Opening and greetings

By Dr. Ami Appelbaum

Bio

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Dr. Ami Appelbaum is the Chief Scientist and the Chairman of Israel Innovation Authority. Dr. Appelbaum has more than 36 years experience in research, development and senior level management in the field of the Semiconductor. Prior to the current job as Chief Scientist, Dr. Appelbaum served for 22 years at numerous executive positions at KLA Tencor, $15.6B Market Cap and world leader in the business of capital equipment for the semiconductor industry based in the Silicon Valley, CA. His most recent job was Corporate Senior Vice President and president of KLA Tencor Israel.

Dr. Appelbaum holds a Doctorate and Master degrees from the Technion, Israel Institute of Technology in Haifa and an Engineering degree from Ben Gurion University in Beer Sheba, all in the field of materials engineering.

Dr. Appelbaum is the author and co-author of more than 50 scientific and technical publications and holds 7 patents in the field of semiconductor equipment and processing.

Activity of the Israeli Graphene Consortium

<u>By Mr. Aner Shoam</u>

<u>Bio</u>

Aner has many years of experience in cultivation, bring up and management of startup companies and advanced technology projects. He has worked for Intel, Matrix and Rafael and was a senior executive and VP of R&D of the communications startup Wavion. Aner initiated and is the CTO of two MAGNET consortiums in Israel, including the Israeli Graphene Consortium. He holds a B.Sc. degree from the Technion in Israel.

Graphene and F-Diamane

By Prof. Rodney Ruoff

Abstract

We present some of the research reported in our Center for Multidimensional Carbon Materials, an Institute for Basic Science Center (IBS-CMCM) at the Ulsan National Institute for Science and Technology (UNIST). CMCM started in 2014 so our scientific studies are about 7 years old or less. Allow me, please, to tell a few stories about studies of carbon we have 'completed' and some that are underway. Support from the Institute for Basic Science (IBS-R019-D1) is appreciated. For those that like to read ahead—please enjoy**:**

doi.org/10.1126/sciadv.abe3767;doi.org/10.1126/science.aao3373;doi.org/10.1002/adma.201903615;doi.org/10.1038/s41565-019-0622-8;doi.org/10.1038/s41565-019-0582-z; doi.org/10.1002/adma.201706504;doi.org/10.1002/adma.201903615;doi.org/10.1002/adma.201706504;doi.org/10.1021/acs.chemmater.9b01729;doi.org/10.1002/adma.201800888); doi.org/10.1002/adma.201707449

Bio

Rodney S. Ruoff, UNIST Distinguished Professor (The Departments of Chemistry, Materials Science, and The School of Energy Science and Chemical Engineering), directs the Center for Multidimensional Carbon Materials (CMCM), an Institute for Basic Science Center (IBS Center) located at the Ulsan National Institute of Science and Technology (UNIST) campus. Prior to joining UNIST in 2014, he was the Cockrell Family Regents Endowed Chair Professor at the University of Texas at Austin from September, 2007. He earned his Ph.D. in Chemical Physics from the University of Illinois-Urbana in 1988, and was a Fulbright Fellow in 1988-89 at the Max Planck Institute für Strömungsforschung in Göttingen, Germany. He was at Northwestern University from January 2000 to August 2007, where he was the John Evans Professor of Nanoengineering and director of NU's Biologically Inspired Materials Institute, and did research at the Molecular Physical Laboratory, SRI International for 6 years after being a postdoctoral fellow at IBM TJ Watson Research Center.

Further information about Rod is at http://cmcm.ibs.re.kr/ and
https://en.wikipedia.org/wiki/Rodney_S._Ruoff

Graphene in Nvidia, why now?

By Dr. Elad Mentovich

Abstract

Graphene is considered as the material of great promise for the future, while so far it has been implemented mainly in low-tech industry.
In this consortium, we would like to suggest Graphene as a new PCB material. This will allow both solving the issue of hot spots cooling as well as high speed operations.
With this in mind, we need to see what is the eco-system required in order for this plan to be implemented in industrial scale

Bio

*NVIDIA

Graduated from the Physical Chemistry department at Tel Aviv University, Israel, where he also earned his M.Sc. (Cum Laude). His dissertation is entitled “Realization of the Molecular Transistor Roadmap”. He earned his B.Sc. (Cum Laude) in Physics and Materials Engineering at Technion, Haifa, Israel in 2005.
Elad published extensively in international academic publications such as Applied Physics Letters, The Journal of Nanobiotechnology, Nano Letters and Advanced Materials.

PCB Technologies solutions for heat dissipation HSD/RF/Microwave designs

By Mr. Yaad Eliya

Abstract

RF/Microwave, high speed digital and high power boards required many considerations and aspects for maximizing thermal and electrical performance.

Designers for high frequency applications must understand critical parameters at the PWB stage. These parameters must be understood in order to eliminate noise, reliability, poor electrical performance, high price and low yield risks. The presenter will highlight innovative & legacy solutions, based on close cooperation between Mil/Aero/Med. designers and the PWB vendor.

Actual field performance sometimes demands “beyond” IPC rules/specification”, and usage of unique materials, process and machinery, that are not common in traditional PCB fab, considered as “must” now days. Therefore, the usage of Graphene in a PCB industry & designs, need a “tailor made” experts, in order to gain the 2 critical advantages that the Graphene bring to the electronic market: heat dissipation/heat spreader, and low skin effect/ low loss for HSD.

In that respect one must provide innovative solutions such as: Implementing Air cavity, Coin, heat sink, low loss conductors, selective final finishes, etc, in a complex design. This is even more critical, when the hybrid/mixed materials / for high speed digital & RF, are combined into a rigid flex stack up.

Bio

Working in PCB Technologies for the last 14 Years, as Technology Manager / R&D / CTO. In the last 6 years as the CTO/PWB division.

B.Sc. Engineering at Ben-Gurion University of the Negev.

Electronic Materials Expert, with especially at Rigid Flex, RADAR / Microwave and RF applications.

Process and machinery design & architecture manager, in the PCB industry.

Responsible for special application development, for Medical/Space & Military segments.

Expert as "tailor made" in design stage application.

Background and experience - TOWER Semiconductor, IAI (Israel Aerospace Industries).

Growth of Atomic-Films: From the Lab to the Fab

By Prof. Ariel Ismach

Abstract

Atomically-thin films have attracted extensive interest in the scientific and industrial communities due to the wide range of properties and potential applications these materials (and their combination) offer. As usual in novel materials research, one of the bottle-necks delaying their implementation into novel and existing technologies would be the ability to grow these atomic-layers on a large-scale, suitable for industrial applications. This however, can be achieved only by a deep understanding of the growth mechanism process.

In this talk, I will briefly review the history of 2D materials with focus on graphene (a single atomic layer of graphite), from early experiments few decades ago to the most recent breakthroughs related to the rational growth of single and few-layer graphene layers. The different growth mechanism of graphene on various substrates will be explained and show how it eventually dictates the nature of the grown film, *i.e*. number of layers, crystallinity, *etc*. I will finalize by describing the growth of hexagonal boron nitride films (*h*-BN), which despite being a more complex system, exhibit some similarities in the growth behavior.

Bio

Professor Ariel Ismach holds a BSc in Materials Engineering from Ben Gurion University of the Negev, and an MSc and PhD in Materials and Interfaces from the Faculty of Chemistry in the Weizmann Institute of Science. He was awarded the Israel Chemistry Society prize for his doctoral thesis on “epitaxial approaches for the self-organization of single-wall carbon nanotubes”. In 2009, he moved to Berkeley for a joint post-doctoral position at the Department of Electrical Engineering, University of California at Berkeley and the Materials Science Division of the Lawrence Berkeley Laboratory. In 2011, he joined the group of Prof. Ruoff in the department of Mechanical Engineering, at the University of Texas in Austin, where he led a small group of students studying the growth and characterization of various 2D materials. He joined the Materials Science and Engineering department at Tel Aviv University in October 2014 where he established a laboratory dedicated to study the growth of 2D atomic-crystals.

Graphene and layered materials for photonics and optoelectronics

By Prof. Andrea Ferrari

Abstract

Graphene and layered materials have great potential in photonics and optoelectronics, where the combination of their optical and electronic properties can be fully exploited, and the absence of a bandgap in graphene can be beneficial. The linear dispersion of the Dirac electrons in graphene enables ultra-wide-band tunability as well as gate controllable third-harmonic enhancement over an ultra-broad bandwidth, paving the way for electrically tuneable broadband frequency converters for optical communications and signal processing. Saturable absorption is observed as a consequence of Pauli blocking and can be exploited for mode-locking of a variety of ultrafast and broadband lasers. Graphene integrated photonics is a platform for wafer scale manufacturing of modulators, detectors and switches for next generation datacom and telecom. These functions can be achieved with graphene layers placed on top of optical waveguides, acting as passive light-guides, thus simplifying the current technology. Heterostructures based on layers of atomic crystals have properties different from those of their individual constituents and of their three dimensional counterparts. The combinations of such crystals in stacks can be used to design the functionalities of such heterostructures, that can be exploited in novel light emitting devices, such as single photon emitters, and tuneable light emitting diodes.

Bio


* University of Cambridge

Andrea Ferrari is Professor of nanotechnology at the University of Cambridge and a Fellow of Pembroke College. He founded and directs the Cambridge Graphene Centre and the EPSRC Doctoral Training Centre in Graphene Technology. He chairs the management panel and is the Science and Technology Officer of the European Graphene Flagship. He is a Fellow of the American Physical Society, the Materials Research Society, the Institute of Physics, the Optical Society, the Royal Society of Chemistry, The European Academy of Sciences, the Academia Europaea, and he received numerous awards, such as the Royal Society Brian Mercer Award for Innovation, the Royal Society Wolfson Research Merit Award, the Marie Curie Excellence Award, the Philip Leverhulme Prize, The EU-40 Materials Prize, The Blaise Pascal Medal. He has over 420 papers, with over 126,000 citations, and an H index of 118.

Slide-Tronics

By Prof. Moshe Ben Shalom

Abstract

A new ferroelectric system, only two-atoms-thick is presented [1]. Stacking two layers of hexagonal boron nitride (hBN) atop each other, with a parallel crystal orientation, results in a permanent electric polarization pointing out of the plane. Furthermore, applying an opposite external electric field switches the vertical polarization by a horizontal sliding between the layers of a full atomic spacing distance. I will describe our atomic force experiment, DFT calculations, and a simplistic cohesion model, allowing us to explore the interfacial-ferroelectricity and its unique Slide-Tronics switching mechanism.

If time allows, I will further discuss our efforts to induce intrinsic electric and magnetic gauge-fields in graphene by particular strain-engineering schemes [2].

[1] https://arxiv.org/abs/2010.05182

[2] https://arxiv.org/abs/1909.09991

https://www.tau.ac.il/~moshebs

Bio

Since Oct 2017, Im an assistant Prof. at TAU, managing the "Quantum Layered Matter Lab". Before that, I spent four years as a post-doc at the Manchester graphene lab and the National Graphene Institute, UK.

My academic education in physics was acquired at TAU, with a research focus on oxide interfaces and highly correlated electronic systems.

Graphene in PCB - Design challenges

By Mr. Boaz Atias

Abstract

Transceivers, solid-state communication devices that receive and transmit electrical, optical and mixed signals are of significant importance for the continuous development of key technologies. As transceiver bandwidth scales rapidly within the demand for future technologies in High Performance Computing and Large Communication Traffic Nodes such as Datacenters. The challenges of cost effective, high performance transceivers manufacturing turns to be one of the main barrier for this development, and our industry puts significant efforts in adding new materials and technologies that will further increase the BW of PCBs.

In this consortium we would examine if Graphene is a suitable material to facilitate the development of such technologies and present the design challenges of PCBs with this material.

Bio

*NVIDIA

Head of Advanced PCB Lab in the Advanced Technologies Group: Holds a position of Sr. Manager, Electro-optical at the Advanced Technologies group At Mellanox Technologies Israel. In his position Boaz is in charge of all of PCB Design for the Advanced Technologies group. At Mellanox Boaz established R&D laboratory – "Advanced PCB Lab" and build up a new Hardware team to achieve 400G capabilities, and beyond. Boaz holds a vast experience [>15 years] of leading successful ultra-high speed electro optical designs. Leading very complex Tunable 10/40/100 Gbps Multi rate Transponders for Metro and long Haul. Prior to joining Mellanox, Boaz worked at several Fabless and Electro-optical companies such as: Optium/Finisar, EFFDON Networks, Tera Chip and Smart-vision.

Torsional electromechanics of carbon and inorganic nanotubes: From fundamentals to devices

By Prof. Ernesto Joselevich

Abstract

What happens when you twist a nanotube? We studied the mechanical and electrical response to torsion of nanotubes of different materials (C, WS_2, BN, and BCN), and found intriguing differences between all of them. We have been able to create torsional resonators based on inorganic nanotubes, and found them to have higher resonant frequencies and quality factors than those based on carbon nanotubes. This demonstrates that inorganic nanotubes could be attractive building blocks for nanoelectromechanical systems (NEMS), including miniaturized gyroscopes and accelerometers.

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[3] *Phys. Rev. Lett.* **2008**, *101*, 195501

[4] *Nano Lett.* **2012**, *12*, 6347

[5] *Nano Lett.* **2014**, *14*, 6132

[6] *ACS Nano* **2015**, *9*, 12224

[7] *Nano Let* **2017** , *17*, 28

Bio

Ernesto Joselevich is a Professor of Chemistry at the Weizmann Institute of Science. His research focuses on the formation, structure and properties of low-dimensional materials (including carbon and inorganic nanotubes, nanowires and 2D materials), their integration into functional nanosystems, and their characterization by mechanical, electrical and optical measurements at the nanometer scale. He has received numerous prizes and awards, including the Israel Chemical Society Excellent Young Scientist Prize (2007), European Research Council (ERC) Advanced Grant (2014), Tenne Prize for Nanoscale Sciences (2016) and Israel Vacuum Society (IVS) Excellence Award for Research (2020).

Mass Production of Graphenefor for Printed Circuit Applications

By Prof. Doron Naveh

Abstract

Integration of graphene in printed circuit boards is driven by the ever-increasing demand for higher bandwidth and power. Graphene technologies bear the potential to enhance the high frequency conductivity and the thermal management of hot spots in printed circuits. This integration requires the supply of graphene materials and the technology of implementation of printed circuit boards with graphene materials. Here, we describe our approach to industrial production of graphene at large volume, low cost and high quality that is designed for achieving the first requirement. In addition, our approach for integration of graphene materials in printed circuit boards will be described.

Bio

Doron Naveh earned his B.Sc. and in Materials Engineering as well as B.Sc. and M.Sc. in Physics from Ben-Gurion University of the Negev, PhD in computational Materials Science from the Weizmann Institute of Science. In 2008 he moved to Princeton University and in 2009 to Carnegie-Mellon University for post-doctoral fellowships, where he started the transition from computational to experimental sciences. In 2012 he started the 2D Materials & Devices Lab in Bar-Ilan Faculty of Engineering, where he is now an Associate Professor.

*Bar Ilan University

Graphene production and application in sensors

By Dr. Amaia Zurutuza

Abstract

Over the past two decades, graphene has attracted a great deal of attention due to its extraordinary properties. When these properties are translated into applications graphene could have a large impact in various industries and markets such as telecommunications, healthcare, automotive, etc. However, for this to occur there are many milestones that have to be achieved such as graphene manufacturing (growth and transfer) and device fabrication at relevant wafer scales, before moving to component fabrication and system integration into the final product.

Graphene's electronic and mechanical properties make it an ideal candidate to be applied in various types of sensors. The sensors' market is extremely large since we are dealing with the automotive, electronics and healthcare industries among others. Therefore, it is an excellent starting platform for graphene applications. For example, the current COVID-19 pandemic has demonstrated the urgent need for fast diagnostics in order to minimise and control its effects, here, biosensors based on graphene field effect transistors (GFETs) have shown great potential as a platform for future diagnostics.

During this talk, I will cover the fabrication of graphene at wafer scale and the use of graphene in various types of sensors including MEMS [1,2], ion sensors (ISFETs) [3-5], gas sensors [6] and biosensors. Depending on the type of sensor, the graphene requirements including the transfer and characterisation vary considerably.

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Bio

She received her Ph.D. degree in polymer chemistry from the University of Strathclyde (Glasgow, UK) in 2002. From 2001 to 2003, she was a Postdoctoral Research Fellow working in two European projects related to molecularly imprinted polymers. In 2004, she joined Ferring Pharmaceuticals (previously Controlled Therapeutics) where she worked in the research of new controlled drug delivery systems as a Senior Polymer Scientist. Her contribution led to the granting of three patents in novel biodegradable and biostable polymers for the controlled release of active compounds. In 2010, she became the Scientific Director of Graphenea. At Graphenea, she leads the research and development activities on graphene-based materials. Since joining Graphenea, she has so far filed for twelve patents and published more than 74 publications in peer reviewed journals, including Nature and Science. Principal Investigator in 21 EU FP7/H2020 funded research projects, 16 collaborative projects including the Graphene Flagship and 3 people training network projects. In the Graphene Flagship, she is a member of the executive board and world package deputy leader in the wafer scale integration (Graphene Flagship) and wafer scale growth (Experimental Pilot Line) workpackages. In addition, she has also given more than 52 invited talks in international conferences. Her research interests include the synthesis, characterization, and future industrial applications of graphene.

Avoiding hot spots: graphene-based conformal coating

By Prof. Oren Regev

Abstract

[a]Oren Regev and [b]Gennady Ziskind

[a]Department of Chemical Engineering and [b]Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel

A printed circuit board (PCB) is an essential component of nearly all forms of commercial electronics where the highly dense electronic components result in elevated operating temperatures (hot spots) that directly affect the performance of the device. Our approach is to employ a conformal polymeric coating over the PCB as a platform for heat dissipation by loading it with high conductivity graphene-based fillers [1-5]. This approach demonstrated effective heat dissipation resulting in a drastic drop in hot spot temperature (~ 30 °C) in a model printed circuit board. The approach could be applied in thermal management applications of miniaturized electronic components.

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4. Ligati, S. et al. *International Journal of Thermal Sciences* 153, 106381 (2020).
5. Shachar-Michaely, G., et al., *Carbon* 176 339-348 (2021).

Bio

Oren Regev is a professor and head of the Chemical Engineering department in the Ben-Gurion University of the Negev, Beer-Sheva, Israel. His research topics include dispersion of nanocarbon materials (e.g., nanotube, graphene, boron nitride) and their integration in polymer matrices to form composite materials for thermal management. He received his PhD in 1992 from the Technion, Israel Institute of Technology and was a visiting scientist in Lund Sweden, Eindhoven and Texas A&M universities. He has published more than 140 research papers (>6000 citations, h-index = 43) and few patents.

https://www.orenregev.org/

Thermometry of nanomaterials and devices

By Prof. Eilam Yalon

Abstract

The advancement of nanoscale electronics has been limited by energy and heat dissipation challenges for over a decade. This difficulty highlights the need for better understanding energy dissipation mechanisms in future microelectronic devices as well as thermal properties at the nanoscale. In this talk I will discuss two nanoscale thermometry techniques and their applications for electronic devices. The first method is scanning thermal microscopy (SThM), which is based on a thermal sensor (thermoresistor or thermocouple) placed on an atomic force microscopy (AFM) head. SThM enables thermal mapping of the sample surface with nanoscale spatial resolution. The second technique, Raman thermometry, enables simultaneous measurements of the device layer and its substrate, yielding unprecedented resolution in the "vertical" direction of heat flow and making it ideal to study energy dissipation at interfaces. Overall, the combination of various thermometry techniques and modeling allows us to better understand the thermal properties of emerging nanomaterials.

Bio

Eilam received the B.Sc. degree in Materials Engineering and Physics and the Ph.D. degree in Electrical Engineering from the Technion—Israel Institute of Technology, Haifa, Israel, in 2009 and 2015, respectively. From 2015 to 2018, he was a Postdoctoral Researcher at Stanford University. He is currently an Assistant Professor at the Andrew and Erna Viterbi Faculty of Electrical Engineering, Technion—Israel Institute of Technology. He is a receptionist of several awards and honors, including Technion excellence in teaching 2018, Northern California Career development Chair 2018, Andrew and Erna Finci Viterbi Fellowship 2016, Ilan Ramon-Fulbright Fellowship 2015, Muriel and David Jacknow Prize 2013, Clore Israel Foundation Scholarship 2013, and IEEE non-volatile memory technology symposium (NVMTS) 2012 best poster award. His current research interests include heat dissipation and energy efficiency in nano electronic devices, memory and computing electronic devices with 2D materials, resistive switching oxides, and phase change chalcogenides.

Nanomanipulation of bilayer graphene contacts

By Prof. Elad Koren

Abstract

Weak interlayer coupling in 2-dimensional layered materials such as graphene gives rise to rich mechanical and electronic properties, in particular in the case where the two atomic lattices at the interface are rotated with respect to one another. The reduced crystal symmetry leads to anti-correlations and cancellations of the atomic interactions across the interface, leading to low friction[1] and low interlayer electrical transport[2]. Using our recent nanomanipulation technology, based on atomic force microscopy, we show that combined electro-mechanical characterization can uniquely address open fundamental questions related to electronic charge transport[2-3] through stacking faulted structures. To this end, we studied experimentally and theoretically the interlayer charge transport in twisted bilayer graphene systems separately for edges and bulk parts. We find that interlayer edge currents are several orders of magnitude larger than in the bulk and therefore govern the transport up until very large critical diameters depending on the potential across the adjacent layers and the angular mismatch angle. In addition, we show that the strong edge transport across the interface is governed by strong quantum mechanical interference effects as opposed to simple interlayer atomic interactions.

[1] E. Koren *et al.*, *Science*, 6235 (2015) 679.

[2] E. Koren *et al.*, *Nature Nanotech*., 9 (2016) 752.

[3] D. Dutta *et al.*, *Nature Comm*, 11 (2020) 4746.

Bio

Elad Koren is heading the Nanoscale Electronics group at the faculty of Materials Science & Engineering at the Technion – Israel Institute of Technology. His research interests are focused on nanoscale (opto)electronics and electromechanical properties of 2-dimensional (2D) layered materials. Before joining the Technion Elad served as a principle investigator in the Physics of Nanoscale System*s* group of the Science & Technology department at IBM Research–Zurich. Elad holds BSc in Biophysics and MSc in Physical Chemistry with the emphasis on photovoltaics, both are from Bar Ilan University, Israel. He received his PhD degree in Engineering, Physical Electronics from the Tel Aviv University, Israel.

Unique Heat Conduction Properties of Graphene – Applications in Thermal Management

By Prof. Alexander A. Balandin

The discovery of unique thermal properties of graphene and few-layer graphene (FLG) [1-2] motivate strong interest to applications of graphene in thermal management. The extremely high thermal conductivity of graphene and FLG, mechanical flexibility and relatively low cost of liquid phase exfoliated (LPE) FLG and reduced graphene oxide make this class of materials particularly promising for thermal management applications. In this talk, I will briefly overview the thermal properties of graphene and FLG, and provide specific examples of applications of graphene and FLG fillers in curing and non-curing thermal interface materials (TIMs), thermal phase change materials (PCMs), and thin-film coatings [3-5]. I will also discuss dual-function graphene-enhanced composites, which can be used for simultaneously thermal management and electromagnetic interference (EMI) shielding [6-7].

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Bio

Alexander A. Balandin received his BS and MS degrees Summa Cum Laude in Applied Physics and Mathematics from the Moscow Institute of Physics and Technology (MIPT), Russia. He received his PhD degree in Electrical Engineering from the University of Notre Dame, USA. He is presently a Distinguished Professor of Electrical and Computer Engineering at the University of California, Riverside (UCR) and the University of California Presidential Chair Professor of Materials Science and Engineering. He serves as a Director of the UCR Phonon Optimized Engineered Materials (POEM) Center. His research interests cover a wide range of nanotechnology, electronics, optics, materials science and thermal fields. Professor Balandin is a recipient of The MRS Medal from the Materials Research Society (MRS) for his discovery of unique heat conduction properties of graphene, IEEE Pioneer of Nanotechnology Award for his nanotechnology research, and The Brillouin Medal for his phononics research. He is an elected Fellow of numerous professional societies, including MRS, APS, IEEE, OSA, SPIE and AAAS. He is among the Clarivate Analytics Highly Cited Researchers. He serves as the Deputy Editor-in-Chief of the Applied Physics Letters. For more information, visit his group web-site: http://balandingroup.ucr.edu/

Next-generation Integrated Electronics Enabled by 2D Materials

By Prof. Kaustav Banerjee

Abstract

Two-dimensional (2D) van der Waals materials such as graphene and various transition metal dichalcogenides (such as WSe_2 and MoS_2) possess a wide range of remarkable properties that make them attractive for a number of applications, including sub-5 nm VLSI (*Physics Today*, Sept. 2016). I will highlight the prospects of 2D materials for innovating energy-efficient transistors, memories, sensors, interconnects, and passive devices targeted for next-generation ICs and the emerging paradigm of the Internet of Things (IoT). More specifically, I will bring forward a few applications uniquely enabled by 2D materials and their heterostructures that have been demonstrated in my lab for overcoming fundamental limitations in nanoelectronics. This includes the invention of the highest inductance-density materials ever made that helped overcome a 200-year old limitation of the Faraday-inductor and has opened up a new pathway for designing ultra-compact IoT systems (*Nature Electronics* 2018); the world's thinnest channel (only two atomic layers of MoS_2) band-to-band tunneling field-effect transistor (TFET) that overcame a fundamental power consumption challenge in all electronic devices since the invention of the first transistor (*Nature* 2015); 2D-2D lateral-heterojunction tunnel-FETs that we pioneered (*IEDM* 2015) to design some of the highest performance TFETs to date and their unique application for designing ultra-energy-efficient neuromorphic circuits; the first 2D-semiconductor channel based FET-biosensor with unprecedented sensitivity and promise of single-molecule detection (*ACS Nano* 2014); as well as a breakthrough CMOS-compatible graphene interconnect technology, which overcomes the fundamental limitations of conventional metals and provides an attractive pathway toward energy-efficient and highly reliable interconnects for next-generation integrated circuits (*IEDM* 2020, 2018, *Nano Letters* 2017). I will conclude with the prospects of monolithic 3D integration with 2D materials (*IEEE J-EDS* 2019) for realizing 3D ICs of ultimate thinness and integration density – particularly enabled by the recently demonstrated "0.5T0.5R" memory architecture (*IEDM* 2020, *IEEE TED* 2021).

Bio

Kaustav Banerjee is Professor of Electrical and Computer Engineering at the University of California, Santa Barbara, and is one of the world's leading innovators in the field of nanoelectronics. His pathbreaking innovations with 2D van der Waals materials and heterostructures are setting the stage for next-generation electronics. This includes the invention of the *Kinetic Inductor using graphene* that changed the course of science and engineering by overcoming a 200-year old limitation, and has been called "a trillion dollar breakthrough" by *Forbes* magazine. He is a Fellow of IEEE, APS, JSPS, and AAAS, as well as a recipient of the prestigious *Bessel Prize* from the Humboldt Foundation. His seminal contributions to nanoelectronics including nanoscale interconnects, 3D integration, and thermal-aware design have been widely commercialized, and recognized with an *IEEE Technical Field Award – The Kiyo Tomiyasu Award in 2015,* one of the institute's highest honors. In 2019, he was identified as one of the world's most influential scientific minds by Clarivate Analytics. More information about him and his research is available at: https://nrl.ece.ucsb.edu/