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

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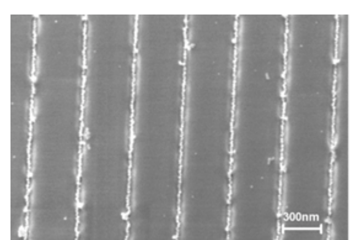
The transfer of nano-science accomplishments into technology is severely hindered by a lack of understanding of barriers to nanoscale manufacturing. Commercial products cannot be realized without first answering many questions, such as how one can assemble and connect billions of nano-scale devices together, or how one can prevent failures and avoid defects. The Center for High-rate Nanomanufacturing is developing tools and processes to enable massive fast directed assembly of nanoelements (such as carbon nanotubes, nanoparticles, etc.) and polymer nanostructures over large areas. To accomplish this, the center is fabricating templates with nanoscale features that are used to assemble nanoelements at high rates and high volume. The assembled nanoelements can be further transferred to another substrate in the same arrangement to form a layer of a device, sensor or another application. Successful use of these templates requires understanding the interfacial behavior and forces required to assemble, detach, and transfer nanoelements, required for guided self-assembly at high rates and over large areas. The template directed assembly is conducted using electrophoresis, dielectrophoresis, chemical functionalization, geometrical confinement and capillary forces.

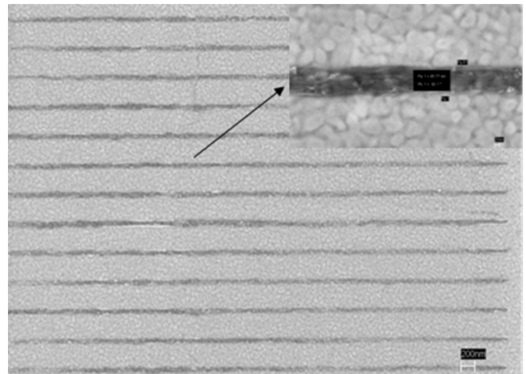
The center has successfully demonstrated the use of the templates to direct the assembly of nanoparticles (down to 10 nm) into nanoscale trenches (down to 30 nm) in a short time (30-90 seconds) and over a large area (> 2.25 cm2). The Center also demonstrated the directed assembly of SWNTs bundles into wires that are 80 nm wide and 100,000 nm long in a short time (30-90 seconds) and over the same large area using nanotrench based templates. The assembly is consistent and complete over a large area with no gaps in the assembly demonstrating the feasibility of our approach to producing nanoscale features at high rates/high volumes. We have also demonstrated that nanotemplates can be used to pattern conducting polymers and that the patterned polymer can be transferred onto a second insulating polymer substrate. Modeling has provided insight and guidance to the nanomanufacturing research. In addition, the center concurrently assesses the environmental, economic, regulatory, and ethical impacts of nanomanufacturing.



Assembly of 10-15 nm particles in nanotrenches.

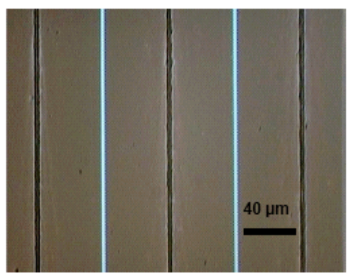
In addition, two new AFM based methods to pattern substrates have been developed. Field-assisted nanopatterning of organics (FANO) utilizes an organic film on an AFM tip and a conducting substrate. Organic molecules are deposited onto the substrate, often as a monolayer, in any desired pattern. An improved charge writing method has also been developed allowing the formation of sub-200 nm features with subsequent assembly of nanoelements such as fullerenes onto the charged lines. The charge-writing technique is especially relevant to high-rate nanomanufacturing as one can envision a reel-to-reel process in which nanotemplates stamp charge line patterns onto flexible plastics followed by rapid assembly of nanoelements.

We have selectively assembled a conducting polymer (PANi) onto a prefabricated patterned template assisted by a DC electric field and developed techniques to transfer the patterned polymer onto a flexible polymeric substrate. **We have also demonstrated the patterned conducting polymers can be transferred onto a second polymer substrate such as polystyrene or polyurethane).** This method allows for the template to be reused, unlike many conventional lithographic technologies, but also provides the potential to fabricate all-plastic electronics, paper-like displays, and biosensors in a cost-efficient and high rate process.

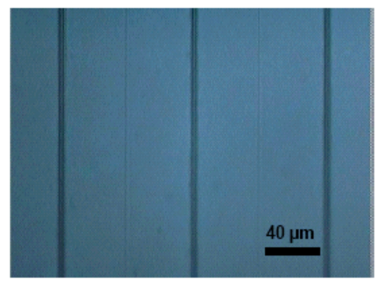


Assembly of SWNTs bundles into nanowires

A critical barrier to the design of nanostructures and devices is the lack of available data on the reliability and properties of nanoscale materials to feed into design and modeling efforts. This project uses a MEMS-based test bed to investigate a range of nanoscale structures. We will look at nanowires (fabricated at NEU) and nanoscale fibers produced at UML using the electrospinning process. The MEMS test bed consists of in-situ SPM and UHV-compatible devices to rapidly cycle strain and temperature of nanoelements and devices to perform a nanoscale pull test on nanoelements.

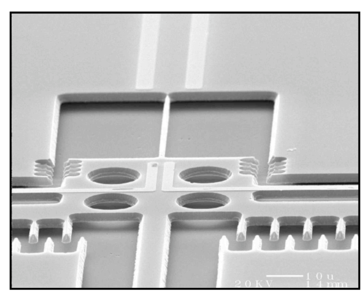


a) PANi-assembled template



b) PU film with patterned PANi

The Center research is based on the integration of the three core universities cross-disciplinary technical expertise, industry connections, and educational and outreach infrastructure. For example, in the directed assembly area, the nanoelements are synthesized and functionalized at UNH, the templates are manufactured at NEU and the assembly of nanotubes and nanoparticles is done at NEU with conjunction with UNH and the polymer assembly is done by UML with templates made at NEU and in collaboration with NEU and UNH.



MEMS devices for characterizing nanowires.

The Center is closely working with industrial partners that make up the industrial advisory board that boasts 18 large and small companies. The CHN IAB membership is: Draper Laboratory, EMC, Environ International, Corp., Foster-Miller, Gillette (Proctor & Gamble), Intel, Konarka Technologies, Motorola, Nantero, Nypro, Polytec PI, Raytheon, Schlumberger, Textron, TIAX, Triton Systems, Tyco Electronics and Zyvex

The Center for High-rate Nanomanufacturing is leveraging current and future efforts in nanoscience and technology by bridging the gap between scientific research and the creation of commercial products by established and emerging industries, such as electronic, medical, and automotive. Long-standing ties with industry will also facilitate technology transfer. Over the past year, CHN has presented the technology, benefits, and societal impact of nanomanufacturing to a wide range of audiences. The undergraduate modules introduced 570 students to nanotechnology. Four new courses, including two three-university courses, were attended by 165 students. Undergraduate researchers, including 38% women and 19% underrepresented minorities, participated in undergraduate research programs. K-12 teacher conferences, a summer institute, research experiences for teachers and faculty presentations have introduced 350 teachers to nanotechnology. The Summer Institute and RET program have provided nanotechnology modules that are implemented into classrooms, and five participants in the RET program have been sharing their modules and implementation experiences with other teachers. Over 1125 K-12 students have been introduced to nanotechnology through CHN programs. The joint program between CHN and the Museum of Science has started its mission of educating the general public about nanomanufacturing.

K-12 teachers listen to a presentation made at the 1st Annual Nanotechnology Conference for K-12 Teachers by CHN trained teachers.

The CHN organized its 4th International Nanomanfacturng Workshop held on June 27 and 28, 2006. The workshop had over 100 attendees from industry and academia and 27 speakers and panelists. The workshop also had many companies and media sponsors. The CHN-sponsored workshops featured educational workshops on ethical reflection and the environmental impacts of nanomanufacturing, including a workshop on "Nanoparticle Health and Safety." International collaboration is strong, with many new research agreement signed with universities in Korea, Japan, Turkey and Northern Ireland.