

EU Graphene Flagship – US NSF Workshop

2D Materials, Heterostructures and Devices

10-12 October, 2016

National Graphene Institute, University of Manchester

This workshop, focused on 2D materials beyond graphene and their heterostructures, will address:

- synthesis of these materials and methods of fabrication of devices;
- physical properties of planar and vertical heterostructures of 2D materials;
- developing predictive modelling and simulation techniques, including 2DM discovery;
- in situ and ex situ characterization of 2D materials.

The workshop aims to catalyse collaborations that can lead to personnel exchange, discuss synergistic mechanisms for sharing research infrastructure to streamline efforts and consolidate resources. The workshop programs will include an Open meeting of Flagship's Division One 'Enabling Science and Materials' and break-out sessions to discuss principles and practicalities of transatlantic collaborations:

- **11 Oct Questions for breakout-sessions (BS1, BS2, BS3)**
 - What are the S&T topics that would benefit most from transatlantic collaboration?
 - What benefits does such collaboration bring in each of those areas, on each side of the ocean?
 - Is there a need / how would it complement existing schemes?
 - What could such a mechanism look like?
 - To what extent are collaborations in place today already addressing the necessary issues?
 - What level of interest should be expected?
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- **12 Oct Questions for breakout-sessions**
 - **BS4 Materials creation strategies, supply & exchange including standards**
 - How to organise materials flow between groups – if any (sharing protocols and best practices)
 - Are standards needed? Standardised characterisation?
 - Is access to complementary facilities a desirable/feasible option?
 - Who should be the target audience: academia, industry, or both?
 - What are concrete goals to be achieved?
 - How to measure progress?
 - **BS5 2DM devices applications & 2DM innovation and commercialization**
 - What TA collaboration can do to accelerate innovation based on new devices?
 - What could be the lowest lying fruits for Trans-Atlantic (TA) collaboration?
 - Would IP rights be a problem for TA collaboration?
 - Who should be the target audience: academia, industry, or both?
 - What are concrete goals to be achieved?
 - How to measure progress?

| October 10 th | |
|--------------------------|---|
| 08:30-09:20 | Registration |
| 09:20 | Opening Session <i>Chair: James Hwang</i> |
| 09:30-09:55 | Atomically thin semiconductors and heterostructures <i>Tony Heinz</i> |
| 09:55-10:20 | Dynamics of photons, plasmons and electrons in 2DM <i>Frank Koppens</i> |
| 10:20-10:45 | From black phosphorus to phosphorene <i>Peide Ye</i> |
| 10:45-11:10 | 2DM heterostructures for tunnelling and optoelectronic applications <i>Konstantin Novoselov</i> |
| 11:10-11:30 | Coffee break |
| | Session: 2DM for devices <i>Chair: Alan Seabaugh</i> |
| 11:30-11:55 | hBN growth @ WP 'Enabling Materials' <i>Annick Loiseau</i> |
| 11:55-12:20 | (Mo,W)Te₂ alloys: phase diagram and phase engineering <i>James Hone</i> |
| 12:20-12:45 | Transition metal trichalcogenides <i>Francois Peeters</i> |
| 12:45-14:15 | Lunch & NGI tours |
| | Open meeting of Flagship's Division One 'Enabling Science and Materials' <i>Chair: Jonathan Coleman</i> |
| 14:15-14:40 | Overview of WP 'Enabling Research' <i>Vladimir Falco</i> |
| 14:40-15:05 | Ab initio modelling of 2DM <i>Matteo Calandra</i> |
| 15:05-15:30 | Surface and interface transport in devices based on semiconducting TMDs <i>Alberto Morpurgo</i> |
| 15:30-15:55 | InSe: from nanosheets to vdW heterostructures <i>Amalia Patane</i> |
| 15:55-16:20 | Coffee break |
| | Open Division One meeting – continued <i>Chair: Tim Wehling</i> |
| 16:20-16:45 | Spintronics in Graphene Flagship <i>Bart van Wees</i> |
| 16:45-17:10 | Spin-orbit and exchange proximity effects in graphene <i>Jaroslav Fabian</i> |
| 17:10-17:35 | Controlling spin dynamics in graphene <i>Stephan Roche</i> |
| 17:35-18:00 | Graphene in heterostructures with metals: superconductivity and magnetism <i>Irina Grigorieva</i> |
| 18:00-19:30 | Reception and Poster Session I |

| October 11 th | | | |
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| | Open Division One meeting – continued <i>Chair: Pertti Hakkonen</i> | | |
| 09:00-09:25 | Overview of WP ‘Enabling Materials’ <i>Mar Garcia-Hernandez</i> | | |
| 09:25-09:50 | Update on TMD growth <i>Andras Kis</i> | | |
| 09:50-10:15 | Large Scale synthesis of TMD films and heterostructure <i>Georg Duesberg</i> | | |
| 10:15-10:40 | Strains and electrons in two dimensional materials <i>Francisco Guinea</i> | | |
| 10:40-11:00 | Coffee break | | |
| 11:00-12:30 | Session: General discussions of collaboration mechanisms within and beyond US/EU research programs <i>Panel: Jari Kinaret, Dimitris Pavlidis, Chagaan Baatar, Jennifer Becker</i> <i>Chair: Wide Hogenhout</i> | | |
| | BoS1: A-J (F3 meeting hall) | BoS2: K-R (F1 discussion area) | BoS3: S-Z (F2 discussion area) |
| 12:30-14:00 | Lunch & NGL tours | | |
| | Session: 2DM Synthesis and production <i>Chair: Wlodek Strupinski</i> | | |
| 14:00-14:25 | Top-down and bottom-up synthesis of 2D TMDs and their device applications <i>Anupama Kaul</i> | | |
| 14:25-14:50 | Epitaxial growth of 2D Chalcogenides <i>Joan Redwing</i> | | |
| 14:50-15:15 | High-mobility graphene from chemical vapour deposition on reusable copper <i>Christoph Stampfer</i> | | |
| 15:15-15:40 | The growth of strained graphene and hexagonal boron nitride by MBE <i>Peter Beton</i> | | |
| 15:40-16:05 | 2DM production via liquid phase processing <i>Stephen Hodge</i> | | |
| 16:05-16:30 | Coffee break | | |
| | Session: Applications of 2DM & heterostructures <i>Chair: Andrey Turchanin</i> | | |
| 16:30-16:55 | Electrons, phonons, and unconventional applications of 2D materials <i>Eric Pop</i> | | |
| 16:55-17:20 | Electronic and photoelectronic properties of hybrid vdW heterojunctions <i>Lincoln Lauhon</i> | | |
| 17:20-17:45 | Heterojunctions of 2DM and their potential applications <i>Huili Grace Xing</i> | | |
| 17:45-18:10 | Black phosphorus optoelectronics and electronics <i>Fengnian Xia</i> | | |
| 18:10-19:30 | Reception and Poster Session I | | |

| October 12 th | | | |
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| | Session: 2DM applications <i>Chair: Cinzia Casiraghi</i> | | |
| 09:00-09:25 | Update on progress, prospects and challenges on flexible 2D electronics <i>Deji Akinwande</i> | | |
| 09:25-09:50 | Electronic, electrodynamic, and optoelectronic technology with vdW Heterojunctions <i>Donhee Ham</i> | | |
| 09:50-10:15 | 2DM nanosculpting and bioelectronics applications <i>Marija Drndic</i> | | |
| 10:15-10:30 | Grab your coffee | | |
| 10:30-11:15 | <table border="1"> <tr> <td>BoS4 (F3 hall): 2DM creation strategies, supply & exchange, including standards <i>Chair: Luigi Colombo</i></td> <td>BoS5 (Discussion area F1): 2DM devices applications & 2DM innovation and commercialization <i>Chair: Chun-Yun Sung</i></td> </tr> </table> | BoS4 (F3 hall): 2DM creation strategies, supply & exchange, including standards <i>Chair: Luigi Colombo</i> | BoS5 (Discussion area F1): 2DM devices applications & 2DM innovation and commercialization <i>Chair: Chun-Yun Sung</i> |
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| 11:15-12:15 | Session: Reports from break-out sessions and general discussions <i>Chair: Ana Helman</i> | | |
| 12:15-14:00 | Lunch & NGL tours | | |
| | Session: Optics of 2DM & heterostructures <i>Chair: Alexander Tartakovski</i> | | |
| 14:00-14:25 | Exchange field Effects in vdW ferromagnetic semiconductor heterostructures <i>Xiaodong Xu</i> | | |
| 14:25-14:50 | Scalable synthesis of WS₂ on graphene and hBN: an all-2D platform for light-matter transduction <i>Camilla Coletti</i> | | |
| 14:50-15:15 | Superconductivity in 2DM and heterostructures <i>Gary Steele</i> | | |
| 15:15-15:40 | Moiré superlattice modulation of optical and topological properties in heterobilayers of TMDs <i>Wang Yao</i> | | |
| 15:40-16:05 | Optical properties of semiconducting TMDs: observations and puzzles <i>Marek Potemski</i> | | |
| 16:05-16:30 | Conclusions and end of the meeting | | |

Abbreviations:

2DM = two-dimensional materials

vdW = van der Waals

TMD = transition metal dichalcogenides