



Emerging Device Nanotechnology for Future Nanoelectronics Applications

Robert S. Chau

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Abstract:

This presentation will cover three topics. First, it will highlight some of the most recent device nanotechnologies implemented by the Silicon industry for advanced CMOS transistors. Second, it will summarize research progress on non-Silicon transistor channel materials (e.g. Germanium and III-V compound semiconductors) and their integration on Silicon substrate for future high-speed and low-power logic CMOS applications. Third, it will describe recent research effort by the device research community on forward-looking devices beyond CMOS. In this research space, carbon-based, spin-based, tunnel-based and exciton-based devices are being explored as alternative switches/devices to either replace or complement CMOS to improve and create new circuit functionalities for future nanoelectronics applications. These emerging devices exhibit unique and interesting characteristics which will be discussed.

Biography:

Robert S. Chau is an Intel Senior Fellow and director of transistor research and nanotechnology in Intel's Technology and Manufacturing Group. Chau is responsible for directing research and development in advanced transistors and gate dielectrics, process modules and technologies, and silicon integrated processes for microprocessor applications. He is also responsible for leading research efforts in emerging nanotechnology for future nanoelectronics applications.

Chau joined Intel in 1989, became an Intel Fellow in 2000 and an Intel Senior Fellow in 2005. During his career at Intel he developed nine generations of Intel gate dielectrics, including the high-K/metal-gate, along with many transistor innovations and process technologies used in various Intel manufacturing processes and microprocessor products. He also introduced many new process modules and novel device nanotechnologies for Intel's future logic processes.

Chau has earned 7 Intel Achievement Awards. He was the co-recipient of the 2008 SEMI Award for North America for the development of Intel's 90nm strained silicon technology, and the 2008 EDN (Electronics Design, Strategy, News) "Innovator of the Year" award for the development of Intel's 45nm high-k metal gate transistor technology.

Chau received his bachelor's and master's degrees and Ph.D. in electrical engineering from The Ohio State University. He holds more than 180 issued U.S. patents and has been elected an IEEE Fellow.



Pioneering Innovation to Drive an Educational and Economic Renaissance in New York State

Michael Liehr

CNSE Vice President for Research
Associate Vice President of Business,
Alliances and Consortia
Professor at CNSE
University at Albany, State University of New York,
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Abstract:

The College of Nanoscale Science and Engineering (CNSE) leverages industry partners, academic and government resources in effective partnerships to enable accelerated R&D. This unique consortium environment creates a viable financial and technical foundation that enhances knowledge-based development of integrated electronics while reducing costs. The presentation will highlight the New York business model, capabilities and infrastructure, along with planned expansion, and also discuss new opportunities based on nanotechnology.

CNSE provides facilities, tooling, a portion of operating expenses, and operates the cleanroom facilities. Partners provide engineering resources, tooling, process IP to enable R&D and customize for their applications, and a portion of operating expenses. Material suppliers, government entities and other academic institutions participate as partners on a customized basis.

Partners have access to IP, R&D results, and manufacturing expertise and gain early access to equipment, supplier BKMs and create synergy with other partners. The state-of-the-art facilities enable faster development cycles with know-how contributions from industrial leaders. Other parties may have access to IP, R&D results, and wafer processing based on available advanced processes.

The existence of advanced facilities, tool and material suppliers, together with IDMs under one roof, combined with strong government support, creates a unique environment that fosters cross-partner joint development activities. The knowledge sharing and close physical proximity results in a fast and economical advanced node R&D.

Biography:

Michael Liehr is a Professor and serves as the CNSE Vice President for Research and Associate Vice President of Strategy, Alliances and Consortia at the UAlbany NanoCollege. He is responsible for strategic research and development for nanoelectronics and 3D packaging alliances at CNSE. His experience spans nanoelectronics research, product and process development, manufacturing, and foundry business P&L.

Prior to joining CNSE, Dr. Liehr served as an IBM executive responsible for Worldwide Semiconductor Manufacturing Strategic Production Alliances for leading-edge semiconductor products. While at IBM, he was responsible for technology transfer, operations and supply management for outsourced semiconductor production of IBM's 90nm, 65nm and 45nm semiconductor-on-insulator (SOI)- based microprocessor technologies to Chartered Semiconductor Manufacturing in Singapore. In addition, he oversaw management of fabricator synchronization for bulk CMOS 65nm through 32nm with Chartered, Singapore; Samsung, Korea; and ST Microelectronics, France.

Dr. Liehr holds a Ph.D. in Physics, is a certified executive project manager, and has authored or coauthored more than 20 patents and over 90 publications.



The National Nanotechnology Initiative Strategic Vision for Responsible Development

Sally Tinkle

Acting Director / Deputy Director, National Nanotechnology Coordination Office

Abstract:

Nanotechnology allows scientists to work at the nanoscale to produce technological advances in such diverse areas as electronics, energy, environmental remediation, medicine, security, and space. The National Nanotechnology Initiative (NNI) was established in 2000 as the Federal Government's multiagency, multidisciplinary research and development (R&D) program to promote nanotechnology innovation and economic benefit. The goals of the NNI are fourfold: (1) to advance a world-class nanotechnology R&D program; (2) to foster the transfer of new technologies into products for commercial and public benefit; (3) to develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; and (4) to support responsible development of nanotechnology. Environmental, health, and safety (EHS) research is essential to successful achievement of all four NNI goals; however, it is most closely linked to the goal of responsible development. To achieve the EHS objectives of responsible development, the NNI agencies collaboratively developed a nanotechnology EHS research strategy that focuses on the use of science-based risk analysis and risk management to protect public health and the environment while also fostering the technological advancements that benefit society. The 2011 NNI EHS Research Strategy serves as guidance to the Federal agencies that produce and use scientific information to develop nanotechnology risk assessments that inform risk management and regulatory decisions. It assists the NNI agencies in achieving their EHS vision of a future in which Nanotechnology provides maximum benefit to the environment and to human social and economic well-being.

Biography:

Dr. Sally Tinkle is the Deputy Director of the National Nanotechnology Coordination Office of the National Science and Technology Council and for the interim, Acting Director. Her responsibilities include facilitation and coordination of the National Nanotechnology Initiative and representation of nanotechnology and the NNI to the stakeholder communities. Additionally, Dr. Tinkle has been named the Coordinator for NNI EHS research activities. Previously, as Senior Science Advisor in the Office of the Director, National Institute of Environmental Health Sciences (NIEHS), National Institutes of Health (NIH), Dr. Tinkle developed the NIEHS nanotoxicology extramural research portfolio and the NIEHS NanoHealth and Safety Enterprise, a framework for public-private partnerships. She has been an active member of the trans-NIH Nanotechnology Task Force and is senior author of the health implications section of the NIH Nanotechnology Report to the NIH Director. At the federal level, Dr. Tinkle co-chaired the Nanoscale Science, Engineering and Technology (NSET) subcommittee of the National Science and Technology Council (2009 – 2010) and is the NSET Nanotechnology Environment and Health Implications working group (NEHI) Task Group Leader for human health and nanomaterials. She is a senior author on the human health sections of the three NEHI environment health and safety (EHS) documents that form the federal approach to EHS research. She is frequently an invited speaker at nanotechnology meetings, both nationally and internationally.

Dr. Tinkle received her PhD from the Department of Physiology at the University of Colorado School of Medicine in Denver, CO and was a postdoctoral fellow at the National Jewish Center for Immunology and Respiratory Medicine, Department of Occupational and Environmental Health Science. Prior to joining NIH, she was the leader of a pulmonary and dermal toxicology laboratory at the National Institute of Occupational Safety and Health in Morgantown, WV.

**Small Things, Large Impact: Qdot(r) Nanocrystals at Life Technologies****Rachel K. Smith**

Staff Scientist, Molecular and Cell Biology Platform
Life Technologies

Abstract:

Life Technologies is a global biotechnology tools company dedicated to improving the human condition. Semiconductor nanocrystals are rapidly taking center stage in fluorescence microscopy due to their marked photostability relative to organic dyes, the wide variety of emission wavelengths available, and their flexible platform for bio- and chemical conjugation. The Qdot(r) nanocrystal product line is a central part of our cellular labeling and detection portfolio, and it is critical to deliver both a tool and a technology to the customer that is reproducible, manufacturable, and scalable. Here, we present the role that the Qdot(r) nanocrystal plays in the life sciences space, as well as discuss the path of bringing a robust nanotechnology to the marketplace

Biography:

Rachel Smith is an analytical chemist in the Nanoscience Division in the Molecular and Cell Biology Platform at Life Technologies. Her research interests lie in developing new analytical methods for characterizing both the inorganic and organic components of semiconductor nanocrystals used in both cellular imaging and next-generation DNA sequencing applications. Rachel holds a B.A. in biochemistry from the University of Oregon and a Ph.D. in analytical chemistry from The Pennsylvania State University. She was a postdoctoral scholar at Lawrence Berkeley National Laboratory and the University of California at Berkeley under the direction of Paul Alivisatos.



The Nanoscale.... another small step for man!

Mike Thompson

Business Manager; Nanotechnology
FEI Company

Abstract:

The nanoscale offers us a measure of many things. One viewpoint that is rarely ventured is to consider the nanoscale as a waypoint in the metrology of human progress. In this keynote we shall take a journey in time and space from the concept of the atom and the boundaries of normal vision down ten orders of magnitude, to the direct imaging and analysis of individual atoms. We have finally arrived in this arena after an uncoordinated global journey of discovery. This journey has extended over two thousands of years, and represents a convergence of technology, research and politics. As a destination the nanoscale in an end-station, we are now at foundations end , a place of atoms and molecules, a place where our world, and cosmos, really work. It has been a remarkable journey as our human senses make us ill-equipped to venture into this dimension. Under ideal conditions, and unaided, we cannot resolve high contrast objects separated by less than 0.1 mm In daily life this resolution is closer to 0.15-0.2mm subject to age. As $0.2\text{mm} = 200,000\text{nm}$, the eye would require an image magnification of 200,000x to see a nanometer at its limit. To comfortably see an object we need to move away from this extreme limit. If we add a comfort factor of say 5x, this would require 1,000,000 x magnification to observe at the nanoscale. Further if we decide to make calibrations to the 0.1 nm level we need to improve our resolution by at least a factor of 10x. The unaided eye now requires a 10,000,000x improvement... ten million time of magnifications to operate in this domain. This domain is at the sub-atomic level; a single carbon atom has a van der Waals radius of 0.17 nm. We construct our past, present and future life around real or virtual images. We are built around our eyes. This is evidenced by the fact that visual processing takes up thirty percent of the cerebral cortex. Touch occupies eight percent and hearing 3 percent of the cortex. Direct visualization down to, and beyond, the nanoscale is significant as our eyes are the main conduit for human learning and understanding. To see is to understand, what the eye sees the intellect can explore. In the absence of tools to enable visualization we are subject to the vagaries of empiricism, hypotheses, models, debate and conjecture. Direct imaging is also significant as a highly efficient and democratic communication medium, as it circumvents all the normal stumbling blocks to communication of language, and culture, and bias, and educational level. On our journey we shall make stops along the way at significant milestones on the path to the subatomic level. We shall review the evolution of imaging, analytical and the micro machining tools based on ion and electron optical based imaging tools and their enabling contribution in research, development and manufacturing; from prediction to proof, from proof to prototype, from prototype to product.

Biography:

Mike Thompson has been actively engaged throughout his career in creating the tools to enable Nanotechnology. Following University he joined the Electron Optics division of Philips, The Netherlands to advance transmission electron microscopy applications in materials science. Here he was active in developing the transmission electron applications in Energy Dispersive X-Ray analysis, Back-scattered electron imaging, Scanning Transmission Microscopy and hybrid transmission-scanning techniques. He was promoted to product manager for the Philips Transmission Electron Microscopes, and subsequently the global management of Philips Electron Optics Sales, Service and Marketing operations. He transferred to the USA to build up the North American Philips Electron Optics Sales and Service division. Following the FEI/Philips merger he transferred to the West coast as VP Marketing, Sales and Service operations for FEI Company and helped lay the foundations of the business processes which have enabled the company's success. He has lectured in 24 countries and has served on the organizational and advisory boards of many US-based Nanotechnology Conferences. He is a past adviser to the National Science, Engineering and Technology [NSET] committee on Nanotechnology. He is keenly interested in promoting the contribution of advanced technology and nanotechnology to the society to the general public. Mike Thompson received his B.Sc.in Materials Science at the University of Surrey, England and his Ph.D. at Cambridge University, England.



Unique Thermal Properties of Graphene: Implications for Graphene Devices and Thermal Management

Alexander A. Balandin

Professor, Electrical Engineering

Chair, Materials Science and Engineering (MS&E)

Founding Chair, Materials Science and Engineering (MS&E) Program

UNIVERSITY OF CALIFORNIA – RIVERSIDE

Abstract:

The fast increasing importance of the knowledge of thermal properties of materials is explained both by practical needs and fundamental science. Heat removal has become a critical issue for continuing progress in Si CMOS technology while better understanding of thermal transport can shed light on many other material properties. We have experimentally established that graphene reveals extremely high intrinsic thermal conductivity and explained the results theoretically. The superior heat conduction properties of “free” suspended graphene do not mean that they will be necessarily preserved when graphene is incased inside semiconductor chips as the heat spreaders or used in composite thermal interface materials. One has to use a special care to preserve graphene’s properties and fully utilize them in practice. Thermal conductivity of graphene layers depends strongly on their size, coupling to the substrate or capping layers, edge roughness and defect concentration. In this talk, I will overview the results pertinent to the thermal conductivity evolution in the few-layer graphene with the increasing number of atomic planes, considering two extreme cases of the phonon thermal transport limited by the intrinsic and extrinsic effects. The high thermal conductivity of graphene is beneficial for all electronic applications. At the same time, thermal conductivity of graphene can be reduced by controlled introduction of disorder, thus, allowing for thermoelectric applications. I will present examples of major improvements in performance of graphene field-effect transistors fabricated on synthetic diamond. The use of highly thermally conductive diamond films instead of silicon-oxide allowed us to exploit the thermal properties of graphene, and increase the breakdown current density and saturation velocity of graphene transistors. The high thermal conductivity, planar geometry of flakes, and recent availability of inexpensive chemically derived graphene in solutions opened up a possibility of graphene applications in the next generation of thermal interface materials. We have demonstrated the thermal conductivity enhancements factors of ~1000% for the polymer – graphene composites, which is much larger than that for conventional filler materials. A general outlook of the CVD graphene synthesis, industrial-scale graphene quality control, and prospects of graphene electronics will conclude the talk. One of the application examples, to be considered in details, will be the triple-mode graphene amplifier and phase detector recently built and demonstrated in our laboratory.

Biography:

Alexander A. Balandin received his BS (1989) and MS (1991) degrees Summa Cum Laude in Applied Physics and Mathematics from the Moscow Institute of Physics & Technology (MIPT), Russia. He received his second MS (1995) and PhD (1996) degrees in Electrical Engineering from the University of Notre Dame, USA. In 1997, he worked as Research Associate in the Quantum Device Laboratory at the University of Nebraska – Lincoln. From 1997 to 1999, he was a Research Engineer in the Device Research Laboratory at the University of California – Los Angeles (UCLA). In 1999 he joined the Department of Electrical Engineering, University of California – Riverside (UCR), where he is Professor of Electrical Engineering and Chair of Materials Science and Engineering (MS&E). He leads the Nano-Device Laboratory (NDL), which he organized in 2000. In 2005, he was Visiting Professor at the University of Cambridge, UK, where he was elected Associate Scholar of Pembroke College. In 2007, he became the Founding Chair of Materials Science and Engineering (MS&E) program at UCR. He led the campus efforts for introduction of BS, MS and PhD degree programs in MS&E.

Prof. Balandin's research interests are in the area of advanced materials, nanostructures and nanodevices. He performs both experimental and theoretical research. He is recognized for his contributions to investigation of the phonon and exciton confinement effects in semiconductor nanostructures; development of the phonon engineering concept; investigation of thermal transport in nanostructures; $1/f$ noise in electronic devices; and device applications of quantum dots and graphene. In 2008, his group discovered the unique nature of thermal conductivity of graphene and explained it theoretically. Balandin group has also succeeded in demonstration of the first low-noise top-gate graphene transistor, graphene triple-mode amplifier, and carried out the first "graphene-like" exfoliation of the atomically-thin films of the topological insulators. Balandin group's achievements were highlighted in *Nature*, *Nature Nanotechnology*, *IEEE Spectrum*, *MIT Technology Review*, *Materials Today* and hundreds other media worldwide.

Prof. Balandin published more than 180 technical papers, 10 invited review chapters, and edited/coauthored three books and five-volume *Handbook of Semiconductor Nanostructures and Nanodevices*. He has given more than 80 invited talks on different aspects of nanotechnology at major international conferences, universities and government organizations. His nanotechnology research was recognized by the ONR Young Investigator Award, National Science Foundation (NSF) CAREER Award, University of California Regents Award, Civil Research and Development Foundation (CRDF) Award, and Merrill Lynch Innovation Award for "commercially valuable engineering research". He is elected Fellow of The Optical Society of America (OSA), The International Society for Optical Engineering (SPIE) and The American Association for Advancement of Science (AAAS). He is Senior Member of IEEE, and Member of Eta Kappa Nu, American Physical Society (APS), Materials Research Society (MRS) and The Electrochemical Society (ECS).

Prof. Balandin serves as one of the two Editors of *IEEE Transactions on Nanotechnology (TNANO)*, and as an Editor-in-Chief of the *Journal of Nanoelectronics and Optoelectronics*. He previously served as an Associate Editor of *TNANO*. His research group participates in the SRC – DARPA Center on Functional Engineered Nano Architectonics (FENA). It took part in the SRC – DARPA Interconnect Focus Center (IFC) and DARPA – DMEA Center for Nanoscience Innovations for Defense (CNID). His research has been supported through grants and contracts from NSF, ONR, AFOSR, ARO, NASA, DOE, SRC, DARPA, CRDF, UC MICRO, IBM, TRW and Raytheon. More information about his research can be found at <http://ndl.ee.ucr.edu/>.