

**SEMINAR**

Mechanical Engineering & Materials Science

""Walking the Feynman’s Talk" – Focused Electron Beam Writing of 3D Nanostructures and 2D Electronic Materials"

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Thursday, September 27

2:45 – 3:45 PM

Brauer Hall, Room 12

**Abstract**

Focused Electron Beam Induced Processing (FEBIP) is an emerging method for atom-by-atom fabrication of topologically complex nanostructures from a variety of materials. Compared to a similar technique based on an ion beam, FEBIP can achieve higher resolution, inflicts less surface damage, and involves more accessible tools. However, FEBIP suffers from low deposition rate, poor material purity, and limitation on a type of precursor materials which can be delivered to a high vacuum environment of the FEBIP chamber. We are developing a family of multi-mode energized micro/nano-jet techniques for local precursor delivery to resolve the FEBID challenges and to expand the range of useful precursors from gas to liquid phase for broader FEBIP applications.

Energized micro/nano-jets of thermally or electro-kinetically energized precursors in both gas and liquid phase provide unique capabilities for localized delivery of precursor molecules to the substrate, thus establishing locally controlled deposition/etching site for FEBIP. This expands the range of usable precursor molecules and enhances the growth rate and purity by selectively tuning of precursor and contaminant sticking and surface diffusion coefficients as well as adsorption/desorption activation energies. Expanding on gas-phase jet delivery of precursors, we recently demonstrated a new approach to FEBIP using liquid phase precursors delivered using a nanoelectrospray jetting process. This new technique, NESA-FEBIP, brings an important new dimension to the concept of controlled local delivery of energized/activated precursors to the substrate by (1) extending the available precursor state from gas to liquid phase and (2) using the focused electric field rather than heating to activate new energy modes of the precursor molecules. Both purely aqueous and organic solvents have been successfully delivered by nanoelectrospray jets, enabling new FEBIP capabilities of (1) dramatically increasing the growth rate of deposition/etching, (2) enabling deposition of composite materials and alloys with tailored electromechanical properties, and (3) fabrication of new, truly 3D topologies of nanostructures that are fundamentally out of reach of current gas-phase FEBID techniques. These unique new capabilities of NESA-FEBIP are matched by the complexity of the underlying physics and chemistry of ion transport and electrochemical reaction interactions, which need to be fully understood in order to take full advantage of and further develop this new mode of FEBIP from liquid phase precursors using energetic (nanoelectrospray-driven) liquid jets.

I will also discuss development and demonstration of a complete set of processing capabilities using FEBIP to fabricate electronic devices from monolayer graphene and carbon nanotubes. These include high resolution, high speed etching, dynamic patterning and n-p-n junction formation by carbon doping of the conduction channel,
formation of low resistance, Ohmic contact at the metal-graphene junctions, and “direct-write” reduction of graphene oxide, forming high electronic mobility conductive line patterns on the substrate.

Acknowledgement: This work was supported by U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering (DE-SC0010729), Semiconductor Research Corporation (GRC Contract 2011-OJ-2221), and AFOSR BIONIC Center (FA9550-09-1-0162).

Biography
Andrei G. Fedorov is the Woodruff Professor in the School of Mechanical Engineering and the Petit Institute for Bioengineering and Biosciences at Georgia Tech. He has been on faculty at Georgia Tech since 2000, and his current research focuses on electron-beam-mediated nanomanufacturing, MEMS-enabled bioanalytical instrumentation, thermal management of high performance electronics, and portable/distributed power generation with synergetic CO2 capture (http://www.me.gatech.edu/faculty/fedorov).

Fedorov’s research has been recognized by peers, including the 2006 Branimir F. von Turkovich Outstanding Young Manufacturing Engineer Award from the Society of Manufacturing Engineers (SME) “for contributions and accomplishments in the manufacturing industry” and the 2007 Bergles-Rohsenow Award in Heat Transfer from the American Society of Mechanical Engineers (ASME) for “sustained contribution to heat, mass, and radiation transfer.” Most recently, Fedorov has been selected to become a recipient of the 2010 Gustus L. Larson Memorial Award, given jointly by Pi Tau Sigma (International Mechanical Engineering Honor Society) and the ASME, in recognition of outstanding achievements in mechanical engineering within ten to twenty years following graduation. Fedorov authored/co-authored over 200 archival articles in premier technical journals and refereed conference proceedings, along with numerous invited and keynote presentations at major national and international conferences. He is a member of International Advisory Board of the Tokyo Tech’s Global Center of Excellence for Energy Science; serves on Editorial Advisory Boards of the Journal Nanoscale and Microscale Thermophysical Engineering, International Journal of Multiscale Computational Engineering, International Journal of Interfacial Phenomena and Heat Transfer, the Journal of Nanoelectronics and Optoelectronics, and Transactions of the Japanese Society of Mechanical Engineers (JSME); and consults a number of government agencies and major corporations worldwide.

Fedorov’s research has led to development of new technologies for various applications, resulting in over 40 issued US patents and pending patent applications. For his inventions of biomedical devices, the World Technology Network (WTN), in cooperation with AAAS Science Magazine, CNN and leading technology companies, selected Dr. Fedorov as a WTN Associate and one of the twenty five “most innovative people and organizations in the science and technology world” nominated for the 2005 World Technology Award in Health and Medicine. Fedorov was an invited participant in the 2006 National Academy of Engineering (NAE) Frontiers of Engineering Symposium, gathering "the nation's top 100 engineers between the ages of 30-45 from academy, industry and national labs." He was recognized with the US National Aeronautics and Space Administration (NASA) Invention & Contribution Board Award for development of catalytic reactor technologies, as well as multiple inventor recognition awards from the Semiconductor Research Corporation (SRC) and Microelectronics Advanced Research Corporation (MARCO). With his students, Fedorov has started three technology companies, in the space of gene/drug delivery microarrays, monitoring of cell therapy manufacturing, and thermal management for laser medicine, to commercialize his inventions. He serves on the Board of Directors of Horizon Theatre Company (http://www.horizontheatre.com/), a leading contemporary theater in Southeast of the United States.