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 wire 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 that will enable high-rate/high-volume bottom-up, precise, parallel assembly of nanoelements (such as carbon nanotubes, nanoparticles, and polymer nanostructures) economically and using environmentally benign processes.

Current nanotechnology research focuses on surface modification, manipulating several to several hundred particles or molecules to be assembled into desirable configurations. The CHN focuses on fast massive directed-assembly of billions to trillions of nanoelements by controlling the forces required to assemble, detach, and transfer nanoelements at high rates and over large areas. Templates with nanoscale uniform and nonuniform patterns created using self-assembled fullerene nano-lines, self-ordering growth of nanoarrays, and nanolithography techniques are used to assemble nanoparticles and SWNTs and to guide the self-assembly of polymer melts. Once the assembly is done, the assembled structures are transferred to a substrate as shown in Fig. 1 where the resulting structures could be a used as an electronic device, sensor, etc. The proposed nanotemplates and processes will accelerate the creation of highly anticipated commercial products and will enable the creation of an entirely new generation of applications because they are developed with scalability and integration as a requirement. The CHN is manufacturing two prototype testbeds; a nonvolatile high-density memory device and a high-sensitivity biosensor.

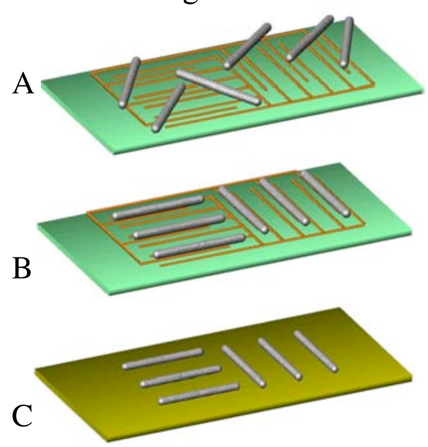

Fig. 1 Nanotubes deposited on template (A), assembled on a nanotemplate (B), and then transferred to second substrates (C).

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 CHN has developed and fabricated templates with nanostructures down to 20 nm and utilized them to conduct directed assembly of carbon nanotubes, nanoparticles and polymers. Figures 2 A shows the assembly of 10-15 nm silica particles inside 30 nm trenches. The FESEM image shows the trenches are covered with nanoparticles with no gaps in the assembly[2]. Figure 2B show the assembly of 50 nm particles in

50 nm trenches with gaps in the assembled particles [2]. Figure 3 shows consistent and continuous directed assembly of SWNTs in sub 100 nm trenches [3].

The CHN is also working on novel synthesis of single-wall nanotubes (SWNTs) with the desired size, functionality, and solubility for high-volume assembly. The CHN also works very closely with partner companies to ensure that the developed nanotemplates can be utilized for their application. The CHN is concurrently developing tools and methods to ensure long-term reliability. Novel reliability and characterization MEMs tools to be used as reliability and characterization tools for nanoelements such as nanowires and their connections as shown in Fig 4. CHN is also developing nanoscale contamination control and defect and fault-tolerance systems.

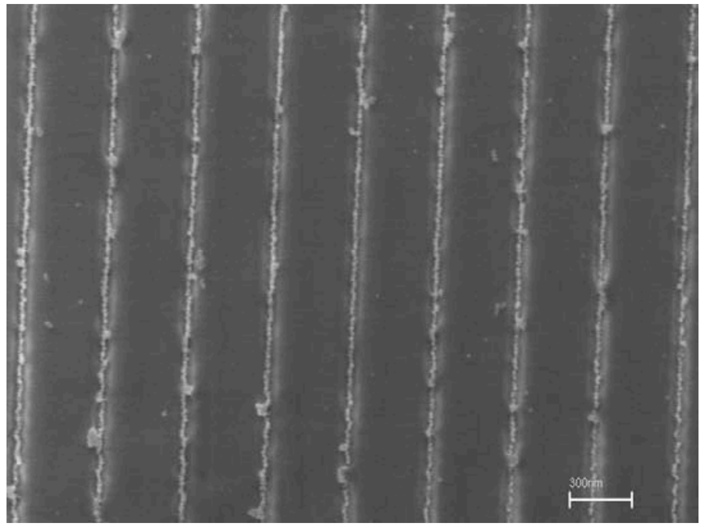

Fig 2A. 10-15 nm silica nanoparticles in 30 nm trenches

In addition, CHN is concurrently assessing the environmental, economic, regulatory, and ethical impacts of nanomanufacturing. The environmental attributes of each process under development is studied. The economic viability in light of environmental and public health findings, and Ethical and regulatory policy issues related to developmental technology are also assessed for all of the developed nanomanufacturing technologies at the Center.

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.

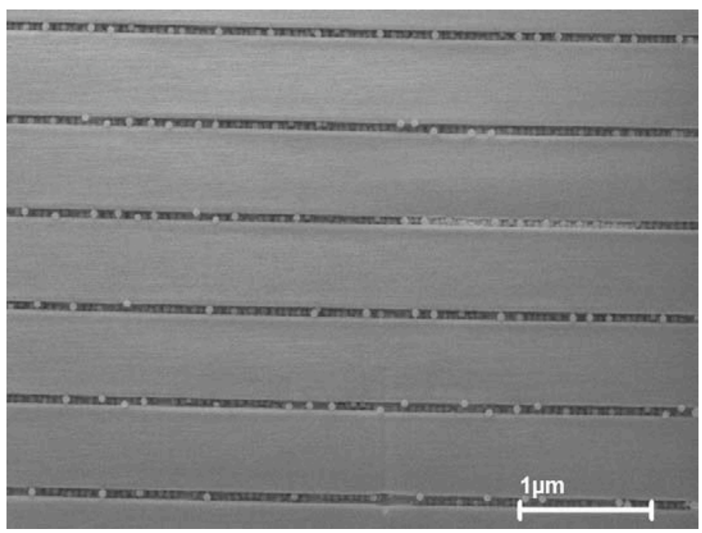

Fig 2B. 50 nm PSL nanoparticles in 50 nm trenches

Broader Impact

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.

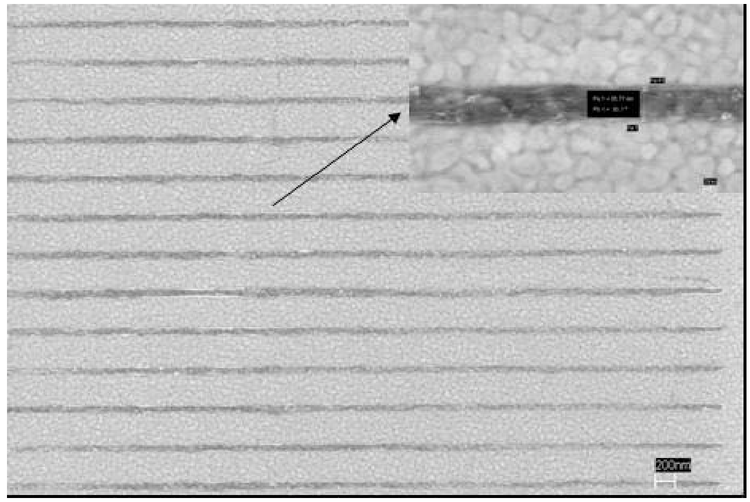

Fig 3. Assembly of SWNTs into sub 100 nm trenches

The CHN is building on existing network of partnerships among industry, universities, and K-12 teachers and students to deliver the much-needed education in nanomanufacturing, including its environmental, economic, and societal implications, to the current and emerging workforce. A graduate seminar, "Introduction to High-rate, Template-based Nanomanufacturing," co-taught face-to-face by faculty from Northeastern University, the University of Massachusetts Lowell, and the University of New Hampshire in spring 2005 attracted 60 to 80 students, post-doctoral researchers, faculty, and other interested parties to each session. One undergraduate student is currently in a coop placement at a CHN industrial partner, Nantero and 14 undergraduates from Historically Black Colleges and Universities are scheduled for research experiences in summer 2005. The Center held a K-12 Nanotechnology Teacher Conference on April 6, 2005 that was attended by 52 practicing math, science or technology teachers from elementary, middle, and high schools; this was prelude to K-12 teacher seminars and research experiences that will be held in summer 2005. Finally, the CHN-sponsored the Third New England International Nanomanufacturing Workshop in June, 2005, will feature technical presentations and educational workshops on ethical reflection and the environmental impacts of nanomanufacturing.

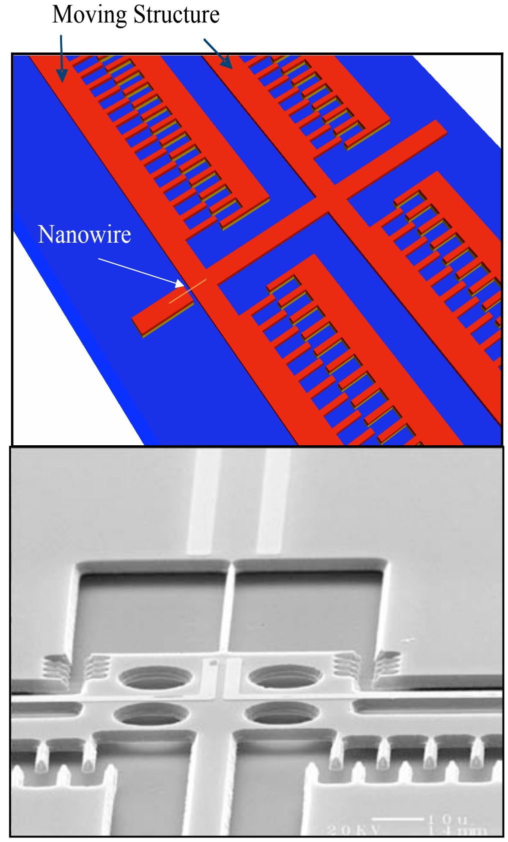

Fig. 4. MEMs Nanowire Tensile Tester for conducting nanoscale tensile test of suspended nanowire using electrostatic combdrive actuator.

References

[1] For further information about this project link to **<www.nano.neu.edu>** or email **<busnaina@neu.edu>**

[2] X. Xiong, P. Makaram, K. Bakhtari, S. Somu, A. Busnaina, J. Small, N. McGruer, G. Miller and J. Park., "Directed Assembly of Nanoelements Using Electrostatically Addressable Templates," MRS, 2005 Fall Meeting, Boston, MA, Nov. 28-Dec. 2, 2005.

[3] P. Makaram, X. Xiong, K. Bakhtari, A. Busnaina, N. McGruer, and G. Miller, "SWNT Directed Assembly Using Nanotemplates," MRS, 2005 Fall Meeting, Boston, MA, Nov. 28-Dec. 2, 2005.