NSF Nanoscale Science and Engineering Center for High-rate Nanomanufacturing (CHN)

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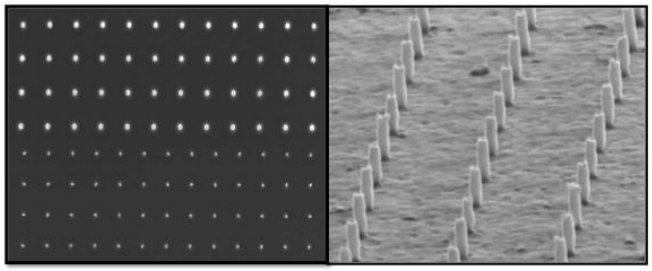
The transfer of nano-science accomplishments into technology relies on understanding and overcoming barriers to nanoscale manufacturing. The Center for High-rate Nanomanufacturing is developing tools and processes that will enable high-rate/high-volume bottom-up, directed, and precise assembly of nanoelements (such as carbon nanotubes, nanoparticles, etc.) and polymer nanostructures. This year, we developed an improved synthesis of pentacene that affords researchers rapid, affordable access to high purity pentacene in excellent yield and without the need for a time consuming purification step. We have also designed and synthesized the first water soluble pentacene derivative. Pentacene thin-films are widely recognized as promising materials for such devices but until now, there have been no water soluble (hydrophilic) derivatives. We have also designed, synthesized and characterized a new acene derivative, TTPO, that shows greater photooxidative and thermal stabilities than any other small bandgap organic semiconductor previously reported. CHN researchers have demonstrated electrophoretic assembly of conducting polymers and transfer to a polymer sheet in a roll to roll process. Damascene templates have been successfully used to assemble carbon nanotubes and transfer them to a polymer film. A novel directed assembly technique to enable rapid, large-scale assembly of nanoparticles over insulating surfaces was developed. With proper control of the assembly process two orders of magnitude increase in speed of the assembly compared to previous results was obtained. Nanotrench templates were used to assemble carbon nanotubes down to 50 nm line widths. The center has also developed many sensors that are based on nanoparticles, nanotubes, or other nanomaterials. A real-time, precise SWNT-based microsenors for glucose levels and dehyderation (salinity) with very high sensitivity and specificity. In addition, a SWNT/active material based Li-Ion battery with higher energy and power density is being developed, fabricated and tested for immediate application. The CHN Responsible Nanomanufacturing research agenda addresses many of the key questions and the research priorities stated in the 2011 NNI EHS Research Strategy. CHN has received a new award to expand existing capabilities on lifecycle assessment for nano-enabled products and will explore the utility of LCA as a decision tool for various stakeholders in the nano-enabled product value chain.

The Center for High-rate Nanomanufacturing is leveraging current and future efforts in nanoscience and technology to bridge the gap between scientific research and the creation of commercial products by established and emerging industries, such as electronics, bio/medical, energy, and materials. CHN's education and outreach efforts have been focused on a range of successful programs and a few new efforts. With the assistance of an REU Site Award, 38 undergraduate researchers, including 19 women, and 12 members of underrepresented groups, participated in CHN's 2011 Summer REU program; an additional seven undergraduates performed research during the academic year. CHN sponsored another K-12 teacher conference (with an attendance of 47) in spring 2011 and advised two K-12 teachers in the summer 2011 RET program. K-12 outreach continued with *Project SMART*, *Nanotech will Travel*, *Building Bridges*, and the *Region IV Middle School Science and Engineering Fair*. Foundation-funded training of teachers in mentoring students' science fair projects continued this year and the partnership with Boston Museum of Science (MOS) continued to produce new benefits. The *Sharing Science* and *REU Science Communication Workshops* that continue to benefit CHN students are being disseminated through the NISENet. The CHN-MOS collaboration has produced additional live presentations, Podcasts, YouTube videos, and other programs designed to educate the general public about nanomanufacturing;

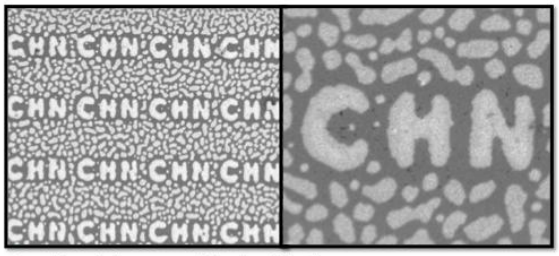
and many CHN graduate students participated in NanoDays 2011. Industry professional development was available through the *New England Nanomanufacturing Summit, Destination Nano,* and short courses. Finally, CHN's nanotechnology game, *Geckoman!* has received over 50,000 hits since it was loaded on a public website. Through these programs and other short events, CHN researchers have continued to present the technology, benefits, and societal impact of nanomanufacturing to a wide range of audiences.

Directed Assembly & Transfer- Capabilities



- High-rate, large-scale assembly
- Size-selective

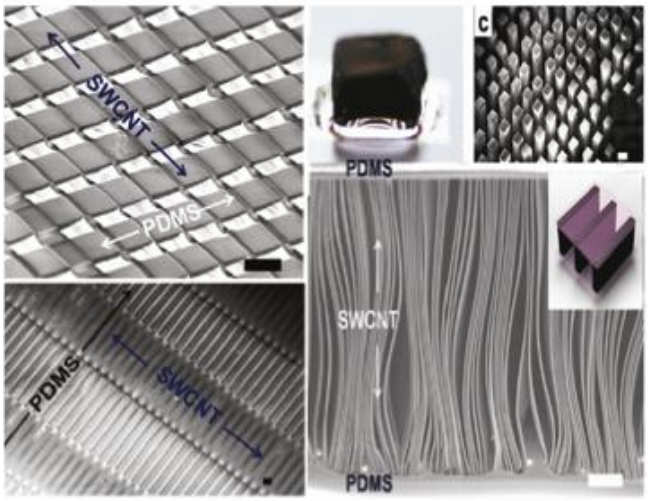
Macromol. Rapid Commun., 27, 1826 (2006) J of Nanoparticle Research, 10, 947 (2008) ACS Nano, 4, 4142 (2010); Appl. Phys. Lett. 91, 063101 (2007); Advanced Materials, 21(17), 794 (2009); Appl. Phys. Lett. 90, 243108 (2007)

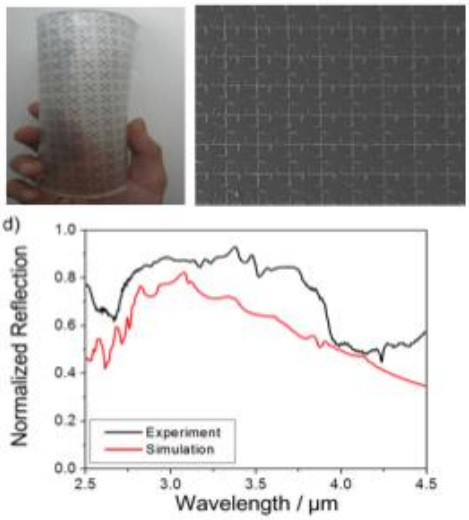


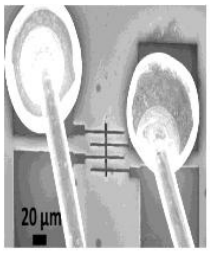
- Rapid assembly (< 30 s)
- Assembly of polymer blends into non-uniform geometries

Advanced Materials, 21(7), 735 (2009); Small, 5(24),788 (2009)

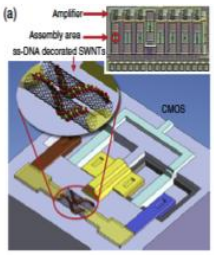
Materials by Design Metamaterials

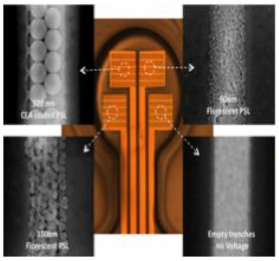




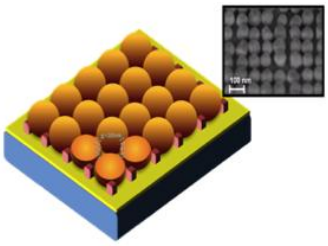


Chemical Sensors





Biosensors



SERS Sensor