are fundamentally different from those predicted by traditional binary collision-based theories. Heat spikes can lead to direct production of large damage clusters and sputtering of atom clusters. Most recently, joint experimental and theoretical efforts have shown that in nanoclusters and nanowires, heat spikes can lead to huge sputtering yields exceeding 1000 atoms and major modification of the entire structure. I will also present a new systematic approach to analyze ion channeling. The results shows that for typical ion implantation conditions, a

large fraction (20-60%) of all crystal directions are channeling. Due to this, even when irradiating polycrystalline materials, one cannot a priori assume channeling effects are negligible.

Vacuum Science & Technology / **262**

Thermal Analysis of Large-scale Cryopump Used in Large Vacuum Leak Detecting System

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A large-scale cryopump (DN1250) used in large vacuum leak detecting system was designed and its performance experimentally investigated by Beijing Institute of Spacecraft Environment Engineering. In the cryopump, the first stage array (radiation shield and baffle) and the second stage cryopanel were cooled by four closed cycle helium refrigerators (two dual stage refrigerators and two single stage refrigerators). The second stage cryopanel were divided into two parts and directly attached to the second stage of two dual stage refrigerators respectively, and were not covered with activated charcoal to avoid pump the helium gas which was the tracer gas in helium mass-spectrum leak detection system. The radiation shield and baffle were also divided into two parts, and each part was cooled by the first stage of one dual stage refrigerators and one single stage refrigerators. The thermal analysis method based on numerical techniques was introduced in this study, the heat transfer in the first stage array and the second stage cryopanel was carefully analyzed to determine important considerations in the thermal design of the cryopump. A performance test system according to the test standards for cryopump was built to test main performance of the cryopump.
The experimental results showed that the structure of first stage array which was optimized by the method could meet the requirement of the second stage cryopanel well. The temperature of the cryopanel was down to 12K within 360min, and the result of experiment was accordant with theoretical analysis conclusion. The test also showed that the pumping speed for N2 of the pump was up to 57,000L/s, the cool down time was about 360min, and the crossover was over than 1,000mbar•L.

Biointerfaces / **344**

Plasma-inspired biomaterials (plenary)

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Plasma as a discharge state of the gas is considered nowadays a cutting edge tool which can manipulate objects at the atomic or molecular scale. On the other hand, the biomaterials are substances that are engineered to possess certain properties which can control the interactions with components of living systems, inducing favourable response from the biological entities, and as such can direct the course of a therapy or diagnostic procedure. In this respect, plasmas can be used to initiate even more favourable or selective responses, making the biomaterials even more suitable for their interaction with biological entities.
The most appropriate plasmas for initiation of these responses and modifications are so-called cold plasmas, which are generated from reduced to atmospheric pressures. Cold plasmas are employed to tailor the surfaces of materials for decades. With the increasing relevance of biomaterials, which can augment or replace partially or totally any tissue, organ or function of the body, in order to maintain

or improve the quality of life of the individuals, the potential of plasmas in the field is extraordinary and has seen some significant advances in last years.
This talk will highlight the most recent developments in the area where plasmas are used directly or indirectly for preparation of biomaterials or biocompatible surfaces. It will cover all general aspects of research which connects plasma and biomaterials, ranging from plasma preparation of biomaterials for different applications (hard tissues such as bone, and soft tissues) including drug delivery applications, antibacterial coatings, and biological interactions of the plasma-prepared surfaces with bacteria, cells and tissues. Novel developments for diagnostics and sensing will be included as well. All of these topical areas were represented in a special issue on "Plasma-inspired biomaterials" published in J. Phys. D: Appl. Phys, 2017.

Vacuum in Accelerators / 303

Turbo molecular pump as main pump in a high-power proton accelerator vacuum system

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J-PARC 3 GeV rapid cycling synchrotron (RCS) is one of the highest beam power proton accelerator, which accelerates 8.3 x 10^13 protons at 25 Hz up to 3 GeV, corresponding 1 MW beam power. Challenges for achieving low pressure region of ultrahigh vacuum (UHV) less than 10^-5 Pa in RCS beam line are the following outgassing source.
1. Outgassing from large surface area of beam pipes and other vacuum devices due to large aperture to accept the burst number of protons.
2. Outgassing of water due to unbakeable beam line to prevent ceramics beam pipes from breaking by excessive stress due to thermal expansion of nearby beam pipes.
3. Additional outgassing originated from high power beam: thermal outgassing due to beam hit to a charge exchange foil or collimators; molecules desorption from vacuum surface by hitting of ionized residual gas.
We focused turbo molecular pump (TMP) as main pump because TMP can evacuate such continuous and additional outgassing with large pumping speed in wide pressure range. It is also possible to evacuate from low vacuum to UHV with only a few hours by using TMP, which ensures users' experimental time after vacuum device maintenance. TMP During more than 10 years operation of the vacuum system, many experiences have been accumulated about the usage of TMP in RCS. In this presentation, we discussed about validity of TMS as main pump in high power proton accelerator by showing the performance of the beam line pressure during the beam operation, few troubles, ease of operation, etc. Further, in anticipation of upgrade higher beam power more than 1 MW, where lower pressure should be required, validity of a combination of TMP and NEG pump will be mentioned.

Vacuum Science & Technology / 202

Structural Improvement of Multiple-Cavity Dry Scroll Vacuum Pump

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Dry scroll vacuum pump (DSVP) has been widely used in many industries with its inherent advantages of outstanding pumping capacity, low power consumption, low vibration and noise and oil free performance in the cavity, resulting in the increasing demand for DSVP. The huge fund has been invested to study DSVP by many research institutes and vacuum equipment manufacturers. However, it is difficult to improve the performance of DSVP, limiting its application. This paper aims to improve the performance and widen the scope of application of DSVP to provide efficient and clean vacuum environment for more industrial areas and the multiple-cavity dry scroll vacuum pump (MCDSVP) was researched in detail. According to the mechanical theory of scroll, the calculation method of MCDSVP was put forward and established, and then compared with the single cavity structure. It was found that the suction speed of multi-chamber was increased by 76.4%, the peak load located in bearing was reduced by 88.8% and the friction loss was reduced by 58.3% compared with that of single chamber under the same comparison standard, which proved the design superiority of MCDSVP. Then taking the four-chamber as an example, the steady-state deformation and stress of the four-chamber dynamic and fixed scroll with gas load, thermal load and multi-field coupling were studied with ANSYS Workbench, respectively. Through the thermo-mechanical coupling analysis of the multi-cavity vacuum pump under the condition of assembly, the optimal radial clearance of each scroll body is 0.06 mm in the four-chamber scroll pump, which provide theoretical guidance for the design and study of the bilateral scroll vacuum pump.

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Intensity Tuning of X-Ray Laser Photon Pulses with Rarefied Gases: The SASE3 Beamline Gas Attenuator at the European XFEL Facility.

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The European XFEL is a 3.4 km long branched underground facility that generates extremely intense X-ray flashes to be used by researchers from all over the world. Located in the Hamburg urban area, it officially began operation in September 2017, and the first experiments are running as scheduled since then. Located at the soft X-ray beamline (SASE3), a gas-based intensity modulation cell is currently being commissioned: the so-called "SASE3 Gas Attenuator" beamline sector comprises almost a 25 m long system that enables the tuning of the transferred photon intensity without compromising the outstanding coherence properties of the beam or collimating it.

This is achieved by a large static clear aperture (20 mm nominal diameter) and windowless transition between the active cell and the rest of the X-ray beam transport system. The complete sector has been qualified as UHV with a base pressure below 5 x 10-9 mbar when there is no gas injected. Also, the active cell can be brought up to 35 mbar, while two symmetrical four-stage differential pumping modules keep the interface pressure with the next vacuum sector below 5 x 10-8 mbar. It is designed to operate with up to 5 selectable gas species (N2, Ar, Kr, Ne, Xe).

To provide the highest pressure control precision, an in-house feedback control system has been developed. Since the device will be used for many and diverse types of experiments, it needs that the subsystems used for the precise pressure measurement and the regulation of the injected gas flow are flexible enough. In this case, two device arrays, one of capacitive vacuum gauges and another of mass flow controllers are working in coordination to extend their intrinsic precision to the required large dynamic range. At the same time, to limit the gas flow transferred from the active gas cell, an effective but easy variable aperture system has been implemented. The first experiments with beam are expected for the second half of 2018.

Vacuum Science & Technology / 265

The optimisation and simulation of vacuum plume field in ground testing for electric thrusters

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The plume field in a vacuum facility for hall thruster ground testing is investigated in detail through a series of simulations using a direct simulation Monte Carlo (DSMC) code. The focus here is on the effects of finite background gas pressure in ground vacuum test facilities under different distribution of technical equipments such as the xenon pump, beam target or shroud. The results show that various structures and location of experimental equipments in vacuum facility are influential to plume field, even the operation and performance of hall thruster. There are also some considerations for distribution of experimental equipments to reach a better and real testing environment. The numerical simulation is great beneficial to the optimization design of test facility and plume effect analysis in ground testing for electric propulsion.

Biointerfaces / 110

Self-Assembling Behavior of Cysteine-Modified Oligopeptides: an XPS and NEXAFS Study

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The achieving of rigorous control over the procedures aiming at modifying surfaces by selective adhesion of bioactive molecules is a mandatory step in view of the realistic applicability of bioengineered materials in the field of tissue engineering. In this context, we report a proof-of-concept study carried out on a Self Assembling Peptide (SAP) on purpose functionalized with cysteine (Cys), as to ideally grant the molecule grafting to gold surfaces. The effectiveness of the surface functionalization in monolayer regime and the molecular stability of the SAP-Cys were probed by X-Ray Photoelectron Spectroscopy (XPS); the highly ordered self-organization attained by the grafting molecules was assessed by means of Angular Dependent Near Edge X-Ray Absorption Fine Structure (NEXAFS) spectroscopy studies. This study opens wide perspectives for efficient chemical modification of surfaces with biomolecules, following a path that involves biocompatible agents only, differently from state-of-the-art paths usually involving specific molecules (as for example APTES) as linkers.

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Erosion and tungsten surface enrichment of Eurofer-97 steel exposed to a deuterium plasma in the GyM linear device

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In future nuclear fusion reactors, the erosion by hydrogenic charge-exchange neutrals will strictly affect the lifetime of the recessed elements of the first wall 1. Among the possible candidates for these components, reduced activation ferritic martensitic (RAFM) steels, such as Eurofer-97, containing small amounts of high-Z elements like tungsten (W), are a valuable economical and technological option.
Due to the higher sputtering yield for hydrogenic particles of iron (Fe) compared to that of W, it was demonstrated [1,2] that Fe of RAFM steels exposed to low energy deuterium (D) ions erodes faster, leading to a W-rich surface. Moreover, it turns out 1 that the erosion dynamics of RAFM steels strictly depends on their temperature (T). Thermal effects like inter-diffusion of Fe and W and also the W segregation toward the surface [3] could indeed respectively enhance and counteract the erosion. However, a comprehensive study of the impact of temperature on W enrichment of RAFM steels is still missing. For a controlled investigation of W enrichment as a function of RAFM steels temperature, Eurofer-97 samples were exposed to the D plasma of the linear machine GyM [3], at three different temperatures: 600 K, 800 K and 1000 K. For each T, five ion fluences, in the range of 4.5×1024 ÷ 2.3×1025 ions m-2, were considered, keeping the ion energy nearly constant to 200 eV by applying a proper negative bias voltage to the samples holder.
The erosion rate was evaluated from profilometry and weight loss. The W enrichment was estimated using Rutherford backscattering and low-energy ion scattering spectroscopies. Possible Eurofer-97 samples compositional changes were investigated after the exposures with depth-profiling X-Ray photoelectron spectroscopy. Considering the highest fluence, preliminary results show that the erosion of Eurofer-97 at 1000 K is ~50% higher than that at 600 K due to inter-diffusion of Fe and W.

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Vacuum in Accelerators / 358

Shape memory alloy technologies for ultra-high vacuum coupling in particle accelerators

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A new generation of ultra-high vacuum (UHV) coupling systems for particle accelerators are currently under investigation at CERN [1,2]. In such systems, the unique thermal recovery features of shape memory alloys (SMAs) are exploited. In particular, thanks to the large strain and stress recovery capabilities of SMAs, ring shaped couplers, to be used as beam-pipe connectors, are being investigated. The use of such technology in restricted access areas, such as the radioactive ones, could result in noticeable advantages, especially during maintenance operations. In fact, SMA couplers can be activated remotely by temperature changes, resulting in significant reduction of the radiation doses collected by the technical personnel.

To this aim, suitable alloy compositions have been selected and special thermo-mechanical training processes have been designed, to satisfy the strict functional constraints in particle accelerators. Both ternary (NiTiNb) and binary (NiTi) alloy systems have been analyzed and their main application limits/advantages have been outlined. Results have shown that leak rate constraints for UHV applications could be easily satisfied (leak rate <10−10 mbar l s−1). Furthermore, thermal mounting/dismounting has been always obtained which allows remote activation and control. Finally, the effects of ionizing radiation on both mechanical and functional responses of SMA couplers are under investigation, by using special facilities at CERN. Preliminary results have shown that leak tightness and thermal dismounting are unaffected by irradiation (up to ~140 kGy).
Thanks to these features, possible applications in the CERN accelerator complex are considered.

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Biointerfaces / 253

Selective biofunctionalization of porous silicon through visible light induced amino silanization

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Since the discovery of porous silicon (PSi), a remarkable field of innovation has been opened through its biological applications. These often require the engineering of an interface between the inorganic material and the biomolecules. This interface is expected to passivate the PSi surface and facilitate the progress of biomolecular immobilization cascades. This process is carried out sequentially through chemical or thermal oxidation and an ulterior crosslinking of an organosilane to the hydroxyl groups generated at the surface. In the present work we first show that the two step process can be simplified through a single step process by using light activation of the PSi surface in ethanol solutions (98%) containing 0.2 % aminopropyltriethoxysilane. Noting the enhanced surface selectivity offered by light induced processes, we secondly take profit of masking and focusing options to generate biofunctional micropatterns on the surface. These have been characterized by X-ray photoelectron spectroscopy and validated by applying sandwich immunorecognition assays optically revealed by fluorescence microscopy.

Vacuum Science & Technology / 199

Integrated Testing Method of Pumping Performance for Dry Vacuum Pump

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Traditional dry pump measurement devices usually only perform single performance measurements under fixed conditions. This paper presents a performance measurement method with highly inte-

grated, high precision and high degree of automation for vacuum dry pump, realizing not only the measurement of the original performance indicators, but also directly measurement main performance in the process of real-time operation. Fully considering the integrated performance measurement method of the measurement object diversity, analyze and improve the structure of the object, put forward the integrated performance measurement method of a variety of functions. To realize the integrated measurement method, choose three basic physical quantities of flow, vacuum degree, temperature to measurement and control, to provide a theoretical basis and the concrete scheme for the integrated performance measurement method of dry vacuum pump. By calculating and comparing the basic principles of various flow measurement methods and the uncertainty, select a measurement method suitable for the integrated measurement system; By contrast to the principle of vacuum measurement and classification, determine the vacuum gauge options; Through the study in combination with the need of integration measurement temperature measuring method, choose the appropriate temperature measuring device. To design and calculate and determine the type and size of the vacuum chamber, optimize the internal structure of the vacuum chamber design and implement the uniformity of temperature and vacuum degree. At the same time, by the positive pressure balance method and in combination with mass flow meter and vortex flow meter and set the balance chamber, the method of implementation under vacuum conditions in wide range, the precise measurement of the small flow rate.

Vacuum Science & Technology / 278

Conditioning methods to reduce ion-induced desorption

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Heavy ion accelerators suffer from pressure increases during operation, triggered by ion-induced desorption. Lost beam ions impinge on surfaces of the vacuum system and gas is released what in turn leads to more beam loss and further pressure increase. This pressure instability is called dynamic vacuum and limits the intensity of the ion beam. A common mitigation technique is the installation of dedicated catchers with minimal desorption yields to eliminate lost beam ions.
With the design and operation of next generation heavy ion accelerators, the problem recurs as these machines have such high intensities that beam loss rates will be similar to primary beam intensities of nowadays machines. To mention the most important, HIAF in China and FAIR in Germany will deliver 1012 U ions per second. Spiral 2 in France will even deliver some 1014 intermediate heavy ions per second that will be directed onto a production target. The amount of desorbed gas in the loss regions of these machines will limit a stable operation of the vacuum system and thereby of the whole machine.
We have investigated and compared conditioning methods to reduce the amount of desorbed gas in the respective areas. The methods are cleaning by the ion beam itself, the so-called beam scrubbing, sputter cleaning by means of a 5 keV Ar sputter gun and thermal annealing at different temperatures. Results will be presented and compared. After all, a reduction of the desorption yield by two orders of magnitude was demonstrated.

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FBG-based diagnostics for large vacuum machines

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In terms of the increasing complexity of fundamental research topics at accelerators the requirements concerning the experimental setup of these large vacuum machines gain more and more impact. One crucial aspect to fulfil these experimental requirements is the necessity of monitoring and capturing the process parameters of the accelerator itself, like temperature or position of vacuum components at different stages inside the accelerator. Due to the large size of an accelerator an effective diagnostic has to be centralized, which ends up in large signal paths of several hundreds of meter. Therefore, the diagnostic signal has to be robust and sensitive enough to avoid external impact and to observe small changes in temperature or position. In addition, to access the differently shaped vacuum components easily, both flexible and local positioning of the sensor inside the vacuum machine is required.

The present contribution concentrates on a fiber-based diagnostic method inside large vacuum machines. The sensors are based on fiber Bragg gratings (FBGs), which are narrow linewidth filters integrated in an optical fiber. The sensors have a length of several mm (typically 8mm). The advantage is that they are immune against electromagnetic radiation and tens or hundreds of sensors can be easily multiplexed. The FBGs are very sensitive to strain and temperature. In combination with a hermetical sealed optical fiber feedthrough, an optical fiber containing a bunch of several FBGs becomes a compact, stable, robust, and flexible network of local sensors to simultaneously monitor and capture process parameters at different positions inside vacuum machines. In the present contribution, a discussion about FBG-based sensors as an ideal sensor network inside the vacuum is stimulated.

Biointerfaces / 156

Optimisation of sputtered film surface bioactivity via structural and chemical variations

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A new and rapidly developing area related to surface antimicrobial performance is emerging to address the increasing resistance to antibiotics. The aim is to reduce infection risks within the medical environment by creating surfaces that can rapidly kill microbes before coming into contact with patients. Such surface coatings have been created which combine chemical and nanostructured microbe killing activity. The antimicrobial performance also need to be linked to high levels of coating durability in order to create surfaces suitable for different types of medical applications with the ability to withstand wear and cleaning cycles.
A wide range of coating compositions have been deposited by sputtering under different energy levels, and the drivers for antimicrobial activity have been mapped. The coating combines two known antimicrobial effects; the use of ionic metal clusters, and the creation of a nanotopography that promotes chemical and electrical activity between features. The work has shown that both effects are required to produce the high levels of antimicrobial effectiveness. Test have shown that under the correct conditions both silver and copper alloys can be combined with oxide or nitride coating structures can result an microbial kill rate of LOG 6 reduction within 2 hours. The layers perform as well as the best nanoclustered pure silver layers, but have the added benefit of high hardness and wear resistance.

Plenary session / 370

Nanostructures and layer stacking in artistic materials: the origin of colors in paintings

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Materials science today provides us with a vision of the processes involved in the creation of a work of art, from the choice of materials to the visual perception of the finished work.
The precious character of the paintings of the old Masters and their uniqueness imply particular cautions and require instruments, which may give the maximum of information directly on the surface of the objects, in-situ in the museums or in the archaeological sites. The implementation of new analytical tools, including various spectroscopies, allows a deep insight on the artistic materials. We will first show applications of different mobile instruments we built recently in the laboratory.
We will then showcase how Cadmium sulfide pigments may assume different hues from yellow to orange, depending on their conditions of formation. During the 19th century, various synthetic routes for CdS nanoparticles synthesis were explored to produce pigments for artists, precipitating cadmium salts with sulfur precursors. Several factors are involved in the colorimetric values of the CdS: structural defects, polymorphism in the crystal lattice and nanometric size of the crystallites. This complexity has postponed the supply of these pigments to the artists for more than 20 years after the discovery of cadmium in 1817. The light-stability of these pigments is also related to the nanometric crystallite size and the degree of crystallinity that has been improved by thermal treatment.

Electronic Materials & Processing / 249

ScAlN: A novel piezoelectric material

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The next generation of smart phones requires bandpass filter based on acoustic wave devices working at frequencies of up to 6 GHz in order to adapt all mobile communication standards available worldwide. To enable high frequency and efficient energy transfer of these devices, highly piezoelectric and very stiff layers are required. Therefore, we have developed thin lay-ers of wurzite ScAlN showing four times the piezoelectric coefficient d33 and a similar stiff-ness in comparison to AlN used for processing surface and bulk acoustic wave devices up to date.

We present investigations of the elastic, dielectric and piezoelectric properties of aluminum scandium nitride (ScAlN) with wurtzite crystal structure by means of first-principles calcula-tions based on density functional theory added by a detailed experimental analysis of struc-tural, mechanical and polarization related effects. The goal of our approach is to use the atom-istic simulations to extract the whole set of tensor components and to confirm the theoretical prediction by experimental measurements for selected tensor coefficients of physical proper-ties relevant for piezoacoustic device design. The results presented include a detailed analysis and comparison of the calculated and the experimental data, such as the lattice coefficients, internal cell parameter, piezoelectric and stiffness matrix, Young´s and bulk modulus, dielec-tric coefficients, mass density, sound velocity as well as coupling factor for Sc-concentrations of up to x = 0.4. In addition, the theoretical and experimental data achieved and supplement-ed by information present in the literature are used to provide complete tensors for certain Sc-concentrations relevant for piezoacoustic devices. Furthermore, the dependence of a high number of physical properties are described in dependence on Sc-concentration taking nonlin-ear effects into account. By a detailed comparison to the properties and coefficients of GaAlN and InAlN alloys we point out novel properties of ScAlN in order to motivate new designs of acoustic wave devices dedicated to operate at very high frequencies.

Plasma Science and Technology / 350

Long-range interactions induced by oriented water molecules within plasma polymeric subsurfaces

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The common definition of "surface" includes surface atoms and molecules, practically extending at the most three layers – typically up to one nanometer. This definition is justified by the fact that many surface properties such as chemistry, wettability or charge density are determined by the top most surface layer. Far less explored are effects due to interactions with deeper subsurface layers, i.e. the region extending over several nanometers underneath the "surface". This subsurface region, however, might significantly contribute to molecular adsorption at the surface via long-range (i.e. >10 nm) interaction forces.
To make use of such subsurface effects, plasma polymer films (PPFs) with defined architecture in the nanoscale were deposited comprising a hydrophobic-to-hydrophilic vertical chemical gradient structure. The organic/inorganic thin films were generated by depositing 1-15 nm-thick layers of plasma-polymerized HMDSO on a hydrophilic, nanoporous base layer of SiOx (with O2/HMDSO in the plasma). Diffusion of water through the hydrophobic terminal layer is still enabled despite the hydrophobic surface properties yielding hydration of the hydrophobic/hydrophilic subsurface structure as demonstrated by neutron reflectometry measurements. The hydrated films were found to strongly affect protein adsorption at the surface thanks to long-range interaction forces induced by oriented water molecules.
Thereby, additional control over adsorption processes and modulation of protein adsorption is enabled which is relevant, e.g., for tissue engineering, wound dressing etc.
Adjusting the thin film architecture of plasma polymer films thus provides an additional parameter to modulate surface properties of materials.

Vacuum in Accelerators / 217

Low Energy Electrons Yield of copper as received and after sputtering

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On the way to High Luminosity LHC the electron cloud build-up has been identified as the main limiting factor. It has been shown that this phenomenon correlates with the secondary electron (SE) yield of the materials used to construct accelerator's vacuum chambers. To this day, different methods have been developed in order to mitigate the electron multiplication process. Currently, there

are solutions (e.g., "beam scrubbing", thin-film coatings and laser engineered surfaces structures.) to lower the maximal value of the SE yield well below 1.3. Moreover, it has been observed that the electron cloud formation is influenced by the time spacing between proton bunches. Simulations show that electrons with energies below 10eV are strongly influencing the electron cloud build-up if those low energy electrons are not reabsorbed within the time interval between bunches. We report on preliminary studies of low energy SE yield of polycrystalline copper as received and after sputtering. Moreover, in order to disentangle the various contributions to the electron yield in the low energy regime - where it is known that the yield-response of a material is determined by an interplay between reflectivity and emission of SEs - we investigated also copper single crystals in two different symmetry directions. Here, the role played by the band structure becomes evident. These studies enable to identify the various contributions influencing the yield. Knowledge about microscopic properties of a material are of essential importance to purposely tune a macroscopic surface, thus to achieve a goal-oriented technological performance.

Plasma Science and Technology / 185

The role of spokes on energy and transport of ions in magnetron sputtering discharges

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Energy distributions of ions in magnetron discharges and ion transport away from the target (cathode) are still not fully understood. In this talk we will provide new insights on this topic. Our measurements suggest that the energy and spatial distributions of ions are related to the phenomenon of spokes. In magnetron discharges, azimuthally non-uniform plasma structures are referred to as spokes. Spokes travel in the dense plasma region above the erosion area of the target. They are observed for most discharge conditions (i.e., pressures and discharge currents) and operation modes of the magnetron, i.e., classical DC magnetron sputtering and high power impulse magnetron sputtering (HiPIMS) [1,2]. In this work, the role of spokes on the energy and transport of ions was investigated by a combined mass and energy analyzer. The instrument was operated in a time-averaged and time-resolved manner. In the time-averaged regime, we recorded the ion energy distribution functions (IEDFs) of single and double-charged ions [3], while in the time-resolved regime we recorded a stream (i.e., time sequence) of individual ions arriving at the instrument's detector. Results of time-resolved experiments demonstrate a strong correlation between the periodicities of ion signal and the rotation of a spoke. From this and previous experiments [4,5] we can conclude that IEDFs of working gas ions are mainly related to the electric field of the spoke, while IEDFs of sputtered ions are affected both by the energy distribution of sputtered atoms and the electric field of a spoke.

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Vacuum in Accelerators / 299

The vacuum concept for the SLS-2 storage ring

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The electron storage ring of the Swiss Light Source (SLS) is supposed to be exchanged for a new one following the principle of a multibend achromat lattice (MBA). The objective is to shrink the horizontal emittance of the electron beam by a factor forty. All vacuum chambers have to be exchanged for chambers with a much smaller cross section to fit into the numerous strong magnets. In order to cope with the conductance limitation, deposition of a non evaporable getter (NEG) film is proposed for the entire ring, for about half of the chambers on top of a copper deposition for reduction of the impedance seen by the beam. A combination of lumped and distributed absorbers will absorb synchrotron radiation generated in the seven principal dipole magnets in each of the twelve cells. The paper discusses potential technical solutions for the vacuum chambers, the photon absorbers and the vacuum control system.

Electronic Materials & Processing / 188

Thermal expansion coefficient and elastic modulus of reactive pulsed-DC magnetron co sputtered piezoelectric AlScN thin films

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$Al_{1-x}Sc_xN$ is an attractive material for radio frequency microelectromechanical systems (RF-MEMS) due to higher piezoelectric coefficient d_{33}=27.6 pC/N (x=0.43) compared to 6 pC/N in pure AlN 1 and increased electromechanical coupling $k_t{}^2$ 2. Mechanical properties such as elastic modulus and coefficient of thermal expansion (CTE) are important for designing RF-MEMS. However, there are very few experimental or theoretical studies of elastic modulus of $Al_{1-x}Sc_xN$ in a large range of compositions (up to x=0.26) [3] and, the CTE of $Al_{1-x}Sc_xN$ thin films has never been reported until now. In this work, reactive pulsed-DC magnetron sputtering process was optimized [4] to produce 1 µm thick highly c-axis oriented $Al_{1-x}Sc_xN$ thin films (up to x=0.32) on 100 mm Si(001) and Al_2O_3(0001) substrates. X-ray diffraction, scanning electron microscopy, piezoresponse force microscopy, and Berlincourt method were used to analyze the film properties. To simultaneously determine the thermal expansion coefficients and the elastic modulus, a thermal cycling was performed [5] and the temperature dependent film stress was then measured. Based on the stress measurement results, CTE was calculated as a function of Sc concentration. Our measurements show average CTE αf= 5.01×10^{-6}/K, biaxial elastic modulus of 300 GPa, and Young's modulus of 216 GPa for $Al_{0.7}Sc{=}_{0.3}N$. The average CTE and elastic modulus measured for AlN fits values found in literature [5]. Consequently, the experimentally determined elastic modulus will allow designing RF-MEMS based on $Al_{1-x}Sc_xN$ with various Sc concentrations and the CTE will enable the device performance prediction at elevated temperatures.

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Plasma Science and Technology / 231

Experimental validation of plasma simulations applied to niobium coating by DC sputtering

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DC bias diode and DC magnetron sputtering are used at CERN for thin film deposition on vacuum components of various sizes, geometries, substrate and coating materials, e.g. amorphous carbon or non-evaporable getter on stainless steel, or niobium on copper radio-frequency accelerating cavities for particle accelerators.
In this context, numerical simulations are studied in order to get insight of the physical phenomena and help the process optimization. A validation with respect to the experimental case is the first necessary step before application to new cases.
We present the benchmarking of a commercial 3D Particle-In-Cell/Monte Carlo code including plasma and transport modules, by comparing numerical results towards experimental data. In order to achieve quantitative validation, input parameters of interest for the simulations include buffer gas nature (i.e. argon or krypton) and ion bombardment induced secondary electron emission properties. Their influence will be detailed for diverse sputtering configurations of an experimental system (coaxial niobium rod cathode and stainless steel anode with or without axial solenoidal magnetic field, compact post-magnetron cathode with permanent magnets), enabling a range of working pressures spanning from 0.001 to 0.1 mbar. Comparison of experimental and simulated results is made in terms of plasma discharge voltage and current, local plasma parameters (as accessible through Langmuir probes) and thickness profiles of the coatings.
Applications to the coating of real radio-frequency accelerating cavities will be discussed with respect to the scaling-up from the simulation compatible low power to real process discharge power.

Vacuum in Accelerators / 300

The vacuum chamber for the SwissFEL Athos-undulator (UE38)

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The SwissFEL facility will have two undulator lines. The one for hard X-rays, with wavelengths of 7 Å (2keV) to 1 Å (12.4 keV), with an electron energy of 5.8 GeV, is named Aramis. The second one, covering the entire soft X-ray range, from about 200 eV to 2 keV with full polarisation control, is named Athos.
Compared to the in-vacuum Aramis-undulators (U15), the Athos-undulators will have a new design, the so-called APPLEX design, where the 4 magnet arrays are out-of-vacuum and can be moved radially in a symmetric way. The minimum gap height is 6.5 mm. To allow this minimum gap the

chamber has an inner diameter of 5mm and a wall thickness of 0.2mm (0/+50µm). Since low electrical resistance and best performance in magnetic permeability (optimal µr=1) is required, the vacuum chamber is made out of galvanized copper (oxygen free, high conductive).
The paper describes the manufacturing techniques of such a thin walled copper vacuum chamber.

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Key Features of Reactive High Power Impulse Magnetron Sputtering

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For many thin film applications, such as optical coatings, energy-related coatings, hard coatings, etc., the coated layers are not single metal thin films, but rather compound coatings obtained from at least one metal (e.g. Al, Ti) or a non-metal (e.g. C, B) and a reactive gas (e.g. O2, N2). This talk will address a promising thin film deposition technology called high power impulse magnetron sputtering (HiPIMS), and how this method differs from conventional processes. Key features in reactive HiPIMS, such as eliminated/reduced hysteresis and stable high-rate deposition in the transition mode, will be discussed. It will be shown that the discharge current evolution plays an important role, which we will analyze by investigating the combined processes of self-sputter recycling and process gas recycling using results from recent plasma process modelling in combination with experimental plasma characterization. Above a critical current density of the order of Jcrit ≈ 0.2 A/cm2, a combination of self-sputter recycling and gas-recycling is generally required. The relative contributions of these recycling mechanisms, in turn, influence both the electron energy distribution and the stability of the discharges. A new framework including a generalized recycling map will be introduced to quantify these effects.

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Hetero-epitaxial AlN grown for GaN-power devices

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Integrated electronic power devices such as HEMTs (high electron mobility transistors) and LEDs are often built of a layer stack of gallium nitride (GaN), aluminium gallium nitride (AlGaN) and/or aluminium indium nitride (AlInN) layers. For the performance of the devices it is essential that such nitride stacks are highly crystalline and defect-free. In order to obtain such perfect structures, suitable substrates or templates are necessary as e.g. silicon carbide, gallium arsenide or aluminium nitride (AlN). AlN templates are typically deposited by metal organic chemical vapor deposition (MOCVD), which is a time- and hence a cost-consuming process.
In the presented work AlN films were prepared on Si(111) by magnetron sputtering using a Clusterline® 200 deposition system from Evatec. Different process parameters such as e.g. film thickness and deposition temperature were varied. A special focus has been set on the interface of Si(111) and AlN and the removal of native oxide on the Si substrates. The effects of the used cleaning procedures wet etching (HF) and plasma etching are compared to each other. The AlN film quality was investigated with X-ray diffraction (XRD), transmission electron microscope (TEM) and atomic force

microscopy (AFM) to study the influence of the process parameters on the crystallinity, the lattice constant and the surface roughness.
TEM images show that the AlN films are highly crystalline and form columns with a width of ca. 45nm. This is confirmed by rocking curve (RC) measurements of the AlN(002) diffraction peak that show for 100 nm of AlN on Si(111) a FWHM of less than 1200 arcsec. Increasing the film thickness reduces the amount of defects in AlN and hence the FWHM of AlN(002). Due to the columnar growth the surface roughness increases with thickness. It is shown that the decrease of the FWHM with the thickness is directly correlated to the increasing surface roughness.
The presented results on crystal quality and surface morphology show that AlN films deposited by magnetron sputtering are suitable to replace the MOCVD templates and can serve as buffer layer for HEMT and LED structures.

Vacuum in Accelerators / 208

CERN experience: Vacuum design, interventions and operation in radioactive environment

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CERN has a long experience in the conception, construction and exploitation of particle accelerators for high-energy physics. CERN accelerator complex consists of several installations facing different challenges concerning radiation activation, damage, contamination, etc. determined by the energy and type of beam: protons, heavy ions, radioactive ion beams, neutrons, etc.
This contribution will give a historical overview of different vacuum activities carried out at CERN related to material validation, design to reduce personnel exposure, tooling, telemanipulation, vacuum interventions in highly radioactive areas and management of radioactive exhaust gases. Present developments face future challenges related to upgrades and new facilities like HL-LHC, FCC and MEDICIS that require a higher degree of remote manipulation and limited access to certain parts of the machine.

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Transferable nanoporous Ca3Co4O9 thin films for wearable thermoelectric applications

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With the emergence of low power and flexible applications, e.g. to power wearable electronics, on-chip cooling etc., the demand for high performance flexible and transferable thermoelectric thin films is on rise. Here, we report the growth of high performance nanoporous Ca3Co4O9 thin films with controlled porosity by a simple and scalable sequential-sputtering-and-annealing method. Ca3Co4O9 is promising not only for its high thermopower and good electrical conductivity but also

important for the nontoxicity, low cost and abundance of its constituent raw materials. Nanoporous films provide a new opportunity to tailor the phononic properties by selective scattering of phonons, but without hampering the electronic transport, leading to the enhancement of thermoelectric efficiency. Two step sputtering-annealing growth is performed by sequentially depositing the multilayered CaO/CoO films on sapphire and mica substrates by rf-magnetron reactive sputtering from metallic targets of calcium and cobalt, followed by reactive annealing in oxygen atmosphere at 700 degree Celsius. A three stage phase transformation from multilayered CaO/CoO films to the final phase of Ca3Co4O9 occurs during annealing. The thermoelectric performance of the films are tunable with the controlled pores in the films. Low electrical resistivity ~ 7 mOhm.cm near room temperature is obtained from the nanoporous films, resulting high power factor, 0.23 mW/mK2 near room temperature, which is comparable to the Ca3Co4O9 thin films without porosity. Furthermore, these nanoporous films are readily to transferable to any arbitrary platform or substrate, due to the tailored weak adhesion between the films and the substrate by formation of nanopillars in the interfacial region. With this transferability and the high power factor near room temperature, the nanoporous Ca3Co4O9 films open avenues for low-temperature use of this material.

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Photo desorption studies on the FCC-hh Beam Screen at the KIT Electron Storage Ring KARA

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In the framework of the EuroCirCol(*) collaboration (work package 4 "Cryogenic Beam Vacuum System"), the fabrication of 3 FCC-hh beam-screen (BS) prototypes has been carried out, with the aim of testing them at room temperature on the KARA (previously known as ANKA) 2.5 GeV light source at Karlsruhe Institute of Technology. The 3 BS prototypes are going to be tested one after the other on a dipole radiation beamline which has been set-up by the collaboration. The name of the installation is BEam Screen TEstbench EXperiment (BESTEX). KARA has been chosen because its synchrotron radiation (SR) spectrum , photon flux, and power, match the one foreseen for the 50+50 TeV FCC-hh proton collider, of which the design study is due in 2019. Each of the 3 BS prototypes, 2 meter in length, implements a different design feature, namely: 1) baseline design (BD), with electro-deposited copper and no electron-cloud (EC) mitigation features; 2) BD with set of distributed cold-sprayed anti-EC clearing electrodes; 3) BD with laser-ablated anti-EC surface texturing. BESTEX is equipped with horizontal and vertical collimators, in order to direct the impinging SR photon fan onto different parts of the BS surfaces. The BS under test can be pivoted about a vertical axis so as to be able to irradiate alternatively the two sides of it, if necessary. A water-cooled photon absorber is placed at the exit of the 2m-long BS. The absorber is equipped with an insulated electrode which can be biased with a voltage so as to collect, or repel, the photo-electrons coming from the far end of the BS or generated on the photon absorber itself. Vacuum gauges are installed on the system upstream, downstream and in the middle of the BS under test. A residual-gas analyzer is also installed in the middle position. This paper will report on the status of BESTEX, the results obtained so far, and the comparison with extensive montecarlo simulations of the expected outgassing behavior under synchrotron radiation.

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Effect of Carrier Doping of InAs Quantum Dots on the Performance of QD Intermediate-Band Solar Cells

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The intermediate band solar cell (IBSC) is one of the promising candidates for the next generation of photovoltaic cells with a maximum theoretical efficiency of 63% at full sunlight concentration 1, and quantum dot (QD) based IBSCs are intensively studied. The QD-IBSCs reported to date often show a drop in the open-circuit voltage at 1 sun, however, the voltage and hence the cell efficiency recover fast under concentrated illumination of sunlight 2. The QD-IBSCs is thus expected to perform better under concentrated sunlight condition in which the photo-generation rate will outperform the recombination rate via IB states. To this end, the QDs are required to be homogeneous and small in size and be tightly packed in the active region of the cell, in order to form an IB or a superlattice miniband that is well separated in energy from the higher energy states. Further, the control of total density of QDs and carrier filling ratio in IB are essential to achieve high efficiency.
In this work, we have investigated the effect of n-type doping of InAs/GaAs QDs and of sunlight concentration on the SC performance. The pre-filling of InAs/GaAs QDs by Si-doping up to 8 electrons/QD was achieved by delta and direct-doping techniques in molecular beam epitaxy (MBE) [3]. A gradual recovery in the open-circuit voltage of QDSC with increasing Si-doping concentration was observed as a result of decrease of recombination via QD states. Under concentrated sunlight illumination, QD states became additionally filled with photo-excited carriers and the open-circuit voltage and efficiency increased non-linearly with concentration ratio in both non-doped and Si-doped QDSCs. We show that both the pre-doping of QDs and the photo-filling by sunlight concentration are effective way to improve the cell performance.
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Hollow cathode discharge for the deposition of amorphous carbon thin films.

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Amorphous carbon thin films with a low Secondary Electron Yield, (SEY), of about 1 can be obtained by sputtering from graphite targets. These coatings have proven to mitigate electron multipacting in particle accelerators and their usefulness depends on the practical applicability to the inner surfaces of the beam pipes. In this contribution we present the development of the sputtering technology, based on the hollow cathode effect, to coat the vacuum chambers of the magnets of the CERN Super Proton Synchrotron "in-situ" (without removing the magnets from their position in the accelerator ring). The glow discharge is characterised by the impedance at different pressures and for different gases (Ar and Ne). The flux and energy distribution function of the ions bombarding the substrate are measured with a retarding field energy analyser. Film thickness and morphology are assessed by scanning electron microscopy and the SEY is measured in an in-house built setup. The optimisation of the coating parameters is discussed.

Vacuum in Accelerators / 209

Update on the Status of the Vacuum Systems of the FAIR Accelerator Complex

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The FAIR (Facility for Antiproton and Ion Research) accelerator complex is under construction at the GSI campus in Darmstadt in Germany. It consists of about 4 km of beam vacuum system, where the vacuum requirements are different for almost all machines. While in the fast ramped SIS100 one has to deal with cryogenic and room temperature operated sections with static vacuum pressure in the lower 10
-12 mbar regime, the 1.5km of high energy beam transfer system have moderate vacuum requirements of 10-8 mbar. The high energy storage ring HESR, which will be built by the Research Center Jülich and Collector Ring CR, to be built by the Budker Institute of Nuclear Physics in Novosibirsk in Russia, will be operated in a pressure range of about 10-10 to 10-9 mbar. In the Super-FRS one has beside the moderate vacuum of 10-6 mbar to 10-8 mbar to cope with a high radiation area close to the target. As the construction and procurement has started an update on the status of vacuum system design and production will be presented.

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Effect on the electrical and morphological properties of Bi incorporation into ZnO:Ga and ZnO:Al thermoelectric thin films

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This work reports the effect on the electrical and morphological properties of co-doping ZnO thin films with Bi and Al/Ga. To do so, a confocal sputtering geometry was used with a Bi target and two intrinsically doped ZnO:Ga and ZnO:Al targets. By depositing at an intentional heating of 200 ºC and applying a post-deposition thermal treatment at 350 ºC and 300 ºC, for ZnO:Ga,Bi and ZnO:Al,Bi, respectively, electrical resistivity values of 1.3×10-3 □·cm and 4.8×10-4 □·cm were achieved, with an optical transmittance above 80%. The X-ray diffraction data shows that all doped ZnO films have a wurtzite hexagonal structure with preferential crystal growth perpendicular to the (002) plane. The Seebeck coefficient was measured for the ZnO:Al,Bi films, where a maximum value of -48 μV·K-1 was registered. The optimized electrical properties were correlated with the preferential crystalline texture along [001] and the corresponding current density applied to the Bi dopant target, J(Bi). ZnO:Al,Bi films present out-of-plane compression stress, which concomitantly increases with

J(Bi), due to higher compact volume of unit cell with lower lattice parameter c when compared with the undoped ZnO. By controlling the incorporation of Bi, the deposition temperature and the post-deposition thermal treatment temperature, improvements on the thermoelectric power factor of ZnO:Ga and ZnO:Al thin films can be achieved. Thermal conductivity results were correlated with the thermoelectric results in order to attain a thermoelectric figure of merit.

Keywords: Thin films, ZnO, Seebeck coefficient, thermoelectric, TCO

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Variational Principles and Applications of Local Topological Constants of Motion for Non-Barotropic Magnetohydrodynamics

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Variational principles for magnetohydrodynamics (MHD) were introduced by previous authors both in Lagrangian and Eulerian form. In this paper we introduce simpler Eulerian variational principles from which all the relevant equations of non-barotropic MHD can be derived for certain field topologies. The variational principle is given in terms of five independent functions for non-stationary non-barotropic flows. This is less than the eight variables which appear in the standard equations of barotropic MHD which are the magnetic field B ⃗the velocity field v ⃗the entropy s and the density ρ. The case of non-barotropic MHD in which the internal energy is a function of both entropy and density was not discussed in previous works which were concerned with the simplistic barotropic case. It is important to understand the rule of entropy and temperature for the variational analysis of MHD. Thus we introduce a variational principle of non-barotropic MHD and show that five functions will suffice to describe this physical system.
We will also discuss the implications of the above analysis for topological constants. It will be shown that while cross helicity is not conserved for non-barotropic MHD a variant of this quantity is. The implications of this to non-barotropic MHD stability is discussed.

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LCLS-II beamline components: from manufacturing to particle free installation

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In 2018 the SLAC vacuum laboratory will prepare, test, particle free clean and assemble all the components of LCLS-II beamline. This presentation will go through the manufacturing process and the quality checks adopted at SLAC to meet the LCLS-II UHV requirements. In addition an overview of the new facilities and procedures put in place to clean and assemble the Particle Free beamline regions will be presented.

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LHC Beam Vacuum Evolution during Run 2 Machine Operation

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The LHC successfully returned to operation in April 2015 after almost 2 years of Long Shutdown 1 (LS1) for various upgrade and consolidation programs. During the machine operation, in Run 2 (2015 - 2017), the LHC operated for more than 3000 fills and reached a total integrated luminosity of 125 fb-1 since the start of the LHC (up to end 2017).
This paper summarizes the dynamic vacuum observations in different locations along the LHC during the dedicated fills as well as during the physics runs with different beam parameters. The beam-induced dynamic pressure rises in presence of synchrotron radiation and electron cloud, have been investigated, benchmarked with simulations and are presented here. A clear beam conditioning effect has been observed in Run 2.

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Characteristics and Low Cost Application Perspectives of Atmospheric Plasma Chemical Vapor Deposition

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There are two major interests in thin film process development: higher quality thin film deposition at lower temperature conditions, and larger area deposition at lower costs of operation. Plasma-enhanced deposition is very useful both for temperature lowering and large area deposition at lower costs, and in addition, it is known that atmospheric operation of plasma-enhanced chemical vapor deposition (PECVD) could minimize high energy ion bombardment. Therefore, atmospheric pressure (AP) PECVD is one of useful approaches for high quality and low cost thin film processing development.
In the first part of the presentation, AP PECVD processes for various gas flow rates, hydrogen dilutions, plasma source powers, plasma source frequencies, and substrate temperatures will be presented. Two inherent features of AP PECVD are confined discharge and radial gas flow, based on which we have designed deposition tool and experimental methods. Design strategies of deposition tools and processing methods in terms of deposition rates and uniformity will be also discussed

based both on experimental results and simulation data.
The second part of the presentation is focused on low cost application perspectives of AP PECVD. Thin film processing using a reactor chamber without a strict control of contamination is usually not appropriate in vacuum-based industries. However, as an alternative approach for the cost reduction in deposition tool production, we investigated process-based method to reduce contamination in a reactor chamber without high vacuum pumping facilities that suffers frequent vacuum-break. We suggest two methods for the reduction of contamination like oxygen inclusion in the thin films as follows: (1) Pre-deposition of thin films on the reactor wall to prevent contamination, (2) and pre-treatment of the reactor wall surface just before the thin film deposition to remove contaminants on the chamber wall. Effective reduction of contamination is demonstrated in both methods, and further perspectives on thin film process development in contaminated environment will be discussed.

Biointerfaces / 374

Surface microstructure of retrieved hip and knee endoprostheses

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Microstructure is a neglected factor in implant design, and a detailed characterization is required to determine the role of prematurely failed implants that determine the biological responses, such as the composition and structure of the surface oxide film, the surface contamination and the surface topography. The release of metal ions and the lack of the wear resistance of biomaterials result in implant loosening, which leads to implant failure. The release of metal nanoparticles and polyethylene debris into the soft tissue at the site of the implants is decisive for osteolysis and the implants' longevity. The surface chemistry of Ti alloys (Ti6Al4V, Ti6Al7Nb) and the CoCrMo alloy of (retrieved and new) hip and knee endoprostheses components were studied in detail using advanced electron spectroscopy techniques FE-SEM, EDS, EBSD, AES and XPS. We will present the findings from the clinical and from the materials science points of view. All the retrieved implants were sent for sonication in Ringer's solution for cleaning and pathology analysis. Afterwards, they were dried and stored in special sterile Wipak Medical Steriking bags. All the X-ray images of implants in the patients are stored in the database of the UKC. The surface chemistry results showed that thin oxide films on the Ti alloys prevent further corrosion, improve the biocompatibility, and affect the osseointegration. It is obvious that we need to keep an optimal microstructure with regards to the corrosion and mechanical properties, which can be controlled through processing parameters and be standardized in the near future.

Poster Session Tuesday / 295

Selective hydrogen etching leads to 2D Bi (111) bilayers on Bi2Se3Large Rashba splitting in topological insulator heterostructure

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Ultrathin bilayers (BLs) of bismuth have been predicated to be a two-dimensional (2D) topological insulator. Here we report on the new route to manufacture the high quality Bi bilayers from 3D topological insulator, a top-down approach to prepare large-area and well-ordered Bi (111) BL with deliberate hydrogen etching on epitaxial Bi2Se3 films. With scanning tunneling microscopy (STM) and X-ray photoelectron spectra (XPS) in-situ, we confirm that the removal of Se from the top of a quintuple layer (QL) is the key factor, leading to a uniform formation of Bi (111) BL in the van der Waals gap between the first and second QL of Bi2Se3. The angle resolved photoemission spectroscopy (ARPES) in situ and complementary density functional theory (DFT) calculations show that a giant Rashba splitting with a coupling constant of 4.5 eV⊠Å in the Bi (111) BL on Bi2Se3. Moreover, the thickness of Bi BLs can be tuned by the amount of hydrogen exposure. Our ARPES and DFT study indicated that the Bi hole-like bands increase with increasing the Bi BL thickness. The selective hydrogen etching is a promising route to produce a uniform ultrathin 2D TI that is useful for fundamental investigations and applications in spintronics and valleytronics.

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Self-Assembly of Few-atomic-layer Sb and Bi on Inert Substrates

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Few-atomic-layer Bi and Sb are 2D semiconductors and potentially also topological insulators useful in spintronics. On graphite and MoS2 with vapor deposition, we observed the self-assembly of several types of Sb and Bi ultrathin films. These nanostructures can be in either the rhombohedral or black phosphorus (BP) crystal structures. Systematic STM-based investigation reveals the crucial roles of diffusion and dissociation of deposited species, as well as the surface stress of these nanostructures in determining the types of crystal structure and lattice periods observed. In particular, they start as compressed highly isotropic cubic- or square-phase nuclei. In a later growth stage, the nuclei undergo a symmetry-breaking transition as strain relaxation occurs. The compressive-state of these nanostructures is attributed to an enormous Laplace pressure induced by surface tension in a nanostructure. The stochastic growth and strain relaxation processes lead to the formation of either straight or branched nanobelts. Based on these understandings, certain morphological control of Sb and Bi nanostructures self-assembled on inert substrates has been accomplished. At a relatively high substrate temperature with a low deposition flux, straight nanobelts form exclusively, whereas at a low temperature and a high flux, branched nanobelts can be dominant. In addition, an organic molecular layer can be used to modify the morphology of Bi nanobelts. The result of our attempt in self-assembly growth of phosphorus and arsenic nanostructures will also be discussed.

Poster Session Tuesday / 281

Thermal induced depletion of cationic vacancies in conducting NiO thin films studied by X-ray absorption spectroscopy at the O 1s threshold

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The electrical properties of oxide materials are strongly influenced by the presence of vacancies and other point defects. Whereas purely stoichiometric oxides are usually poor conductors, vacancies can significantly increase their electrical conductivity, being of n-type in the case of oxygen vacancies, like in ZnO, 1, or p-type in the case of cationic vacancies, like in NiO 2. Many applications of these materials depends to a high extent on their electrical conductivity, like those related to chemical sensors, solar cells, or electrochemical capacitors.

In previous works we have investigated NiO thin films grown by magnetron sputtering from a NiO target with variable oxygen content in the plasma [3-5]. We found that the electrical conductivity of the films depends on the concentration of Ni vacancies, and we found this concentration to be dependent on the oxygen content in the plasma [3]. Among other techniques, we used X-ray absorption spectroscopy (XAS) at the O 1s threshold as a reliable technique to get a direct measure of the density of vacancies in our samples [4]. In this work we show, using XAS at the O 1s threshold, that a thermal annealing of NiO thin films with a certain vacancy concentration decreases this concentration and can even lead to stoichiometric NiO. Changing the probing depth of XAS we were able to see that the transition towards stoichiometric NiO starts at the surface. Two different types of experiments were carried out. A first set of samples was annealed at different temperatures during growth, and a second set was grown at room temperature and annealed subsequently, during the XAS measurements. In both cases the observed effect was very similar.

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