GRAPHENE MALAYSIA 2016

8 - 9 NOVEMBER 2016
KUALA LUMPUR, MALAYSIA

ABSTRACTS BOOK

Organisers:

NANOMALAYSIA™ PHANTOMS foundation

Supported by:

MOSTI — Kementerian Sains, Teknologi dan Inovasi / Ministry of Science, Technology and Innovation

MITI Malaysia — Ministry of International Trade and Industry

Strategic Partners:

Agensi Inovasi Malaysia

MIDA — Malaysian Investment Development Authority

National Graphene Action Plan 2020

www.graphenemalaysiaconf.com

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MINISTERS´ STATEMENTS

YB DATUK SERI PANGLIMA MADIUS TANGAU
Minister of Science, Technology and Innovation
(Malaysia)

"Graphene as I see it, can re-energise Malaysia's economy to become more competitive in the sense that economic growth is sustained and the nation can now create and maintain an environment for wealth creation.
Malaysia's new economy will be accelerated by industry development; generating wealth from Science, Technology and Innovation particularly through graphene-based products such as high value tyres, better performing plastics and longer lasting batteries."

YB DATO' SRI MUSTAPA MOHAMED
Minister of International Trade and Industry
(Malaysia)

"Researchers from all around the globe have been scrambling to better understand graphene, dubbed as the supermaterial. As such, the Graphene Malaysia 2016 conference is timely in providing valuable insights and platform to further discuss the potential of graphene to be a key material in industries such as automotive, electronics and medicine. Graphene could be the resource that will drive the next era of human history, but we cannot unlock its true potential without addressing the challenges that come with it. Malaysia is keen to be part of this process."

NANOMALAYSIA'S CHAIRMAN STATEMENT

YBHG. PROF. EMERITUS DATO' IR. DR. MOHAMAD ZAWAWI BIN ISMAIL
Chairman of NanoMalaysia Berhad
(Malaysia)

"Materials throughout history have affected the development of society as we have seen with iron, brass and steel, and in the last two decades silicon materials have enabled the advancement of computers and the ubiquity of information technology. Today, the emergence of the supermaterial graphene is set to alter the future. It is hard to imagine that a single layer of graphite which is graphene could take some amazing properties, enough to have drastic implications for the future of physics, engineering, and industry. This is what inspired us in NanoMalaysia for the last five years to think of a wide range of uses for the material. At the same time encouraging government, university, and industry collaboration in order that the nation will not miss the opportunity to reap benefits from it. We are happy to co-organise Graphene Malaysia 2016, a platform for networking and collaboration and welcome all participants."

FOREWORD

On behalf of the Organising Committee we take great pleasure in welcoming you to Kuala Lumpur for the first edition of the Graphene Malaysia International Conference.

Graphene Malaysia 2016 is jointly organized by NanoMalaysia Berhad and Phantoms Foundation with the support of the Ministry of Science, Technology and Innovation (MOSTI), Ministry of International Trade and Industry (MITI). Malaysian Investment Development Authority (MIDA), Agensi Inovasi Malaysia (AIM) and the National Graphene Action Plan 2020 act as the strategic partner for this event. The conference will be centered on graphene industry interaction and collaborative innovation. The event is launched under the National Graphene Action Plan 2020 (NGAP 2020), which is expected to generate about 9,000 jobs and RM20 (US$4.86) billion GNI impact by the year 2020.

The conference will feature a plenary session and extensive thematic workshops (Graphene production / Applications of graphene and related materials / Metrology, characterization and standardization / Funding & infrastructure support) and a significant exhibition.

We are indebted to the following institutions for their help and/or financial support:
Ministry of Science, Technology and Innovation (MOSTI) | Ministry of International Trade and Industry (MITI) | National Graphene Action Plan 2020 (NGAP2020) | Agensi Inovasi Malaysia (AIM) | Malaysian Investment Development Authority (MIDA).

We would also like to thank the following companies for their participation as exhibitors: RGS Corporation Sdn Bhd, Aseptec Sdn Bhd, Anton Paar Malaysia Sdn Bhd, LabAlliance Sdn Bhd, Quasi-S Technology, Metrohm (Malaysia) Sdn Bhd, aNexus, Nexus Analytics Sdn Bhd, Malaysian Investment Development Authority (MIDA), MIMOS Semiconductor (M) Sdn Bhd, Crest NanoSolutions (M) Sdn Bhd, Grafoid Inc., QuantumWise A/S and NanoMalaysia.

We would also like to thank all the speakers and attendees that joined us this year.

We truly hope that Graphene Malaysia 2016 serves as a platform for interaction and collaboration.

In addition, thanks must be given to the staff of all the organizing institutions whose hard work has helped in planning this conference.

DR. REZAL KHAIRI AHMAD
Chief Executive Officer
NanoMalaysia Berhad (Malaysia)

DR. ANTONIO CORREIA
President
Phantoms Foundation (Spain)

SPEAKER'S PROFILE

AHMAD KHAIRUDDIN ABDUL RAHIM

Malaysian Investment Development Authority, Malaysia

He is currently the Executive Director, Manufacturing Development (Resource) of the Malaysian Investment Development Authority (MIDA), a Government agency that drives investments into the manufacturing and services sectors in Malaysia. His portfolio covers three (3) industries namely Chemical and Advanced Materials, Food Technology and Sustainable Resources and Life Sciences and Medical Technology. He holds a Masters Degree in International Business and started his career with MIDA in 1991. Since joining MIDA, he had served in several divisions in MIDA. He was also involved in various projects on industrial development, such as the formulation of the Third Industrial Master Plan, Green Technology Master Plan and the Eleventh Malaysia Plan (2016-2020) and a Secretariat to the Malaysian Logistics Council. Currently, he is a member to the Industry Advisory Panel (IAP) for three (3) high potential growth industries namely Chemical & Advanced Materials, Medical Devices and Pharmaceuticals; among the prominent subsectors in Eleventh Malaysia Plan.

MURNI ALI

NanoMalaysia Berhad, Malaysia

Received her Bachelor of Science (Hons) Biomedical Degree from UPM and Master of Business Administration in International Business from University of East London, United Kingdom. With more than 10 years' experience in the field of Business Development and Marketing, she is currently heading the National Graphene Action Plan 2020 Office.

Ms. Murni brings diversified experiences in operations and managerial functions of the Business Development and Marketing fields. Well defined understanding of the business-technology interface and capacity to identify and align clients' emerging technology needs with products and services, she has been involved in various business-development disciplines underscores expertise in engaging decision makers and devising winning sales strategies and solutions exercises.

RAZIF ABDUL AZIZ

Cradle Fund Sdn. Bhd., Malaysia

Mr. Encik Razif Abdul Aziz serves as Chief Operating Officer at Cradle Fund Sdn Bhd since January 2016. Previously, he joined Malaysian Biotechnology Corporation (BiotechCorp) in 2006.

Mr. Aziz served as the Chief Operating Officer of Malaysian Genomics Resource Centre Berhad since December 3, 2012. He is a Barrister-at-Law from Lincoln's Inn, London (1992). Mr. Aziz holds a degree in Law from Coventry Polytechnic in 1991.

FRANCESCO BONACCORSO

Istituto Italiano di Tecnologia (IIT) - Graphene Labs, Italy

Gained a PhD from the Department of Physics, University of Messina in Italy after working at the Italian National Research Council, the Engineering Department of Cambridge University (UK) and the Department of Physics and Astronomy of Vanderbilt University (USA).

In June 2009 he was awarded a Royal Society Newton International Fellowship at the Engineering Department of Cambridge University, and elected to a Research Fellowship at Hughes Hall, Cambridge. In April 2014 he joined the Istituto Italiano di Tecnologia, Graphene Labs. He was responsible in defining the ten years scientific and technological roadmap for the graphene flagship programme. His research interests encompass solution processing of carbon nanomaterials (such as graphene, nanotubes and nanodiamonds) and inorganic layered materials, their spectroscopic characterization, incorporation into polymer composites and application in solar cells, light emitting devices, lithium-ion batteries and ultrafast lasers.

CHESTER BURTT

Grafoid Inc., Canada

Chester Burtt is a Director of critical material developers Focus Graphite Inc. and Stria Lithium Inc. He also serves as Director of Strategic Development for Grafoid Inc, a global leader in graphene application development.

Mr. Burtt is President of Chester Burtt & Associates Ltd. ("CBAL") a corporate and public affairs advisory firm that specializes in connecting private and public companies with domestic and international opportunities. CBAL arranges for the provision and supply of financial services in mergers, acquisitions and joint ventures. Working through an international network and associate firms, CBAL has a 25-year history of offering a full range of services to assist companies with strategy development and decisions to best suit their investor and corporate relations.

Mr. Burtt graduated from Wilfrid Laurier University in Waterloo, Ontario with an MA in Political Science and spent some 15 years working in the Canadian political arena.

ANTONIO H. CASTRO NETO

National University of Singapore, Singapore

Professor A. H. Castro Neto got his Ph.D. in Physics at University of Illinois at Urbana Champaign in 1994. In 1994, he moved to the Institute for Theoretical Physics at the University of California at Santa Barbara as a postdoctoral fellow.

In 1995, he became an Assistant Professor at University of California at Riverside. In 2000, he moved to Boston University as Professor of Physics. At Boston, Prof. Castro Neto became one of the leading theorists in the study of graphene. In 2010, Prof. Castro Neto became the Director of the Graphene Research Center and Distinguished Professor at the National University of Singapore . In 2003, Prof. Castro Neto was elected a fellow of the American Physical Society. He is the colloquia Editor for Reviews of Modern Physics, and co-editor for Europhysics Letters. Prof. Castro Neto has authored more than 200 manuscripts and has published in prestigious journals including Science, Nature Materials, Nature Physics, and Physical Review Letters, and has over 12,000 citations. Prof. Castro Neto has given more than 200 seminars worldwide.

ANTONIO CORREIA

Phantoms Foundation, Spain

Antonio Correia is the founder and President of the Phantoms Foundation & Doctor in Physics (Université Paris 7, France). Has worked in France at the CNRS and the CSIC in Spain, both national research institutes.

Currently, he is president of the Phantoms Foundation, a non-profit organization created in November 2002 in Madrid, and serves also as the Coordinator of the Eureka Cluster on Graphene and 2D materials, nanoSpain and M4nano (nano for modelling) networks and of the nanotechnology plan for ICEX (Spain Trade & Investment). Has been involved in more than 15 EU funded projects and author of more than 60 publications and book chapters. He serves also as a Chairman of major conferences in Graphene Worldwide.

PEDRO M. DA COSTA

King Abdullah University of Science and Technology
KAUST, Saudi Arabia

He is an Assistant Professor at the Materials Science and Engineering Program of the King Abdullah University of Science and Technology (KAUST) and Adjunct Assistant Professor at the University of Aveiro (UA), Portugal .

Previously, he was a Junior Research Group Leader at UA while also holding a position as Alexander von Humboldt Fellow at the IFW-Dresden, Germany. Dr. Costa worked as a post-doctoral research associate at the National Institute for Materials Science (NIMS), Japan, and, before that, at the Department of Materials Science and Metallurgy of the University of Cambridge, United Kingdom. He has been a short-term visitor on various occasions at IFW-Dresden, NIMS, Technical University of Denmark, Monash University (Australia), McMaster University (Canada) and University of Heidelberg (Germany). His graduate studies were carried out under the supervision of Prof. Malcolm L. H. Green FRS, at the Inorganic Chemistry Laboratory, University of Oxford, United Kingdom.

PEDRO GOMEZ-ROMERO

ICN2 (CSIC-BIST), Spain

BSc and MSc Universidad de Valencia, Spain. PhD in Chemistry, Georgetown University, USA, 1987, with Distinction. CSIC Researcher since 1990 (ICMAB, 1990-2007).

Sabbatical as NATO Senior Research Fellow at the National Renewable Energy Laboratory (Golden, CO, USA, 1998-99). CSIC Full Research Professor (2006-) and Group Leader of NEO-Energy lab at CIN2 (CSIC) (2007-2013) now part of ICN2. Fellow of the Royal Society of Chemistry. Directs projects on hybrid organic-inorganic nanostructures, nanocomposite materials for energy storage and conversion (lithium batteries, supercapacitors, PEM FCs, solar-thermal energy, nanofluids, graphene). Author of 102 (ten to the two) scientific publications in refereed international journals.

SHU-JEN HAN

Nanoscale Science & Technology IBM T.J. Watson Research Center, USA

Dr. Shu-Jen Han is a manager and Research Staff Member at the IBM T. J. Watson Research Center. He holds a Ph.D. in Materials Sci. & Eng. and Ph.D. minor in Electrical Engineering from Stanford University (2007), and a B.S. from National Tsing-Hua University, Taiwan (1999).

His current research activities encompass the heterogeneous integration using low-dimensional carbon nanomaterials to develop novel nanodevices, for applications such as post-Si electronics, optoelectronics, plasmonics and biosensing. His group is recognized for demonstrating the world's most advanced graphene circuit as well as the smallest carbon nanotube transistors that could outperform Silicon. He has authored or co-authored over 70 technical publications and his research has been featured by media. He holds over 100 US patents, and was appointed as IBM Master Inventor (2012, 2015).

AZMAN BIN HASSAN

Universiti Teknologi Malaysia, Malaysia

He is a Professor and currently serving as a Deputy Dean (Research and Innovations) in the Faculty of Chemical Engineering, Universiti Teknologi Malaysia (UTM). He is also serving as a UTM Senate member for the last four years.

He started his career with UTM in 1984 and was appointed as a Professor in 2007. He received his PhD from Loughborough University (UK) in 1997. He was the Deputy Director (Research Publications) for Research Management Center from 2008 to 2011. From 2012 to 2013, he was the Director of Research Publications Center. He was the Head of Polymer Engineering Department from 2002 to 2008. His area of research interests includes, polymer blends, thermal characterization, toughened polymers, natural fibres composites, graphene, nanocomposites and flame retardant polymers. He has published over 300 papers in journals and conferences proceeding and book chapters. He is currently the Editor-in-Chief of the Malaysian Polymer Journal and Perintis eJournal. He has also been appointed as reviewer for more than 20 different journals.

KUAN-TSAE HUANG

AzTrong, USA/Taiwan

He is an expert in Graphene and graphene commercialization in heat spreading, battery & supercapacitor, composites and other graphene applications. He had 20+ years working at IBM, was a Vice President, played a key role to help IBM successfully transformed into a global service company, in charge of e-commerce implementation, intellectual capital and asset Management, solution offerings, etc.

He is an experienced business transformation and implementation consultant. Dr. Huang's career included the President of National Taiwan Normal University; visiting faculty of several universities in Singapore, US and Taiwan; National Institute of Health, US, etc. He is also an experienced entrepreneur in Silicon Valley. Currently, he is the Chairman/CEO of AzTrong (Graphene & Applications), Senior Advisor to Ditthavong & Steiner patent law firm, Ditthavong & Steiner, Chairman of Taskco e-Business Corporation.

AMIRUDDIN KEMAT

Malaysia Debt Ventures Berhad (MDV), Malaysia

He is the Senior Vice President, Corporate Planning Division of Malaysia Debt Ventures Berhad (MDV). He is a graduate of University of Alabama, USA and obtained his degree in Bachelor of Science & Business Administration majoring in Corporate Finance & Investment Management.

He has over 15 years of broad-based management and extensive business development experience in various industries. His credentials also include more than 10 years in the financial institutions undertaking credit evaluation, business development and structuring credit facilities for the SMEs. He was previously with PBA Holdings Bhd (PBAHB) undertaking responsibilities on enhancing business network, strengthening stakeholder relations, identifying business opportunities, ensuring good corporate governance and overseeing the group risk management plan. His scope of work also expanded after being appointed as the Risk Management Committee Chairman of PBAHB group who leads and facilitates the implementation of risk management plan holistically. Prior to this, he was the Business Development Manager of IFS Capital (M) Sdn Bhd which is responsible in building up revenue channels covering credit assessment, business development and identifying business potential and target sectors.

KRZYSZTOF KOZIOL

FGV Cambridge Nanosystems, UK

He is the co-founder and Executive Director of FGV Cambridge Nanosystems, involved in the technology development and responsible for business development and corporate governance of the Company

He co-shares this role with his academic positions as director of studies at Pembroke College Cambridge, Head of Electric Carbon Nanomaterials research and president of The International Society of Nanoscience.

Krzysztof graduated with a first class degree in Chemistry and Chemical Engineering from Silesian University of Technology in Poland in 2001, and subsequently with a PhD in Materials Science from University of Cambridge. At the University of Cambridge he held prestigious positions of Oppenheimer Research Fellow and Royal Society University Research Fellow. Krzysztof is a reviewer for various international journals and author of more than 130 peer reviewed scientific articles, 2 book contributions and 16 patents.

TAAVI MADIBERK

Skeleton Technologies, Estonia

He is the Co-Founder and Chief Executive Officer at Skeleton Technologies. His business development, sales and marketing and company management skills have been instrumental in setting-up and driving growth.

He has been the driving force for excellent customer traction, (the company counts as customers European Space Agency and several Tier 1 automotives), business strategy (leveraging the advantage in materials technology to energy storage cells and modules), product development and fundraising from venture capital, private equity and public sources in German, Estonian and EU level. Mr Madiberk brings knowledge from the IT, locomotive and NGO sectors from his experience prior to Skeleton Technologies.

ABDUL RAHMAN MOHAMED

Universiti Sains Malaysia, Malaysia

Has been appointed by the Ministry of Higher Education as the Deputy Vice-Chancellor, Industry and Community Network of Universiti Sains Malaysia for a term of three years effective from 1st of May 2016.

A Top Research Scientist in Malaysia (TRSM) and an expert in Reaction Engineering and Catalysis, Air Pollution Monitoring and Control, Fuel Technology and Nanotechnology obtained his undergraduate degree in Chemical Engineering from the University of Southern California, USA and later graduated with a master of science (Chem. Eng.) and PhD in the same field from the University of New Hampshire, both in the United States. Professor Dr. Abdul Rahman Mohamed began his career at USM as a lecturer in 1993. He has served as the Director of the Industry Collaboration Centre as well as being among the main academicians heading the Research and Development Division of 'Collaborative Research in Engineering, Science and Technology'. He is well-known as a researcher and scientist with more than 80 grants awarded to him internationally, valued more than RM18 million, and having publications with high-impact citations, in addition to hundreds of research papers in various well-renowned academic journals, along with academic and professional networks from various countries including Japan and France.

PONTUS NORDIN

Saab AB, Saab Aeronautics, Sweden

Technical Fellow, Overall Design and Airframe Technologies.

Pontus Nordin has more than 35 years of experience from technology development related to materials and processing-, design and manufacturing of composite structures. His current focus is development of aerostructures with multifunctional properties and improved airframe performance through engineered nanocomposite materials.

NORAZIRA BINTI OTHMAN

NANO*Verify* Sdn .Bhd., Malaysia

Master of Engineering (Materials and Technology), University of Malaya, Malaysia. Bachelor of Science with Honours (Chemical Technology), Universiti Kebangsaan Malaysia (National University of Malaysia). Operation Executive (NanoVerify Sdn Bhd):

- Monitoring and ensuring the smoothness of the development activities
- Supporting the Managing Director from time to time
- Identify reference materials for NANOVerify Programme (SOPs and International Standards
- Identify partners and labs for NANOVerify Programme

KU KOK PENG

Performance Management & Delivery Unit (PEMANDU), Malaysia

He joined PEMANDU in Aug 2010 as Associate Director, Communications & Investor Relations. Since Aug 2011, he is Director for ETP Investment, working with various investment agencies to coordinate, promote, track and report investment as well as PEMANDU's permanent representative to the Investment Committee co-chaired by the Minister of International Trade & Industry and PEMANDU CEO.

In July 2012, he added Palm Oil & Rubber NKEA to his portfolio and assumed the Innovation portfolio in March 2014.

Ku co-authored a Harvard Business School case study on the ETP published in late 2012. In summer 2013, he participated in the International Visitor Leadership Programme by the State Dept of States.

Previously, Ku served FleishmanHillard for seven years and last held the position of Managing Director, Market Development, SEA.

ELENA POLYAKOVA

Graphene Laboratories Inc., USA

She founded Graphene Laboratories in 2009 and serves as its President and Chief Executive Officer. Dr. Polyakova has been Co-Chief Executive Officer of Graphene 3D Labs, Inc. since August 12, 2015 and served as its Chief Operating Officer from August 11, 2014 to August 2015.

Dr. Polyakova has been a Member of Advisory Board at Lomiko Metals Inc. since April 30, 2013. She has been a Director of Graphene 3D Labs, Inc. since August 8, 2014. Dr. Polyakova is an invited speaker at many international forums and conferences, and her input on the graphene industry is regularly published by journalists covering business and technology. Dr. Polyakova has won numerous awards for her entrepreneurship. She received her Masters' degree in Physics and Applied Mathematics with honors from the Moscow Institute of Physics and Technology, and her Ph.D. in Chemistry from the University of Southern California.

MARK ROZARIO

Agensi Inovasi Malaysia (AIM), Malaysia

Mark Rozario was Group Managing Director of a Malaysian listed property group, before stepping down to assume his current role at AIM in 2011. He is charged with driving AIM, a government statutory body chaired by the country's prime minister, to implement a national innovation strategy.

AIM was created to jump start wealth creation through knowledge, technology and innovation to stimulate and develop the innovation eco-system in Malaysia by laying down the foundation of innovation to inspire and produce a new generation of innovative entrepreneurs. Mr. Rozario graduated with a BSc degree in Economics from the London School of Economics and is a Fellow of the Institute of Chartered Accountants in England and Wales.

ANTHONY SCHIAVO

Lux Research Inc., Singapore

Anthony Schiavo is an Analyst based in Lux Research's Singapore office. Anthony is a member of the Advanced Materials team, where he conducts research on technical and market trends in areas such as advanced ceramics, metamaterials, composites and coatings.

Prior to joining Lux Research, Anthony received a B.S. in Materials Science and Engineering from Virginia Tech. While at Virginia Tech, Anthony researched biomaterial composite and nanoparticle technology and ethics.

GOPI SEKHAR

GB Sekhar Sdn. Bhd, Malaysia

Mr. Gopinath B. Sekhar has over 33 years of work experience involved in a wide range of activities from commercial trading, manufacture and processing of palm oil and Rubber to Research and Development in polymers, recycling and sustainable solutions. His production process experience ranges from installation and up-grading capacity to running a wide variety of large production units.

The last 15 years with specific involvement in rubber technology, development of processing technologies and application solutions. Having personally developed several new proprietary technologies of commercial significance related to rubber recycling and incorporation of recycled content into value added applications focus of activities have been in Rubber.

ADISORN TUANTRANONT

National Electronics and Computer Technology Center (NECTEC), Thailand

Received B.S. degree in Electrical Engineering from King Mongkut's Institute of Technology Ladkrabang (KMITL) in 1995 and the M.S. and Ph.D. degrees in Electrical Engineering (Photonics and MEMS) from University of Colorado at Boulder in 2001.

From 2001-2014, he has been the Lab director of Nanoelectronics and MEMS Laboratory, National Electronic and Computer Technology Center (NECTEC) in Thailand. Since 2012, he found and works as Director at Thai Organic and Printed Electronics Innovation Center (TOPIC), NSTDA. He authors more than 110 refereed journal papers and 300 international proceeding papers including 1 International PCT patent, 5 granted Thai patents and more than 25 patents holding. He also actively works as Executive Advisor at Thailand Advanced Institute of Science and Technology (THAIST), National Science Technology and Innovation Policy Office, Ministry of Science and Technology of Thailand. He is co-founder of two startup companies, Innophene and ThaiKK Tech. He also is founder of Graphene Thailand, the first graphene research community and networking cluster in Thailand. From 2016, he is elected to be General Secretary of Materials Research Society of Thailand (MRS-Thailand).

VICKNESWARAN VELOO

Scomi Chemicals, Malaysia

Vick has over 19 years of experience in the oil & gas industry. He was previously with Baker Hughes, specializing in drilling and completion fluid systems as well as production chemicals. He led the Engineering Group for the entire Baker Hughes product lines ranging from drilling system tools to well completion systems in Saudi-Bahrain Geomarket as Associate Technical Engineering Director.

In his current role as Chief Technology Officer for Scomi Chemicals, he is responsible for developing technologies and delivering new products at an international level. He's also in charge of overseeing the strategic direction for SESB's fluids and chemical systems in global oil & gas applications. Vick holds a Bachelor Degree in Chemical Engineering from the Malaysian University of Technology and is a member of the Society of Petroleum Engineers. He is also a registered practicing engineer with Board of Engineers, Malaysia.

ARCHANA VENUGOPAL

Texas Instruments, USA

She is a Technologist in Texas Instruments: Analog Technology Development (ATD) group. Over the past eight years, she has immersed herself in graphene research at the University of Texas at Dallas (UTD) and at Texas Instruments – and she is making quite a name for herself in the research community.

She is interested in the development of two-dimensional materials such as graphene. Archana is recognized around for her contributions to research in the form of ATD-Kilby Labs projects, her ATD "Breakthrough Ideas" projects and direct-funded university projects related to graphene. Archana has invented or co-invented more than a dozen projects and has filed (or is in the process of filing) 13 patent applications -12 related to her work on graphene.

WAN RAIHANA WAN AASIM

Malaysian Technology Development Corporation (MTDC), Malaysia

She is an Assistant Vice President at Malaysian Technology Development Corporation (MTDC). At MTDC, her role is to conduct assessment and due diligence on technologies to be commercialised under MTDC's funding programme.

During the three years that Wan Raihana has been at MTDC, she has worked closely with researchers, entrepreneurs and government officials and gained extensive experience in technology transfer and commercialisation.

Prior to joining the corporate world, Wan Raihana was a researcher at the BRAINetwork Centre for Neurocognitive Science of Universiti Sains Malaysia. During her time there, she headed a research team that studied the role of brain steroids in memory and learning. Wan Raihana has 10 years experience in Analytical Chemistry and is a Subject Matter Expert in gas chromatography for the American Chemical Society. She is also a certified HRDF trainer, specialising in subjects related to neurocognition and emotional intelligence.

WON JONG YOO

Samsung-SKKU Graphene-2D Center (SSGC), South Korea

Received his BS and MS degrees from Seoul National University in Korea. In 1993, he received his Ph.D. degree from Rensselaer Polytechnic Institute in USA in the area of the plasma etching properties of Si and SiO_2. Before joining Sungkyunkwan University (SKKU) in 2006, he was an associate professor with National University of Singapore (NUS) where he conducted his research on silicon devices and plasma processes.

His main industrial experiences were research and development in the areas of semiconductor material/device processes at Samsung Semiconductor Research Center, Korea and IBM Research Center. He is currently leading the collaboration research between Samsung and SKKU for developing future graphene devices as the director of Samsung-SKKU Graphene Center. The areas of his current research interests are the electronic and photonic application of 2-dimensional materials including graphene and transition metal dichalcogenides, the fabrication of novel devices using 2-dimensional materials, and the electrical property of memory devices using nano-structures. He has authored or co-authored about 200 journal and conference papers.

HONGWEI ZHU

Tsinghua University, China

He is a Professor of School of Materials Science and Engineering, CNMM Researcher, affiliated Faculty of Graduate School at Shenzhen, Tsinghua University.

He received his B.S. degree in Mechanical Engineering (1998) and Ph.D. degree in Materials Processing Engineering (2003) at Tsinghua University. After Post Doc. studies in Japan and USA, he began his independent career as a faculty member at Tsinghua University (2008~present). His research involves multi-scale synthesis and assembly, characterizations and applications of nanomaterials. He has authored 2 books and 6 invited book chapters, received 15 CN patents, 1 US patent and published 200+ papers with a H-index of 46.

ORGANISERS

PHANTOMS FOUNDATION

The Phantoms Foundation based in Madrid, Spain, focuses its activities on Nanoscience and Nanotechnology (N&N) and is now a key actor in structuring and fostering European Excellence and enhancing collaborations in these fields. The Phantoms Foundation, a non-profit organisation, gives high level management profile to National and European scientific projects (Involved in 11 European projects in the last 10 years either as coordinator or partner) and provides an innovative platform for dissemination, transfer and transformation of basic nanoscience knowledge, strengthening interdisciplinary research in nanoscience and nanotechnology and catalysing collaboration among international research groups.

The Foundation also works in close collaboration with Spanish and European Governmental Institutions to provide focused reports and catalogues on N&N related research areas:

- Coordinator/Editor of the Catalogue of Nanoscience & Nanotechnology Companies in Spain (published for the 6th time), which provides a general overview of the Nanoscience and Nanotechnology companies in Spain and in particular the importance of this market research, etc.
- The most recent document is the Catalogue of Graphene companies worldwide, which provides a general overview of the Graphene industry worldwide in this emerging field and in particular the importance of this market research, etc. Editions: 2014, 2015 and 2016.

Currently, one of the main core activities is to organize International conferences, meetings and workshops in particular in the “Graphene and 2D Materials” area:

- Graphene Conference Series main organizer www.grapheneconf.com
- Graphene Canada Conference Series main organizer www.graphenecanadaconf.com
- graphIn International Symposium (Graphene Industry – Challenges & Opportunities) main organizer www.graphinconf.com
- grapChina Conference Series co-organizer www.grapchina.com

More info: www.phantomsnet.net

NANOMALAYSIA BERHAD

In the National Innovation Council meeting on the 29th of October 2009 chaired by the Right Honorable Prime Minister, Nanotechnology was identified as one of the new growth engines for the New Economic Model (NEM).

On the 14th of February 2011, the National Innovation Council convened and agreed that a nanotechnology commercialisation agency was needed and corresponding activities must be aligned with Agensi Inovasi Malaysia's (AIM) initiatives.

NanoMalaysia Berhad was incorporated in 2011 as a company limited by guarantee (CLG) under the Ministry of Science, Technology and Innovation (MOSTI) to act as a business entity entrusted with nanotechnology commercialisation activities. Some of its roles include:

- Commercialisation of Nanotechnology Research and Development
- Industrialisation of Nanotechnology
- Facilitation of Investments in Nanotechnology
- Human Capital Development in Nanotechnology

More info: www.nanomalaysia.com.my

SUPPORTED BY

MOSTI
KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI
MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

MITI
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MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY

STRATEGIC PARTNERS

NATIONAL GRAPHENE ACTION PLAN 2020

MIDA
MALAYSIAN INVESTMENT DEVELOPMENT AUTHORITY

AGENSI INOVASI MALAYSIA

National Graphene Action Plan 2020 (NGAP 2020)

The National Graphene Action Plan 2020 (NGAP 2020) lays the foundation for Malaysia to catalyse several existing and emerging industries to increase global competitiveness. It is a result of an extensive collaboration between the Malaysian government, private sectors, companies, domestic and international research institutes and academia to assess how Malaysia can benefit from the potential of Graphene.

Key focus areas under the National Graphene Action Plan 2020 include :

1. Rubber
2. Plastics
3. Nanofluids
4. Li-ion battery/ ultracapacitor
5. Conductive ink

Delivery Framework :

1. Awareness building & facilitating “projects”.
2. Access to R&D funding and prototyping.
3. Information on graphene supply.
4. Access to technical experts.
5. Scale up support.
6. Coordinating implementation and monitoring process

Visit our website: www.nanomalaysia.com.my
Facebook: www.facebook.com/NGAP2020
Twitter: www.twitter.com/ngap_2020

MALAYSIAN INVESTMENT DEVELOPMENT AUTHORITY

Malaysian Investment Development Authority (MIDA)

Incorporated as a statutory body under the Malaysian Industrial Development Authority (MIDA) Act, the establishment of MIDA in 1967 was hailed by the World Bank as "the necessary impetus for purposeful, positive and coordinated promotional action" for Malaysia's industrial development. Today, MIDA's is Malaysia's cutting-edge, dynamic and pioneering force in opening pathways to new frontiers around the globe. MIDA assists companies which intend to invest in the manufacturing and services sectors, as well as facilitates the implementation of their projects. The wide range of services provided by MIDA include providing information on the opportunities for investments, as well as facilitating companies which are looking for joint venture partners.

For more information: www.mida.gov.my

EXHIBITORS

RGS Corporation Sdn. Bhd.
(Company No: 864802-V)

RGS Corporation is representing a well know high-end analytical equipment manufacturers providing a solution to customer through scientific discovery, technological development, reliable products and highest quality of support. One of our principle, TechnoSpex Pte Ltd is a manufacturer and developer specializing in micro-spectroscopy for both scientific and industrial markets. We provide complete systems or compact modules that integrate seamlessly with the most upright dark field, polarization, DIC and/or fluorescence microscopes, with mapping capability option. Our uRaman and uSight series of products provide users with state-of-the-art spectroscopy measurement down to 1um spot size with research grade performance, and yet remains highly compact and affordable.

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Anton Paar develops, produces and distributes highly accurate laboratory instruments and process measuring systems, and provides custom-tailored automation and robotic solutions. It is the world leader in the measurement of density, concentration and CO_2 and in the field of rheometry. Anton Paar GmbH is owned by the charitable Santner Foundation.

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Lab Alliance Sdn Bhd is a Malaysia based company incorporated in 2001 with its core business focus in distributing analytical, life sciences and material characterization instruments. LabAlliance's motto "Exploring Scientific Possibilities", wholly acknowledge, respects and supports client's ideas and further position value added inputs to help our customer achieves their research goal.

Whether a laboratory is engaged in academic research, environmental testing, medical diagnostics, pharmaceuticals, petrochemicals or food testing, LabAlliance is able to provide laboratory solutions from a wealth of technologies to meet their full spectrum of needs. We work closely with technology manufacturers and customers to help address global trends that impact human health and the environment, and to anticipate future scientific needs. We believe we have the needed solutions to improve the efficiency of the entire laboratory, from sample prep to data interpretation and management.

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These instruments are essential for both Q/C and Research, for the analysis of materials and semiconductors, chemicals and petrochemicals, food and agriculture, environmental, protein research, and are commonplace in most analytical labs in government regulatory and educational

For more information: www.nexus-analytics.com.my

MIDA
MALAYSIAN INVESTMENT DEVELOPMENT AUTHORITY

Incorporated as a statutory body under the Malaysian Industrial Development Authority (MIDA) Act, the establishment of MIDA in 1967 was hailed by the World Bank as "the necessary impetus for purposeful, positive and coordinated promotional action" for Malaysia's industrial development. Today, MIDA's is Malaysia's cutting-edge, dynamic and pioneering force in opening pathways to new frontiers around the globe. MIDA assists companies which intend to invest in the manufacturing and services sectors, as well as facilitates the implementation of their projects. The wide range of services provided by MIDA include providing information on the opportunities for investments, as well as facilitating companies which are looking for joint venture partners.

For more information: www.mida.gov.my

MIMOS
SEMICONDUCTOR

MIMOS SEMICONDUCTOR (M) Sdn. Bhd. provides R&D shared facilities and services as part of the Malaysian Economic Transformation Programme (ETP) under the Electrical and Electronics National Key Economic Area (E&E NKEA). We aim to be a major catalyst for the development of the E&E industry in Malaysia and the region by offering a flexible engagement model, short turnaround time and integrated value-added services at competitive prices. Among the services offered are Failure Analysis/Material Analysis, Reliability Testing, Wafer & IC Testing, IC Design, Wafer Fabrication & Wafer Prototyping, Rapid Product Prototyping, Nano & MEMS Fabrication & Synthesis, Nanocharacterisation (under the NANOVerify programme) and Hands-On Skills Development Programme

These instruments are essential for both Q/C and Research, for the analysis of materials and semiconductors, chemicals and petrochemicals, food and agriculture, environmental, protein research, and are commonplace in most analytical labs in government regulatory and educational

For more information: www.mimos.my

QuantumWise develops simulation software which enables the simulation of electrical and other materials properties at the atomic-scale. The software is used by major semiconductor companies and a growing presence in the chemical and materials industry, as well as several hundred universities and government labs. The company builds on the long tradition for quantum mechanical research in Denmark and employs a team of top researchers with PhD's in physics, chemistry or computer science. The Company, started in 2008, has more than 30 employees worldwide. It has recent years shown 30% growth rates. It is awarded 2015 and 2016 Børsen Gazelle company.

For more information: www.quantumwise.com

In the National Innovation Council meeting on the 29th of October 2009 chaired by the Right Honorable Prime Minister, Nanotechnology was identified as one of the new growth engines for the New Economic Model (NEM).

On the 14th of February 2011, the National Innovation Council convened and agreed that a nanotechnology commercialisation agency was needed and corresponding activities must be aligned with Agensi Inovasi Malaysia's (AIM) initiatives.

NanoMalaysia Berhad was incorporated in 2011 as a company limited by guarantee (CLG) under the Ministry of Science, Technology and Innovation (MOSTI) to act as a business entity entrusted with nanotechnology commercialisation activities. Some of its roles include:

- Commercialisation of Nanotechnology Research and Development
- Industrialisation of Nanotechnology
- Facilitation of Investments in Nanotechnology
- Human Capital Development in Nanotechnology

For more information: www.nanomalaysia.com.my

CONTRIBUTIONS - INDEX

KEYNOTE AND INVITED SPEAKERS

ORAL PRESENTATIONS

POSTER PRESENTATIONS

Ahmad Khairuddin Abdul Rahim

Malaysian Investment Development Authority (MIDA), Malaysia

Advanced Materials (Graphene): Investment Opportunities in Malaysia

The presentation outlined updates on Government policies, incentives, facilities and support services available for local and foreign investors to invest in the manufacturing and services sectors. The wide range of services provided by MIDA includes providing information on the opportunities for investment in the advanced materials (graphene) based product.

Murni Ali

NanoMalaysia Berhad, Malaysia

NanoMalaysia - National Graphene Action Plan 2020

Malaysia's aspiration to become a high-income nation by 2020 with improved jobs and better outputs is driving the country's shift away from "business as usual," and towards more innovative and high value add products. Graphene, an emerging, highly versatile carbon-based nanomaterial, presents a unique opportunity for Malaysia to develop a high value economic ecosystem within its industries. Isolated only in 2004, Graphene's superior physical properties such as electrical/ thermal conductivity, high strength and high optical transparency, combined with its manufacturability have raised tremendous possibilities for its application across several functions and make it highly interesting for several applications and industries. Currently, Graphene is still early in its development cycle, affording Malaysian companies time to develop their own applications instead of relying on international intellectual property and licenses. Faced with the need to push forward a multitude of development priorities, Malaysia must be targeted in its efforts to capture Graphene's potential, both in terms of "how to compete" and "where to compete". This National Graphene Action Plan 2020 lays out a set of priority applications that will be beneficial to the country as a whole and what the government will do to support these efforts. Since any innovation action plan has to be tailored to the needs and ambitions of local industry, Malaysia will focus its Graphene action plan initially on larger domestic industries (e.g., rubber) and areas already being targeted by the government for innovation such as energy storage for electric vehicles and conductive inks. In addition to benefiting from the physical properties of Graphene, Malaysian downstream application providers may also capture the benefits of a modest input cost advantage for the domestic production of Graphene.

NanoMalaysia Berhad (NanoMalaysia) has been appointed as the Lead Agency to execute the National Graphene Action Plan 2020, aligned with their mandate to nurture nanotechnology development and its commercialization. At this juncture, timing is the key determinant in making sure Malaysian companies has the first mover advantage to enable them to move up the value chain and gaining access to the global market. To conduct a comprehensive analysis, a wide variety of application areas for Graphene were considered. These applications were assessed for technological feasibility by 2020, total size of the opportunity globally and relevance to Malaysia. Based on these criteria, five applications were selected as initial priority focus areas for Malaysia: lithium-ion battery anodes and ultracapacitors, rubber additives, nanofluids (drilling fluids and lubricants), conductive inks, and plastic additives. Together, these applications have the potential to contribute to achieving additional gross national income impact of more than RM 20 billion and to help create 9,000 new jobs for these industries in Malaysia by 2020.

Razif Abdul Aziz

Cradle Fund Sdn Bhd, Malaysia

Funding your Nanotech Venture – Cradle Fund's Perspective

Funding options available to innovators looking to bring their nanotech based investments to market.

Francesco Bonaccorso

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Large scale production of 2D crystals-based composites for energy and (opto)electronic applications

Graphene and other bi-dimensional (2D) crystals, thanks to their excellent and complementary properties, are emerging as promising materials to improve the performance of existing devices or enable new ones [1-6]. In addition, the possibility to assembly such 2D crystals in vertical heterostructures will provide a rich toolset for the creation of new, tailored materials [1,2]. Nevertheless, a key requirement for the widespread applications in the field of flexible (opto)electronics and energy storage and conversion devices relies in the development of industrially scalable, reliable, inexpensive production processes [2]. Here, a balance between ease of fabrication and material quality with on-demand properties is a must.

In this context, liquid-phase exfoliation of bulk layered materials [2,4] is offering a simple and cost-effective pathway to fabricate various 2D crystal-based (opto)electronic and energy devices, presenting huge integration flexibility compared to conventional methods. Here, I will show our scaling up approach for the solution processing of 2D crystal based on wet-jet milling of layered materials. Moreover, I will present an overview of 2D crystals for flexible and printed (opto)electronic [7-9] and energy applications [10-16], from the fabrication of large area electrodes [3,14] to devices integration.

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Chester Burtt

Grafoid Inc., Canada

Grafoid: Collaboration is the key to graphene's commercialization

Bilateral co-operation in the low carbon economy offers opportunities for graphene producers. In the coming years, strong bilateral relationships for the commercialization of graphene will flourish. These relationships will bring together mine-to-market industry players to propel application developments that meet market demand.

The natural flake graphite market has changed dramatically in the last five years from a dig-and-sell commodity business to a value-added product business driven by national and international factors. The industry is being shaped by two catalysts - climate change and the graphene revolution.

Globally, national governments are committing to stringent emission targets and are implementing policies that foster innovation and propel new material advancements. Traditional mining industries, weakened by the global commodity downturn, are searching for ways to revive their businesses, while new material enterprises, such as value-added graphite and graphene start-ups seek to leverage these game-changing opportunities.

The introduction of legislation to greenhouse gas emissions is dramatically changing the critical material sectors. As more and more countries ratify the Paris Accord, the faster industry will adopt change.

China's 13th Five Year Plan calls for China to become an innovation power, pushing the boundaries of the technological frontier and moving up the value-added chain in diverse industrial sectors. Six Strategic Emerging Industries are intended to rebalance the economy toward more advanced technologies, and three of those have near-and-medium term implications for graphene's advancement and commercialization - they are: energy storage and distribution, advanced materials and new-energy vehicles.

Grafoid is poised to take advantage of change. As a graphene research, development and investment company, it has positioned itself to expand its base of collaborative commercial alliances for diverse application development. Grafoid's investment in a patented one-step production process has led to an affordable suite of graphene products that are applied to application developments with joint venture partners at Grafoid's Global Technology Centre

(GGTC), in Kingston, Ontario, Canada. Further, it has partnered with the Canadian Government to build the world's first automated mass production graphene line. As a founding member of the 2GL Platform (www.2GLPlatform.com) and the GO Foundation, Grafoid integrates mining, science, engineering, application development, manufacturing and marketing into its operations.

No one company can do it alone. Commercialization of graphene will succeed when our industry works together in collaboration, fitting all the necessary pieces together with financial resources, industries' needs, capabilities and ideas. This requires cooperation, education and outreach on our part.

Prof. Antonio H. Castro Neto

Director, Centre for Advanced 2D Materials and Graphene Research Centre
National University of Singapore, Singapore

2D Materials: Science, Technology and Standards

In the last 5 years there has been exciting discoveries in the area of 2D materials that unveiled new physical phenomena and created new technological opportunities. However, material quality remains a limiting factor in making 2D materials into new markets. In this seminar I will cover several aspects of this growing research area.

Antonio Correia
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"Graphene and 2D Materials" EUREKA Cluster: Fostering European Competitiveness

The "Graphene & 2D Materials" EUREKA cluster is defined as a complementary enabling and accelerator instrument in the European scene, fully piloted by industries to further take graphene from the mature research developed at academic laboratories into the European society in the space of 5 years, boosting economic growth, jobs creation and international leadership and investment attractiveness. This cluster will help Europe having a more dominant position in graphene patenting, will deploy the proper winning industrial strategies to gain worldwide competitiveness, and will ensure that for all promising industrial sectors of technology innovation, a fully integrated EU-value chain is established, integrating into consortia the relevant actors from low to high Technology Readiness Levels (TRL).

The cluster will clarify the differentiating potential in all sectors where EU-industries is strong and could further gain in competitiveness, and will develop proper incentives towards the achievement of EU-leadership in the fields of graphene commercialization and graphene-driven technology improvement. The cluster will elaborate and foster industrially-driven innovation strategies, that will take advantage of the existing excellent science and transnational platforms in Europe (national networks, Graphene-Flagship, etc.), and will focus on solving current challenges which are limiting the time to market and business growth of graphene-related EU companies.

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Validating the chemical analysis of nanocarbons with certified reference materials

The production of Nanocarbons such as graphene and carbon nanotubes often requires the use of transition metals, thus it is often the case that non-C impurities are introduced in sample batches. To promote the introduction of these materials in consumer goods and technological applications it is essential that reliable information is provided regarding the quantification of these non-intentional elements. It is therefore critical to develop Metrology and Standardization methods and materials for Nanocarbons. Certified Reference Materials (CRM) for Nanocarbons were recently announced by two institutions, the National Institute of Standards and Technology (NIST) US [1] and the National Research Council (NRC) of Canada [2].

Up until now, the complexity of batch-scale elemental quantification for nanocarbons has resulted in neutron activation analysis (NAA) becoming the “gold standard” of analytical methods to address this issue. NAA is non-destructive, accurate and, most importantly, does not require the use of standards. Whilst superior, NAA is not a routine technique for elemental quantification as it requires a large infrastructure with an integrated neutron source. Alternatively, analytical chemistry laboratories often resort to other techniques such as those based in inductively coupled plasmas (ICP). Whether hyphenated to optical emission (OES) or mass (MS) spectrometers, the ICP methods are the “de facto” staple in bulk quantitative elemental analysis of nanocarbons worldwide. Still, one major roadblock persists - the sample preparation step.

During this communication, I will describe some of the recent steps that our group in KAUST has undertaken to resolve this matter. In this, we have made use of the two CRMs available which assisted in validating the approach used for the digestion of nanocarbon samples such as single-walled carbon nanotubes [3, 4].

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What could be better than graphene for energy storage?

Graphene seems to be by all accounts the advanced material of choice for years to come. Its unique combination of mechanical, electrical, optical and chemical properties add to its chemical simplicity to incite potential applications in a wide variety of applications from flexible electronics to biomedicine to energy.

In the field of energy, and in particular for energy storage, graphene is no exception and it has already been claimed as a champion material for supercapacitors providing large active area for capacitive double-layer storage. What then could be better than graphene for energy storage?

Hybrid materials offer the opportunity of building synergies thus leading to improved performance over their individual components.[1] In that way, hybrids based on graphene and a variety of molecular species[2.3] or extended phases[4] have been used to design materials with enhanced activity. A wise choice of electroactive species can for instance improve the energy density of graphene-based supercapacitors through hybridization. Furthermore, in our group we have gone beyond the conventional solid state electrode format and have developed graphene electroactive nanofluids as liquid electrodes for flow cells. This novel electrode format is also prone to the development of hybrid materials. In this conference this general hybrid approach, with some emphasis on our own group results will be presented in relation to graphene-based materials for energy storage and illustrative examples discussed.

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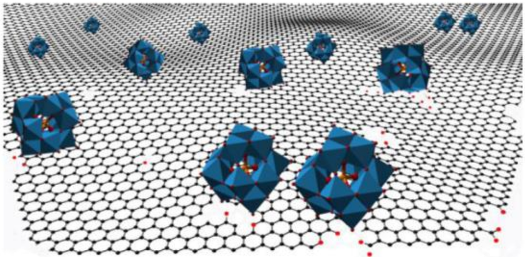
Figures



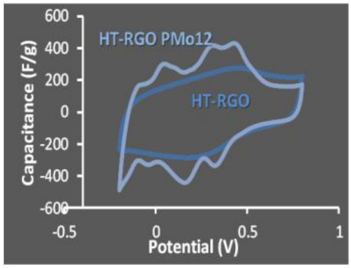


Figure 1: Reduced graphene oxide modified with polyoxometalates (left) lead to hybrid (faradaic + capacitive) energy storage as shown on the Cyclic Voltammogram on the right

Shu-Jen Han

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Nanoelectronics Based on Graphene and Beyond

Graphene has attracted much interest as a future channel material in high-frequency electronics because of its superior electrical properties. Recent development has been shifted from the device level study to the circuit level demonstration. I will review and discuss several key challenges for large-scale graphene device fabrication, including high quality gate dielectric, large-area film transfer, and output current saturation. I will discuss our effort of developing graphene IC in the past few years, starting with a simple 1-stage mixer built on a SiC piece, toward the recent demonstration of a high-performance three-stage graphene IC that fully preserves graphene transistor quality post-IC fabrication. Beyond graphene, more suitable 2D materials with energy bandgap for electronics applications are being aggressively investigated. I will discuss some recent progress of transition metal dichalcogenides and black phosphorus based transistors in my group. In addition, other applications such as plasmonics and photodetectors using these novel 2D materials will be discussed.

Azman Hassan and Reza Arjmandi

Department of Bioprocess and Polymer Engineering, Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, Skudai, Johor Bahru 81310, Malaysia

Graphene Reinforced Polymer Nanocomposites: Recent Development and Opportunities

Graphene is a unique material with a Young's modulus of 1 TPa and a strength of 130 GPa which has emerged as a subject of enormous scientific interest due to its exceptional electron transport, mechanical and thermal properties, and high surface area. Graphene can be incorporated into the polymer matrices by different techniques, such as in situ polymerization, solution casting and melt blending method. When incorporated appropriately into the polymer matrices, these thin carbon sheets can significantly improve the properties of host polymers at extremely small content. Various studies have been reported on the effects of graphene on different types of polymers such as polyethylene terepthalate (PET), polycarbonate (PC), polypropylene (PP), and polymer blends such as PET/PP and PC/acrylonitrile butadiene styrene. It can be noted that the dispersion of the graphene fillers is an important issue that needs to be addressed as it influences the properties of the polymer nanocomposites. This presentation will provide an overview of the recent studies of effect of graphene on various properties of polymer nanocomposites properties. The properties covered are mechanical, thermal, flammability and electrical. Potential applications of graphene reinforced polymer composites will also be provided.

Kuan-Tsae Huang

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Graphene Commercialization Challenges and Opportunities

There are two different methods for producing graphene. Bottom up and top down. Bottom up uses chemistry to assemble carbon atoms in order to create the monolayer structure known as chemical vapor deposition (CVD). Top down refers to the exfoliation of the stacked layers of graphite into smaller multi-layers graphene. To date, exfoliation is still the best technique for producing a defect-less smaller multi-layer of graphene.

There are many challenges and opportunities for graphene based on its applications, such as:

- How to up-scaling graphene production?
- How to maintain the quality in large quantities of graphene production?
- How to produce the right type of graphene for a particular application?
- How to make graphene consistently?
- How to disperse graphene?
- How to measure graphene?
- How to achieve the real benefits of graphene?
- How to handle graphene effectively?
- How to create graphene enriched products and value?

This talk will try to address some of these issues.

Amiruddin Kemat

Malaysia Debt Ventures Berhad (MDV), Malaysia

Strategizing your business for debt financing

Technology starts-up always have a task to gain access for debt financing structures due to business maturity, sustainability of business yet proven, revenue tracking at infant stage and other diversities of challenges. Despite positioning well to cater for angle investors, venture capitals, keystone investors and latest trend the crowd funding.

Debt financing will facilitate continuity growth of the company as well as strengthening financial position and leveraging its capital for commercial funding and capacity raising capital from the market. Financial planning for debt financing should start at early stage thus all options are in the road map to ensure financing is accessible over the life of business till been bought over.

Dr Krzysztof K.K Koziol

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Large scale sustainable production of graphene for real-life applications

In order to achieve industrial scale deployment of advanced nanomaterials like graphene, it is important to manufacture them at the quality and quantity levels required to satisfy their expected performance. The large scale graphene manufacturing process developed by FGV Cambridge Nanosystems in United Kingdom is capable of making the material without the need of catalyst, substrate, solvents and any liquid processing. We are able to engineer graphene at the molecular level to achieve the desired material quality with maximum performance on macroscopic scale. The continuous large scale production of pure graphene is carried out by direct conversion of natural gas, like methane or biomethane, achieving highest quality and purity level of the material. Due to the scale of the production and the nature of precursors used, the graphene generated on a very large scale is very affordable and capable of serving the large volume demand required by many industries. Graphene has been demonstrating its usefulness in a plethora of applications, it will enable technologies which otherwise would be impossible to use, it will revolutionise our industry and manufacturing processes of many products. Selected applications in, automotive, aerospace and construction will be discussed with some of the immediate prototypes presented.

Figures

FGV | Cambridge Nanosystems

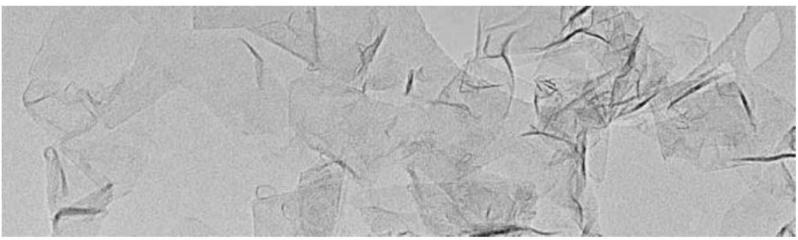

Figure 1: Single layer, ultra high purity CamGraph produced from biogas.

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Graphene Ultracapacitors – the Skeleton of Electric & Hybrid Power Systems

Skeleton Technologies as a company and our success in the energy storage industry are based on heavy emphasis on R&D on what we call "curved graphene", a patented nanoporous carbide-derived carbon, which allows to create hexagonal one-layer graphene structured inside the carbon electrode. The patented synthesis process allows to finely engineer the pore size and distribution which guarantees a very large surface area of 2000 m^2/g, but more importantly a perfect match between the electrolyte ions and carbon pore sizes. This ensures that the whole material "works" and allows for higher capacitance, but also lower internal resistance and higher electrochemical stability. Developing curved graphene has been an on-going process ever since and advancements made in its properties have directly translated to generations of SkelCap ultracapacitor cells with increasingly higher energy and power densities. Up-to-date company has invested USD 30 M for development and manufacturing ramp-up, allowing it to reach commercial scale and build a strong customer base ranging from German Tier1 automotives to the European Space Agency.

Skeleton Technologies has solved the industrial implementation challenge facing all graphene material companies by forward integration. Curved graphene has provided Skeleton Technologies' ultracapacitors with an unmatched competitive advantage: our ultracapacitors deliver twice and energy density and four times the power density compared to competing products. Developing of proprietary technology in the full value chain from ultracapacitor electrodes, cell, modules and energy storage system has allowed this advantage to directly carry to our customers and their applications, providing significant energy savings across industries including automotive, heavy transportation, maritime, renewable energy, energy production and storage, and aerospace.

The automotive sector uses ultracapacitors in start-stop systems, regenerative braking, voltage support units and electric turbochargers, where our SkelCap cells offer a huge weight, volume, and cost advantage compared to our closest competitor, not to mention a higher power density. A 5,7 kW SkelCap cell weighs 178g and has a volume of 0.124 litres. Maxwell cells, the current market leader, offer only 5.5 kW of power in a cell that weighs 510g and has a volume of 0.4 litres. We can offer more power with a cell that is three times smaller and lighter.

We are the only manufacturer that can offer hybrid electric busses with the technology to reliable operate in hot climates. Due to higher efficiency Skeleton cells generate less heat from charge/discharge cycles enabling hybrid electric busses to operate on both sides of the equator.

The future of renewable energy is very much tied to the technological developments in the energy storage sector. Our SkelGrid 2,5 MW Pulse Power Supply container can be used to stabilize the grid in times of peak consumption and lows of production. To reach 2,5 MW, only 1250 SkelCap SCA3200 cells are needed, compared to nearly 2600 of competing cells with same weight and volume needed to reach the same amount of power.

Lastly, full energy storage solutions are the key to unlocking graphene ultracapacitor potential, Firstly, Skeleton has been successful in reducing fuel consumption of trucks by up to 25%. Successful road trials for a ultracapacitor based KERS have been carried out and the company is currently expanding the program. Secondly, Skeleton has successfully hybridized diesel-based port cranes, which allows to reach up to 40% cost savings for the customer. RTG port cranes equipped with Skeleton Technologies' full energy storage system. Both markets represent a significant opportunity, which can only be addressed with a full energy storage system.

Curved graphene is a competitive advantage our competitors have no answer to. That doesn't mean we are done, though. Skeleton Technologies is just getting started and we are constantly working on improving our technology to help our customers save more energy.

Abdul Rahman Mohamed

Universiti Sains Malaysia, Malaysia

Simultaneous growth of monolayer graphene on nickel-copper bimetallic layered catalyst

Graphene, a layer of carbon arranged in sp^2-bonded carbon atoms arranged in a honeycomb structure, has become the main subject of research around the world since 2004 when a free-standing graphene was successfully exfoliated mechanically. The attractiveness of graphene lies in the remarkable electrical, mechanical, thermal and optical properties, enabling it to be potentially used in myriad applications. Chemical vapor deposition (CVD) is the most promising method to produce a wafer-scale graphene because it allows easier separation of graphene from the catalytic substrate. CVD is widely known to involve in the decomposition of a carbon feedstock with the aid of heat and metal catalysts. Ni and Cu are two most widely studied catalysts due to moderate and low carbon solubility, respectively. However, both Ni and Cu require different extreme conditions to grow monolayer graphene. Our research work has shown that monolayer graphene could be grown simultaneously on polycrystalline Ni and Cu foils by Ni-Cu bilayer catalyst under single atmospheric CVD process. High uniformity and quality of the monolayer structure of graphene was evidenced by Raman spectroscopy mapping and High resolution transmission electron microscope (HRTEM). Our straightforward bimetallic catalyst allows the control of carbon diffusion to the area between Ni and Cu surfaces. In particular, carbon access is reduced to the inner Ni surface, while Cu behaving as a carbon barrier. The growth mechanism of monolayer graphene facilitated by carbon diffusion through the bulk and Ni grain boundary, in which the driving force comes from the concentration gradient of carbon-rich surface to carbon-lacked surface. The results show that free-standing high-quality monolayer garphene can be synthesized in a controlled and simple way with an affordable catalyst system.

Pontus Nordin

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Graphene and related Nano Materials for Aerospace Applications

Due to superior weight efficiency when compared to other structural materials, most commercial and military aircraft of today use a significant amount of carbon fiber/thermoset plastic materials in primary and secondary airframe applications. Fiber composites may account for 25 to 50% of the aircraft structural weight and more than 75 % of the aircraft outer surface area in contact with the air stream.

Aerospace-grade carbon fiber/epoxy composite materials generally have excellent in-plane mechanical properties, but less impressive out-of-plane laminate properties can limit their use in many applications. This is due to the brittle nature of both commonly used matrix materials and carbon fibers but also due to lack of structural reinforcement in the laminate z direction. The anisotropic properties of layered carbon fiber laminates allow for optimized designs with low weight and high structural efficiency, but they also present significant challenges in design, especially for complex geometry airframe structures with out-of-plane loads. Most airframe components need to be joined with other components to form a large assembly of parts. A critical laminate property, affecting the design and weight of structural joints using mechanical fasteners is the low bolt bearing strength of carbon fiber composites. It makes bolted joints in carbon fiber structures heavier than corresponding joints in Aluminum structures. Also, laminate electrical properties of these composite materials, controlled by the resistive carbon fibers and the insulating epoxy matrix, are highly anisotropic. Carbon fiber laminates in typical aircraft applications such as wing skin panels and wing leading edges therefore need a metallic surface mesh for lightning strike protection and currently used anti-ice and deicing systems for carbon fiber wings rely on metallic layers for resistive heating. Thermal properties such as conductivity and expansion of carbon fiber laminates are also anisotropic.

A combination of carbon fiber polymeric composites and metals, e.g. Aluminum and Titanium alloys, is often used in order to meet airframe functional requirements. Such multifunctional designs can be complicated due to significant differentials in thermal expansion, risk of galvanic corrosion or other effects of dissimilar or conflicting material properties. Thermal stresses in the out-of-plane z direction may result in matrix cracks and local delaminations in low fracture toughness composites. In addition to mechanical loads, airframe components must survive certain in-service impacts and brittle composite materials, in contrast to metals, lack plastic deformation as an energy absorbing mechanism.

Future multifunctional airframe components benefit from the use of new efficient multifunctional composite materials and Saab Aeronautics, with partners, have focused recent materials research and development on nano-engineered carbon fiber composites. Based on testing and evaluation of early versions, this new class of multifunctional nanocomposite materials can be used to overcome the limitations of currently used carbon fiber/epoxy prepreg materials.

The use of aligned carbon nanotubes, dispersed graphene flakes or combinations of nanotubes and graphene in carbon fiber/epoxy composite prepreg materials is a strong candidate solution when multifunctional composite materials and structures are developed for future aerospace applications. This class of nano-engineered composite materials combine the mechanical properties of carbon fibers with mechanical, electrical and physical properties of carbon-based nano materials. Nano-scale reinforcement of ply interfaces in carbon fiber/epoxy laminates with aligned carbon nanotubes and/or dispersed graphene can significantly increase interlaminar fracture toughness and other mechanical properties. Electrical conductivity of carbon fiber composites can be improved and tailored through the addition of graphene flakes in the resin matrix phase of the composite materials. Future multifunctional airframe composites using engineered matrix reinforcement from carbon nanotubes and graphene have the potential to outperform currently used materials in terms of weight, cost and overall efficiency.

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Norazira Binti Othman

NANO*Verify* Sdn .Bhd., Malaysia

NANO*Verify* Programme : Protecting Consumer's Right Through Product Labelling & Certification

NANO*Verify* Programme is a voluntary certification programme for process and product with claims of nano-elements in the range of 1 to 100 nanometer (nm). It is the 6^{th} nano-certification programme available worldwide. Nowadays, there are numbers of nanotechnology products available in the market. In order to ensure that Malaysia is filled with genuine nanotechnology products and to act on claims of fake products, NanoMalaysia Berhad (NMB) is taking an initiative to create a verification & certification programme to monitor and facilitate nanotechnology companies and products in the market. This programme is manage by Nano*Verify* Sdn. Bhd. (NVSB) wholly owned subsidiary under NMB in collaboration with SIRIM QAS International Sdn. Bhd. as the operator of the programme.

Ku Kok Peng

Performance Management & Delivery Unit (PEMANDU),
Malaysia

National Graphene Action Plan 2020: Transforming Innovation Delivery

The National Graphene Action Plan 2020 is probably the first attempt at an end-to-end active facilitation to deliver innovation, from awareness building and project execution and funding to scale-up support, monitoring and reporting. If proven successful, it is potentially a model that can be replicated to fast-track innovation in other strategic sub-sectors.

Elena Polyakova

Graphene Laboratories Inc., USA

Advanced graphene composites for 3D printing and other high end applications

Graphene based composites are expected to be the largest segment in the emerging graphene market. While there have been reports of consumer products made from polymers embedded with graphene nanoplatelets, the added-value of graphene is not highlighted. Our company had recently announced that it was successfully in developing a state-of-the-art graphene composite material under the trade name of G6-Impact™. This graphene composite material will be intended for industrial users in the automotive, robotics, drone aerospace and military sectors.

Graphene composite materials are prepared using multiple components which are processed together to enhance existing properties. Our G6-Impact™ composite material is developed based on a mixture of High Impact Polystyrene (HIPS) resin, Carbon Fibers and Graphene Nanoplatelets. The G6-Impact™ impressive properties are ensured by the Company's proprietary formulation and micro-mixing technique. Across industries, mechanical parts and complex electronic devices are increasingly subjected to shock, friction, vibrations, and harshness. G6-Impact™ holds a combination of excellent stiffness, toughness as well as impact and vibration absorption. G6-Impact™ will be an optimal material for applications where vibration damping is required on firm surfaces that could include sporting gear, power tools handles, automotive parts, and aerospace components.

Datuk Mark Rozario

Agensi Inovasi Malaysia, Malaysia

Paving the Way for Graphene in Malaysia

In 2013, Malaysia began exploring the right opportunities for its domestic industries by identifying which Graphene-enabled applications can catalyse growth regionally.

Agensi Inovasi Malaysia (AIM) was tasked together with NanoMalaysia Berhad. (NMB) with coming up with a National Graphene Action Plan to assess how Malaysia could benefit from the potential of Graphene.

The National Graphene Action Plan 2020 (NGAP2020) was the result of an extensive collaboration between the Malaysian government, private sector companies, domestic and international research institutes, and academia. NGAP2020, now being implemented by NMB under the guidance of the NGAP2020 Steering Committee aims to define how Malaysia can benefit from the considerable potential of Graphene, and set an approach and roadmap to capture this potential.

Capturing this opportunity will require concerted efforts across several stakeholder groups in the public, private and academic sectors. NMB and AIM are committed to assisting its companies, and play an active role in initiating and promoting the development of a Graphene ecosystem. This entails building awareness about the versatility of Graphene and its potential applications, and encouraging companies to invest in R&D, prototyping and early commercialisation. In parallel, the government through NMB and AIM will facilitate access to Graphene suppliers, domain experts, and prototyping facilities; assist with navigating the IP landscape; and provide access to any available funding support.

AIM intends to continue supporting NMB to pave the way for Graphene in Malaysia by providing AIM's various approaches to innovation as stated in its mandate which is to jump start wealth creation through knowledge, technology and innovation to stimulate and develop the innovation eco-system in Malaysia via six key approaches to innovation

1. Cultivating a thinking culture
2. Innovation for and by society
3. Facilitating industry-academia collaboration
4. Transforming Strategic sectors
5. Innovating organisations
6. Catalyse commercialisation

Anthony Schiavo

Lux Research Inc., Singapore

Graphene Global Outlook: Roadmap for applications and opportunities

Graphene captured the imagination of industry for years before falling victim to hype and oversupply. Despite these setbacks, the market for graphene continues to grow. Recently, graphene companies have begun to strengthen ties to academia even as new forms of graphene have begun to emerge. This talk will give a global perspective on the graphene market, and discuss needed innovations and business strategies for growth.

Gopi Sekhar

GB Sekhar Sdn. Bhd, Malaysia

The Significance of Nano Graphene Reinforcement in Rubber Compound Applications

The need for more sustainable feedstock in rubber compound applications with specific reference to the largest consumer being passenger car and commercial vehicle tyres. Graphene introduction into rubber compounds challenges and opportunities. Graphene in Tyre related rubber compound applications complementing carbon black towards greater performance and sustainability. Graphene as a partial replacement for carbon black in tyre based applications providing economies of scale for the Graphene industry.

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Status of Graphene Research and Industry in Thailand

Graphene, emerging as a true 2-dimensional material, has received increasing attention due to its unique physicochemical properties (high surface area, excellent conductivity, high mechanical strength, and ease of functionalization and synthesis). Printed Electronic also is a new wave of large-area electronics and flexible electronics manufactured by printing technology. Thailand can catch the opportunity using the fusion of these two emerging technologies. With the complete infrastructure from upstream to downstream industries from Petrochemical, Chemical Synthesis, Printing and Electronics Industry, it is sufficient to start development of graphene industry in Thailand. This invited talk is about to show how to synthesize graphene and use as a conductive ink for fabrication of transparent conductor in printed electronics. Also the applications in novel nanosensors that has higher sensitivity and lower detection limit and applications [1] in field of graphene composite [2] are presented. The recent activities of graphene research and industry in Thailand including graphene-related Startups, graphene cluster/consortium and the roadmap of Graphene Thailand will be presented.

Keywords: Graphene; Sensor; Synthesis, Composite, Printed Electronics

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Figures

Figure 1: Graphene conductive Ink by Innophene (Haydale Thailand) and Graphene-based Electrochemical Biosensors researched and commercialized in Thailand.

Vickneswaran Veloo

Scomi Chemicals, Malaysia

Nano-Graphene Engineered Lubricant for Drilling Fluids

Scomi together with the technical partner had developed series of nano graphene engineered product in mass production scale, one of the latest product that had been field trial successfully in the region is a graphene enhanced product that provides superior lubricity and thermal stability to the water based drilling fluids. It is a blend of proprietary fluids engineered with nano graphene, where graphenes will penetrates into microscopic pores of the tubular metal, crystalized in layers under high pressure, forming a protective film to improve lubricity, prevent bit balling, improve BHA's life span, improve ROP, and most important of all improving fluids' thermal stability.

Laboratory performance test with EP/Lubricity Tester indicated 70-80% torque reduction on a water based salt polymer mud system, compared to conventional lubricants of only 30-40% reduction. The product had been field trial in a HTHP onshore well with temperature up to 176°C (349°F), and hard formation reducing the bits' life span to only 2-3 days. During the field trial, it's noticed that 2-3% of the product had improved ROP 125%, actual reaming torque reduction of 20%, bit's life span increased >75%, fluids loss reduction of 30% with 40% polymers concentration reduction compared to planned mud formulation. The improvement in drilling performance and bits' life span had significantly reduced operator's operational time and cost. Graphene itself has superior mechanical properties such as tensile strength of 130 gigapascals, weight of 0.77 mg/m^2, Young's Modulus of 0.5 TPa, specific strength of 4.7 – 5.5 x10^7 N.m/kg, melting point of 4510K. Obviously graphene will be a very robust material for drilling and exploration activities. Considering material cost, application methodology, as well as HSE concerns, nano graphene has chosen to be suspended in the surfactant based carrier fluids prior introduced into the drilling fluids. And thus the product limitation will based on the limitation of the carrier fluid instead of graphene material. This graphene enhanced lubricant is biodegradable, thermally stable up to 300°C, suitable for moderate salinity drilling fluids up to approximately 140,000 mg/l of chloride content.

The lubricant forms a lubricating film known as tribofilm by both physical adsorption (i.e. physisorption) and chemical adsorption (i.e. chemisorption) which involves physical and chemical changes of both solids and lubricant molecules that are influenced by tribological conditions. The chemical reaction leading to boundary lubrication is initiated by temperature, pressure or mechanical contact (shearing forces and drilling).

The lubricant is designed to find areas of high friction, shear or pressure and its effective concentration is high at the point of friction. The carrier fluid is formulated to facilitate migration of protective nanoparticles to the metal surface. The lubrication mechanism is controlled by chemical structure of nano materials and their ability to form a strongly bonded protective film on the rubbing surfaces. The film is stable at extreme pressure and temperature. The nano graphene will invade into the microscopic spaces and chemically bonded to the metal surface, allowing the tubulars to tolerate extreme heat, and abrasions. Upon high pressure and temperature, the lubricant containing nano graphene gets crystallized in layers, causing the tubular surface shear and slide easily, thus lowering the friction coefficient. The crystallized nano graphene layers also prevent direct contact between metal surfaces, hence minimizing metal wear. The nano graphene coating also prevent oxidation, where the nano particle will displace the rust and carbon varnishes. They also change the morphology and surface characteristics of metal surface, creating a self healing friction barrier. The nano graphene coating also balling of the “fines” onto the metal surface, preventing bit balling and allowing the bit to freely cut the new formation. Once the nano graphene film is formed on the metal surface, it doesn’t depends on the carrier fluid, it will remained on the metal surface disregard fluids contamination such as water and solids that might affect the carrier fluid. This differentiate the product from other liquid or solids type of lubricants where its depletion rate is low and also low dosage is required.

In one of the PTTEPI Myanmar onshore block drilling campaign, the reservoir section consisted of sand interbedded with shale is classified as hard formation, causing slow ROP and consumed several bits during the reservoir drilling in the first few wells. In order to reduce client’s operating cost and improve ROP, Scomi has offered PTTEPI the graphene enhanced lubricant solution and after performing a comprehensive laboratory test.

With the success of the first field trial on nano graphene engineered drilling fluids, Company is in the midst of developing series of graphene enhanced product to cater more challenging drilling and production conditions.

Archana Venugopal

Texas Instruments, USA

Graphene devices and integration: A primer on challenges

Graphene has been of interest to the physics and electrical engineering community alike since its isolation in 2004 and the Nobel Prize in 2010. There has been tremendous research effort on material evaluation and growth. Reported applications include RF transistors, ballistic devices, spin valves, gas sensors, optical modulators and in flexible electronics, to name a few [1].

Whilst there have been several demonstrations of applications that are unique or dramatically enhance what is available in the market today, at this time efforts toward consistent/reliable graphene device fabrication and large scale integration are still immature. There are unique issues, independent of application, which affect graphene devices and integration efforts.

Contact resistance (R_c) is one such problem. Metal on graphene is in practice, a metal - semimetal system, so the traditional Schottky barrier induced R_c is zero. However measurements have yielded R_c to be a few hundred ohms and contact resistivity 10^{-5} to 10^{-6} Ω-cm^2. In comparison, contact resistivity of silicided Ni and Pt contacts used in industry have been measured to be as low as 10^{-8} Ω-cm^2 [2-4]. Though there have been several papers evaluating metal- graphene interface interactions and Rc reduction mechanisms, there is still no known consistent solution. Mobility is another such instance. Mobility (μ) is used as a benchmark parameter for gauging the quality of a device based on differences in process, material, etc. In graphene (on substrate), μ has been reported to be as high as 60,000 cm^2/Vs [5]. In addition to a known substrate, source and fabrication dependence, there have been preliminary studies that have shown mobility to vary as a function of channel dimensions [6-10]. This dependence contributes to an overestimation of mobility in small channel devices, which is rarely corrected for.

A first step towards utilization by industry entails comparison with what already exists and evaluating if the addition of graphene will help enhance an application by opening up new markets while not drastically increasing cost. A prerequisite towards evaluation is effort on correcting the known issues and fabricating devices that are consistent and reliable. The purpose of this talk is to highlight and discuss the issues that have been seen in this field and are as necessary to address as coming up with an application to begin with.

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Carrier Transport at the Interface of 2-Dimensional Materials

Two dimensional (2D) materials are recently being investigated very intensively, with some of them holding great promise as semiconducting materials for future nano-electronics, beyond current Si technology which face hard limitation in performance enhancement due to excessive power dissipation during high frequency operation, as they present a range of achievable bandgaps and high electrical carrier mobility, and ultra-thin body with efficient electrostatic control. These properties, combined with mechanical flexibility, enable 2D materials to be very promising candidates that can meet major requirements for electronic and photonic devices operated in emerging future mobile and IoT environment.

However, formation of proper electrical contacts to nanoscale 2D materials (e.g. transition metal dichalcogenides: TMDs) is becoming a major challenge in realizing the performance of the 2D material-based devices. According to recent studies, the observed two-terminal mobility in single-layer TMD devices is unexpectedly low [1], due to high contact resistance (R_c) induced between metal contact and TMDs. It is known that many 2D crystals are subjected to strong Fermi level pinning when they are in contact with metals. That is, the pinning is responsible for the observed high Schottky barrier height and high R_c. In this work, we investigate Schottky barrier heights at the interfaces [2] formed between mono- or bi-layer molybdenum dichalcogenides and Ti, Cr, Au, Pd. For MoS_2 and $MoTe_2$, by obtaining I – V characteristics for various temperatures. According to our results, it is interesting to find that the pinned energy level was located near the conduction band edge for MoS2 whereas it was near the intrinsic level for $MoTe_2$.

Meanwhile, we explore the different metal MoS_2 contacts and investigate the charge carrier injection mechanisms and their transition from one to another across the interfacial barrier [3]. Low temperature measurements on MoS_2 field effect transistor are carried out and R_c as the function of temperature is studied. As the result, the obvious transition from thermionic emission at high temperature to quantum mechanically tunneling of charge carriers at low temperature along the junction is observed. Furthermore, at a low temperature, the nature of the tunneling behavior is spotted by the current-voltage dependency. Interestingly, direct tunneling at a low bias and Fowler-Nordheim tunneling at a high bias is realized for a Pd-MoS_2 contact due to the effective barrier shape modulation by biasing. However, at the same bias conditions only direct tunneling is observed for a Cr-MoS_2 contact.

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Graphene-on-surfaces for multifunctional applications

Graphene has the potential for creating thin film devices, owing to its two-dimensionality and structural flatness. Assembling graphene-based building blocks into hybrid structures or composites with diverse targeted structures has attracted considerable interests for understanding its new properties and expanding the potential applications. The integration of graphene into a device always involves its interaction with supporting substrates, making this interaction critical to its real-life applications. This presentation will focus on three "graphene-on-surfaces" hybrid structures. I) Graphene-on-semiconductor: We prove that graphene-on-Si can function as a quality Schottky junction with high photoelectric conversion [1]. Graphene serves multiple functions as transparent electrode, active junction layer, hole collector and anti-reflection layer in graphene-on-semiconductor heterojunction photo-devices, such as solar cells and photodetectors, and could be extended to other optoelectronics; II) Graphene-on-polymer: We design tiling structures in graphene, composing overlapped graphene plates and realize high sensitivity strain sensing, which can measure either tiny or large strains with record high gauge factors [2]. By future combining artificial intelligence with digital signal processing, the graphene based sensing system will represent a new smart tool to classify and analyze signals in fields of vital signs monitoring, displays, robotics, fatigue detection, and in vitro diagnostics; III) Graphene-on-ceramic: We develop graphene oxide (GO)-based membranes for highly efficient ion separation and water desalination. Due to the narrow dimension of nano-capillaries and the co-existence of sp^2 aromatic channels with various oxygen functionalities, GO membranes can afford excellent selectivity towards various ions based on molecular sieving effect and diverse chemical interactions, showing promises in filtration and separation [3].

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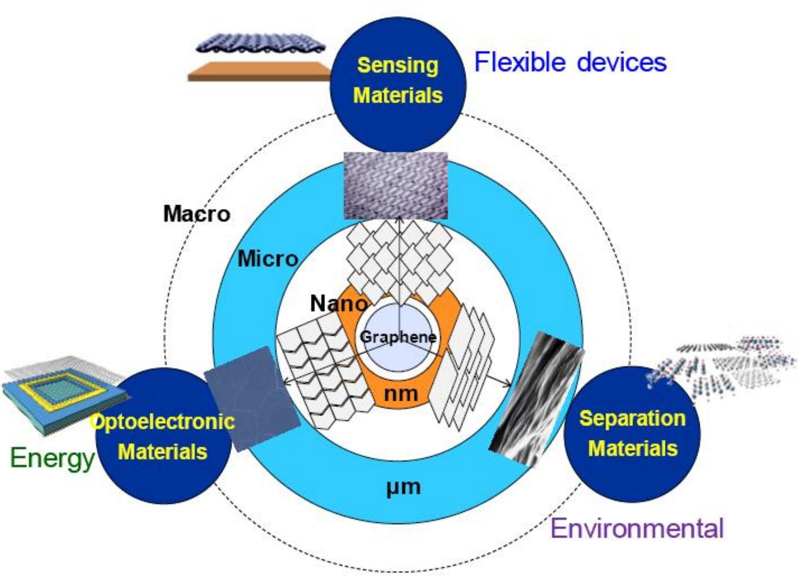
Figures



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Marriage of Graphene and Cellulose for Reinforced Composite Preparation

The synthesis and utilization of graphene have received considerable attention among the scientific community, with a progressive viewpoint on graphene as an ideal candidate for fillers in composites. However, some drawbacks and limitations have emerged in utilizing graphene for composite processing. The methods that thus far employed usually produce non-dispersible graphene in aqueous solution or organic solvent since graphene is hydrophobic in nature. Owing to this regards, electrochemical exfoliation technique with the assistant of surfactant was employed in this study thus preventing these drawbacks with aimed to produce stable and homogenous graphene suspension. The technique also allows a direct assembly of graphene for composite preparation via solvent intercalation and significantly overcome graphene indispersibility issue. Cellulose, being the potential marriage candidate for the composite matrix in this study is underpinned by its widespread capability as a natural and ubiquitous polymer while receiving much research interest by the scientific community. By taking advantage of reusing wastepaper, we provide a recycling alternative for cellulose material processing, wastematerial conversion and the production of the composites. Transmission electron microscopy (TEM) images showed a relatively transparent, thin and crumpled-silk like structure of graphene. Structural analysis of the cellulose were investigated by ATR-FTIR and X-ray diffraction. TEM and scanning electron microscopy analysis were both carried out for imaging analysis of graphene-cellulose composite. The presence of graphene as reincorporating agent and their marriage chemistry and possible mechanistic interaction of graphene-cellulose was significantly investigated in this project. The reinforcing ability of graphene-cellulose in the polymer composite was reflected through the improvement in the tensile strength. The mechanistic interaction of graphene-cellulose composite is conceptualized by Lindman effect behavior of cellulose and through amphiphilic capacity of sodium dodecyl sulphate as a surfactant.

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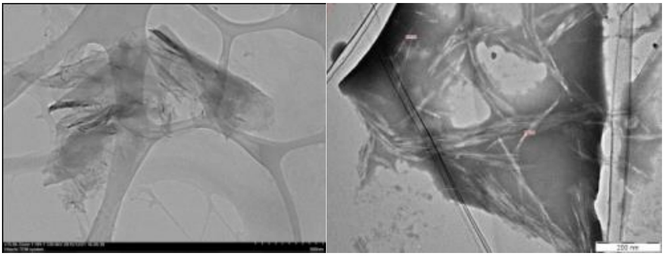
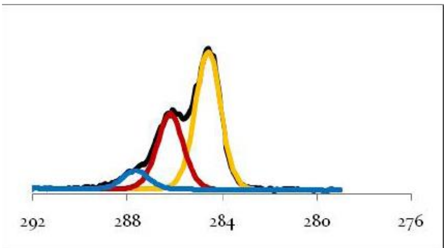
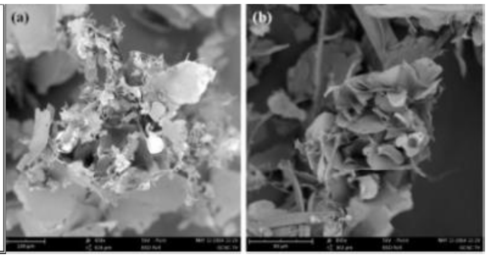
Figures







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The Preparation of Graphene on Nanostructured Porous Silicon Substrate by Mechanical Exfoliation Method

Nanostructured porous silicon is a versatile nanomaterial was discovered by Canham in 1990. Nanostructured porous silicon is able to luminesce at visible light under UV excitation. The structures consists of hillock and valley like at the size of 10-50 nm diameter with several micrometre high. Porous Silicon has high surface to volume ratio at around 500 cm^{-1} Therefore, it is suitable for a nano-template for synthesis other nanomaterials. In this work the graphene was synthesised on the nanostructured porous silicon substrate by utilizing it high surface to volume ratio structure. Graphene known as 2D nano-meterials with hexagonal carbon structure with sp^3 bonding. The formation of graphene through the mechanical exfoliation of HOPG is very encouraging. The graphene was observed through the Raman spectroscope and micrograph from FESEM. It was indicated the formation of few layers Graphene based on D and G peaks Raman spectroscopy. The influence of high surface to volume ratio of substrate to the formation of graphene will be explained.

Keyword: Nanostructured Porous Silicon, Graphene, Mechanical Exfoliation, Raman Spectroscopy

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Nanocarbon for energy storage

The necessity of developing cleaner, safer and efficient energy technologies has become critical now than ever. Nanotechnology for all its known benefits could offer effective solutions for the emerging energy crisis. Tailored nanostructures of carbon such as graphene and carbon nanotubes are well known for their ability to tune electrical properties and allow development of lighter and efficient high energy storage devices [1,2]. The interest of energy storage industry in these structures has been on going for a long time. However, as it remains a fact, the limitations in producing these incredible structures on a larger scale have been a hurdle to fully investigate the commercial benefit of these structures. Until recently, when there have been several technological breakthroughs that enabled production of some of these carbon nanostructures at a larger scale [3]. Though the major barrier in joining academic and industrial interests has been overcome as a result of these recent breakthroughs, there still remain some gaps before establishing a complete commercial applicability of these structures.

We have investigated several nanocarbon systems and tailored them for high surface area along-with micro and meso porosity. These tailored systems in combination with the right electrolyte have shown an improvement in the performance of supercapacitor devices both at lab-scale and large-scale. Here, we report a comparison of a standard activated carbon that has a specific capacitance of 102.7 F/g with two of our tailored nanocarbon systems that show an improved specific capacitance of 127.1 F/g and 140.0 F/g. We believe that these results are a mere start towards achieving better performances and developing cost-effective supercapacitor systems for a plethora of energy applications.

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Enhancing Composite Materials with Functionalized Graphene & CNTs

Tremendous industry interest in novel carbon materials has developed over the past 25 years, first with the discovery of carbon nanotubes (CNTs) in the early nineties and then again with the isolation and characterization of graphene that led to a Nobel Prize in Physics in 2010. However, industry players both small and large are still struggling with the challenge of putting these materials into real products. One of the primary obstacles has been with the hydrophobic nature of these materials that lead to poor dispersion, making them difficult to use in many applications – such as composite materials. Haydale has developed a low-temperature plasma process for the treatment and functionalization of both CNTs and graphene that can promote better dispersion into a variety of targets and that can help unlock the full potential of these materials. Third-party work by the Aerospace Corporation has shown the benefit of Haydale's functionalization process in epoxy resins [1], and this talk will present further data showing how functionalization of CNTs and graphene can lead to higher performance in a variety composite materials.

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Thin Layer Graphene for Biomedical Applications

Monolayer graphene has been widely studied for usage in nanoelectronics, nano energy, biomedics, photonics and environmental protection. In biomedical field, graphene can function as structural layer for tissue engineering, transport mechanism in drug delivery, and active layer for improving bioNEMS devices' efficiencies. Here we present our work on thin layer graphene as an active layer for improving efficiencies of a NEMS micro supercapacitor and a NEMS biosensor. We developed a vertically aligned graphene interdigital micro supercapacitor for powering biomedical implants and wearable electronics. The high energy density micro supercapacitor is intended to replace the conventional Li-Ion batteries which are troublesome when integrated into biomedical implants. Our basic MEMS interdigital micro supercapacitor has a specific power of 2.18 mW/cm^2. Vertically aligned graphene on supercapacitor's interdigital fingers increases the device's active surface area, thus capable of increasing its specific power threefold. On the other hand, in graphene based FET biosensor for detecting ADH in artificial kidney, we used monolayer graphene as an active layer. The aptamers coated graphene FET has an ADH detection sensitivity range of 1-500 pM, which threshold is sufficient for detection of ADH in artificial kidney application. The presented integration of thin layer graphene in bioNEMS devices open up possibilities of the infinite usage of graphene technology in biomedical applications.

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Scalable MoS_2 phototransistors with ultra low power consumption and high light/dark current ratios

Over the last 12 years, there were a lot of investigations on the basic properties of two dimensional (2D) materials. An amount of interesting properties have been observed by using techniques which are adapted only for research purpose. All of these methods are not scalable, which delays the process of mass production of electronics. Recently, how to build up scalable devices with commercial realistic properties has attracted attention of global researchers. In this work, we fabricated scalable MoS_2 phototransistors using scalable processes, such as chemical vapor deposition (CVD), photolithography, e-beam evaporation and plasma ion etching (see figure 1). Results indicate successful fabrication of MoS_2 phototransistors, as the typical output and transfer characteristics have been observed. The phototransistors show ultra low power consumption and high light/dark current ratios. The hysteresis of the devices has been minimized by introducing an annealing step with controlled time (after fabrication process). By studying the MoS_2 channels after a longer annealing process, we observe that these performances are related to the small domain size of the polycrystalline monolayer MoS_2 sheet (164 ± 54 nm in diameter, see figure 2).

Figures

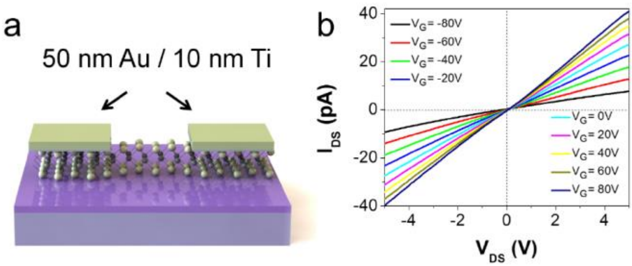

Figure 1: (a) Schematic of the monolayer MoS_2 phototransistor; (b) Output characteristic at different back-gate voltages for the MoS_2 phototransistors with channel width of 20 µm.

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Mott insulator phase transition in graphene

Mott insulator phase transition is one of the mechanisms that allow application of graphene on low power electronic devices. It has been shown in literature [1] that the phase transition of a spinless system into charge-density-wave (CDW) state occurs at a smaller short-range coupling when the long range coupling is increased. Here, we examine the Mott insulator phase transition into spin-density-wave (SDW) state by considering Gross-Neveu model with spin. Contrary to CDW phase transition and the conventional wisdom, our renormalization group (RG) calculation shows that the SDW phase transition occurs at a larger onsite potential when the nearest neighbor potential is increased.

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Graphene-on-Silicon Technology to Advance Power Semiconductor Devices

Graphene-on-Silicon process technology has been developed in MIMOS Wafer FAB since 2015 to improve the performance of power semiconductor devices. MIMOS, have discovered that direct deposition of graphene layers as a heat spreader on silicon substrate could reduce the junction temperature in Schottky rectifier device hence improving safe operating area (SOA) of the power device. The development of graphene heat spreader in power semiconductor devices could improve its performance and create more efficient power supplies for a range of applications. Reduced graphene oxide (rGO) layer has been used in this study. Multiple layers of rGO flakes that are overlapped and interconnected are deposited on silicon surface with trench array structures to form the Schottky contact. Prototype of Graphene-on-Silicon Schottky Diode developed by MIMOS showed the leakage current improved by two-orders of magnitude when tested under high operating temperature (>80°C) with comparison to the conventional metal silicide (Titanium Silicide and Cobalt Silicide). With this success, MIMOS extends its graphene study by developing Graphene-on-Silicon process technology platform for fabrication of power semiconductor devices i.e. Schottky Diodes, Power MOSFETs. The aim is to advance the existing power semiconductor process platform by using nanotechnology.

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Plasma Surface Modification of Graphene Sheet with Enhanced Pressure Sensing Performance

The concept of piezoresistive effect in graphene has been previously implemented in the many kinds of graphene-based pressure sensors [1-3]. However, poor sensing capabilities of the sensors with small gauge factors, resulting from limited modified electronic bands remains a major problem for their practical use [4]. In this paper, we address the sensing problem by enhancing piezoresistive effect in the graphene sheet using a straightforward NH_3/Ar plasma surface modification. The changes in the graphene in terms of its morphology, structure, chemical composition, and electrical properties before and after the surface modification were investigated in detail. The electromechanical characterization demonstrated that plasma-modified graphene sheet (PGS) exhibits a significant increase in sensitivity by one order of magnitude compared to graphene sheet (GS) with a minimum detection of ~15.0 Pa. The plasma-doping introduced nitrogen (N) atoms inside the graphene structure and was found to play a significant role in enhancing the pressure sensing performance. This was due to the synergistic effect from the formation of the geometrical effect as well as the modulation of the graphene bandgap. The high sensitivity and good robustness demonstrated by the fabricated pressure sensor with the PGS suggest a promising route for simple, low-cost, and ultra-high resolution flexible sensors.

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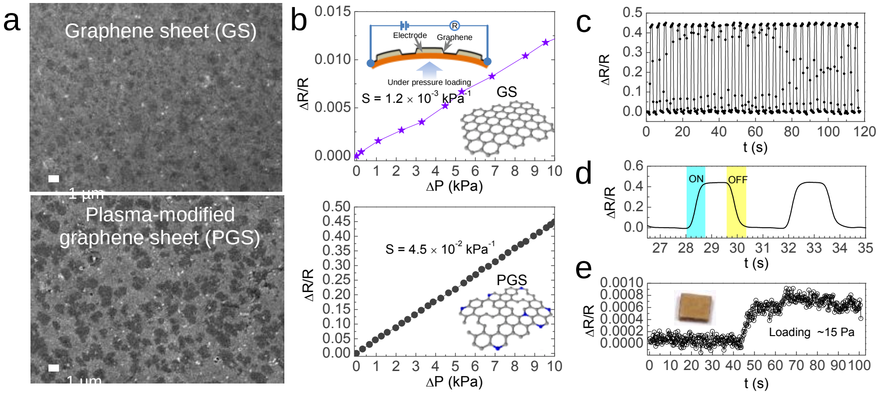

Figure 1: a) FESEM images of graphene sheet (GS) and plasma-modified graphene sheet (PGS). (b) Relative change in resistance of fabricated pressure sensor incorporated with GS and PGS in response to applied differential pressure. (c-d) Multi-cycle test of repeated loading and unloading and the response and recovery time at ~10 kPa. (e) Real-time response to the application of a piece of paperboard with a weight of 38.5 mg loaded on the 0.25 cm^2 back surface of sensor (corresponding to ~15.0 Pa)

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Ballistic and phase coherent transport in high-mobility graphene antidote lattices made on h-BN

Antidot lattice is a two-dimensional conductor with a regular array of holes. This is one of typical systems that show wave-particle duality. To date, antidot lattice of Dirac electron system is less explored as compared with conventional two-dimensional electron gas. Here we show particle and wave nature of Dirac electrons in antidot lattices. Particle nature was observed as commensurability magnetoresistance arising from ballistic electron transport in a triangular antidot lattice of high-mobility graphene that was made on h-BN (Fig. 1). For the mono- and bilayer graphene antidote lattice devices with carrier mobility of about $3x10^4$ cm^2/Vs and mean free path of about 400-600 nm, we observed bipolar magnetoresistance peaks that originate from commensurability of cyclotron orbits with the antidot lattice. Detailed study of the magnetoresistance peak as a function of carrier density revealed that the commensurability occurred when cyclotron diameter matches the lattice constant, i.e, $2R_c=a$, where R_c is a cyclotron radius and a is a lattice constant [1]. Shapes of the magnetoresistance traces were approximately reproduced by numerical calculation of conductivity components using a semiclassical Kubo-type formula for chaotic orbits. The peaks appeared when the carrier mean free path was approximately larger than the lattice constant, which quantitatively agreed with our experiment. On the other hand, wave nature was observed as small period magnetoresistance oscillations that are reproducible from sweep to sweep.[2] In particular, near B=0 we found magnetoresistance oscillation with a period of $\Phi = h/2e$, which is the Altshuler-Aronov-Spivak (AAS) oscillations arising from interference of coherently back-scattered paths with time reversal symmetry. AAS oscillations share a common origin with the weak localization or anti-localization in two-dimensional electron system. The phase of the AAS oscillations was the same as that originating from weak localization rather than weak anti-localization, in that R_{xx} exhibited a local maximum rather than a local minimum at the vicinity of zero magnetic fields. This is different from a simple prediction that AAS oscillations with the phase same as anti-localization should occur in monolayer graphene because of π-Berry phase. Our experiment indicated that system was influenced by frequent inter-valley scattering possibly due to boundary scattering. We also observed that AAS oscillations switched to the Aharonov-Bohm (AB) type oscillations with a (h/e)-period in higher magnetic fields.

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Preparation and evaluation of Copper particles on reduced graphene oxide as an efficient electrocatalyst for enhancing electrochemical performance of the Lithium-Thionyl Chloride Batteries

Lithium-thionyl chloride cell (Li-$SOCl_2$) has a metallic lithium anode and a liquid cathode comprising a porous carbon current collector filled with thionyl chloride. It delivers a voltage of 3.6V and is cylindrical in shape, in 1/2AA to D size, with spiral electrodes for power applications and bobbin construction for prolonged discharge. Among of all primary batteries, lithium thionyl chloride batteries have the highest voltage and energy, longest storage period, and the least self-discharge rate.

The chief objective of this work is to evaluate the effect of Cu/rGO composites as an electrocatalyst for enhancing the thionyl chloride cathodic reduction on the cathode side of Li/$SOCl_2$ battery when a load is connected.

Graphene oxide (GO) was prepared through Marcano-Tour's method. After ultrasonication, washing, pH neutralization and centrifuging, GO solution was sonicated for 30 min, and then Cu $(NO_3)_2.3H_2O$ aqueous solution was added followed by stirring overnight. Then $NaBH_4$ aqueous solution was added drop wise under N_2 atmosphere. To be sure the full reduction of copper on GO, excess amount of $NaBH_4$ was used. After the reaction completion, the mixture was allowed to stir for 24 h. Then the black suspension was filtered and washed for several times with DI water and absolute ethanol to remove residual reactant ions. Then, the prepared sample dried in the oven at 45 ºC. To improve the crystallinity of Cu, the product was annealed in the tube furnace at 650 ºC under N_2/H_2 (95/5) atmosphere for 90 min (heating rate= 3 ºC/min) [1].

The crystalline structure of the sample was determined by X-ray diffraction (XRD) using a Bruker advanced diffractometer with CuKα ($\lambda_{CuK\alpha}$ = 0.154 nm) radiation. Fourier transform infrared spectroscopy (FT-IR) was used to investigate the reduction of GO via mentioned preparation method by a Jasco-680 (Japan) spectrometer with scanning at wavenumber range of 400–4000 cm^{-1}.

All electrochemical characteristics were measured by SCRIBNER 850E test station. The electrochemical measurements were carried out in a designed test cell which made by PTFE and 316 stainless steel. Obtained results indicate that, adding Cu/rGO to the cathode of batteries, influence the charge transfer process during the reduction of thionyl chloride. Moreover, a higher discharge voltage was obtained in whole range of loaded currents based on polarization curves data. The results also demonstrated that cathode modification by Cu/rGO nanocatalysts in Li-$SOCl_2$ batteries enhances the battery capacity significantly.

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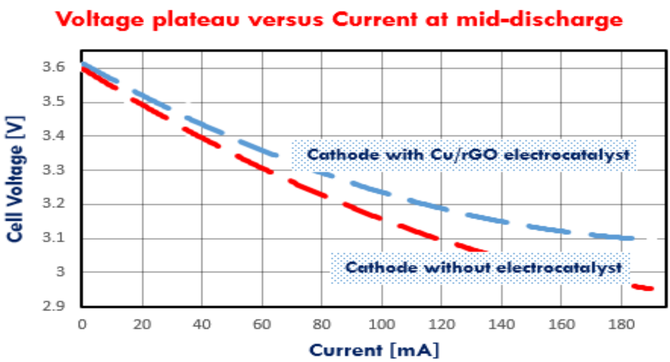

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Enhanced Hole Mobility of CVD Transition Metal Dichalcogenide Monolayer by Metal Nanoparticles

Tungsten diselenide (WSe_2) is an attractive transition metal dichalcogenide material, since its Fermi energy close to the mid gap makes it an excellent candidate for realizing p–n junction devices and complementary digital logic applications. Doping is one of the most important technologies for controlling the Fermi energy in semiconductors, including 2D materials. Moreover, the Fermi level engineering or doping in monolayer WSe_2 is still relatively unexplored. Recently, Fang et al have reported transistors based on WSe_2 using high-k materials as the gate dielectrics, where the chemically doped source/drain contacts exhibit low contact resistances. Selective treatment with potassium is able to form degenerately doped n+ contacts for electron injection while NO_2 treatment forms p+ contacts [1–3]. Liu et al have demonstrated the n-type WSe_2 FET by using indium as a contact metal [4]. Chuang et al have revealed that graphene can be a work-function-tunable electrode material for few-nanometre WSe_2 FETs [5]. It is noted that the small molecules adsorbed on the 2D materials tend to desorb from the surfaces and the alkali metals are known to be sensitive to moisture and oxygen. Here we present a simple, stable and controllable p-doping technique on a WSe_2 monolayer, where a more p-typed WSe_2 field effect transistor is realized by electron transfer from the WSe_2 to the gold (Au) decorated on the WSe_2 surfaces. Related changes in Raman spectroscopy are also reported. The p-doping caused by Au on WSe_2 monolayers lowers the channel resistance by orders of magnitude. The effective hole mobility is ~100 (cm^2/Vs) and the near ideal subthreshold swing of ~60 mV/decade and high on/off current ratio of $>10^6$ are observed. The Au deposited on the WSe_2 also serves as a protection layer to prevent a reaction between the WSe_2 and the environment, making the doping stable and promising for future scalable fabrication.

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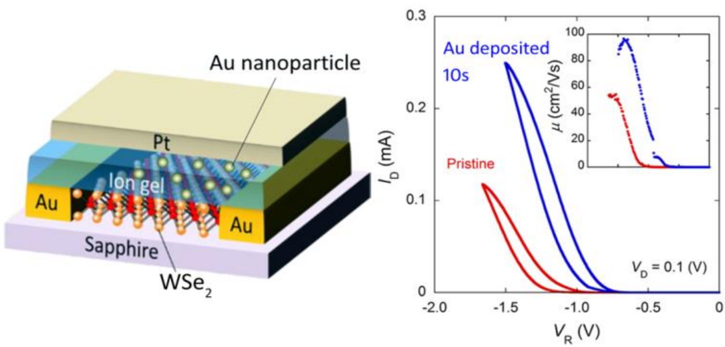

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Possibility of application of two-domain model for graphenic materials with high electrical conductivity

Origin of magnetism in carbon materials is often ascribed to dangling bonds on zigzag edge of graphene planes. However, for amorphous carbon experimental evidences are scarce due to two reasons: first, there is no definite model of amorphous carbon, second, carbon tends to react with 3*d*-metals, while even traces of paramagnetic metal ions can corrupt picture from magnetism of carbon as it is. Is it possible that their magnetism and high electric conductivity is due to the same mechanisms as in graphenic materials with sp^2 hybrydization?

Here we report the first step in a complex approach of solving this problem with synthetic, spectroscopic and computational methods. The aim of the work on this stage was to synthesize ultra-pure carbon, prove its purity and amorphicity, characterize its magnetic properties by EPR spectroscopy and magnetic measurements, and propose a zeroth-order computational model of spin centers able to describe the magnetic properties. Very well known carbon material produced by carbonization of phenol-formaldehyde (PhF) resin was chosen due to large number of works, allowing various methods of material characterization, simple synthesis and relatively easy purification of the precursors. The resulting material showed no traces of paramagnetic metals, and its microstructure was characterized by TEM. Molecular model for the magnetic and EPR data interpretation was constructed basing on recently developed model of amorphous carbon produced from PhF resin [1]. These results were compared with EPR data on reduced graphene.

Neither magnetism of the edge-located paramagnetic defects [2], nor antiferromagnetic ordering observed for magnetic moment associated with carbon vacancies in graphene [3], can explain the temperature dependence of EPR signal. More sophisticated model comprising both graphene-derived parts and connecting carbene atoms was used, and DFT calculations were applied to simulate its thermal-dependent properties. Combined experimental and computational demonstrated that untypical temperature dependence of EPR signal intensity can be ascribed to interaction between localized and delocalized (conducting) electrons in the bulk, with ratio between them being related to conformation of carbene-type atoms connecting graphene sheets.

Acknowledgments: Computational resources were provided by the Centre for Research in Molecular Modeling (CERMM) and Calcul Québec.

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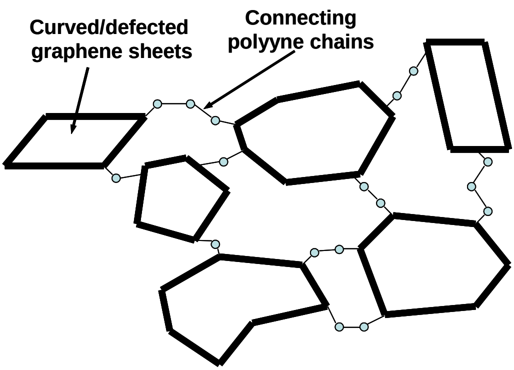

Figure 1: Schematic representation of two-domain model of amorphous carbon

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Graphene wrapped MnO_2 nanostructures for desalination via capacitive deionization

Graphene is an optimal electrode in the capacitive deionization (CDI) units if the specific capacitance could be improved. In this study, novel strategy for rapid transformation of graphite into graphene-intercalated with nanostructure MnO_2 with morphology control is introduced by one-pot reaction, low-time consuming and eco-environmentally method. Conversion of graphite into the graphene structure was suggested through vigorous oxidation using ammonium peroxysulphate and hydrogen peroxide in the presence of manganese sulfate followed by a reduction step using piperidine under a microwave irradiation. It was explained that the formation of MnO_2 nanostructures during the exfoliation process has a great impact to separate the graphene sheets as the metallic nanostructures wedged among the sheets. Interestingly, morphology control could be performed: MnO_2 nanorod and MnO_2 nanoparticles @graphene could be prepared. As an electrode in the CDI unit, the synthesized MnO_2-nanorods @graphene showed the excellent results in the specific capacitance (292 F/g), distinct electrosorp- tive capacity (5.0 mg/g), good salt removal efficiency (93%) and distinguished recyclability.

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Single Crystal Graphene Growth on Reusable Iridium/Sapphire Substrates

Iridium (Ir) is a favourable metal catalyst for chemical vapour deposition (CVD) growth of graphene because of the low C solubility, high melting temperature and chemical stability. In this study, we investigated epitaxial growth of single-crystal graphene sheets by CVD on Ir films on sapphire and demonstrated reusability of the Ir/sapphire substrates [1]. Ir films were prepared by RF magnetron sputtering on α-Al_2O_3(0001) (c-plane sapphire) substrates. X-ray diffraction measurements showed that Ir(111) was epitaxially grown on sapphire. Graphene sheets, which were grown by low-pressure CVD on Ir(111)/sapphire at a growth temperature of 1000˚C using CH_4 and H_2 gases, were characterized as high quality and mono-layer graphene by Raman spectroscopy (Fig.1(a)). Reflection high energy electron diffraction observation revealed that graphene was epitaxially grown on Ir(111) as graphene < $1\bar{1}00$ > // Ir < $11\bar{2}$ > / sapphire < $11\bar{2}0$ > (Fig.1(b)) and was quasi-single crystal. A transfer technique, which utilized electrochemical H_2 bubble generation at the graphene/Ir interface in a NaOH aqueous solution [2], was applied and the graphene transfer onto SiO_2/Si(100) was demonstrated. Repeated CVD growth and electrochemical transfer of graphene using the same Ir(111)/α-Al_2O_3(0001) in three cycles were demonstrated (Fig.1(c)) and high quality of the three transferred graphene sheets was confirmed by Raman spectroscopy (Fig. 1(d)). The high melting temperature and chemical stability of Ir can inhibit the morphological change of the Ir surfaces during CVD growth and transfer processes, which may lead to good reusability of the substrates. The results suggest a possibility for applications to practical graphene production using reusable Ir/sapphire substrates.

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Figures

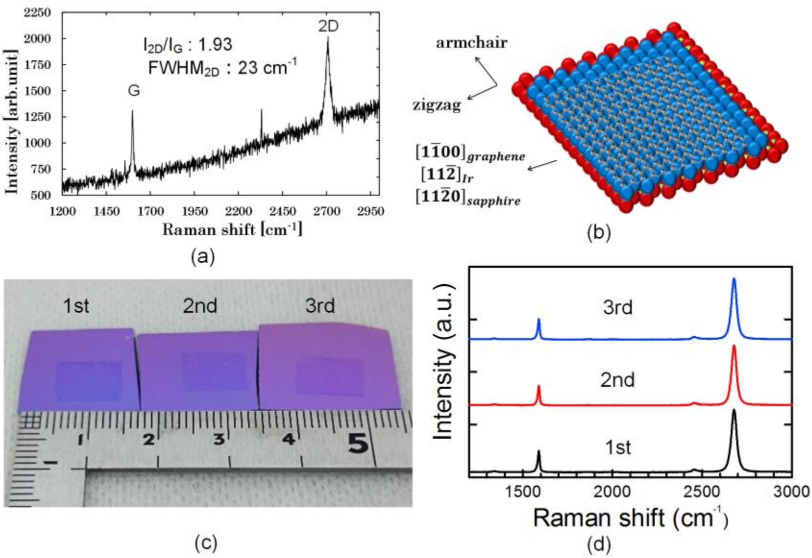

Figure 1: (a) Raman spectrum of graphene on Ir(111). (b) Schematic of the in-plane crystal orientation relationship. (d) Three graphene sheets fabricated using the same Ir(111)/sapphire substrate (d) Raman spectra of the three transferred graphene sheets in the three cycles.

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Chemical doping for Low Contact Resistance and De-Pinning at the Interface of Molybdenum Based Chalcogenides and Metals

MoS_2 and $MoTe_2$ are the promising two dimensional materials, having sizable band gap that is suitable for future semiconductor applications. However, large Schottky barrier is induced along these materials and contact metals interface due to strong Fermi level pinning. Also, the high contact resistance (>10 kΩμm) due to the high Schottky barrier sets off small source-drain current, so that it limits the usage of novel semiconductor device.1) In this work, we investigate the interfacial Schottky barrier formed between mono- or bi-layer MoS_2, $MoTe_2$ and Ti, Cr, Au, Pd. By varying temperature in the range from 170 to 470 K, we obtained their current – voltage and hysteresis characteristics so as to determine accurate Schottky barrier heights and their relative pinning factors. The interface trap density and charge neutral levels are calculated from the measured pinning factors. They show that the defect density affects the degree of pinning and we can predict the location of the pinned energy levels from it. Benzyl viologen and gold chloride are the effective n- or p-type doping solutions for MoS_2 and $MoTe_2$. Using these chemical dopants, we can achieve a reduced contact resistance < 3 kΩμm and de-pinned interfaces. These results are found to be crucial to resolve the Fermi level pinning and high contact resistance issues of two dimensional materials, which can be used to develop highly efficient, flexible devices based on two dimensional materials.

Refernces

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Electrochemical characteristics of enzyme/graphene electrodes

Graphene is attractive as electrode materials for biofuel cells because of its high electrical conductivity and chemical stability. The enzyme electrode with high current density and excellent reproducibility can be fabricated by utilizing two-dimensional structure of graphene with a large specific surface area and high uniformity. Stable immobilization of the enzyme is important in applications of enzyme-based biofuel cells. To our knowledge, there are few reports on evaluation of the electrochemical characteristics of enzyme-immobilized graphene planer sheets prepared by chemical vapor deposition (CVD). We focus on CVD-grown graphene sheets as electrode materials for biofuel cells because they are highly uniform, and the shape and size can be accurately controlled by conventional photolithography processes. In this study, we immobilized enzyme on CVD-grown graphene sheets by physical adsorption and evaluated electrochemical characteristics of the enzyme/graphene electrodes.

Graphene sheets were grown by CVD on Cu foil. To evaluate the intrinsic electrochemical characteristics, the graphene sheets were transferred onto electrochemically inert SiO_2/Si substrates by a using polymethyl methacrylate (PMMA) method. The transferred graphene sheets were confirmed to be monolayer by Raman spectroscopy. We immobilized an enzyme, glucose oxidase (GOx), in two ways. One was the easiest procedure, deposition adsorption, in which the graphene sheets were soaked for 12 h in GOx solution [1]. The GOx/graphene electrodes were covered by cellulose membranes to prevent desorption of GOx. The other procedure used noncovalent functionalization of the graphene surface. 1-pyrenebutanoicacid succinimidyl ester (PBSE) was used as a chemical linker on graphene [2]. The pyrenyl group of PBSE interacts strongly with the graphene surface by π-stacking and the succinimidyl ester parts combine with the amino base of GOx. The graphene sheets were soaked in 1mM PBSE in pure methanol for 3h, followed by soaking in GOx solution for 12 h. Electrochemical characteristics of these electrodes were measured by cyclic voltammetry (CV) at a scan rate of 10 mV/s in phosphate buffered saline (PBS:pH 7.0) containing glucose of 25 mM.

Figure 1 shows a frequency modulation atomic force microscopy (FM-AFM) image of GOx/PBSE/graphene electrode in ultrapure water. It is evident that GOx is immobilized on the graphene surface because three dimensional structures were observed on initially flat graphene surface. Fig. 1 shows the cyclic voltammograms recorded using graphene (dotted line), GOx/graphene (dashed line), and GOx/PBSE/graphene (straight line) electrodes. GOx catalyzes the oxidation reaction of glucose and current due to the oxidation reaction is generated by the addition of glucose. As shown in Fig. 1, the current responses were clearly observed for two enzyme-immobilized electrodes, in which the current density of the GOx/PBSE/graphene electrode had twice as high as that of the GOx/graphene electrode. The results suggested that the immobilization of the enzyme using PBSE formed strong connectivity between graphene and the enzyme, leading to a higher current density.

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Figures

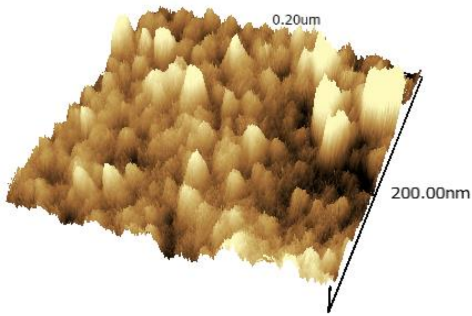

Figure.1 : FM-AFM image of GOx/PBSE/graphene

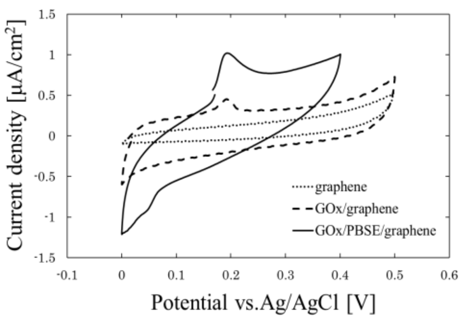

Figure 2: cyclic voltammograms of each electrode

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Quantum Monte Carlo study of the fermi velocity enhancement in graphene

The electronic property of graphene has been extensively studied in the past decade [1]. There is still ongoing debate on the role of electron-electron interaction in graphene [2]. In this work, we adapt the quantum Monte Carlo method to account for the long range Coulomb interaction in graphene. By analyzing the Fermi velocity of the half-filled Coulomb model in honeycomb lattice, we found the strong coupling regime and weak coupling regime are governed by two types of theory, namely, the renormalization group study that works when long range interaction dominates, and Gross-Neveu theory that works when short range interaction dominates. We deduce that neither theory alone can describe the physics of realistic graphene, because realistic graphene is located in the regime where the effects of long range interaction and short range interaction are competing with each other.

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