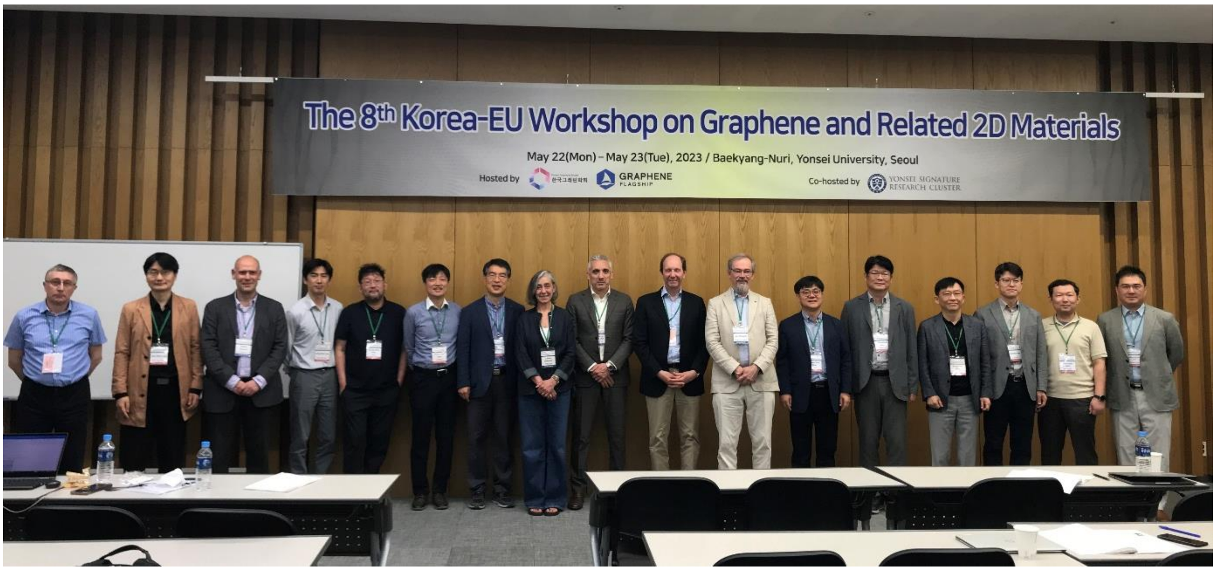
The 8th Graphene Flagship EU-Korea Workshop on Graphene and related 2D materials

Baekyang-Nuri, Yonsei University, Seoul (Republic of Korea)

22 – 23 May 2023



Workshop report

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Overview of workshop activities

The 8th Korea-EU workshop on Graphene and Related Materials took place on 22-23 May 2023 in Seoul, Republic of Korea. The event was co-organised by the Graphene Flagship and local hosts of Seoul National University and Yonsei University and was chaired by Prof. Jari Kinaret (Chalmers University) and Prof. Hyeon Suk Shin (Ulsan National Institute of Science & Technology, UNIST). Programme chairs were Prof. Paolo Samorì (University of Strasbourg) and Prof. Tae-Woo Lee (Seoul National University).

This 2-days meeting gathered 26 participants from the European and the Korean delegations. Latest research results and scientific achievements from both delegations were presented by key representatives through 22 talks.

Similarly to previous international workshops organised in the framework of the EU-Korea collaboration, this meeting provided an effective platform for the delegates to exchange practices and ideas around current topics of interest related to graphene and related 2D materials.

Particular emphasis was given to fundamental studies of the materials' properties through multiscale characterisation, as well as to novel 2D materials synthesis and engineering approaches.

Among emerging topics of interest for both delegations, application development and commecialisation were largely highlighted. Novel applications of graphene and 2D materials were discussed within several domains, including photonics (optical communication), biomedical field (artificial muscles), electronics and energy (interface band engineered 2D semiconductors, flexible and stratchable 2D electrodes, electrothermal applications for consumer electronics).

The inspiring discussions and exchanges that emerged during the workshop activities and during the various social events (kindly organised by the local hosts) were enthusiastically received by all the participants. At the closure of this 2-day workshop, a session was dedicated to the discussion of future perspective and outlook of the collaboration between Graphene Flagship and Korea. The delegates from both sides reconfirmed their interest in continuing the collaboration in the upcoming Horizon Europe phase, and expressed their willingness in actively supporting the organisation of future joint initiatives.

Programme

Workshop venue: Baekyang-Nuri, Yonsei University (Seoul)
Room, Kwak Joung-Hwan Challenge Hall

Indicated time corresponds to the Korea Standard Time zone (KST, UTC/GMT +9).

May 21, 2023	
19:00 – 21:00	Reception (venue: Juyu Byeoljang D Tower Branch)

May 22, 2023		
09:10 – 09:20	Welcome and Opening Remarks	
Session 1 *Chair: Tae-Woo Lee*		
09:20 – 09:40	*Jari Kinaret*	Graphene Flagship: a look at its ten years' voyage and the way ahead
09:40 – 10:10	*Hyeonsik Cheong*	Optical spectroscopy of twisted TMD heterostructures
10:10 – 10:40	*Paolo Samorì*	Advances in 2D semiconductors-based multifunctional high-performance electronics
10:40 – 10:50	***Coffee break***	
10:50 – 11:20	*Sang Ouk Kim*	From Graphene Oxide Liquid Crystal to Artificial Muscle
11:20 – 11:50	*Francesco Bonaccorso*	2D Materials for energy applications
11:50 – 13:15	***Lunch break***	
Session 2 *Chair: Paolo Samori*		
13:15 – 13:45	*Sunmin Ryu*	Interferometric Second-Harmonic Generation in Two-Dimensional Heterocrystals
13:45 – 14:15	*Byung Hee Hong*	Electrothermal Applications of Graphene for Consumer Electronics
14:15 – 14:45	*Laura Ballerini*	2D materials to modulate brain networks and synapses
14:45 – 15:15	*Gwang-Hyoung Lee*	Heterointerface Engineering in van der Waals Heterostructures by Interlayer Interaction
15:15 – 15:30	***Coffee break***	
Session 3 *Chair: Gwan-Hyoung Lee*		
15:30 – 16:00	*Tae-Woo Lee*	MXene and Graphene 2D Electrodes for Flexible and Stretchable Optoelectronics

16:00 – 16:30	*Mar Garcia Hernandez*	Are 2D materials limited to Van der Waals layered materials?
16:30 – 17:00	*Andrea Ferrari*	Pending
17:00 – 17:30	*Chul-Ho Lee*	Interface Band Engineering Toward High-Performance 2D Semiconductor Electronics
17:30 – 18:00	Closing of the first day workshop	
18:00 – 20:00	Dinner (venue: Hyeongje Grilled Short Ribs)	

May 23, 2023		
Session 4 *Chair: Marco Romagnoli*		
09:10 – 09:40	*Young-Woo Son*	Unconventional Phase Transitions in Layered 2D Materials
09:40 – 10:10	*Vladimir Fal'ko*	Ferroelectric domain structures in twistronic TMD bilayers
10:10 – 10:30	***Coffee break***	
10:30 – 11:00	*Xinliang Feng*	Advances in Organic 2D Crystals - From On-Water Surface Chemistry to Functional Applications
11:00 – 11:30	*Jong-Hyun Ahn*	Direct growth of MoS2 on low temperature substrates for emerging electronics
11:30 – 12:00	*Inge Asselberghs*	Enabling 2D-materials process-transfer from lab-to-fab
12:00 – 13:30	***Lunch break***	
Session 5 *Chair: Jong-Hyun Ahn*		
13:30 – 14:00	*Heejun Yang*	Van der Waals Heterostructures for Orbital Gating in Photo-transistors and Electronic Spectroscopy
14:00 – 14:30	*Marco Romagnoli*	Graphene based photonics for optical communications
14:30 – 15:00	*Hyeon Suk Shin*	Current Status and Challenges of hBN Growth by Chemical Vapor Deposition
15:00 – 15:30	*Cheol-Joo Kim*	Engineering Grain Boundaries in 2D Materials for Emergent Properties
15:30 – 16:00	EU-Graphene Workshop Planning Discussion	
16:00	Closing remarks (Hyeon Suk Shin)	

List of speakers and participants

Title	Last name	First name	Institution	Country
Prof.	Kinaret	Jari	Chalmers University	Sweden
Prof.	Samorì	Paolo	University of Strasbourg	France
Dr.	Bonaccorso	Francesco	BeDimensional	Italy
Dr.	Asselberghs	Inge	IMEC	Belgium
Prof.	Fal'ko	Vladimir	The University of Manchester	United Kingdom
Prof.	Ballerini	Laura	International School for Advanced Studies (SISSA)	Italy
Prof.	Garcia Hernandez	Mar	The Spanish National Research Council (CSIC)	Spain
Dr.	Romagnoli	Marco	National Inter-University Consortium for Telecommunications (CNIT)	Italy
Prof.	Ferrari	Andrea	University of Cambridge	United Kingdom
Prof.	Feng	Xinliang	Technical University of Dresden	Germany
Prof.	Ahn	Jong-Hyun	Yonsei University	Republic of Korea
Prof.	Cheong	Hyeonsik	Sogang University	Republic of Korea
Prof.	Cho	Kilwon	Pohang University of Science and Technology (POSTECH)	Republic of Korea
Prof.	Choi	Sung-Yool	Korea Advanced Institute of Science & Technology (KAIST)	Republic of Korea
Prof.	Hong	Byunghee	Seoul National University	Republic of Korea
Prof.	Kim	Sang Ouk	Korea Advanced Institute of Science & Technology (KAIST)	Republic of Korea
Prof.	Kim	Cheol-Joo	Pohang University of Science and Technology (POSTECH)	Republic of Korea
Prof.	Kim	Kwanpyo	Yonsei University	Republic of Korea
Prof.	Lee	Gwan-Hyoung	Seoul National University	Republic of Korea
Prof.	Lee	Tae-Woo	Seoul National University	Republic of Korea
Prof.	Lee	Chul-Ho	Seoul National University	Republic of Korea
Prof.	Lee	Seoung-Ki	Pusan National University	Republic of Korea
Prof.	Ryu	Sunmin	Pohang University of Science and Technology (POSTECH)	Republic of Korea

Prof.	Shin	Hyeon Suk	Ulsan National Institute of Science & Technology (UNIST)	Republic of Korea
Prof.	Son	Young-Woo	Korea Institute for Advanced Study (KIAS)	Republic of Korea
Prof.	Yang	Heejun	Korea Advanced Institute of Science & Technology (KAIST)	Republic of Korea

BOOK OF ABSTRACTS

8th Korea-EU Workshop on graphene and related 2D materials

Title: Advances in 2D semiconductors-based multifunctional high-performance electronics

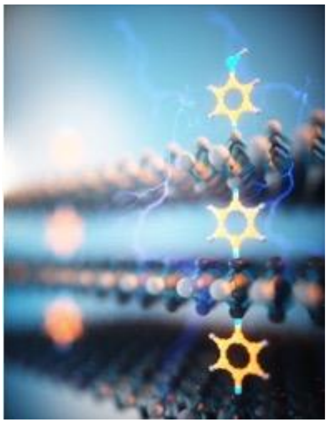
First and last name: Paolo Samorì

Affiliation: ISIS, University of Strasbourg

Short Biography:
Paolo Samorì is Distinguished Professor at the University of Strasbourg and Director of the Institut de Science et d'Ingénierie Supramoléculaires (ISIS). His current research interests comprise 2D materials, supramolecular chemistry, responsive interfaces, and development high-performance multifunctional materials and (nano)devices for energy, sensing and optoelectronic applications. He is member of different national academies of science and of technology as well as European academies. He received numerous awards. He is presently Associate Editor of ACS Nano.

Abstract:

Two among the greatest challenges in 2D electronics are the enhancement of the electrical characteristics and harnessing their multifunctional nature.
Device performance of solution-processed 2D semiconductors in printed electronics has been limited so far by structural defects and high inter-flake junction resistance. Covalently interconnected networks of transition metal dichalcogenides (TMDs) potentially represent an efficient strategy to overcome both limitations simultaneously. Yet, the charge transport properties in such systems have not been systematically researched. In this study we have unveiled the charge transport mechanisms of printed devices based on covalent MoS_2 networks via multiscale analysis, comparing the effects of aromatic *vs*. aliphatic dithiolated linkers, by performing temperature-dependent electrical measurements and exploiting a novel analysis based on percolation theory corroborated by density functional calculations to gain deeper insight into the electronic increased connectivity.[1] We also used a novel stepwise microfluidic-assisted approach, based on defect engineering of TMDs, to demonstrate for the first time the solution-processing of 2D heterostructures with enhanced electrical characteristics and novel functionalities. [2]
On the other hand, the functionalization of 2D materials to engineer hybrid systems via the controlled interfacing of the two surfaces of 2D semiconductors (CVD or scotch tape) either in a symmetric or asymmetric fashion with molecular switches has been demonstrated as a powerful way to confer additional properties to WSe_2, thereby rendering 2D material-based transistors capable to respond to four different independent stimuli.[3]
Our modular strategies relying on the combination of 2D material with molecules offer a simple route to generate multifunctional coatings, foams and nanocomposites with pre-programmed properties to address key global challenges in electronics, sensing and energy applications.



[1] S. Ippolito et al.: (a) *Nat. Nanotech.* **2021**, *16*, 592; (b) *Adv. Mater 2023 (DOI: 10.1002/adma.202211157)*
[2] H. Qiu et al : (a) *Adv. Mater.* **2019**, *31*, 1903402, (b) *Adv. Mater.* **2020**, 32, 1907903, (c) *ACS Nano* **2021**, *15*, 10668, (d) *Adv. Funct. Mater.*, **2021** *31*, 2102721.

Figure: 1,4-benzenedithiol molecules healing sulfur vacancies in solution-processed MoS_2 and covalently bridging adjacent flakes, to create percolation pathways for the charge transport in FETs.

8^{th} Korea-EU Workshop on graphene and related 2D materials

Title: 2D materials to modulate brain networks and synapses

First and last name: Laura Ballerini

Affiliation: International School for Advanced Studies – SISSA Trieste, Italy

Short Biography:

Laura Ballerini research focuses on the interactions between neurons and nanomaterials or bioactive-nanodevices. Her scientific strategy is the convergence between biophysics, nanotechnology and neurophysiology, potentially leading to a new generation of nanomedicine applications in neurology. After a post doc at UCL, London UK, she became associate and then full professor of Physiology at the International School for Advanced Studies-SISSA, Trieste, Italy.

Abstract:

By virtue of nano-scaled dimensional domains combined with peculiar chemical-physical properties graphene-based nanomaterials (GBNs) are increasingly engineered in advanced drug-delivery platforms or in interfacing devices to treat central nervous system (CNS) diseases. GBNs developed to interface neuronal functions might propel new biomedical devices, enabling CNS modulation. This new class of materials can improve exploring fundamental biological phenomena as well as contribute to clinical applications. I will present our results concerning GBNs interfacing neurons, I will describe the ability of such materials to regulate neuronal functions by modulating synaptic activity in vitro and in vivo.

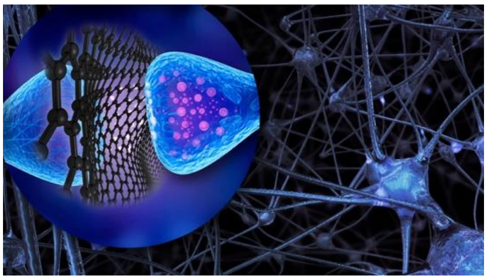


Figure: Sketched small graphene oxide flakes interfacing neuronal synapses

Title: 2D Materials for energy applications

First and last name: Francesco Bonaccorso

Affiliation: BeDimensional S.p.A., via Lungotorrente Secca 30R, 16163 Genova, Italy

Short Biography:

Francesco Bonaccorso is the Deputy of the workpackage Innovation of the Graphene Flagship, and He was responsible in defining the S&T roadmap for the project. He is the Scientific Director of BeDimensional SpA and visiting Scientist at the Istituto Italiano di Tecnologia. He gained the PhD from the University of Messina. In 2009 he was awarded a Royal Society Newton International Fellowship at Cambridge University, and elected to a Research Fellowship at Hughes Hall, Cambridge, where he also obtained a MA. He is author of 14 patents and more than 190 publications that have been cited more than 36000 times. He was featured as 2016 Emerging Investigator by J. Mater. Chem. A and in 2019 by ChemPlusChem. In 2018 he was recognized as Highly cited Scientist by Clarivate Analytics. In 2019 he received the Magister Peloritanus by Accademia Peloritana dei Pericolanti and ExAllievi Eccellenti by the University of Messina. He co-founded Cambridge Graphene Ltd and BeDimensional SpA.

Abstract:

In this presentation, we will provide a brief overview on some key applications in the energy sector of graphene and related two-dimensional materials (GRMs)[1-3] produced by BeDimensional S.p.A. We will provide an insight on the production of GRMs in liquid phase by wet-jet milling[3], showing its simple and cost-effective pathway towards the development of GRMs-based energy devices. We will demonstrate how GRMs produced by wet-jet milling present huge integration flexibility compared to GRMS produced with other methodologies. We will show key results in some application areas such as energy storage[4-6] and conversion[7-10] devices as well as anticorrosion coatings [11].

[1] F. Bonaccorso, et al., Materials Today, **15**, (2012) 564.
[2] F. Bonaccorso, et. al., Adv. Mater., **28**, (2016) 6136.
[3] A. E. Del Rio Castillo et. al., Mater. Horiz., **5**, (2018) 890.
[4] F. Bonaccorso, et. al., Science, **347**, (2015) 1246501.
[5] E. Pomerantseva, et al., Science **366** (2019) eaan8285.
[6] W. Brehm, et al., Energy & Fuels **36**, (2022) 9321.
[7] L. Najafi et al., Adv. Ener. Mater., **8**, (2018) 1703212.
[8] E. Lamanna et al., Joule, **4**, (2020) 865.
[9] S. Bellani, et al., Chem. Soc. Rev., **50**, (2021) 11870.
[10] S. Pescetelli et al., Nature Energy, **7**, (2022) 597.
[11] M. A. Molina-Garcia et al., JPhys Materials (2023) in press.

Title: Enabling 2D-materials process-transfer from lab-to-fab.

First and last name: Inge Asselberghs

Affiliation: imec, Leuven, Belgium

Short Biography:

Inge Asselberghs is Program Manager Process and Module Innovation at imec. She received the M.Sc. and Ph.D. degrees in chemistry from the University of Leuven, Leuven, Belgium. After a Post-Doctoral Fellowship in nonlinear optics, she joined imec in 2011. Her research interest covers new materials, process set-up, and integration pathfinding from the laboratory scale to fab infrastructure. She holds the position of division leader of the 2D-experimental pilot line, an EU funded initiative working on the enablement of 2D-materials-based device fabrication in an industry-relevant environment.

Abstract:

Over a decade, success stories with 2D-materials are moving from “intriguing science” to “unique applications” in various applications fields like sensors, photonics, spintronics and electronics [1] to name a few. While each of these applications, require a different set of challenges to be addressed, many commonalities are found in enabling the process transfer from lab-to-fab. While the performance gap between natural crystals and synthetic layers has almost vanished, like reported by Liu et al. [2] showing the mobility improvement up to 120 cm2/Vs for bilayer MoS2, other integration aspects like automated layer transfer [3] and interface control are key for outstanding device performance and wafer-uniformity [4-5-6]. Here, pathfinding activities will be highlighted in enabling process transfer from lab to fab.

[1] Lemme et al., Nat Commun (2022). https://doi.org/10.1038/s41467-022-29001-4
[2] Liu et al, Nature (2022). https://doi.org/10.1038/s41586-022-04523-5
[3] Brems et al. (2023) VLSI TSA, T8-5.
[4] Wu et al. (2021) doi: 10.23919/VLSICircuits52068.2021.9492495
[5] Asselberghs et al. (2020) IEEE International Electron Devices Meeting (IEDM),
doi: 10.1109/IEDM13553.2020.9371926
[6] Smets et al. (2021) IEEE International Electron Devices Meeting (IEDM), doi:
10.1109/IEDM19574.2021.9720517.

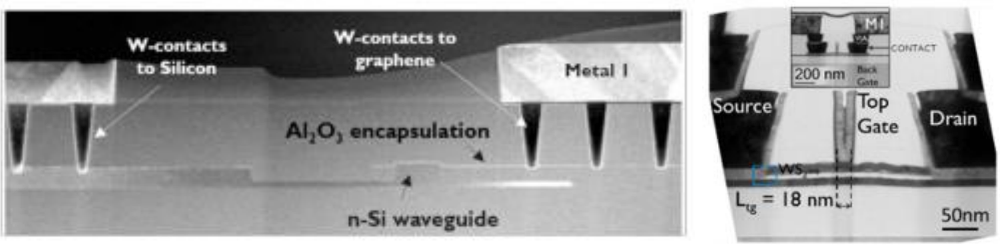


Figure 1: TEM view of a wafer-scale integrated graphene photonics device (left) and TMDC based transistor (right) taken from [4] and [5], respectively.

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Title: Graphene based photonics for optical communications

First and last name: Marco Romagnoli

Affiliation: Consorzio nazionale interuniversitario per le telecomunicazioni (CNIT), Italy

Short Biography:

Head of Advanced Technologies for Photonic Integration and Scientific Responsible at CNIT PNTLab (Photonic Networks and Technologies) in Pisa and former Director in R&D dept. His expertise is in particular in the area of photonic technologies for telecommunications. After a Laurea Degree in Physics at the University of Rome (La Sapienza), in 1983 he started his activity at IBM Research Center in San Jose. In 1984 he joined Fondazione Ugo Bordoni in the Optical Communications Department working on optical components and transmission systems. In 1998 he joined Pirelli. In Pirelli R&D Photonics served as director of Design and Characterization and Chief Scientist. In 2001 he pioneered the activity on Si Photonics and started the development platform for optical components, specifically silica based PLC's, SiN and Si. In Oct 2010 he joined PhotonIC Corp, a Si-Photonics company, as Director of Boston Operations and visiting scientist at MIT (Massachusetts Institute of Technology). In this period he contributed to the demonstration of the electrically pumped Germanium laser. Presently he is involved in the field of Photonic Integration and in particular in Graphene Photonics for optical telecom, datacom, sub-THz and quantum communications.

Abstract:

Graphene is an ideal material for optoelectronic applications. Its photonic properties give several advantages and complementarities over Si photonics. For example, graphene enables both electro-absorption, electro-refraction modulation. It can be used for optical add–drop multiplexing with voltage tuning, eliminating the current dissipation used for the thermal detuning of microresonators, for thermoelectric-based ultrafast optical detectors that generate a voltage without transimpedance amplifiers and for direct sub-THz optoelectronic conversion. In this presentation a vision for graphene-based integrated photonics will be provided along with a review of graphene-based transceivers and a comparison with existing technologies.

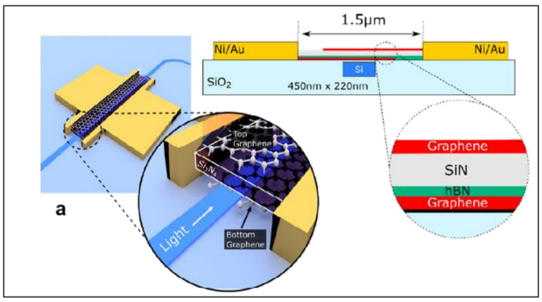

Figure: example of graphene modulator cross section in a silicon photonics platform

Title: Are 2D materials limited to Van der Waals layered materials?

First and last name: Mar Garcia-Hernandez

Affiliation: CSIC, Consejo Superior de Investigaciones Científicas, Spain

Short Biography:

Madrid (1959). Prof. Mar Garcia-Hernandez has a long trajectory in Experimental Condensed Matter Physics and Material Science. Her research in strongly correlated oxides heterostructures with application in spintronics is a central topic in her lab as well as 2D materials. She leads the WP "Enabling Materials" of FG. She has published more than 300 SCI papers and leads the 2D Foundry group at ICMM/CSIC https://sites.google.com/view/2dfoundry

Abstract:

During the last decades, there has been enormous advances in the synthesis of 2D Van der Waals (VdW) materials, their heterostructures and twisted homostructures, that have attracted the attention of the scientific community. However, the representation of robust orders like ferroelectricity, ferromagnetism or superconductivity, although extremely interesting from a fundamental viewpoint, is scarce among these materials. Here we propose a strategy to incorporate highly correlated states by combining 2D VdW with non VdW ultrathin complex transition metal oxides (TMOs) in hybrid architectures [1]. We also explore the new physics emerging from twisted layers of TMOs that render new property landscapes only attainable with TMOs as freestanding layers [2].

[1] Sergio Puebla et el. Nano Letters 22 , 7457-7466, (2022)

[2] Gabriel Sanchez- Santolino et al arXiv preprint arXiv:2301.04438, (2023)

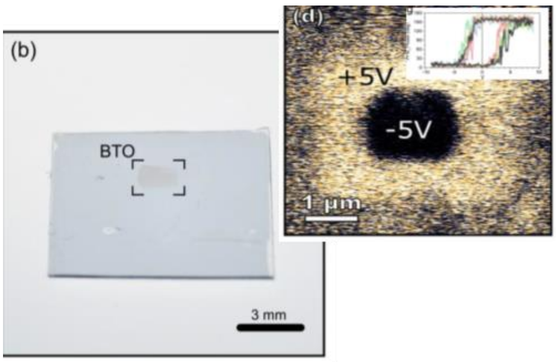

Figure 1: Delaminated BaTiO3 BTO) at the mm scale. Free standing BTO layers keep the ferroelectric functionality at RT

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Title: Ferroelectric domain structures in twistronic TMD bilayers

First Name: Vladimir

Last Name: Falko

Affiliation: University of Manchester

Short Biography:

Vladimir Falko MAE is condensed matter theorist responsible for several advances in the theory of electronic and optical properties of atomically thin two-dimensional crystals and their heterostructures (graphene, transition metal dichalcogenides, post-transition metal chalcogenides), and he worked on various general aspects of quantum transport and fundamentals of nanoelectronics. His current interest is focused on 2D materials twistronics. He is Professor of Condensed Matter Theory at the University of Manchester and Director of the National Graphene Institute, and he leads WP Enabling Science in Graphene Flagship.

Abstract:

We discuss lattice structure and physical properties of twisted bilayers of transition-metal dichalcogenide. We show that for ‘marginally’ (small-angle) lattice reconstruction results in the neworks of domains with the energertically preferential stacking and domain walls, which are similar to dislocations in bulk crystals. In some cases, such domains feature weak interfacial ferroelectric polarisation, switchable by the mututal sliding of the two monolayers. This gives rise to the tunability of domain structure by an out-of-plane electric field, manifested in the hysteretic field-effect transistor operation and readable optically by the linear Stark shift of the interlayer excitons.

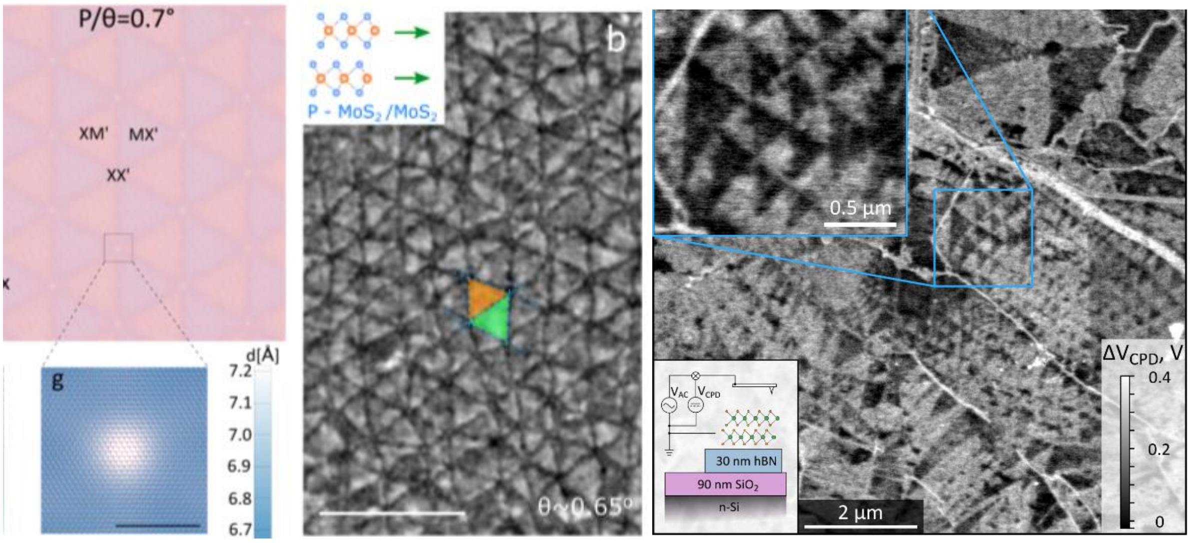

Figure: Calculated (left) and measured using STEM (middle) domain structure of reconstructed MoS_2/MoS_2 bilayer with parallel orientation of unit cells (R-type). Right: SKPM map of a large-area twistronic bilayer demonstrating ferroelectric polarization of domains.

Title: Advances in Organic 2D Crystals —From On-Water Surface Chemistry to Functional Applications

First and last name: Xinliang Feng

Affiliation: Max Planck Institute of Microstructure Physics & Technische Universitaet Dresden

Short Biography:

Prof. Feng is a director at the Max-Planck Institute of Microstructure Physics and the head of the Chair of Molecular Functional Materials at Technische Universität Dresden. He has been awarded several prestigious prizes such as IUPAC Prize for Young Chemists (2009), 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, 2014-2022), *Small* Young Innovator Award (2017), Hamburg Science Award (2017), EU-40 Materials Prize (2018), ERC Consolidator Grant Award (2018). He is a member of the European Academy of Sciences (2019), Academia Europaea (2019), and German Academy of Science and Engineering (acatech, 2021). He is an Advisory Board Member for *Advanced Materials*, *Chemical Science, Journal of Materials Chemistry A*, *ChemNanoMat*, *Energy Storage Materials*, *Small Methods*, *Chemistry -An Asian Journal, Trends in Chemistry, etc*. He is the Head of ESF Young Research Group "Graphene Center Dresden", Working Package Leader of WP Functional Foams & Coatings for European Commission's pilot project "Graphene Flagship", and spokesperson for the DFG Collaborative Research Center for the Chemistry of Synthetic 2D Materials (2020-).

Abstract:

In contrast to the tremendous efforts dedicated to the exploration of graphene and inorganic 2D crystals such as metal dichalcogenides, boron nitride, black phosphorus, metal oxides, and nitrides, there has been much less development in organic 2D crystalline materials, including the bottom-up organic/polymer synthesis of graphene nanoribbons, 2D metal-organic frameworks, 2D polymers/supramolecular polymers, as well as the supramolecular approach to 2D organic nanostructures. One of the central chemical challenges is to realize a controlled polymerization in two distinct dimensions under thermodynamic/kinetic control in solution and at the surface/interface. In this talk, we will present our recent efforts in bottom-up synthetic approaches toward novel organic 2D crystals with structural control at the atomic/molecular level. On-water surface synthesis provides a powerful synthetic platform by exploiting surface confinement and enhanced chemical reactivity and selectivity. We will particularly present a surfactant-monolayer assisted interfacial synthesis (SMAIS) method that is highly efficient in promoting the programmable assembly of precursor monomers on the water surface and subsequent 2D polymerization in a controlled manner. 2D conjugated polymers and coordination polymers belong to such material classes. The unique 2D crystal structures with possible tailoring of conjugated building blocks and conjugation lengths, tunable pore sizes and thicknesses, as well as impressive electronic structures, make them highly promising for a range of applications in electronics, optoelectronics,

and spintronics. Other physicochemical phenomena and application potential of organic 2D crystals, such as in membranes, will also be discussed.

[1] Wang, M. et al. *Nat. Mater.* In press (2023)
[2] Sabaghi, D. et al. *Nat. Commun.* **14**, 760 (2023).
[3] Zhang, Z. et al. *Nat. Commun.* **13**, 3935 (2022).
[4] Wang, Z. et al. *Nat. Synth.* **1**, 69-76 (2022).
[5] Wang, Z. et al. *Adv. Mater.* **34**, 2106073 (2022).
[6] Lu, Y. et al. *Nat. Commun.* **13**, 7240 (2022).
[7] Seki, T. et al. *Chem* **7**, 2758-2770 (2021).
[8] Liu, K. et al. *Angew. Chem. Int. Ed.* **60**, 1-7 (2021).
[9] Sahabudeen, H. et al. *Angew. Chem. Int. Ed.* **59**, 6028-6036 (2020).
[10] Qi, H. et al. *Sci. Adv.* **6**, eabb5976 (2020).
[11] Park, S. et al. *Angew. Chem. Int. Ed.* **132**, 8295-8301 (2020).
[12] Zhang, T. et al. *Nat. Commun.* **10**, 4225 (2019).
[13] Dong, R. et al. *Nat. Mater.* **17**, 1027-1032 (2018).
[14] Sahabudeen, H. et al. *Nat. Commun.* **7**, 13461 (2016).