GRAPHENE FLAGSHIP KOREAN GRAPHENE SOCIETY

Graphene Flagship EU-Korea Workshop
Graphene and related 2D materials

Kursaal Congress Centre, San Sebastian, Spain
08-09 September 2018

Workshop Report

Contents

Overview

The 4th EU-Korea Workshop on Graphene and Related Materials was held on 8-9 September 2018 in San Sebastian, Spain immediately before the Graphene Week 2018 conference. The workshop aim was to be a forum for the exchange of experiences, practices and ideas related to the current and emerging topics associated with the basic chemistry approach, materials synthesis, application development and commercialization for graphene and related 2D materials. In addition, the objective was to explore further possibilities for collaborative research opportunities between researchers in Europe and Korea. This was a follow up of three workshops already organised, the first workshop was held in Busan (Republic of Korea) in 2015, the second in Copenhagen (Denmark) in 2016 and the third in Jeju Island (Republic of Korea) in 2017. The meeting was jointly prepared and co-chaired by Korean and European researchers.

Workshop chairs: Prof. Jari Kinaret (Sweden) and Prof. Sung-Yool Choi (Republic of Korea)

Program chairs: Prof. Paolo Samori (France), Prof. Xinliang Feng (Germany), Prof. Sang Ouk Kim (Republic of Korea) and Hyeon Suk Shin (Republic of Korea)

The workshop gathered 22 participants (13 from Korea and 9 from Europe), coming mainly from academic institutions. Speakers gave 19 talks that have shown the breadth of activities and topics covered by their respective research groups. The selection of the scientific speakers and participants was done by the two groups of organizers. All presentations stimulated questions and discussions.

The workshop was opened by Prof. Samori and Prof. Choi who set the scene and introduced the overall goals for the meeting. Prof. Kinaret presented the status of the Graphene Flagship and the plans for the Core3 project. He indicated that opportunities and threats have been identified and the Graphene Flagship is now moving toward addressing them. Large scale production, materials uniformity and toxicity hype have been identified as main threats. The question of establishing collaborations outside the Graphene Flagship was discussed. However, this remains a challenge as the EC system is not ready for such collaborations.

Prof. Choi, the workshop chair from Korea introduced the 13 Korean delegates attending the event, and the Korean Graphene Society. He also highlighted the major research institutes and centres involved in GRM research in Korea and some results highlights from nationally funded projects. Prof. Choi presented also his research on graphene electrode for OLEDs.

Several Graphene Flagship work-packages (Enabling Materials, Health and Environment, Electronic Devices, Functional Foams & Coatings, Management, Dissemination) and leading Korean institutions active in GRM research were represented at the meeting which offered a unique opportunity for direct exchanges and development of new collaborations.

Common challenges and opportunities for collaborations

In the final discussion session, participants identified areas of common interest that include mainly fundament science on graphene and related materials (GRM) chemistry, materials synthesis, functionalisation, processing and device engineering.

Participants welcomed the availability of mobility grants under the Graphene Flagship Core 2 which allow young researchers from Europe to perform research stays in laboratories in Korea; however, they are unsubscribed. This opportunity should be further explored, and Korean participants mentioned that support for travel grants for Korean scientists is available on Korea side as well. Discussions between the co-chairs will continue on this issue in order to explore the possibilities for exchanges.

At the end of the meeting, there was clear interest to continue the series of workshops by organising the next workshop again in Seoul, Korea, in 2019. The dates of the event need to be decided and Korean partners will propose several dates to see which feet best the EU colleagues.

There was consensus that for the next workshop:

- the workshop should be held jointly with a conference or another event taking place in Korea;
- having companies attending the workshop was discussed and it was agreed that this seems to be a good idea. The option will be further explored by Korean participants;
- another option to involve companies is to organise a seminar during the workshop or to perform a tour of several companies. A 2-day workshop and a tour to several companies on the 3rd day could be envisaged for the next workshop edition.

Programme

Time	8 September	9 September
09:00-09:30		**Study of Electronic Properties of 2D Materials and Their Heterostructures** *Suklyun Hong*
09:30-10:00		**Organic 2D Materials: Grand Challenges and Opportunities** *Xinliang Feng*
10:00-10:30		**Two dimensional materials for organic devices and hydrogen evolution reaction** *Soo Young Kim*
10:30-11:00		**Coffee break**
10:00-10:30		**Understanding optical absorption and luminescence in hBN: a tool for a characterisation metrics from bulk to the monolayer** *Annick Loiseau*
11:30-12:00		**Interlayer Engineering in van der Waals Heterostructures for Advanced Electronics** *Gwan Hyoung Lee*
12:00-13:00	**Registration**	**Graphene opto-electronics for wearables, data communications, image sensing and plasmonics** *Frank Koppens*
12:30-14:00	**Lunch**	**Lunch**
14:00-14:30	**Opening session EU-Korea Workshop** *Chair: Paolo Samorì, Hyeon Suk Shin*	**2D nanomaterials for EMI shielding applications** *Chong Min Koo*
14:30-15:00	**Graphene Flagship** *Jari Kinaret*	**Tunable bandgap and Dirac fermions in black phosphorus** *Keun Su Kim*
15:00-15:30	**Introduction to Korean Graphene Society** *Sung-Yool Choi*	**Atomic Level Engineering of Wafer-scale van der Waals Semiconductors** *Kibum Kang*
15:30-16:00	**Recent Advances in the Chemistry of Graphene and Other 2D Materials** *Maurizio Prato*	**Hybrid Graphene Hydrogels: Smart Soft Materials** *Ester Vazquez*
16:30-17:00	**Coffee break**	**Coffee break**
16:30-17:00	**Graphene and 2D materials for wearable and bioelectronics** *Jong-Hyun Ahn*	**Structural and electronic-state phase transition in layered materials and its neuromorphic applications** *Heejun Yang*
17:00-17:30	**Supramolecular engineering of 2-D materials: chemical tailoring of multifunctional foams and coatings** *Paolo Samorì*	**Electrical uniformity of large-area graphene** *Peter Bøggild*
17:30-18:00	**Graphene Oxide Liquid Crystals and Relevant Functional Nanostructures** *Sang Ouk Kim*	**Photon and Energy Conversion through Atomically Thin Semiconductor Heterojunctions** *Chul-Ho Lee*

18:00-18:30	**Growth and Functionalization of Graphene on insulators** *Mar Garcia Hernandez*	**Discussion on next steps and future collaborations**
19:30-21:00	**Workshop Dinner (Urepel Restaurant,** *Salamanca Pasealekua 3, Donostia)*	**Workshop Dinner** ***(Ni Neu Restaurant,*** *Av. de Zurriola, 1, 20002 Donostia, San Sebastián)*

Participants

Title	Last name	First name	Institution	Country
Professor	Ahn	Jong-Hyun	Yonsei University	Korea
Professor	Bøggild	Peter	Technical University of Denmark	Denmark
Professor	Choi	Sung-Yool	KAIST	Korea
Doctor	Ciubotaru	Ana-Maria	European Science Foundation	France
Professor	Feng	Xinliang	Technical University of Dresden	Germany
Professor	Garcia Hernandez	Mar	CSIC	Spain
Professor	Hong	Suklyun	Sejong University	Korea
Professor	Jang	Ho Won	Seoul National University	Korea
Professor	Kang	Kibum	KAIST	Korea
Mrs	Karim	Nishad	University of Cambridge	United Kingdom
Professor	Kim	Keun Su	Yonsei University	Korea
Professor	Kim	Sang Ouk	KAIST	Korea
Professor	Kim	Soo Young	Chung-Ang University	Korea
Professor	Kinaret	Jari	Chalmers University of Technology	Sweden
Doctor	Koo	Chong Min	KU-KIST	Korea
Professor	Koppens	Frank	ICFO	Spain
Professor	Lee	Chul-Ho	Korea University	Korea
Professor	Lee	Gwan Hyoung	Yonsei University	Korea
Mrs	Loberg	Luciana	Chalmers University of Technology	Sweden
Doctor	Loiseau	Annick	CNRS	France
Mrs	Novoselova	Elena	Chalmers University of Technology	Sweden
Professor	Prato	Maurizio	University of Trieste	Italy
Professor	Samorì	Paolo	University of Strasbourg	France
Professor	Shin	Hyeon Suk	UNIST	Korea
Professor	Vazquez	Ester	Universidad de Castilla - La Mancha	Spain
Professor	Yang	Heejun	Sungkyunkwan University	Korea

Speakers and abstracts

Graphene and 2D materials for wearable and bioelectronics

Jong-Hyun Ahn
Yonsei University, Korea

Short biography:

Jong-Hyun Ahn holds Underwood distinguished professor at Yonsei University, Korea. He has worked as a director of the centre for strain engineered electronic devices, supported by National Research Foundation of Korea and an associate editor of NPG Asia Materials. His research includes fundamental and applied aspects of nanomaterials and fabrication for flexible and stretchable electronic devices, and recent interest focuses on graphene and other 2D materials for flexible and wearable electronics. Jong-Hyun Ahn has authored more than 200 papers and is an inventor of more than 70 patents and has received numerous scientific awards, including the National Young Scientist Award and the IEEE George Smith Award.

Abstract:

Rapid advances in synthesis of graphene and 2D materials and fabrication methods for functional devices enable sophisticated types of functionality and their application to various emerging electronics, such as wearable and bioelectronics, that cannot be addressed with conventional materials. In this talk, I present the manipulation of 2D materials, and use in various device components for wearable and bio-sensors. Examples of devices include wearable devices such as touch and tactile sensors, and bio-integrated electronics such as bioabsorbable sensors and epidural electrotherapy for epilepsy [1-4].

References:

[1] M. Kang et al., *"Graphene-based Three-Dimensional Capacitive Touch Sensor for Wearable Electronics"*, ACS Nano, 11, 7950 (2017)
[2] M. Choi et al., *"Flexible Active-Matrix Organic Light-Emitting Diode Display Enabled by MoS2 Thin-Film Transistor"*, Science Advances, 4, eaas8721 (2018)
[3] X. Chen et al., *"CVD-Grown Monolayer MoS2 in Bioabsorbable Electronics and Biosensors"*, Nature Communications, 9,1690 (2018)
[4] S.W. Park, et al., *"Epidural electrotherapy for epilepsy"*, Small, in press

Electrical uniformity of large-area graphene

Peter Bøggild
Technical University of Denmark, Denmark

Short biography:

Bøggild obtained his PhD in low temperature solid state physics at the Copenhagen University in 1998, became associate professor at Technical University of Denmark in 2002 and full professor in 2013. He has worked in numerous areas, mainly nanomechatronics, nanometrology, surface engineering, material synthesis and microfabrication, but is today is leading a group entirely focusing on carbon nanomaterials and other 2D materials. Particular areas of interest are van der Waals heterostructures, ballistic nanoelectronics and devices, ultrahigh resolution patterning of 2D materials, as well as growth, transfer and metrology of large-area 2D materials. He is involved in various national and european projects including the graphene flagship. He has published more than 70 papers on carbon nanomaterials as well as 10 graphene related patent applications and is committed to push graphene fundamental research towards real and viable technology.

Abstract:

I will discuss uniformity and disorder in graphene at very different scales and how the disorder is expressed in electronic properties. For fabrication of large-area graphene, high quality is not just about high carrier mobility but also high uniformity – on all scales. In collaboration with P. Jepsen, DTU Fotonik, we use terahertz time domain spectroscopy to measure the electronic properties of graphene without physical contact (Fig 1a) and compare with multi-configuration electric measurements1. The absorption of THz radiation by graphene is governed by low-energy intra-band transitions, that are directly coupled to the ac conductivity. A closer look at the conductivity spectrum reveals interesting details of carrier scattering on line-defects (grain boundaries) on the submicron scale. By extracting the scattering time, we can produce maps of the carrier mobility and carrier density, and study how the quality and uniformity depends on growth and transfer of large-scale graphene (Fig 1b).

I will present several recent examples from Graphene Flagship collaborations that highlight how uniformity analysis can improve the understanding of synthetic graphene and help in optimisation. Graphene grown by chemical vapor deposition (CVD) on silicon carbide wafers is a promising approach, which however depends on the substrate morphology. By combining terahertz time-domain spectroscopy with other characterisation techniques, including micro four-point probes (M4PP), Kelvin probe force microscopy and confocal Raman spectroscopy, we study the microscopic substrate disorder and correlate this with three distinct regions on the graphene wafers, with very different levels of uniformity [2].

References:

[1] P. Boggild, D. M. A. Mackenzie, P. W. Whelan, D. H. Petersen, J. D. Buron, A. Zurutuza, J. Gallop, L. Hao, P. U. Jepsen (2017) *Mapping of the electrical properties of large-area graphene, 2D Materials*, 4, 042003.

[2] Patrick R. Whelan, Vishal Panchal, Dirch H. Petersen, David M. A. Mackenzie, Christos Melios, Iwona Pasternak, John Gallop, Frederik W. Østerberg, Peter U. Jepsen, Wlodek Strupinski, Olga Kazakova, and Peter Bøggild, *Electrical homogeneity of epitaxial graphene on silicon carbide*, unpublished.

Introduction to Korean Graphene Society

Sung-Yool Choi
KAIST, Korea

Short biography:
Prof. Sung-Yool Choi is a Professor of Electrical Engineering, KAIST, and is serving the 4th Presidentship of the Korean Graphene Society.
Prof. Choi received his BS, MS, and Ph.D. degrees all from the Department of Chemistry, KAIST, in 1991, 1994, and 1998, respectively. Before joining KAIST, he had been with the Basic Research Laboratory at Electronics and Telecommunications Research Institute (ETRI), Korea, as a senior/principal researcher. He invented the flexible memristor based on graphene oxide films in 2009, which opened the novolatile memory and neuromorphic applications of the graphene-related materials. He also demonstrated a large-area organic light-emitting diode with the graphene anode electrode for the first time in 2010.
Prof. Choi joined the faculty of the School of Electrical Engineering, KAIST in November 2011. His primary research objectives have been to understand the underlying principle in the conduction/switching behavior of a single molecule or molecular-scale materials and to develop functional devices utilizing these materials. His academic contributions are mainly in the applications of graphene and 2D materials to novel electronic and display devices.
He has authored more than 130 refereed papers and contributed more than 170 presentations at conferences. He holds 34 Korean and 14 US patents, 3 of which were licensed to electronics and display companies. He received several academic awards including the Prime Minister's Award for Research Innovation in Nanotechnology at Nano Korea 2015, the KIDS Award Silver in IMID 2016, and the Prize for Academic Excellence of KAIST in 2017. In KAIST, he is leading the Graphene/2D Materials Research Center from Apr. 2012, and the Center for Advanced Materials Discovery towards 3D Display from Nov. 2016.

Organic 2D Materials: Grand Challenges and Opportunities

Xinliang Feng
Technical University of Dresden, Germany

Short biography:

Prof. Feng is the head of the Chair of Molecular Functional Materials at Technische Universität Dresden. He received his bachelor's degree in analytic chemistry in 2001 and master's degree in organic chemistry in 2004. Then he joined the Max Planck Institute for Polymer Research for PhD thesis, where he obtained his PhD degree in April 2008. In December 2007, he was appointed as a group leader at the Max-Planck Institute for Polymer Research, and in 2012, he became a distinguished group leader.

His current scientific interests include organic synthetic methodology, organic synthesis and supramolecular chemistry of π-conjugated system, bottom-up synthesis and top-down fabrication of graphene and graphene nanoribbons, 2D polymers and supramolecular polymers, 2D carbon-rich conjugated polymers for opto-electronic applications, energy storage and conversion, new energy devices and technologies. He has published more than 410 research articles which have attracted more than 30000 citations with H-index of 83.

He has been awarded several prestigious prizes such as IUPAC Prize for Young Chemists (2009), Finalist of 3rd European Young Chemist Award, European Research Council (ERC) Starting Grant Award (2012), Journal of Materials Chemistry Lectureship Award (2013), ChemComm Emerging Investigator Lectureship (2014), Fellow of the Royal Society of Chemistry (FRSC, 2014), Highly Cited Researcher (Thomson Reuters, 2014-2017), Small Young Innovator Award (2017), Hamburg Science Award (2017), EU-40 Materials Prize (2018). He is an Advisory Board Member for Advanced Materials, Journal of Materials Chemistry A, ChemNanoMat, Energy Storage Materials, Small Methods and Chemistry -An Asian Journal. He is the Head of ESF Young Research Group "Graphene Center Dresden" and Working Package Leader of WP Functional Foams & Coatings for European Commission's pilot project "Graphene Flagship".

Abstract:

In the past decade, as inspired by the discovery of graphene, two-dimensional (2D) materials which possess a periodic network structure and with a topographical thickness of atomic/molecular level, have emerged as the new paradigm of materials with enormous potentials, ranging from electronics and optoelectronics to energy technology, membrane, sensing and biomedical applications. Various fabrication strategies have been developed to attain high quality 2D materials. Among of them, mechanical exfoliation remains the most popular protocol to isolate single-layer high quality 2D materials for fundamental physical studies. In contrast to the tremendous exploration of graphene and inorganic 2D crystals such as metal dichalcogenides, boron nitride, black phosphorus, metal oxides and nitrides, the study on organic 2D crystal systems including the bottom-up organic synthesis of graphene, 2D metal-organic frameworks, 2D polymers/supramolecular polymers as well as supramolecular approach to 2D organic nanostructures remains under development.

In this lecture, we will present our recent efforts on the synthetic approaches towards novel 2D organic materials with structural control at the atomic/molecular-level or at the meso-scale. First, we will present the solution synthesis of 2D sp2-carbon based conjugated polymer frameworks as the new generation covalent-organic frameworks. Second, we will introduce the latest development on the synthetic 2D conjugated polymers including 2D Schiff-base type covalent polymers and 2D metal-dithienene/diamine coordination supramolecular polymers at the air-water or liquid-liquid interfaces. The resulting 2D conjugated polymers exhibit single-layer feature, good local structural ordering and with a size of cm2. The functional exploration of such 2D single-layer conjugated polymers for the electrical and mechanical properties, as well as serving as efficient electrocatalytic water splitting catalysts will be demonstrated. Third, we will introduce the self-assembly of a host-guest enhanced donor-acceptor interaction, consisting of a tris(methoxynaphthyl)-substituted truxene spacer, and a naphthalene diimide substituted with N-

methyl viologenyl moieties as donor and acceptor monomers, respectively, in combination with cucurbit[8]uril as host monomer toward monolayers of an unprecedented 2D supramolecular polymers at liquid-liquid interface. Finally, we will present the supramolecular approaches to synergetic control the multi-component assembly, which results into 2D conducting polymers, such as polypyrrole and polyaniline nanosheets featuring 2D structures and with adjustable mesopores with/without on various functional free-standing surfaces. The unique structure with adjustable pore sizes (5–20 nm) and thickness (35–45 nm), enlarged specific surface area as well as high electrical conductivity make 2D conducting polymers promising for a number of applications. The future perspective and outlook regarding the goal towards highly crystalline organic 2D materials will be provided.

Growth and Functionalization of Graphene on insulators

Mar Garcia Hernandez
Consejo Superior de Investigaciones Cientificas, Spain

Short biography:

Mar Garcia Hernandez did her PhD in Molecular Physics on reduction of vib-rotational hamiltonians and simulations of High resolution vib-rotational bands of symmetric tops, at CSIC. During her first and second postdocs (Rutherford Appleton Lab. UK, IEM/CSIC), she switched to Experimental Condensed Matter Physics (Molecular Liquids and Glasses), using Neutron Scattering Techniques, using also molecular Dynamics and Reverse Montecarlo with focus on excita she got a tenured position at CSIC on Experimental Physics and a year later I joined the Materials Science Institute of Madrid (ICMM/CSIC). Currently, she is Professor at CSIC and Head of the Magnetism and Magnetotrasnport lab at ICMM. Her works in complex interfaces heterostructures of highly correlated systems with application in spintronics. She is also involved in the study of 2D materials, in particular, she coordinates the WP Materials in the Flagship Graphene and coordinates the Spanish Excellence Graphene Network. She has founded the Spanish Graphene Alliance ", the Spanish association of graphene producers and end users. She develops also permanent magnets in several projects funded by the EU and superconductors. She has been involved on the development of magnetic nanoparticles for cancer hyperthermia therapies. She has stablished solid collaborations with industry in graphene and have joint projects and collaborations with several companies in this topic. She has received the innovation Prize 2017 from the Spanish Forum of innovative Companies, a forum that represent the largest companies in the country with relevant R+D activity (Airbus, Talgo, Tecnalia, Indra etc....) most of them in the stock market.

She has published more than 260 SCI publications, in international journals. She is the scientific director of the Nationwide contest "Arquimedes", promoting research among undergraduate students in all fields supported by the Spanish Ministry of Education and Universities. She holds important activity in dissemination of Science for broad audiences and is deeply involved in actions to promote women in Science

Abstract:

Direct growth of graphene films on dielectric substrates (quartz, silica and Si covered with native oxide) by remote electron cyclotron resonance plasma assisted chemical vapor deposition r-(ECR-CVD) is reported at low temperature. Using a two-step deposition process–nucleation and growth–by changing the partial pressure of the gas precursors at constant temperature, mostly monolayer continuous films, with grain sizes up to 500 nm are grown, exhibiting transmittance larger than 92% and sheet resistance as low as 900 $\Omega\ sq^{-1}$. The grain size and nucleation density of the resulting graphene sheets can be controlled varying the deposition time and pressure. In addition, first-principles DFT-based calculations have been carried out in order to rationalize the oxygen reduction in the quartz surface experimentally observed. This method is easily scalable and avoids damaging and expensive transfer. The proposed low temperature direct synthesis on an insulating substrate improves compatibility with current industrial processes. We show hereafter a mechanism for promoting highly specific covalent bonding of any amino-terminated molecule and a description of the operating processes.

Study of Electronic Properties of 2D Materials and Their Heterostructures

Suklyun Hong
Sejong University, Korea

Short biography:

Dr. Suklyun Hong is Professor of Physics and Director of Graphene Research Institute at Sejong University in Seoul, Korea. He earned his B.S. ('88) and M.S. ('90) in Physics from Seoul National University in Korea. After then, he went to US and received his Ph.D. in Physics from University of Pennsylvania in 1995. He was Research Fellow at Georgia Institute of Technology during 1995-1997 and Research Associate at Oak Ridge National Laboratory during 1997-1999. In 1999, he joined in Department of Physics at Sejong University in Korea as a faculty member, where he is now Professor of Physics. He served as Dean of College of Natural Sciences and Member of Council of Sejong University during 2012-2014. For the physics community, he served as Vice Executive Director (2009-2010), Treasurer (2013-2014), and Editor of Journal of The Korean Physical Society (2012-2015) at the Korean Physical Society, and also served as organizing committee member of many conferences and workshops. Since 2010, he has been Director of Graphene Research Institute, which is the first government-funded institute of graphene research in Korea. He also serves as Member of C20 (Computational Physics) of The International Union of Pure and Applied Physics (IUPAP) since January 2015. His research area is theoretical/computational condensed matter physics with an emphasis on electronic and structural properties of nanoscale low-dimensional materials such as graphene, h-BN, TMDs, and carbon nanotubes.

Abstract:

Graphene and other two-dimensional (2D) materials such as hexagonal boron nitride (h-BN), transition metal dichalcogenides (TMDs), and transition metal phosphorous trichalcogenides (MPTs) have attractive physical and chemical properties in relation to the application of nanodevices. To understand electronic properties of these 2D layered materials and their heterostructures, we have performed density functional theory calculations.

First, we investigate atomic intercalation between graphene nanoribbon (GNR) and h-BN sheet. To find the effect of atomic intercalation on the geometrical and electronic properties of GNR on h-BN sheet, various types of impurity atoms are considered. It is found that the impurity atoms are more stable at the edge than in the middle region. In particular, the lithium or nickel atom has a very small energy difference (~0.2 eV) between two embedding positions, which means that Li or Ni atom may be relatively easy to intercalate in the structure.

Next, we study the reduction of the Fermi level pinning (FLP) at Au–MoS2 interfaces by atomic passivation on Au(111). To reduce the FLP at Au–MoS2 interfaces, we consider several atoms (S, O, N, F, and H) that can passivate the surface of Au(111). Passivating atoms prevent the direct contact between Au(111) and MoS2, and thus FLP at Au–MoS2 interfaces is reduced by weak interaction between atom-passivated Au(111) and MoS2. Especially, FLP is greatly reduced at sulfur-passivated Au-MoS2 interfaces with the smallest binding energy. Furthermore, fluorine-passivated Au(111) can form ohmic contact with MoS2, representing almost zero Schottky barrier height (SBH). We suggest that SBH can be controlled depending on the passivating atoms on Au(111). Finally, we report on ferromagnetic contacts between Ni(111) and MoX2 (X = S, Se, or Te). Our calculations show that the FLP occurs at Ni-MoX2 interfaces and Schottky barrier types are varied depending on MoX2. Interestingly, spin splitting occurs at the conduction band offset or valence band offset, depending on the X type in the MoX2, and a spin magnetic moment is induced on MoX2 by Ni(111) due to the ferromagnetic nature of Ni.

Ho Won Jang
Seoul National University, Korea

Short biography:

Ho Won Jang is an Associate Professor in Department of Materials Science and Engineering, Seoul National University. He earned his Ph.D. from Department of Materials Science and Engineering, Pohang University of Science and Technology, in 2004. He worked as a Research Associate at University of Wisconsin-Madison from 2006 to 2009. Before he joined Seoul National University in 2012, he worked at Korea Institute of Science and Technology as a Senior Research Scientist. His research interests include nanostructured thin films of oxides, 2D materials, halide perovskites, and noble and transition metals for nanoelectronics, solar water splitting, chemical sensors, plasmonics, metal-insulator transitions, and ferroelectricity.

Atomic Level Engineering of Wafer-scale van der Waals Semiconductors

Kibum Kang
KAIST, Korea

Short biography:

Kibum Kang is an assistant professor of Materials Science and Engineering at KAIST, South Korea. He received his B.S and PhD degree in Materials Science and Engineering from POSTECH, South Korea (2007 and 2012 respectively). After 4 years of postdoc experience in Jiwoong Park group in Cornell University and the University of Chicago (2013~2017), he joined KAIST (2018). His research focuses on investigating atomic-level engineering using metal-organic chemical vapor deposition (MOCVD) and nano/2D materials for next-generation semiconductors.

Selected publications:

[1] High-Mobility Three-Atom-Thick Semiconducting Films with Wafer-Scale Homogeneity, Kibum Kang et. al., Nature, 520, 656 (2015)

[2] Layer-by-Layer Assembly of Two-Dimensional Materials into Wafer-scale Heterostructures, Kibum Kang et. al., Nature, 550, 229 (2017)

[3] Coherent, Atomically Thin Transition-metal Dichalcogenide Superlattices with Engineered Strain, S. Xie, L. Tu, Y. Han, L. Huang, K. Kang, K. U. Lao, P. Poddar, C. Park, D. A. Muller, R. A. DiStasio Jr., and J. Park, Science, 359, 1131 (2018)

Abstract:

High-performance semiconducting films with precisely engineered thicknesses and compositions are essential for developing next generation electronic devices, which are becoming more integrated, complex, and multifunctional. My talk will introduce the novel processes that enable atomic-scale control of the thickness and spatial composition of semiconducting films on the wafer-scale. These processes include: (i) the wafer-scale generation of monolayer van der Waals semiconductors such as transition metal dichalcogenides (TMDs) via metal-organic chemical vapor deposition (MOCVD), (ii) the atomic-level engineering of vertical thickness and composition through the layer-by-layer assembly of TMD monolayers, and (iii) the transfer of atomically engineered films, using their van der Waals nature, onto arbitrary substrates. These capabilities provide a new material platform for both fundamental research and practical applications, including incorporation into existing integrated circuit technology to form hybrid materials (i.e. TMD/CMOS) and boost electrical and optical functionality.

Tunable bandgap and Dirac fermions in black phosphorus

Keun Su Kim
Yonsei University, Korea

Short biography:

Keun Su Kim is an experimental condensed-matter physicist. His scientific interest has been focussed on the band structure of 2D crystals (black phosphorus and transition-metal dichalcogenides) measured by angle-resolved photoemission spectroscopy (ARPES). He received his Ph.D. at Yonsei University, Korea, and then worked as a postdoctoral researcher at the Advanced Light Source, Lawrence Berkeley National Lab, USA. He started his appointment as an assistant professor in Pohang University of Science and Technology (POSTECH) in November 2013, and recently moved to Yonsei University (March 2017).

Abstract:

Two-dimensional (2D) crystals have emerged as a class of materials that may impact our future electronics technologies. A key issue is controlling their electronic band structures to overcome the limit of natural properties. Black phosphorus is an emergent 2D semiconductor that has attracted broad interest owing to its promising device characteristics. In this talk, I will introduce our recent angle-resolved photoemission spectroscopy (ARPES) studies on a universal mechanism to modulate the band gap in 2D van der Waals semiconductors, black phosphorus [1] and 2H transition metal dichalcogenides [2]. The widely tunable band gap of black phosphorus could be exploited to create a topologically nontrivial state with a pair of Dirac fermions protected by its crystalline symmetries [3]. I will also briefly talk about future directions towards many-body interactions and emergent phenomena, such as 2D magnetism and 2D superconductivity [4].

References:

[1] J. Kim et al., Science 349, 723 (2015)
[2] M. Kang et al., Nano. Lett. 17, 1610 (2017)
[3] J. Kim et al., Phys. Rev. Lett. 119, 226801 (2017)
[4] M. Kang et al., Nature Mater. in press (2018)

Graphene Oxide Liquid Crystals and Relevant Functional Nanostructures

Sang Ouk Kim
KAIST, Korea

Short biography:

Prof. Sang Ouk Kim is the Professor in the Department of Materials Science and Engineering at KAIST, and the director of National Creative Research Initiative Center for Multi-Dimensional Directed Nanoscale Assembly and Graphene Liquid Crystalline Fiber Center, Daejeon, South Korea. He obtained his Ph.D at KAIST in 2000 and experienced postdoctoral research at University of Wisconsin-Madison, USA from 2001 to 2002. Prof. Kim has published more than 200 SCI journal papers and delivered more than 350 invited presentations thus far. He is the recipient of numerous prestigious awards including Presidential Young Scientist Award and KAIST Academic Grand Prize. Prof. Kim is serving as an associate editor of Energy Storage Materials (Elsevier) and editorial board members for 9 scientific journals published by RSC, ACS, Wiley, Elevier, Springer, etc. His research group is actively researching on the nanoscale assembly & chemical modification of various nanomaterials including graphene-based materials.

Abstract:

Graphene Oxide Liquid Crystal (GOLC) is a newly emerging graphene-based material, which exhibits nematic type colloidal discotic liquid crystallinity with the orientational ordering of graphene oxide flakes in good solvents, including water. Since our first discovery of GOLC in aqueous dispersion [1], this interesting mesophase has been utilized over world-wide for many different application fields, such as liquid crystalline graphene fiber spinning, highly ordered graphene membrane/film production, prototype liquid crystal display and so on [2,3]. Interestingly, GOLC also allow us a valuable opportunity for the highly ordered molecular scale assembly of functional nanoscale structures. This presentation will introduce our current status of GOLC research particularly focusing on the nanoscale assembly of functional nanostructures. Besides, relevant research works associated to the nanoscale assembly and chemical modification of various nanoscale graphene-based materials will be presented [4,5].

References:

[1] J. E. Kim, T.H. Han, S.H. Lee, J.Y. Kim, C.W. Ahn, J.M. Yun, S.O. Kim, Angewandte Chemie International Edition, 50, 3043 (2011).

[2] R. Narayan, J.E. Kim, J.Y. Kim, K.E. Lee, S.O. Kim, Advanced Materials, 28, 3045 (2016).

[3] J.Y. Kim, S.O. Kim, Nature Materials, 13, 325 (2014).

[4] U. N. Maiti, W. J. Lee, J. M. Lee, Y. T. Oh, J. Y. Kim, J. E. Kim, J. W. Shim, T. H. Han, S. O. Kim, Advanced Materials, 26, 40 (2014).

[5] S. H. Lee, D. H. Lee, W. J. Lee, S. O. Kim, Advanced Functional Materials, 21, 1338 (2011).

Two dimensional materials for organic devices and hydrogen evolution reaction

Soo Young Kim
Chung-Ang University, Korea

Short biography:

Soo Young Kim received the B.S., M.S., and Ph. D. degrees in materials science and engineering from Pohang University of Science and Technology (POSTECH), Pohang, South Korea, in 2001, 2003, and 2007, respectively. His Ph. D. research interests include improvement of electrical and optical properties in organic light emitting diodes (OLEDs) using rare-earth metal oxide and characterization of interface dipole between metal and organic material. During his post-doctoral period in Georgia Institute of Technology, USA, he focused on converting graphene oxide to graphene using thermo-chemical nanolithography technique. After starting assistant professor in Chung-Ang University, Seoul, South Korea, in 2009, he has been interested in the modulation of the properties of two-dimensional materials such as graphene, graphene oxide, transition metal dichalcogenides, and their applications. He combined his experience about optoelectronic devices with two-dimensional materials so that his research is focused on the optimization of two-dimensional materials' properties and their application to energy devices, such as OLEDs, organic photovoltaics, perovskite solar cells, light emitting diodes, and gas sensors. During the sabbatical year as a visiting professor at University of Chicago in 2015, he has learned the synthesis of nano particles based on metal sulfides, organic perovskite materials, and inorganic perovskite materials. Therefore, he is now trying to apply perovskite nano particles to the light emitting diodes and solar cells.

Abstract:

Recently, MoS2 and WS2 have attracted increasing attention because of their great potential. The oxidation state of the Mo and W atoms is +4 and that of the S atom is -2, meaning that MoS2 and WS2 are terminated with S atoms on the upper and lower side. The lone-pair electrons on the surfaces and the absence of dangling bonds in MoS2 and WS2 layers enhance the stability against reactions with other chemical species. Transition metal dichalcogenides (TMDs) were prepared by chemical vapor deposition method or sonication process. This seminar will show that TMDs could be used as charge transport layers in organic light emitting diodes (OLEDs) and photovoltaic cells (PVs). Furthermore, the hydrogen evolution reaction system using TMDs as catalysts is also discussed.

First, TMDs were used in order to enhance the stability in air comparing to poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) (PEDOT:PSS). TMD layers with a polycrystalline structure were synthesized by a chemical deposition method using uniformly spin-coated (NH4)MoS4 and (NH4)WS4 precursor solutions. OLEDs and OPV cells based on TMD showed two to six times longer stability in air compared with PEDOT:PSS based devices. Second, TMD layers were applied as the hole transport layer as well as the template for highly polarized OLEDs. The MoS2 nanosheets were patterned by rubbing/ion-beam treatment. The use of patterned MoS2 nanosheets not only tuned the polarization of the OLEDs but also dramatically improved the device performance as compared with that of devices using untreated MoS2. Third, TMD layers were applied as catalyst for hydrogen evolution reaction.

Graphene Flagship

Jari Kinaret
Chalmers University of Technology, Sweden

Short biography:

Jari Kinaret is the leader of the Condensed Matter Theory (CMT) group at the Department of Physics at Chalmers University of Technology (Sweden) and the Director of the Graphene Flagship. He has a background in theoretical physics and electrical engineering and received his PhD in Physics from the Massachusetts Institute of Technology in 1992. He has been at Chalmers since 1995 and his research focuses on electrical and mechanical phenomena on the nanoscale. Jari Kinaret is a member of The Royal Swedish Academy of Engineering Sciences (IVA).

2D nanomaterials for EMI shielding applications

Chong Min Koo
KU-KIST, Korea

Short biography:F

Dr. Koo is a Head of Materials Architecturing Research Center in Korea Institute of Science and Technology (KIST). He is also currently serving as a professor of KU-KIST Graduate School of Science and Technology, Korea University. He recieved his BS degree from Hanyang University, and MS and Ph.D. degree from Korea Advanced Institute of Science and Technology in Chemcial Engineering. He won the several awards including LG Chemical Best Research Award (2007), LG Group Best Research and Development Award (2007), KIST Best Research Team Award (2011, 2015), KIST Unsung Hero Award (2012), KIST Award (2016, 2017), Songgok Award (2017), Young Fellow (2017), Young Scientist Award in the Korean Society of Industrial and Engineering Chemistry (2017). His group is interested in nanostructured polymers, nanomaterials and polymer nanocomposites for EMI shielding, thermal conduction, actuators and energy storage device applications.

Abstract:

Lightweight electromagnetic interference (EMI) shielding materials have been attracted much attention for a wide range of applications in the modern high-power electronics, portable devices, and self-driving cars, as the highly integrated and high-speed wireless communication devices suffer from undesirable electromagnetic interference effect that not only deteriorates the performance of the devices but also brings serious concern on harmful health problem to human. In this presentation, I would like to briefly demonstrate that 2D nanomaterials including sulfur-doped graphenes and transition metal carbides (MXenes) can be considered as the best candidates for lightweight EMI shielding materials, as the 2D nanomaterials are lightweight, low-cost, and easily processable shielding materials. Sulfur-doping on graphene induces strong n-doping effect that gives rise to the strong improvement in electrical conductivity. Ti3C2 MXenes are also highly metallic. The large electrical conductivity of sulfur-doped graphenes and transition metal carbides (MXenes) is responsible for the exceptional EMI SE performance.

Graphene opto-electronics for wearables, data communications, image sensing and plasmonics

Frank Koppens
The Institute of Photonics Sciences (ICFO), Spain

Short biography:

Prof. Frank Koppens obtained his PhD in experimental physics at Delft University, at the Kavli Institute of Nanoscience, The Netherlands. After a postdoctoral fellowship at Harvard University, since August 2010, Koppens is a group leader at the Institute of Photonic Sciences (ICFO). The quantum nano-optoelectronics group of Prof. Koppens focuses on both science and technology of novel two-dimensional materials and quantum materials.

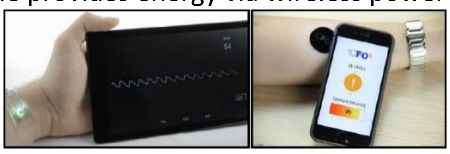
Koppens has received the ERC starting grant, the ERC consolidator grant, three ERC proof-of-concept grants, the Christiaan Hugyensprijs 2012, the national award for research in Spain, and the IUPAP young scientist prize in optics. In total, Koppens has published more than 70 refereed papers (H-index above 43), with more than 35 in Science and Nature family journals. Total citations >15.000. Prof. Koppens is vice-chairman of the executive board of the graphene flagship program, a 1B€ project for 10 years. He is also the leader of the optoelectronics work package within the flagship.

Abstract:

Electrical control and detection of light and polaritons are at the heart of nano-photonics and opto-electronics. Two-dimensional materials have emerged as a toolbox for in-situ control of a wide range of polaritons: plasmons, excitons and phonons [1]. By stacking these materials on top of each other, heterostructures of these materials can be controlled at atomic scale, with extremely high quality and clean interfaces. In this talk, we will show several examples of 2d material heterostructure devices with novel ways of exciting, controlling and detecting polaritons [2,3,4,5].

We also show various types of ultra-fast and highly efficient photodetectors [6] and modulators for data communications applications. Graphene device promise a broadband response, high switching rates, small footprint and CMOS compatibility.

Graphene based light sensors are inherently flexible and transparent and can be integrated with low-cost CMOS technology [7], hence providing a disruptive platform for future wearables and vision devices. We will show a prototype non-invasive wellness monitor that is conformal to the human body so that it can reliably extract vital signs such as heart rate, breathing rate and oxygen saturation. Furthermore, we present a graphene-based UV-sensing patch. It records harmful UV-exposure on the skin. The patch does not need a battery as a smartphone provides energy via wireless power transfer.



References:

[1] Polaritons in layered two-dimensional materials. Low et al., Nature Materials (2016).
[2] Probing the Ultimate Plasmon Confinement Limits with a Van der Waals heterostructures. Alcarez et al., Science (2018)
[3] Tuning quantum non-local effects in graphene plasmonics. Lundeberg et al., Science (2017)
[4] Thermoelectric detection and imaging of propagating graphene plasmons. Lundeberg et al., Nature Materials (2016)
[5] Ultra-confined acoustic THz graphene plasmons revealed by photocurrent nanoscopy. Alonso-Gonzalez et al., Nature Nanotechnology (2016)
[6] High-Responsivity Graphene–Boron Nitride Photodetector and Autocorrelator in a Silicon Photonic Integrated Circuit. Ren-Jye Shiue et al. Nano Letters, 15 (11), 2015.
[7] Broadband image sensor array based on graphene–CMOS integration. Goossens et al., Nature Photonics 11.6, 366-371 (2017)

Photon and Energy Conversion through Atomically Thin Semiconductor Heterojunctions

Chul-Ho Lee
KU-KIST, Korea

Short biography:
Chul-Ho Lee received his B.S. (2005) and Ph.D. (2011) from the Department of Materials Science and Engineering of Pohang University of Science and Technology (POSTECH), Korea. After his Ph. D course, he worked in the Department of Physics (with Prof. Philip Kim) at Columbia University, United States, as a postdoctoral fellow. In 2014, then, he joined the faculty of the KU-KIST Graduate School of Converging Science and Technology at Korea University. His current researches focus on the growth, characterization and applications of low-dimensional nanomaterials such as 2D semiconductors and graphene.

Abstract:
The recent advent of semiconducting transition metal dichalcogenides (TMDCs) with exceptional optical properties, combined with the ability to build artificial van der Waals heterostructures, enables the realization of unique atomically thin heterojunctions for applications in photon (or energy) conversion as well as fundamental studies at an ultimate thickness limit. In this talk, I will first discuss photon conversion processes in vertically-stacked p-n heterojunctions (WSe2-MoS2) and monolithically-fabricated oxide/semiconductor heterojunctions (WO3-WSe2), which exhibited highly efficient and fast conversion. Utilizing such an ultrafast charge transfer at the interface, in addition, atomically thin type-II heterojunctions can be utilized as a catalyst for photo-electrochemical (PEC) water splitting. As the second subject of the talk, I will present the characterization of enhanced PEC performances of the MoS2-WS2 heterojunction catalyst for hydrogen evolution reaction. Lastly, I will further present the wafer-scale growth of monolayer TMDCs and their epitaxial heterojunction bilayers using metal-organic chemical vapor deposition (MOCVD) for future practical applications.

Interlayer Engineering in van der Waals Heterostructures for Advanced Electronics

Gwan Hyoung Lee
Yonsei University, Korea

Short biography:

Dr. Gwan-Hyoung Lee is associate professor and material scientist at Yonsei University. He received Ph.D. in Materials Science and Engineering from Seoul National University in 2006. During graduate school, he worked at University of Illinois at Urbana-Champaign as a visiting scholar in 2002. After graduation, he joined Samsung electronics as a senior engineer, developing LCD backlight unit and OLED devices. He moved to Columbia University as a postdoctoral research scientist in 2010. From 2014 to present, he is working as a faculty in Materials Science and Engineering of Yonsei University. His research activities include the investigation of fundamental properties of two-dimensional (2D) materials, growth of 2D materials, surface modification of 2D surface, and 2D-material-based heterostructure devices for electrical and optical applications.

Abstract:

Two-dimensional (2D) materials have brought a great deal of excitement to nanoscience community with their attractive and unique properties. Such excellent characteristics triggered highly active researches on 2D material-based electronic devices. New physics observed only in 2D semiconductors allow for development of new-concept devices by using their valleys, tunnelling effect, photoluminescence, and optical responsivity. Recently, van der Waals heterostructures (vdWH) have been achieved by putting these 2D materials onto another, in the similar way to build Lego blocks. Assembly of 2D blocks for van der Waals heterostructures provide a big playground for engineers and physicists to investigate unprecedented properties of 2D materials and fabricate multi-functional electronic devices. However, understanding of interlayer interaction should be deepened for realization of new functions and high performance of electronic devices based vdWHs. In this talk, I will talk about interaction of 2D layers in vdWHs and interlayer engineering for vdWH electronic devices. In a stack of equivalent 2D flakes, the vertical interlayer resistance is smaller than lateral junction resistance due to negligible interaction of the stacked layers, which can be used to lower contact resistance. Also, by utilizing band alignment of 2D materials and tunable work function of graphene, exceptional functions of the van der Waals heterostructure devices were achieved, enabling us to fabricate electrically tunable light emitting transistors. For high integrated 2D devices, we developed a novel patterning technique by using XeF2 gas and fluorographene via contacts for graphene interconnects embedded in a vdWH. Our results show that engineering of interlayer interaction is critical for vdWH-based electronics.

Understanding optical absorption and luminescence in hBN: a tool for a characterisation metrics from bulk to the monolayer

Annick Loiseau
CNRS-ONERA, France

Short biography:

Annick Loiseau, Director of Research, is leader of the Low Dimension Materials group at the Laboratoire d'Etude des Microstructures (LEM), a joint Research Unit CNRS – ONERA, ONERA being the French Aerospace Lab. She has a large expertise field in Condensed Matter Physics, Nanoscience and TEM techniques. Since 1998 she has implemented at CNRS-Onera interdisciplinary research programs on Nanoscience, first focused on nanotubes and extended now to graphene and other 2D materials. She is also Head at CNRS of the National and International Research networks (GDR and GDR-I) 'Graphene and Nanotubes: Science and Applications' (acronym is GNT) acting as a delocalized Graphene Centre. This Centre coordinates synergies between research units to initiate, sustain and cross-link the research on graphene, and other 2D materials on prioritized topics. Today, the GDR GNT gathers more than 50 research teams from CNRS research units. She is the national contact for France in the European Initiative 'Flagship Graphene' and member of its Executive Board. Her research is focused on the structure and growth mechanism of carbon single wall nanotubes, synthesis of layered structures, the demonstration of their spectroscopic properties by luminescence and EELS and the understanding the exciton physics in BN layers. She has published about 300 papers, received the CNRS Physics Silver Medal (2006), the Ancel Prize from French Physics Society (1999) and the Grand Prix from French Science Academy (1988)). She has been made Chevalier de la Légion d'Honneur by the French Research Department in 2010.

Abstract:

hBN layers meet a growing interest for deep UV LED [1] and has become a strategic material for the fabrication of van der Waals heterostructures. Stacked with any other 2D material it can reveal the best of their physical properties [2]. However, hBN optoelectronic properties remain much less characterized and understood than other 2D materials.

In this talk, we review recent advances made thanks to the development of appropriate spectroscopies in the UV range - cathodoluminescence (CL) at 4K and Raman [3,4], angular resolved EELS [5] combined with ab initio simulations and tight binding modelling [6]. Thanks to these tools, a h-BN characterization metrics has been developed on the basis of their original optical properties, governed, in the energy range 5.5 – 6 eV, by strong excitonic effects easily trapped at structural or chemical defects [3]. We shall discuss the interplay between structure, defects and spectroscopic properties and how these properties can be further exploited for sample benchmarking [3, 7]. Beyond this effort, the talk will also address the recent advances made for the understanding of the high luminescence observed although bulk hBN is an indirect band gap material [1,8,9]. To that aim, the efficiency of radiative recombinations has been measured on a reference single crystal using temperature - dependent CL and compared to that diamond and ZnO [10]. The luminescence of hBN is confirmed to be unusually high and is found to remain constant from 10 to 300K. Enlighting analysis of this behaviour is provided by ab initio calculations of the exciton dispersion in bulk hBN. First, the lowest-energy exciton (iX) is found at 5.97eV and to be indirect, as expected for an indirect band gap, with a binding energy equal to 300 meV. This dispersion behaviour accounts for an assignation of the luminescence to phonon assisted recombinations of the indirect exciton as proposed in [11] and for the assignation of the tiny peak observed in CL spectra at 5.956 eV to the zero-phonon radiative recombination of iX [10]. Further iX high binding energy is consistent with the temperature behaviour of the luminescence, the high yield being the signature of a strong exciton phonon coupling. Second, calculations also confirm the direct exciton (dX) with a binding energy of 670 meV [10], an energy which turns to be only 100 meV above the indirect one. It comes out that bulk hBN displays a peculiar behaviour

where luminescence and optical absorption are due to different excitons, one resonant and one non-resonant [10].

References:
[1] K. Watanabe et al Nature Mat, 3 (2004), 404
[2] C. R. Dean et al., Nature Nanotech, 5, 722 (2010).
[3] L. Schué et al., 2D Mat., 4, 015028 (2017)
[4] I. Stenger et al., 2D Mat., 4, 031003 (2017).
[5] F. Fossard et al, Phys. Rev. B96, 115304 (2017)
[7] L. Schué et al., Nanoscale, 8 (2016), 6986
[8] B. Arnaud et al, Phys. Rev. Lett., 96 (2006), 026402
[9] L. Sponza, et al, Phys. Rev. B, 97 (2018), 075121
[10] L. Schué et al, arXiv:1803.03766v1 [cond-mat.mtrl-sci]
[11] G. Cassabois et al, Nature Photonics 10, 262 (2016)

Recent Advances in the Chemistry of Graphene and Other 2D Materials

Maurizio Prato
University of Trieste, Italy

Short biography:

Has published more than 600 papers on international peer reviewed Journals, with a total of around 45,000 citations and an h-index of 114 (Google Scholar) or 103 (Web of Science). Has been invited to more than 200 conferences and workshops in the last 10 years as a plenary or keynote speaker and has given more than 50 invited talks in Universities or research centres all around the world.

PROFESSIONAL CAREER

1978	Laurea degree, University of Padova, Department of Organic Chemistry
1983-1992	Assistant professor, University of Padova
1986-1987	Postdoctoral fellow, Yale University, New Haven, USA, Chemistry Department
1991-1992	Visiting scientist, University of California, Santa Barbara, USA, Institute for Polymers and Organic Solids
1992-2000	Associate professor, University of Trieste
2000-	Full professor, University of Trieste
2001-	Visiting professor, Ecole Normale Superieure, Paris, France
2008-	Recipient of the ERC Advanced Research Grant, European Research

Abstract:

The organic functionalization of carbon allotropes, including graphene, nanotubes and fullerenes, offers several advantages:

1) Improved solubility and easier handling of otherwise intractable materials;

2) Additional functions can be implanted on the carbon skeleton, such as chromophores, electroactive units, drugs, etc.;

3) Potential toxicity of the carbon materials can be at least partially lifted by organic functionalization, thanks to improved solubility and debundling in physiological media.

However, differently from fullerenes and nanotubes, carbon atoms in a perfect defect-free graphene structure are all planar and hybridized sp2. This makes graphene a very stable and unreactive chemical species. In order to force the reactivity of graphene, either we need to employ particularly reactive species, or we need to activate graphene towards additions.

During this talk, we will discuss the various approaches to graphene functionalization and will also analyze other important challenges in graphene chemistry, such as the lack of standardization in the production of the graphene family members. Control of lateral size, aggregation state (single vs. few layers) and oxidation state (unmodified graphene vs. oxidized graphene) is essential for the translation of this material into standardized applications. We will also address the toxicological impact and the limitations in translating graphene into advanced materials.

Supramolecular engineering of 2-D materials: chemical tailoring of multifunctional foams and coatings

Paolo Samorì
University of Strasbourg, France

Short biography:

Paolo Samorì (Imola, Italy, 1971) is Distinguished Professor (PRCE) at the Université de Strasbourg (UNISTRA), Director of the Institut de Science et d'Ingénierie Supramoléculaires (ISIS) and Director of the Nanochemistry Laboratory. He is also Fellow of the Royal Society of Chemistry (FRSC), Fellow of the European Academy of Sciences (EURASC), Member of the Academia Europaea and Junior Member of the Institut Universitaire de France (IUF). He obtained a Laurea (master's degree) in Industrial Chemistry at University of Bologna in 1995. In 2000 he received his PhD in Chemistry from the Humboldt University of Berlin (Prof. J. P. Rabe). He was permanent research scientist at Istituto per la Sintesi Organica e la Fotoreattività of the Consiglio Nazionale delle Ricerche of Bologna from 2001 to 2008 and Visiting Professor at ISIS from 2003 to 2008. He has published >280 papers on nanochemistry, supramolecular sciences, materials chemistry, and Scanning Probe Microscopies with a specific focus on graphene and other 2D materials as well as functional organic/polymeric and hybrid nanomaterials for application in opto-electronics, energy and sensing. His work has been awarded various prizes, including the E-MRS Young Scientist Award (1998), the MRS Young Scientist Award (2000), the IUPAC Prize for Young Chemists (2001), the "Vincenzo Caglioti" Award (2006), the "Nicolò Copernico" Award (2009), the "Guy Ourisson" Prize (2010), the ERC Starting Grant (2010), the CNRS Silver Medal (2012), the Spanish-French "Catalán-Sabatier" Prize (2017), the German-French "Georg Wittig - Victor Grignard" Prize (2017), the RSC Surfaces and Interfaces Award (2018) and the EURASC Blaise Pascal Medal (2018). He is Associate Editor of Nanoscale (RSC) and Member of the Advisory Boards of Advanced Materials, Small, ChemPhysChem and ChemPlusChem (Wiley-VCH), Chemical Society Reviews, Chemical Communications and Journal of Materials Chemistry (RSC), ACS Nano and ACS Omega (ACS).

Abstract:

The interfacing of molecular science with 2-dimensional materials, by mastering the supramolecular approach, is a powerful route to tune of the dynamic physical and chemical properties of 2D materials, by imparting them novel functions, with the ultimate goal of generating multifunctional hybrid systems for applications in (opto)electronics, sensing and energy.

In my lecture, I will review our recent and most enlightening findings on the covalent and non-covalent functionalization of layered materials to create artificial responsive hetero-structures as well as functional foams and coatings which can operate as selective chemical sensors for ions and polar molecules. Finally, I will describe how the same approaches can be exploited to fabricate highly sensitive pressure sensors which can monitor heartbeats, thus holding great potential for their integration in medical diagnostic devices or sport apparatus.

Our approaches provide a glimpse on the chemist's toolbox to generate multifunctional 2D materials-based nanocomposites with ad-hoc properties to address societal needs in electronics, sensing and energy applications.

Hyeon Suk Shin
UNIST, Korea

Short biography:

Hyeon Suk Shin is a professor at Department of Chemistry and Department of Energy Engineering, Ulsan National Institute of Science and Technology (UNIST), Korea. He received his PhD from Department of Chemistry at POSTECH in 2002. After working as a postdoctoral fellow at University of Cambridge, UK and subsequently as a research Professor at POSTECH, he joined UNIST in 2008. He received Creative Knowledge Award (Minster Award by Ministry of Science, ICT, and Future Planning) in 2015, outstanding researcher award (Materials Chemistry Division, KCS) in 2015, the Faculty of the Year award of UNIST in 2014, and the Minister award of Ministry of Knowledge Economy, Korea in 2012. His current research is focused on 2D materials, including graphene, h-BN, transition metal dichalcogenides, and their heterostructures, and their applications for electro-catalysts and (opto)electronic devices.

Hybrid Graphene Hydrogels: Smart Soft Materials

Ester Vazquez
Universidad de Castilla-La Mancha, Spain

Short biography:

Prof. Ester Vázquez obtained her PhD degree from the University of Castilla-la Mancha (UCLM) in 2000. She performed her doctoral research mainly in the Microwave and Sustainable Chemistry group of UCLM, working on microwave-assisted organic reactions in dry media. She also spent a few months at the University of Zaragoza, studying silica-supported Lewis acids for catalysis and at the Karolinska Institute in Stockholm, working on microwave applications in radiolabelling tracers for positron emission tomography (PET). After finishing her PhD, she carried out her postdoctoral training in Trieste, Italy, working on biological applications of fullerenes and new fullerene derivatives in the group of Professor Maurizio Prato, in the frame of a European Research Training Network. She then joined the Faculty of Chemistry at UCLM in 2001, completing other short stays in Trieste in 2002 and 2003. In 2007 she received the "Ibn Wafid de Toledo"Price for young researchers of Castilla-La Mancha. She was promoted to associate professor in 2010 and she became director of the Instituto de Investigación Científica Aplicada (IRICA) in April 2017. The scientific career of Professor Vázquez shows a clear evolution from pure organic synthesis to the chemistry of advanced functional materials. Since she started her independent career, she has focused her research efforts on the functionalization and purification of carbon nanostructures using non-conventional methodologies, demonstrating how scaling-up of the modified carbon nanostructures is possible using green protocols. Her group uses microwave radiations for the activation of carbon nanostructures in solvent-free conditions, preparing multifunctional derivatives that can serve as versatile synthons in materials science and biological applications. She has also applied ball milling methodologies in dry media to shorten and functionalize carbon nanotubes and for the preparation of graphene. The ball milling approach allows the production of highly dispersed graphene materials in organic solvents and it is one of the best ways of producing graphene suspensions in water, which enables, for instance, the study of interactions of graphene with biological bodies and the incorporation of graphene in smart gels with applications on controlled drug delivery, tissue engineering and soft robotics. This work, has permitted the collaboration with industrial partners, such as Antolin group and numerous European groups within the framework of the Graphene Flagship project.

Abstract:

The synthesis of different soft polymer networks, by in situ polymerization in the presence of graphene derivatives, is a suitable approach to attain three-dimensional hybrid materials. The role of the nanomaterial within the polymer network is primarily intended for the reinforcing (i.e. increasing the stiffness and toughness), however, the presence of graphene can also enhance features such as biocompatibility and responsiveness to external stimuli [1]. These syntheses require the production of large amounts of graphene materials, and for this reason, top-down methods, such as exfoliation of graphite, are generally favoured.

Ball milling of graphite in the presence of melamine, developed in our labs, is a method of choice to exfoliate graphite and generate dispersions of few-layer graphene in many solvents, including water. Moreover, water dispersions can be lyophilized giving rise to a fine powder [2]. The re-dispersion of this powder can be easily achieved by mild sonication in polar solvents including aqueous media. This advantage is crucial for the subsequent interaction of graphene with the organic monomers, giving rise to truly hybrid composites.

During this talk, we will discuss optimized ways to use graphene for the preparation of hybrid hydrogels, which behave as multistimuli responsive materials.

[1]. S. Merino, C. Martín, K. Kostarelos, M. Prato and E. Vázquez. ACS Nano, 9, 4686-4697, (2015).
[2] J. M González-Domínguez, V. León, M. I. Lucío, M. Prato, E. Vázquez, Nature Protocols. 13, 495 – 506, (2018)

Structural and electronic-state phase transition in layered materials and its neuromorphic applications

Heejun Yang
Sungkyunkwan University, Korea

Short biography:

He received his PhD in physics with a subject on graphene by scanning tunneling microscopy and spectroscopy (STM/STS) from Seoul National University (Korea) and University Paris-Sud XI (France, a joint degree) in 2010, and experienced industrial device studies in Samsung Electronics from 2010 to 2012. Then, he conducted his research on graphene spintronics in CNRS/Thales as a postdoc from 2012 to 2014. With his research background on molecular and nanometer-scale studies (in Seoul and Paris) and electric and spintronic device physics (in Samsung and CNRS/Thales), he moved to Sungkyunkwan University as an assistant professor on March 2014 and started original device studies with phase engineering of low-dimensional materials. He has proposed novel and conceptual interface devices such as 'Graphene Barristor' and 'Ohmic homojunction contact between semiconductor channel and metal electrodes'.

Abstract:

Two-dimensional (2D) interfaces with diverse three-dimensional materials' contact have long been an issue familiar to scientists and engineers. These days, together with 2D materials and emerging 1D edge contact, the 2D interfaces are attracting renewed interests for various applications such as next-generation devices. In particular, polymorph engineering in group 6 TMDs, such as MX2 with M=(Mo, W) and X=(S, Se, Te), has allowed an intriguing theme in the interface science, a formation of homojunction in a single material.
In this talk, I will briefly review diverse researches on 2D TMDs beyond graphene and interesting features of the 2D materials' interfaces including graphene/Si junctions [1]. Then, homojunctions between metallic (1T') and semiconducting (2H) MoTe2, generated by two methods (laser irradiation and contacting to low work function material), will be discussed [2]. The synthesis of high quality MoTe2 has been a key for these studies [3,4]. Based on the 2D layered materials, we have been studying neuromorphic devices like below. Although significant efforts have been made to emulate the biological synaptic transmission such as short-term and long-term plasticity and memory, synaptic computation, which is vital for information processing and decision making in neural network, has remained technically challenging in an efficient way without using numerous transistors and capacitors. I will present our recent work on synaptic computation based on Joule heating and versatile doping induced metal-insulator transition in a single monolayer-molybdenum disulfide (MoS2) device with a biologically comparable energy consumption (~ 10-14 J) [5]. A circuit with our tunable excitatory and inhibitory synaptic devices demonstrates a key function for the realization of the most precise temporal computation in the human brain, sound localization: detecting an interaural time difference by suppressing sound intensity- or frequency-dependent synaptic connectivity. This work opens a way to implement synaptic computing for real neuromorphic applications, overcoming the limitation of scalability and power consumption in conventional CMOS-based neuromorphic devices.

References:

[1] Heejun Yang et al., Science 336, 1140 (2012)
[2] Suyeon Cho et al., Science 349, 625 (2015)
[3] Dong Hoon Keum et al., Nature Physics 11, 482 (2015)
[4] Heejun Yang et al., Nature Physics 13, 931 (2017)
[5] Linfeng Sun et al., Nano Letters DOI: 10.1021/acs.nanolett.8b00994 (2018)