Integrated microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS) will rival, and perhaps surpass, the societal impact of integrated circuits. The MEMS-based tilt sensor allows a smart phone to sense its orientation. The MEMS-based accelerometer enables a video game controller to transfer a user’s swing into a tennis game. Hundreds of exciting MEMS-enabled applications are expected to grow by orders of magnitude when NEMS technology becomes available. The volume of a NEMS device is roughly 10⁹ times smaller than that of a MEMS device.

With support from the Defense Advanced Research Projects Agency (DARPA) and several university and industrial sponsors, iMINT conducts tightly integrated fundamental studies to establish a necessary knowledge base to facilitate the successful integration of NEMS and MEMS. In particular, research studies are driven by a future system with nanowire/nanotube/graphene devices powered by an embedded battery charged by an embedded solar cell. iMINT annual research funding level, including cost-share, is approximately $4 million per year.

Recent Highlights

- Professor Ronggui Yang received the ASME Bergles-Rohsenow Young Investigator Award in Heat Transfer for developing modeling and experimental tools to understand micro/nanoscale thermal transport and for innovative applications of micro/nano-structure in macroscale forms for energy conversion and thermal management. Yang won an NSF CAREER Award and was named one of the world’s top 35 young innovators by Technology Review, a magazine published by the Massachusetts Institute of Technology.

- Assoc. Professor Se-Hee Lee and his team of collaborators at NREL received an R&D 100 Award for their invention for the PowerPlane UX Microbattery, a solid-state thin-film battery. Se-Hee Lee was elected a founding Fellow of the new Renewable and Sustainable Energy Institute, RASEI is a new joint institute between CU-Boulder and the U.S. Department of Energy’s National Renewable Energy Laboratory in Golden, Colorado.

Sponsors and Collaborators

- Defense Advanced Research Projects Agency (DARPA)
- University of California - Los Angeles
- University of Texas - Austin
- National Institute of Standards and Technology
- NREL
- Lockheed Martin
- Ibiden USA
- DuPont
- DRS Technologies
- General Motors
- QinetiQ - North America

iMINT Director: Professor Yung-Cheng “YC” Lee

Yung-Cheng “YC” Lee is a professor of mechanical engineering and the director of DARPA Center on Nanoscale Science and Technology for Integrated Micro/Nano-Electromechanical Transducers (iMINT) at the University of Colorado at Boulder. He also is the administrative director of the Nanomaterials Characterization Facility. From 1993 to 2002, he was the associate director of the NSF Center for Advanced Manufacturing and Packaging of Microwave, Optical and Digital Electronics (CAMPMoDE). Prior to joining the university, he was at AT&T Bell Laboratories, Murray Hill, New Jersey. Dr. Lee's research focuses on the integration of microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS) with microelectronic, optoelectronic and microwave devices.

Dr. Lee was an associated editor of ASME Journal of Electronic Packaging (2001-2004) and a guest editor for special issues on packaging for micro/nano-scale systems for IEEE Transaction on Advanced Packaging (2003, 2005 and 2007). He is an ASME Fellow and has received numerous awards, including the NSF Presidential Young Investigator, SME Outstanding Young Manufacturing Engineer Award, CU-ME Woodward Outstanding Mechanical Engineering Faculty Award, and ASME Electronic and Photonic Packaging Division's Mechanics Award.

Dr. Lee received his bachelor's degree in mechanical engineering from the National Taiwan University in 1978, and the master's and PhD degrees from the University of Minnesota in 1982 and 1984 respectively.
The Nanomaterials Characterization Facility (NCF) at CU-Boulder. The NCF provides education and user access to state-of-the-art instruments for nanotechnology. Our current instruments include: Field Emission Electron Microscope (FESEM), Low Vacuum Electron Microscope (LVESEM), Atomic Force Microscope (AFM), Confocal Laser Scanning Microscope (CLSM), Dual Beam Focused Ion Beam (FIB), a Nano Indenter, X-ray Photoelectron Spectroscopy (XPS), Energy Dispersive Spectroscopy (EDS), and Electron Backscatter Diffraction (EBSD).

The Colorado Nanofabrication Laboratory (CNL) at CU-Boulder: The CNL is an open user facility whose mission is to provide expertise, facilities, infrastructure and testing environments to enable and facilitate interdisciplinary research in microelectronics, optoelectronics, and MEMS. The CNL is one of the 14 members of the National Nanotechnology Infrastructure Network (NNIN), supported by the National Science Foundation.

The next proposed phase of the iMint Center involves the creation of an ALD Collaboratory. The new Collaboratory will provide ALD services to CU researchers and outside users.

Research Projects

- GaN nanowires achieve superior semiconductor properties because they do not have internal defects and are manufacturable since they are grown on silicon substrates. The defect-free structure allows us to investigate fundamental issues with accurate measurements. Such a structure is also critical to future devices such as: a) a light emitting diode (LED) with high efficiency and low thermal resistance; b) a solar blind sensor with a gain at 360 nm of 10^5 to 10^6; or c) a resonator sensor with atto-gram resolution at room temperature.

- Graphene, one-atom-thick planar sheet of atoms, has proven to be the strongest material ever measured with breaking strength of ~125 GPa. We have identified graphene as the best material for a nano-switch because of its extremely high Young’s modulus (1 TPa), electrical conductivity and thermal conductivity. A graphene-based transistor is also critical to reduce power of RF electronics. Compared with carbon nanotubes, graphene has promising manufacturability for a nano-switch because of its potential for wafer-level processing.

- Atomic layer deposition (ALD) and molecular layer deposition (MLD) technologies can coat surfaces of nanowires, graphene sheets or other nano-structures for a system, with as little as a single atomic or polymer molecular layer for effective electrical, optical, thermal and mechanical interfaces to significantly improve device integration. ALD/MLD technology is also critical to moisture/oxygen barrier coatings that can increase polymer’s hermeticity by >100,000X. Extremely thin (2 or 5 nm), yet mechanically tough ALD/MLD-based inorganic coating will not crack even under high stresses/strains when compared to CVD-based coatings. Enabled by such a superior barrier coating, IMINT is able to deliver flexible circuit board prototypes filled with liquid and vapor for 1000 W/mK thermal conductivity cooling capabilities and is now targeting 30,000 W/mK.

- State-of-the-art infrared (IR) imaging bolometers are based on a suspended membrane that absorbs IR light. Fabricated with multilayers of tungsten and alumina, ALD-enhanced bolometers offer significant improvements over traditional bolometers by reducing the membrane thickness 1-2 orders of magnitude. This reduced thickness substantially lowers the heat capacity and thermal conductance of the membrane, resulting in imaging rates 100s of times faster than the state-of-the-art with equal or better sensitivity. Further, the atomic-layer thickness control of ALD films provides unprecedented opportunities for targeting different spectra, potentially allowing for THz, UV, and x-ray imaging.

- The miniaturization of Joule-Thomson (J-T) coolers have shown great potential for small size, low noise, fast response, and high efficiency micro cryogenic coolers (MCC) for low power N/MEMS sensors. With the same heat lift, a J-T MCC’s power input can be as little as 1/10th of a Stirling cooler’s size. An IMINT polymer-based 15 mm × 4 mm × 90 μm MCC heat exchanger has achieved a 190 K stable temperature with a five-component mixed refrigerant under a low operation pressure ratio. By utilizing water-scale processing, the MCC will be very compact, manufacturable, reliable, cost-effective, and scalable down to microscopic sizes.

More Information

Y.C. Lee
Professor and Director, IMINT
University of Colorado Boulder
427 UCB, Boulder, CO 80309-0427
303-492-3393
leyc@colorado.edu

Kurt Maute
Associate Dean for Research
Joseph Negler Endowed Professor
College of Engineering and Applied Science
University of Colorado Boulder
422 UCB, Boulder, CO 80309-0422
303-735-2103
maute@colorado.edu

Jeffrey G. Sczechowski
Assistant Dean for Research Opportunities
College of Engineering and Applied Science
University of Colorado Boulder
422 UCB, Boulder, CO 80309-0422
303-492-2615
sczechowski@colorado.edu