Guest lecture in the Nanotechnology From Lab To Product seminar series (PSE 590A)

IGERT
Program in Nanotechnology Innovation

Carbon Nanotubes for Potential Electronic and Optoelectronic Applications

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Thursday, March 1

4:30-5:30 pm   A-111 Conte   All Are Invited

Significant progress has been made recently on carbon nanotube based field effect transistors (CNTFET), in terms of understanding both their scaling and performance limits. In the first part of the talk, I will focus on chemical doping schemes utilizing molecules and a charge transfer mechanism to obtain self-aligned, unipolar CNTFETs to meet the performance challenges. We demonstrate an ability to change carrier injection properties; and to improve device performance in both ON- and OFF-states. In particular, oxidizing and redox-active molecules are introduced to modify the workfunction of the source and drain electrodes of CNTFETs and, correspondingly, of their Schottky barriers. We demonstrate successful ambipolar-to-unipolar conversion and p-to-n polarity switching of CNTFETs. I will also discuss the challenges we are faced with before a competitive CNT-based technology can be developed.

In the second part of the talk, I will focus on the opto-electronic properties of carbon nanotubes. We demonstrate electroluminescence from CNTFETs operated under both ambipolar and unipolar transport conditions. In ambipolar transport, with appropriate biasing we can inject electrons and holes simultaneously from the source and drain of the nanotube, and observe radiative e-h recombination from individual CNTs. CNTFETs provide a novel form of molecular light source that requires neither external doping nor well defined space charge region as in conventional LEDs. In addition, they also allow the tuning of the emission position along the length of a CNT over tens of microns by varying the gate potential. In unipolar transport, a single type of carrier is injected and accelerated under high local electric fields at intra-molecular junctions to energies sufficient to create strongly correlated e-h pairs (excitons). This excitation mechanism is ~1000 times more efficient than recombination of independently injected electrons and holes, and it results from weak electron-phonon scattering and strong electron-hole binding caused by one-dimensional confinement. Such experiments provide new insights into the transport processes in carbon nanotubes. They allow us to follow the fronts of the electron and hole currents under varying bias conditions, determine the recombination lengths and recombination times, observe defects, etc.

Dr. Jia Chen received her Ph.D. in physics in 2000 from Yale University where she pioneered breakthroughs in molecular memories and circuits. Her work was recognized as part of the 'Breakthrough of the Year' in Science magazine in 2001, and was widely reported in the New York Times, Scientific American, Wired Magazine, and elsewhere. In 2000, she joined the IBM Microelectronics Division in East Fishkill, New York, where she was a technical leader and a key resource to many projects, including advanced lithography techniques, process integration and device design for high-speed 90 nm node state-of-the-art CMOS. In 2003, she joined the IBM Watson Research Center, Yorktown Heights, New York in the area of nanotechnology as a research staff member. She has found novel methods to drastically improve the electronic properties of high performance carbon nanotube devices, new ways to generate intense light from an ultra-small source, and new methods to self-assemble these materials. Her recent research focuses on carbon nanotubes and nanoscaled materials-based electronic and optoelectronic devices and technologies. A fellow of the United Engineering Foundation since 2000, and a fellow of the World Technology Network since 2006, she was recognized as one of the top 35 technology innovators under the age of 35 (TR35, whose innovative work has profound impact on today's world) by MIT's Technology Review Magazine in 2005, and highlighted as the top nano-technologist. In 2006, she was honored as one of the top 15 innovators of Nano50 by NASA's Nanotech Briefs, as the "best of the best" – the innovative people that have significantly impacted the state of the art in nanotechnology and that will move nanotechnology to key mainstream markets. Recently, she was recognized as Best Small Tech Researcher of the Year by Small Times magazine, and one of the top 80 brightest young engineers by the National Academy of Engineering. She holds U.S. and foreign patents on molecular devices, memory storage devices, CMOS processes and devices, carbon nanotube electronic and optoelectronic devices. She is the author of over 50 professional publications, and a frequent invited/keynote speaker at professional conferences. In her spare time, she serves on the committee of the Women in Technology group and organizes leadership panels and conferences. She has also found time to mentor middle school students as well as graduate school students, and has lectured at MIT, Yale, Stanford etc.