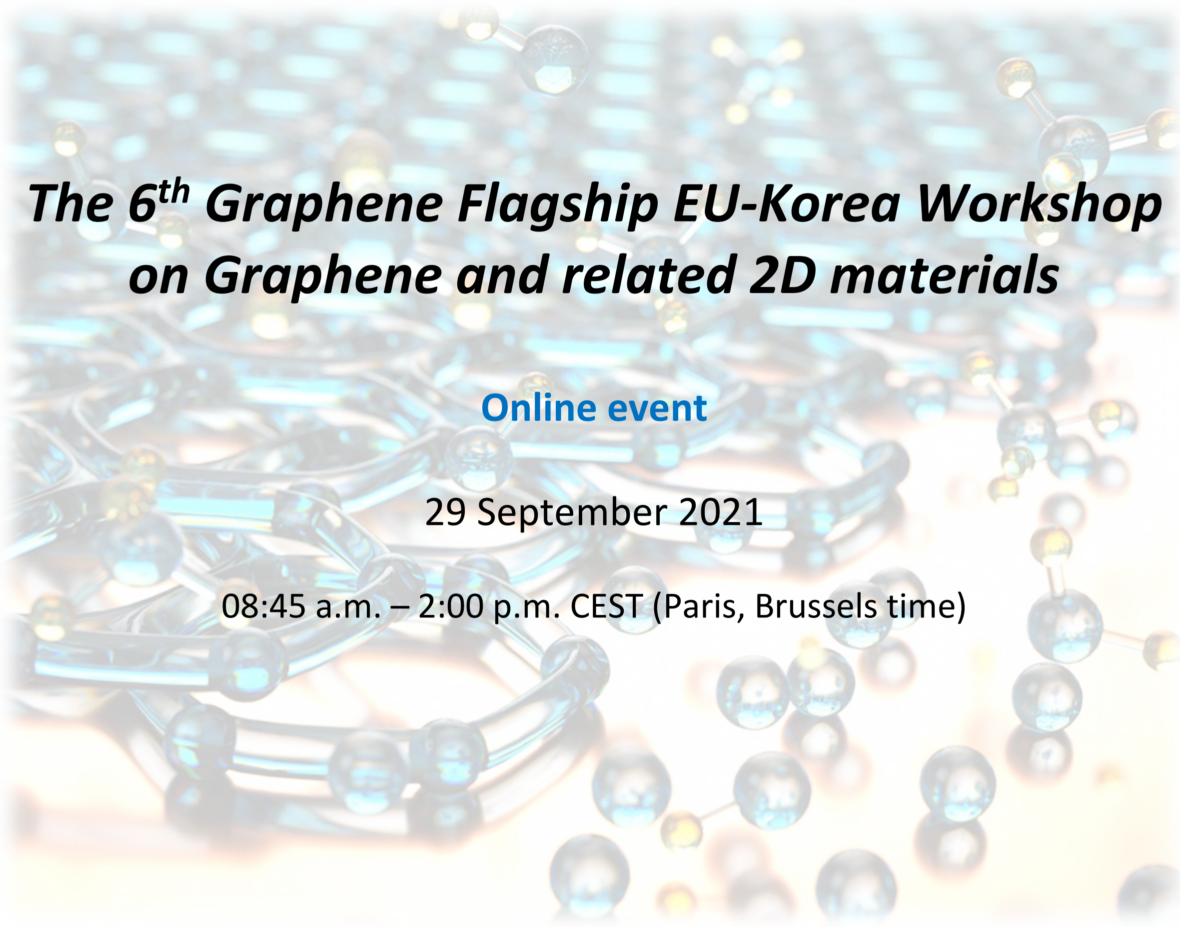
GRAPHENE FLAGSHIP

KOREAN GRAPHENE SOCIETY



The 6th Graphene Flagship EU-Korea Workshop on Graphene and related 2D materials

Online event

29 September 2021

08:45 a.m. – 2:00 p.m. CEST (Paris, Brussels time)

Overview

The 6th EU-Korea Workshop on Graphene and Related Materials was held online on 29 September 2021. The goal of this workshop was to keep interactions with overseas partners active and continue to foster exchange of experiences, practices and ideas related to the current and emerging topics associated with the basic chemistry approach, materials synthesis and application development of graphene and related 2D materials in the field of sensors, energy storage and opto-electronics.

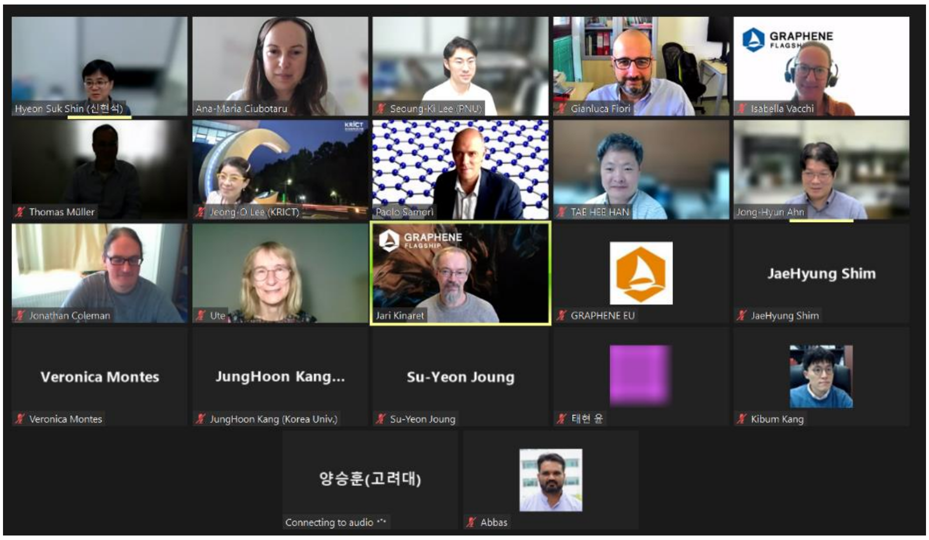
This was a follow up of four most successful workshops already organised, the first workshop was held in Busan (Republic of Korea) in 2015, the second in Copenhagen (Denmark) in 2016, the third in Jeju Island (Republic of Korea) in 2017, the fourth in San Sebastian (Spain) in 2018 and the fifth in Seoul (Republic of Korea) in 2019. The meeting was jointly prepared and co-chaired by Korean and European researchers.

Workshop chairs: Prof. Jari Kinaret (Sweden) and Prof. Jong-Hyun Ahn (Republic of Korea)

Program chairs: Prof. Paolo Samori (France) and Prof. Hyeon Suk Shin (Republic of Korea)

The workshop gathered over 30 participants, coming from academic institutions and industry. Speakers gave 10 talks, five from each side, that have shown the breadth of activities and topics covered by their respective research groups. The selection of the scientific speakers was done by the two groups of organizers. All presentations stimulated questions and discussions.

The workshop was opened by Prof. Samori 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 Horizon Europe phase. Prof. Ahn also welcomed the participants and the opportunity to meet.



Common challenges and opportunities for collaborations

The workshop covered topics related to graphene and related materials production, characterisation, tuning of properties and applications.

Identified during the last in-person workshop as one of the topics to be addressed in future events, (bio) chemical sensing was addressed through a series of talks related to bio and gas sensing. Part of the presentations focused also on GRM for energy (storage) applications and wearable electronics, as well as graphene and 2D-nanosheets for printed electronics and strain sensors.

Below are some topic examples addressed during the workshop

- Characterisation:
    - With a Cc/Cs correction TEM instrument with higher resolution it has become possible to study the migration of defects in low-dimensional materials and understand this mechanism by quantomechanical calculations. As next step the study of amorphous material is envisaged.
- Applications:
    - 2D materials inks for printed semiconductors, transistors etc. on substrates such as paper as a green solution, for applications in different fields like i.e., anti-counterfeiting, product freshness surveillance and portable healthcare applications.
    - Cost efficient biodevices working with graphene such as a quenching platform to detect E-coli, available at Graphene Flagship spin-off Graphenica Lab.
    - Graphene substrate for enhanced cell imaging commercialized by MCK TECH.
- Properties:
    - Fiber formation and coagulation mechanism to improve the properties of fibers for neuro-robotics, fibrous textile devices and smart textile sensors.
    - Preparation of highly stable rGO in solution to be used in the anode for lithium-ion batteries. This technology is being transferred to HNS Co., Ltd South Korea.
    - Electrical properties of nanosheets for i.e., printed graphene-nanosheet strain sensors.

At the end of the meeting, there was clear interest to continue the series of workshops by organising the next workshop in 2021 as a side event of the Graphene Week 2021 to be held in Munich, Germany. This would also be an optimal opportunity for Korean scientists working on GRMs to attend the conference and present their latest science and technology at the Graphene Week 2021.

Programme

Indicated time corresponds to the Central European Summer Time (CEST) zone (Paris, Brussels time)

September 29th, 2021		
08:45 – 09:00	**Welcome and introduction** Jari Kinaret, Jong-Hyun Ahn, Paolo Samori and Hyeon Suk Shin	
Chair: Paolo Samori		
09:00 – 09:25	**Ute Kaiser**	The electron-beam as stimulus and probe to modify and understand properties of functional low-dimensional materials
09:25 – 09:50	**Tae Hee Han**	Assembly of 2-dimensional nanomaterials into fibers and their applications
09:50 – 10:15	**Gianluca Fiori**	Printable Electronics Enabled by two-dimensional materials: an experimental and theoretical investigation
10:15 – 10:40	**Seung Yol Jeong**	Chemically exfoliated graphene for energy storage applications
10:40 – 11:05	**Arben Merkoçi**	Graphene and its versatility as building block of innovative biosensors
11:05 – 11:15	**Coffee break**	
Chair: Hyeon Suk Shin		
11:15 – 11:40	**Moon-Ho Jo**	Direct light-lattice interactions in atomically thin van der Waals semiconductors
11:40 – 12:05	**Seoung-Ki Lee**	Layer Selective Synthesis of 2D Heterostructure Using Photothermal Treatment
12:05 – 12:30	**Jonathan Coleman**	Electrical and electrochemical applications of liquid exfoliated nanosheets
12:30 – 12:55	**Jeong-O Lee**	Applications of graphene based on intrinsic properties of graphene
12:55 – 13:20	**Thomas Muller**	Ultrafast machine vision with 2D material photodetector arrays
13:20 – 14:00	**Final discussion**	

List of speakers

Title	Last name	First name	Institution	Country
Prof.	Jonathan	Coleman	Trinity College Dublin	Ireland
Prof.	Gianluca	Fiori	University of Pisa	Italy
Assoc. Prof.	Tae Hee	Han	Hanyang University	Korea
Dr.	Seung Yol	Jeong	Korea Electrotechnology Research Institute (KERI)	Korea
Prof.	Moon-Ho	Jo	Pohang University of Science and Technology (POSTECH)	Korea
Prof.	Ute	Kaiser	Ulm University	Germany
Prof.	Seoung-Ki	Lee	Pusan National University	Korea
Dr.	Jeong-O	Lee	Korea Research Institute of Chemical Technology	Korea
Prof.	Arben	Merkoçi	Catalan Institute of Nanoscience and Nanotechnology (ICN2)	Spain
Assoc. Prof.	Thomas	Mueller	Vienna University of Technology	Austria

List of participants

Title	Last name	First name	Institution	Country
Prof.	Moon-Ho	Jo	POSTECH	Korea
Prof.	Seoung-Ki	Lee	Pusan National University	Korea
Dr.	Jeong-O	Lee	Korea Research Institute of Chemical Technology	Korea
Prof.	Tae Hee	Han	Hanyang University	Korea
Dr.	Seung Yol	Jeong	Korea Electrotechnology Research Institute (KERI)	Korea
Prof.	Jonathan	Coleman	Trinity College Dublin	Ireland
Prof.	Gianluca	Fiori	University of Pisa	Italy
Prof.	Ute	Kaiser	Ulm University	Germany
Prof.	Arben	Merkoçi	ICN2, Barcelona	Spain
Assoc. Prof.	Thomas	Muller	TU Wien	Austria
Prof.	Jari	Kinaret	Chalmers University	Sweden
Prof.	Jong-Hyun	Ahn	Yonsei University	Korea
Prof.	Hyeon Suk	Shin	Ulsan National Institute of Science and Technology	Korea
Prof.	Paolo	Samori	University of Strasbourg	France
Mr.	Syed	Sarfraz	University of Bari	Italy
Prof.	Gwan-Hyoung	Lee	Seoul National University	Korea
Mr.	Yonas	Tsegaye Megra	Sungkyunkwan University	Korea
Mr.	Jejung	Kim	Yonsei University	Korea
Mr.	Yoon Seok	Kim	Korea University	Korea

Mr.	Jaehyung	Shim	Korea University	Korea
Mr.	Jin	Kim	Korea University	Korea
Prof.	Yong-Hoon	Kim	KAIST	Korea
Mr.	Muhammad Sabbtain	Abbas	Sungkyunkwan University	Korea
Dr.	Chang Hwan	Kang	Hanon systems	Korea
Prof.	Hyeonsik	Cheong	Sogang University	Korea
Mr.	Woojoo	Kwon	EVERCHEMTECH CO., LTD	Korea
Ms.	Young-Ju	Choi	EVERCHEMTECH CO., LTD	Korea
Ms.	Hyeyoung	Goh	EVERCHEMTECH CO., LTD	Korea
Mr.	Gil Hwan	Lim	Chonnam National University	Korea
Mr.	Hansung	Lee	Chonnam National University	Korea
Dr.	Verónica	Montes Carcia	University of Strasbourg	France
Dr.	Fernando	Gomollón-Bel	University of Cambridge	United Kingdom
Dr.	Ana	Helman	European Science Foundation	France
Dr.	Isabella	Vacchi	European Science Foundation	France
Dr.	Ana-Mara	Ciubotaru	European Science Foundation	France
Ms.	Camelia	Steinmetz	European Science Foundation	France

BOOK OF ABSTRACTS

The electron-beam as stimulus and probe to modify and understand properties of functional low-dimensional materials

Ute Kaiser
Electron Microscopy of Materials Science, Central Facility for Electron Microscopy, Ulm University, Germany

Short biography:

Ute Kaiser received her Diploma and her PhD in Crystallography (Physics) from the Humboldt University Berlin and her Habilitation in Experimental Physics from the Friedrich-Schiller University, Jena, Germany, in 2002. Since 2004 she is full professor at Ulm University in the Physics Department and Head of Ulm's Materials Science Electron Microscopy within the Central Facility of Electron Microscopy. Her research interests comprise the areas of TEM methods and instrumentation development, optimization, and applications. At present, her research activities are in the fields of battery, semiconductor, and catalysts materials, with strong emphasis on basic understanding of structure and properties of low-dimensional materials. From 2009 till 2018 she was the Scientific Director of the SALVE (Sub Angstroem Low-Voltage Electron Microscopy) project to realize a low-voltage TEM, corrected for chromatic and spherical aberration. By means of this unique TEM instrument, she dedicates her work to unravel the crystallographic and electronic properties of 2D materials and to understand the different processes of beam electron interactions and material's property engineering on the atomic scale. Ute Kaiser has more than 390 publications, with an H-index H-Index 69 (Google Scholar) and was „highly cited researcher" in 2018, is a frequently asked invited speaker at conferences and holds several honorary adjunct positions. She is currently the Physical-Sciences Editor for the Journal Micron.

Abstract:

Two-dimensional (2D) materials exhibit properties, which often differ strongly from those of their bulk counterparts and may alter even by changing the positions of a single atom. Graphene liquid cells as well as single-walled carbon nanotubes can act as container to realize controlled reactions or translations of molecules confined in the narrow space of the container.
It is a growing demand in materials sciences to unravel the atomic and electronic structure of advanced low-dimensional material to understand their properties at the atomic scale. For this purpose, a new type of transmission electron microscopes, the so-called SALVE microscope, operating at electron accelerating voltages between 80kV and 20kV has been developed recently. It allows undercutting most of the materials knock-on damage thresholds and enables sub-Angstroem resolution down to 40kV by correcting not only the geometrical aberrations of the objective lens but also its chromatic aberration in a large field of view in a single-shoot image, just allowing to study the dynamic of interactions in only one image [1-5].
In this study we demonstrate that the electron beam in the transmission electron microscope (TEM) can act as stimulus and initiator for reactions while imaging the result of the interactions. Thus, detailed understanding of the electron beam – specimen interactions is a crucial task. We present recent results on atomically-resolved, time-dependent in-situ TEM imaging using the our low-voltage SALVE instrument. First, we elucidate the accelerating-voltage-dependent formation of defects in the case of single-layer MoS_2. The results suggest that knock-on damage and electronic excitations are combined in the TMD materials and lower drastically the knock-on damage threshold. Density functional theory molecular dynamics shows that excitations in the electronic system can form vacancies through ballistic energy transfer at electron energies, which are much lower than the knock-on threshold for the ground state [6].

We further identify the structure of electron-beam-induced defects and their electronic properties and follow the migration paths and associated property changes in a variety of 2D TMD and TMPT crystals [6-8]. We show that also 2D polymers and their defects can be resolved at near-atomic level when selecting the appropriate accelerating voltage [9]. On the more fundamental base, we show that differentiating between the bond nature by measuring the distance between two metal atoms is possible, when confined in the narrow space of a SWNT [10]. Although rotational motions have been observed in carbon-nanotube-based mass transfer systems [11,12], we show here the interaction between the moving matter and the carbon nanotube and its application for carrying metal atoms to a nucleation seed, realizing in situ observation of metal nucleation. We identify three main processes prior to heterogeneous nucleation and demonstrate the roles of the amorphous precursors and the existence of an energy barrier before nuclei formation. In all three cases we find that crystal nucleus formation occurs through a two-step nucleation mechanism [13]. Finally, we intercalate bilayer graphene in-situ by lithium, study in-situ the lithiation and delithiation processes, as well as the formation process of the new high-density crystalline Li- phase [14].

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We thank the DFG and the state Baden-Württemberg in the frame of the SALVE project as well as the European Union’s Horizon 2020 programme Grant agreement No. 881603.

Assembly of 2-dimensional nanomaterials into fibers and their applications

Tae Hee Han
Department of Organic and Nano Engineering, Hanyang University, Korea

Short biography:

Tae Hee Han is an Associate Professor in the Department of Organic and Nano Engineering at Hanyang University, South Korea, and group leader in the Hybrid Functional Nano Materials Laboratory, Seoul, since 2012. Currently, he is also working as a vice-leader of the Human-Tech Convergence Program of BK21 Four Plus. He obtained his Ph.D. in the Department of Materials Science and Engineering from Korea Advanced Institute of Science and Technology (KAIST, South Korea) in 2010. Before joining Hanyang University, he worked as a Postdoctoral Fellow in the Department of Materials Science and Engineering at Northwestern University, USA, until 2012. His main research interests focus on the fundamental understanding of chemistry and physical behaviors of 2-dimensional nanomaterials, such as graphene and MXenes. In particular, his research group is extensively studying the assembly of carbon-based functional materials into multiscale structures, including flexible fibers and films, and their energy harvesting/conversion and storage applications.

Abstract:

The range of applications of graphene-based assembled materials can be expanded by modification of the mechanical traits of these materials. The mechanical properties of a material can be modified through structure control. For example, tailoring the inner structures of graphene foams and films yields materials with diverse mechanical traits and varied applications. Graphene fibers, the latest emerging class of graphene-based assembled materials, have been widely researched in the areas such as wearable electronic/energy applications owing to their unique properties and flexibility. In this talk, first, I will introduce the reconstruction strategies of 2-dimensional (2D) nanomaterials into functional materials. Graphene oxide (GO) sheets can assemble into 1-dimensional (1D) fibers through the structural control manner via a large-scale wet-spinning assembly. In particular, our straightforward and continuous wet-spinning strategy is beneficial to fabricate multiscale dimensional fibers with high electroconductivity, flexibility, and mechanical strength. Second, two allotropes of carbon nanomaterials that can be assembled into high torsional strength fibers through rheological control will be introduced. Two distinctive building blocks, including GO and CNTs, are wet-spun in a coagulation bath to form hybrid fibers with highly oriented inner structures. CNTs and GO interact with each other and direct the structural manipulation. Finally, to conclude, I will introduce a deformable $Ti_3C_2T_x$ MXene gel of well-defined multiscale structures prepared by self-assembly of 2D sheets. By taking advantage of strong molecular interactions, mechanically strong fibers can be fabricated by drawing the MXene gel. Due to its defect-free structure, $Ti_3C_2T_x$ MXene fiber has dense lamella and a highly aligned multiscale structure. Like electrical wire, $Ti_3C_2T_x$ MXene fibers exhibit outstanding electrical conductivity and a high mechanical modulus compared with other MXene-based assemblies.

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Printable Electronics Enabled by two-dimensional materials: an experimental and theoretical investigation

Gianluca Fiori
Dipartimento di Ingegneria dell'Informazione, University of Pisa, Italy

Short biography:

Gianluca Fiori is Professor of Electronics at University of Pisa, from which he obtained the PhD in 2005. Prof. Fiori's field of activity includes the modelling, the fabrication and electrical characterization of novel devices based on new architectures and new materials. Prof. Fiori has a renowned expertise in assessing device performance against Industry requirements, through the exploitation of purposely-devised multi-scale, multi-physics in-house atomistic simulators.

Prof. Fiori's interest also focuses on printed electronics, aiming at obtaining fully printed integrated circuits on flexible substrates as paper.

Abstract:

Two-dimensional materials (2DMs) have already demonstrated to be an added value in a wide range of applications, due to their extraordinary mechanical and electrical properties shown so far.
From an electronic perspective, one would like to reach the same excellent results obtained on rigid substrates [1,2], but on flexible substrates, while allowing to reach the goal of wearable, flexible and printed electronics [3].
In this talk, I will show recent results on this topic, while addressing the main issues and potentials this technological option is currently facing, and providing performance projections through a purposely devised theoretical approach.

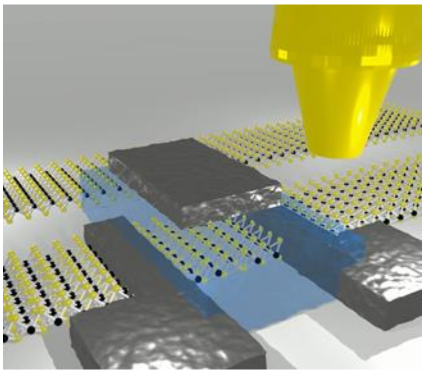

Figure 1: Sketch of an inkjet printed transistor exploiting 2DMs

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Chemically exfoliated graphene for energy storage applications

Seung Yol Jeong
Nano Hybrid Technology Research Center, Korea Electrotechnology Research Institute (KERI), Korea
Department of Electro-Functionality Materials Engineering, University of Science and Technology (UST), Korea

Short biography:

Dr. Seung Yol Jeong was educated at the Sungkyunkwan University (SKKU) and received a Ph.D. in condensed matter physics and specifically carbon nanotubes and device applications. Additionally, he did post-doctoral studies at the department of materials science and engineering at Rutgers University (USA), and his interest was in the production of high-quality CNTs and graphene. Currently, he is working as a principal researcher at Nano Hybrid Technology Research Center, Korea Electrotechnology Research Institute (KERI) and a professor at the department of electro-functional materials engineering, University of Science and Technology (UST). His research focus is high-quality and reduced graphene oxide (rGO) with stable dispersion as a conductive ink or paste to apply electronic and energy storage devices. Specifically, he is developing an appropriate rGO as an intermediate material for applying the secondary battery and mass production.

Abstract:

Conducting ink or paste are necessary to apply various energy and electronic devices such as secondary battery, supercapacitors, flexible display, and transistors. In particular, solution-processable graphene is possible for preparation of various electrodes with respect to energy storage devices due to its superior properties such as mechanical and chemical stability and high electrical conductivity. Chemically exfoliated graphene (CEG) has been of great attention for solution-processable application such as conducting ink, paste, and composites due to its dispersion and processibility. Also, it provides the most practical approaches for adaptation to large-scale manufacturing processes. In order to the practical use of CEG, the production involves several essential steps for the chemical oxidation, exfoliation, subsequent reduction of graphite oxide and stable dispersion. Here, we introduce highly conductive CEG paste or ink by effective chemical oxidation, shear induced exfoliation, and cation-π interaction for stable dispersion of reduced graphene oxide (rGO). Colloidal suspensions of high quality rGO in polar solvent such as water, which contain a small amount of defect, have been unobtainable due to the hydrophobic nature of graphene. In particular, a stable dispersion in an aqueous solution is essential for preserving the unique properties of the nanostructures and efficient processability for the application of energy storage devices. Production of highly conductive and concentrated rGO is made possible by the modified oxidation of graphite, the shear-induced exfoliation and the presence of monovalent cation–π interactions in aqueous solution. The stable dispersion of rGO could be directly applicable for silicon-rGO complex as anode materials for lithium-ion batteries. The highly conductive solution-processable rGO has exellent potential for the practical use of lithium-ion battery to decrease volume expansion for silicon active materials.

Electrical and electrochemical applications of liquid exfoliated nanosheets

Jonathan N Coleman
School of Physics, CRANN and AMBER Research Centers, Trinity College Dublin, Dublin 2, Ireland

Short biography:

Jonathan Coleman is the Professor of Chemical Physics at Trinity College Dublin. His research involves production of 2D materials such as graphene and molybdenum disulphide for applications in nanocomposites, energy storage, sensing and electronics. He has published approximately 330 papers in international journals including Nature and Science, has a h-index of 93 and has been cited ~50,000 times. He was recently listed by Thomson Reuters among the world's top 100 materials scientists of the last decade and was named as the Science Foundation Ireland researcher of the Year in 2011. Prof Coleman has been involved in a number of industry-academic collaborative projects with companies including Hewlett-Packard, Intel, SAB Miller, Nokia-Bell Labs and Thomas Swan.

Abstract:

Liquid phase exfoliation (LPE), is a simple and versatile method to exfoliate layered crystals like graphite, BN and MoS2 to give 2-dimensional nanosheets such as graphene in large quantities. These dispersions can be straightforwardly processed, allowing the production of composites or the printing of nanosheet networks. In this talk, I will discuss our latest results on exfoliation of new layered materials, for example SnP3, which displays superlative lithium storage. I will also describe the printing of size-selected nanosheet networks using aerosol jet printing as well as their electrical properties. By combining networks of different nanosheet types, it is possible to form heterostructures for device applications. For example, using graphene electrodes and high permittivity BiOCl nanosheets as dielectric, it is possible to print capacitors with dielectric constants >50. Alternatively, when mixed with a polymer conductive nanosheets can yield extremely sensitive strain sensors. Finally, I will demonstrate that a number of non-layered materials can be converted to nanosheets using LPE. Such quasi-2D materials demonstrate outstanding performance in a number of applications, for example Li ion battery electrodes.

Direct light-lattice interactions in atomically thin van der Waals semiconductors

Moon-Ho Jo
Mueunjae Chair Professor, Pohang University of Science and Technology (POSTECH), Korea
Associate Director, Center for Artificial Low Dimensional Electronic Systems, Institute for Basic Science (IBS), Korea

Short biography:

Prof. Moon-Ho Jo is Mueunjae Chair Professor of Dept. of Materials Science and Engineering, Pohang University of Science and Technology (POSTECH) and Associate Director of Center for Artificial Low Dimensional Electronic Systems, Institute for Basic Science (IBS). Moon-Ho Jo received his Ph.D. in Materials Science at University of Cambridge (2001), with a dissertation on electron-spin tunneling in half-metallic manganites. He joined the faculty of the Department of Materials Science and Engineering at POSTECH in 2004 after a postdoctoral fellowship in Department of Chemistry/Physics at Harvard University. He was appointed Associate Fellow of The Korea Academy of Science and Technology in 2015. His current research interests include (1) atomic scale heteroepitaxial growth of semiconductors and strongly correlated materials, (2) light-matter interactions at atomically thin materials, as well as (3) electron transport and laser transport spectroscopy in atomic scale materials.

Abstract:

The bond dissociation energy of atomically thin van der Waals (vdW) semiconductors is relatively weaker typically ranging 2-3 eV, compared to elemental semiconductors, thus one can immediately access to direct light-lattice interactions with conventional light sources for spectroscopy [1]. In this talk, we discuss a series of our recent works on selective light-lattice interactions in atomically thin vdW semiconductors toward realization of two-dimensional (2D) integrated circuitry (ICs). Complementary doping on a semiconductor is an elementary process to build monolithic ICs. However, for 2D vdW semiconductors, the construction of monolithic ICs remains challenging because of the absence of a locally selective doping method. Toward this end, we first demonstrated a simple method of "programmable writing" of various 2D ICs on atomically thin vdW semiconductor host lattice by exploiting a novel concept of self-aligned doping with a scanning light probe, in analogy to ion implantation in Si CMOS technology [2]. Then, we discovered that such direct light-lattice interactions can be selective and reversible with the choices of light colors, i.e., "reconfigurable" photo-induced doping using different photon energies, which were supported by visual and spectroscopic evidence of individual n- and p-dopants at the atomic scale [3]. This simple doping enables one to repeatedly inscribe and erase the carrier types and concentrations of an identical semiconductor channel at room temperature with conventional light sources. We indeed showed diverse CMOS ICs using such light probes, including n-p-n (p-n-p) bipolar junction transistor amplifiers, radial p-n photovoltaic cells and reconfigurable CMOS inverter-switches [2-3]. At the end, we discuss another recent example of atomically thin photo-memtransistors, which can be viewed as an atomistic synapse networks in hardware-based artificial neural networks technology [4].

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Layer Selective Synthesis of 2D Heterostructure Using Photothermal Treatment

Seoung-Ki Lee
School of Materials Science and Engineering, Pusan National University, Pusan National University, Korea

Short biography:

Seoung-Ki Lee received the B.S. and Ph.D. degrees in School of Advanced Materials Science & Engineering from the Sungkyunkwan University, Republic of Korea in 2010 and 2014, respectively. After Postdoctoral work with Yonsei University and Smalley-Curl Institute and the Nano Carbon Center at RICE University, he joined the Korea Institute of Science and Technology (KIST) as a senior researcher in 2016. Since 2021, he has worked as an Assistant Professor in the School of Materials Science and Engineering, Pusan National University, Republic of Korea. His research interests include the synthesis of low-dimensional materials, flexible electronics, and wearable sensor systems.

Abstract:

The heterostructures constructed from transition-metal dichalcogenides (TMDs) have attracted considerable interest in the fields of physics and chemistry and for practical applications, because they offer tunability of the properties, such as the band offset, carrier density, and polarity. However, the complexity of synthesis processes so far is delaying the successful integration of the heterostructure device array on a large scale, hindering the realization of its great potentials.
Here, structure controllable synthesis of TMDs (e.g., MoS_2, WS_2) is suggested by the facile solution-based selective precipitation method. The novel approach provides specific control of the microstructure of MoS_2, such as thickness, shape and interspacing, resulting in a well-aligned patterned MoS_2 structure. Moreover, we confirmed that the MoS_2/WSe_2 heterojunction with a sharp interface between vertical layers could be realized using a pulsed laser annealing system. Through experimental and theoretical studies, the underlying principles of selective synthesis was established. As a proof of concept, we demonstrated the behaviour of a MoS_2-based optoelectric sensor, a skin-attachable motion sensor in this study.

Graphene and its versatility as building block of innovative biosensors

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Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and The Barcelona Institute of Science and Technology, Spain

Short biography:

Arben Merkoçi is currently ICREA Professor and director of the Nanobioelectronics & Biosensors Group at Institut Català de Nanociencia i Nanotecnologia (ICN2), part of Barcelona Institute of Science and Technology (BIST). After his PhD (1991) at Tirana University (Albania), in the topic of Ion-Selective-Electrodes (ISEs) Dr. Merkoçi worked as postdoc and senior researcher/invited professor in the field of nanobiosensors and lab-on-a-chip technologies in Italy, Spain, USA and since 2006 at ICN2. Prof. Merkoçi research is focused on the design and application of cutting-edge nanotechnology and nanoscience-based cost/efficient biosensors. The paper/plastic-based nanobiosensors involve integration of biological molecules (DNA, antibodies, cells and enzymes) and other (bio)receptors with micro- and nanostructures/motors and applied in diagnostics, environmental monitoring or safety and security. He has published around 310 peer review research papers (H index: 70 WOS; 85 GS), supervised 30 PhD students and has been invited to give plenary lectures and keynote speeches in around 200 occasions in various countries. Prof. Merkoçi is Co-Editor In Chief of Biosensors and Bioelectronics and member of Editorial Board of other journals. He is co-founder of two spin-off companies, PaperDrop dedicated to nanodiagnostics and GraphenicaLab to electronic printing. See more details on his group and CV at:
https://icn2.cat/en/nanobioelectronics-and-biosensors-group
https://www.icrea.cat/security/files/researchers/files-maintenance/full_cv_amerkoci_0.pdf
http://www.nanobiosensors.org/group-leader/

Abstract:

Graphene is attracting the biosensors community since many years with the objective to explore new biosensing mechanisms or enhance the performance of existing biosensing technologies taking advantages of its physical (electrical, optical etc.) properties combined with the rich chemistry that allow offering of interesting coupling strategies with various detection platforms. We have been studying several graphene-related materials (GRM) such as graphene oxide (GO) and graphene quantum dots (GQDs) evidencing advantageous phenomena and characteristics with interest for building innovative biosensing platforms and even smart devices such as nano/micromotors for a myriad of uses including sensing. One of the very interesting properties has been quenching of the fluorescence induced by GO or photoluminescence of GQDs that can easily operate in synergy with various other nanomaterials (ex. nanoparticles) and platforms (including paper, plastic) opening the way to several unprecedented biosensing strategies and unique nanomotor technologies. Examples related to the design and application of simple, sensitive, selective and rapid biosensing platforms using GRMs will be shown. These will include from a GO – based microarray & lateral flow technologies taking advantages of high quenching efficiency of GO to a “turn ON by a pathogen” device as a highly sensitive detection system using plastics or paper/nanopaper substrates. GQDs–based sensors for contaminants detection based on the use of multifunctional composite materials that enable rapid, simple and sensitive platforms in connection to smartphone including an electroluminescent-based approach will be discussed as well. Electrical platforms to be used as point of care for pathogens detection are another important technology that we are developing and some of the obtained results will be shown. This work is supported by EU (Graphene Flagship), CERCA Programme / Generalitat de Catalunya.

Applications of graphene based on intrinsic properties of graphene

Jeong-O Lee
Advanced Materials Division, Korea Research Institute of Chemical Technology, Korea

Short biography:

Dr. Jeong-O Lee received Ph.D. in physics from Jeonbuk National university in 2001 and joined Korea Research Institute of Chemical Technology (KRICT) in 2003 after spending two years in TU Delft as a postdoctoral researcher. Her research focuses on device applications of carbon nanomaterials, especially on chemical and biosensors fabricated with carbon nanomaterials. She is currently working as a principal researcher in KRICT, trying to bridge the gap between carbon nanomaterials and practical applications of them.

Abstract:

Since the discovery of graphene over a decade ago, unprecedented properties of graphene were actively investigated to commercialize this wonder material. However, only a few graphene-based products made to the market, and most of them are composites based on graphene. As discussed in the recent review article by Wei Kong et al., (Nature Nanotechnology 14, 927 (2019)) we believe that it is crucial to find a market that can utilize “the special properties of graphene”; i.e., finding a unique product that can be made with graphene only, for successful commercialization of graphene. In that prospect, here we show two application examples utilizing intrinsic properties of graphene. In the first example, transparency of graphene has employed to provide functional thin films. Epitaxial growth of ZnO nanowires, catalytic thin film electrodes, and synthesis of ultra-thin metal films and their applications will be demonstrated. In the second example, we show hydrophilic graphene can be an ideal imaging plate for microscopy. Chemical inertness, optical transparency and excellent electrical properties of graphene enable electron microscopy and fluorescence microscopy imaging of biological specimens (insulating materials) at the same time. Being a single-atom-thick semimetal, graphene enabled electron microscopy imaging of biological specimens without any post-treatment. Moreover, much improved z-axis resolution has achieved in array tomography imaging by applying multi-energy deconvolution (MED) technique, which is not possible with metallic substrates due to high-intensity back-scattered electrons from the substrates.

Ultrafast machine vision with 2D material photodetector arrays

Thomas Mueller
Vienna University of Technology, Institute of Photonics, Austria

Short biography:

Thomas Mueller received his M.S. and Ph.D. degrees in Electrical Engineering from TU Vienna in 2001 and 2004, respectively. In 2007 he joined the IBM Watson Research Center, USA, as a Postdoc, working on carbon-based optoelectronics. At the end of 2009 he returned to TU Vienna, where he currently holds an Associate Professor position. His research focuses on electronic and optoelectronic devices based on two-dimensional materials. He (co-)authored more than 100 peer-reviewed publications in leading scientific journals. Selected awards include the START-Prize, the Fritz Kohlrausch-Prize, and the AScINA Award.

Abstract:

Machine vision technology has taken huge leaps in recent years and is now becoming an integral part of various intelligent systems, including autonomous vehicles and robotics. Usually, visual information is captured by a frame-based camera, converted into a digital format and processed afterwards using a machine-learning algorithm such as an artificial neural network (ANN). The large amount of (mostly redundant) data passed through the entire signal chain, however, results in low frame rates and high-power consumption. Various visual data pre-processing techniques have thus been developed to increase the efficiency of the subsequent signal processing in an ANN. In this talk I will demonstrate that an image sensor can itself constitute an ANN that can simultaneously sense and process optical images without latency. The device is based on a reconfigurable two-dimensional (2D) semiconductor photodetector array with the synaptic weights of the network being stored in a continuously tuneable photoresponsivity matrix. I will discuss both supervised and unsupervised learning and demonstrate that the sensor can be trained to classify and encode images that are optically projected onto the chip with a throughput of 20 million bits per second - 6 orders of magnitude higher than state-of-the-art.