Research Centers

Center for Integrated Circuits and Systems

Professor Hae-Seung Lee, Director

The Center for Integrated Circuits and Systems (CICS) at MIT, established in early 1998, is an industrial consortium created to promote new research initiatives in circuits and systems design, as well as to promote a tighter technical relationship between MIT's research and relevant industry. 6 faculty members participate in the CICS: Hae-Seung Lee (director), Duane Boning, Anantha Chandrakasan, David Perreault, and Charles Sodini. In September 2013, we welcomed our newest CICS faculty member, Vivienne Sze. Prof. Sze's research focuses on joint design of algorithms, architectures and circuits to build energy efficient and high performance systems. Her work on implementation-friendly video compression algorithms was used in the development of the latest video coding standard HEVC/H.265, enabling it to deliver better compression than previous standards, while still achieving high processing speeds and low hardware cost. She aims to develop energy-aware algorithms and efficient architectures for various energy-constrained applications including portable multimedia, health monitoring and distributed sensing.

CICS investigates a wide range of circuits and systems, including wireless and wireline communication, high-speed and RF circuits, microsensor/actuator systems, imagers, digital and analog signal processing circuits, biomedical circuits, and power conversion circuits, among others.

We strongly believe in the synergistic relationship between industry and academia, especially in practical research areas of integrated circuits and systems. CICS is designed to be the conduit for such synergy. At present, participating companies include Analog Devices, IBM, Linear Technology, Maxim Integrated, Marvell Technology Group, MediaTek, and Texas Instruments.

CICS's research portfolio includes all research projects that the 6 participating faculty members conduct, regardless of source(s) of funding, with a few exceptions. Technical interaction between industry and MIT researchers occurs on both a broad and individual level. Since its inception, CICS recognized the importance of holding technical meetings to facilitate communication among MIT faculty, students, and industry. We hold two informal technical meetings per year open to CICS faculty, students, and representatives from participating companies. Throughout each full-day meeting, faculty and students present their research, often presenting early concepts, designs, and results that have not been published yet. The participants then offer valuable technical feedback, as well as suggestions for future research.

More intimate interaction between MIT researchers and industry takes place during work on projects of particular interest to participating companies. Companies may invite students to give on-site presentations, or they may offer students summer employment. Additionally, companies may send visiting scholars to MIT or enter into a separate research contract for more focused research for their particular interest. The result is truly synergistic, and it will have a lasting impact on the field of integrated circuits and systems.

Energy Frontier Research Center for Excitonics

Professor Marc A. Baldo, Director

The Energy Frontier Research Center (EFRC) for Excitonics is a collaboration between Massachusetts Institute of Technology, Harvard and Brookhaven National Laboratory. Our objective is to supersede traditional electronics with devices that use excitons to mediate the flow of energy. Excitons are quasiparticle excitations consisting of a bound electron and hole that mediate the absorption and emission of light, especially in disordered and low-dimensional materials.

The motivation for excitonics is that conventional electronic devices can be difficult to manufacture; their constituent materials require very high levels of order, and achieving such low entropy in a semiconductor requires expensive and energy intensive fabrication. For example, the energy payback time for a crystalline silicon solar cell is on the order of 2 years, and at current manufacturing growth rates, it is expected to take at least 20 years to produce enough silicon-based solar cells to make a significant impact on the world energy supply. Similarly, epitaxial growth constraints are likely to limit solid state lighting sources to a small fraction of the overall demand for lighting.

There is an alternate approach that is more suitable for large scale production. In the Center for Excitonics, we address materials with only short-range order. Such nanostructured materials are compositions of nano-engineered elements such as organic molecules, polymers, or quantum dots and wires, in films bound together by weak van der Waals bonds. These materials are characterized by excitons that are localized within the ordered nanostructures. Excitons provide a unique means to transport energy and convert between photons and electrons. Due to localization of excitons, the optical properties of the films are relatively immune to longer-range structural defects and disorder in the bulk. And in contrast with the painstaking growth requirements of conventional semiconductors, weak van der Waals bonds allow excitonic materials to be readily deposited on a variety of materials at room temperature.

We address two grand challenges in excitonics: (1) to understand, control and exploit exciton transport, and (2) to understand and exploit the energy conversion processes between excitons and electrons, and excitons and photons.

(1) Exciton Transport: We are developing new theory to explain and model the movement of excitons in complex nanostructures. We build artificial excitonic antennas that absorb and guide light in nanofabricated circuits of molecular chromophores, J-aggregates, quantum dots and nanowires. We characterize coherence and energy transfer in our antennas using scanning probe microscopy and our recently developed technique of fully phase coherent 2-d Fourier transform spectroscopy. Finally, our excitonic technologies will be applied to low cost solar cells and luminescent solar concentrators, which promise power efficiencies > 30%.

(2) Exciton Dynamics: We are developing new theory for the dynamics of exciton formation and separation. Applications include increasing the efficiency of organic light emitting devices by up to a factor of four and characterizing the fundamental efficiency limits of excitonic solar cells.

We possess two important tools that are unique to the center: Cathodo-luminescence Scanning Transmission Electron Microscopy (CL-STEM), which is used to characterize the structure-function relationships of excitonic nanomaterials, and Superconducting Nanowire Single-Photon Detectors (SNSPDs). SNSPDs can conclusively determine the efficiency of multiple carrier generation, a process with enormous potential for solar cells. Finally, we aim to characterize the link between exciton annihilation and device degradation.

MIT/MTL Center for Graphene Devices and 2D Systems

Professor Tomás Palacios, Director

The MIT/MTL Center for Graphene Devices and 2D Systems (MIT-CG) brings together, MIT researchers and industrial partners to advance the science and engineering of graphene and other two-dimensional materials.

Graphene and other two-dimensional (2D) materials are revolutionizing electronics, mechanical and chemical engineering, physics and many other disciplines. The MIT-MTL Center for Graphene Devices and 2D Systems aims to coordinate most of the work going on at MIT on these new materials, and brings together MIT faculty and students, with leading companies and government agencies interested in taking these materials from a science wonder to an engineering reality.

Specifically, the Center explores advanced technologies and strategies that enable 2D materials, devices and systems to provide discriminating or break-through capabilities for a variety of system applications ranging from energy generation/storage and smart fabrics and materials, to optoelectronics, RF communications and sensing. In all these applications, the MIT-CG supports the development of the science, technology, tools and analysis for the creation of a vision for the future of new systems enabled by 2D materials.

Some of the multiple benefits of the Center's membership include complimentary attendance to meetings, Industry Focus days, and webcasting of seminars related to the main research directions of the Center. The members of the Center also gain access to a resume book that connects students with potential employers, as well as to timely white papers on key issues regarding the challenges and opportunities of these new technologies. There are also numerous opportunities to collaborate with leading researchers on projects that address some of today's challenges for these materials, devices and systems.

MIT/MTL Gallium Nitride (GaN) Energy Initiative

Professor Tomás Palacios, Director

The MIT/MTL Gallium Nitride (GaN) Energy Initiative (MIT-GaN) is an inter-departmental program that brings together 10 MIT faculty and more than 40 other researchers and industrial partners to advance the science and engineering of GaN-based materials and devices for energy applications.

The GaN Energy Initiative provides a holistic approach to GaN research for energy applications and it coordinates work on the growth, technology, novel devices, circuits and systems to take full advantage of the unique properties of GaN. The GaN Energy Initiative is especially interested in developing new beyond-state-of-the-art solutions to system-level applications in RF power amplification, mixed signal electronics, energy processing and power management, as well as advanced optoelectronics. Most of the work is done on GaN materials and devices which are compatible with Si fabrication technologies, in close collaboration with industrial partners to accelerate the insertion of these devices into systems.

The MIT/MTL Gallium Nitride(GaN)Energy Initiative organizes numerous activities to advanced GaN. Some of these activities include webcast of seminars and annual meetings, as well as joint collaborations with industry partners. The Initiative also elaborates a resume book of graduating students and provides timely access to white papers and preprints through its website.

The MIT Medical Electronic Device Realization Center

Professor Charles Sodini, Director

The vision of the MIT Medical Electronic Device Realization Center (MEDRC) is to revolutionize medical diagnostics and treatments by bringing health care directly to the individual and to create enabling technology for the future information-driven healthcare system. This vision will in turn transform the medical electronic device industry. Specific areas that show promise are wearable or minimally invasive monitoring devices, medical imaging, portable laboratory instrumentation, and the data communication from these devices and instruments to healthcare providers and caregivers.

Rapid innovation in miniaturization, mobility, and connectivity will revolutionize medical diagnostics and treatments, bringing health care directly to the individual. Continuous monitoring of physiological markers will place capability for the early detection and prevention of disease in the hands of the consumer, shifting to a paradigm of maintaining wellness rather than treating sickness. Just as the personal computer revolution has brought computation to the individual, this revolution in personal medicine will bring the hospital lab and the physician to the home, to emerging countries, and to emergency situations. From at-home cholesterol monitors that can adjust treatment plans, to cell phone-enabled blood labs, these system solutions containing state-of-the-art sensors, electronics, and computation will radically change our approach to health care. This new generation of medical systems holds the promise of delivering better quality health care while reducing medical costs.

The revolution in personal medicine is rooted in fundamental research in microelectronics from materials to sensors, to circuit and system design. This knowledge has already fueled the semiconductor industry to transform society over the last four decades. It provided the key technologies to continuously increase performance while constantly lowering cost for computation, communication and consumer electronics. The processing power of current smart phones, for example, allows for sophisticated signal processing to extract information from this sensor data. Data analytics can combine this information with other patient data and medical records to produce actionable information customized to the patient's needs. The aging population, soaring healthcare costs, and the need for improved healthcare in developing nations are the driving force for the next semiconductor industry's societal transformation, *Medical Electronic Devices*.

The successful realization of such a vision also demands innovations in the usability and productivity of medical devices, and new technologies and approaches to manufacture devices. Information technology is a critical component of the intelligence that will enhance the usability of devices; real-time image and signal processing combined with intelligent computer systems will enhance the practitioners' diagnostic intuition. Our research is at the intersection of Design, Healthcare, and Information Technology innovation. We perform fundamental and applied research in the design, manufacture, and use of medical electronic devices and create enabling technology for the future information-driven healthcare system.

The MEDRC has established a partnership between microelectronics companies, medical device companies, medical professionals, and MIT to collaboratively achieve needed radical changes in medical device architectures, enabling continuous monitoring of physiological parameters such as cardiac vital signs, intracranial pressure and cerebral blood flow velocity. MEDRC research projects are defined jointly by faculty and researchers, physicians and clinicians, along with our industrial partners. A visiting scientist from a project's sponsoring company is present at MIT. Ultimately this individual is the champion that helps translate the technology back to the company for commercialization and provide the industrial viewpoint in the realization of the technology. MEDRC projects have the advantage of insight from the technology arena, the medical arena, and the business arena, thus significantly increasing the chances that the devices will fulfill a real and broad healthcare need as well as be profitable for companies supplying the solutions. With a new trend toward increased healthcare quality, disease prevention, and cost-effectiveness, such a comprehensive perspective is crucial.

Now a part of MIT's Institute for Medical Engineering and Science, MEDRC is a focal point for engagement with researchers across MIT, the medical device and microelectronics industry, venture-funded startups, and the Boston medical community. The Center fosters the creation of prototype devices and intellectual property and aims to serve as the catalyst for the deployment of medical devices that will reduce the cost of healthcare in both the developed and developing world.