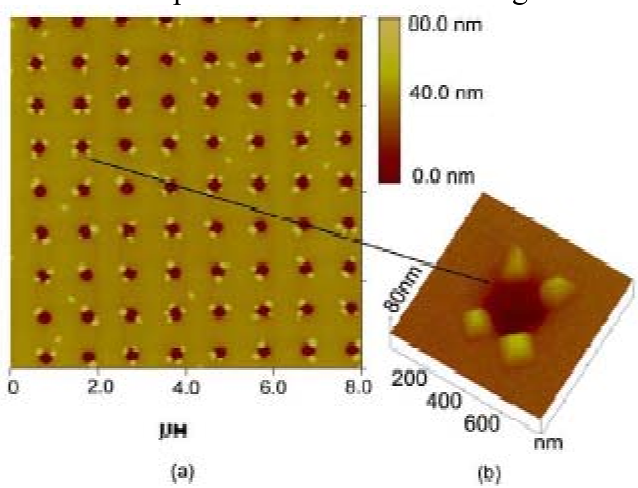
Multi-Dimensional Collaborations with Pacific Northwest National Laboratory

The Center for Nanoscopic Materials Design is working closely with researchers at the Department of Energy's William R. Wiley Environmental Molecular Sciences Laboratory operated by the Pacific Northwest National Laboratory (PNNL). The collaborative effort is exploring guided growth of metal oxide nanodots, using surface patterning tools at the University of Virginia and deposition systems at PNNL. During 2003, MRSEC and PNNL researchers demonstrated for the first time the guided growth of Cu2O nanodots on single crystal SrTiO3 substrates. Efforts involving Cu2O - SrTiO3 continue in 2004 and have been augmented by additional studies involving growth of NbO2 on TiO2 single crystals.

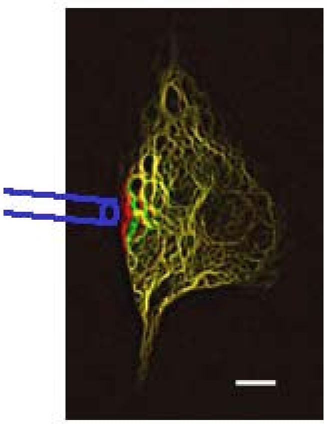
Explorations of this second system have been motivated by a MRSEC activity that considers the societal and ethical implications of nanotechnology throughout the process of discovery. If NbO2 nanodots can be grown in specific locations on the TiO2 substrate, these nanodots could become adhesion sites for biomolecules which in turn serve as adhesion sites for cells. Definition of cellular adhesion site spacing at the nanoscale would provide biomedical researchers with new tools for unlocking the mysteries associated with such processes as wound healing and atherosclerosis.



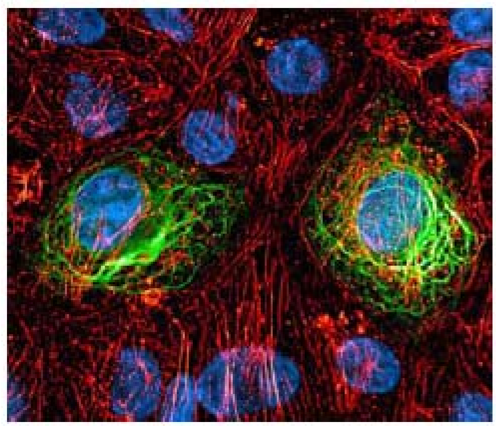
Atomic force images of patterned growth of copper oxide islands on strontium titanate substrates. The location of the islands is controlled by nanoscale holes created in the substrate surface by a gallium focused ion beam

Control of Endothelial Cell Cytoskeletal Mechanics by Focal Adhesion to Nano-Printed Extracellular Matrix Substrates (B. Helmke, C. Choi, G. Duncan)

Endothelial cells lining the arteries become dysfunctional during development of arterial disease and following balloon angioplasty to reopen clogged arteries. Engineering cell behavior to restore artery wall function or to design artificial bypass grafts requires an understanding of how cells sense and react to their environment. We are developing novel approaches for nanopatterning proteins that control cell adhesion in order to understand how surface interactions determine cell structure and function. This project promotes interdisciplinary interactions among students in Biomedical Engineering, Electrical Engineering, Materials Science, and the School of Medicine. In addition, Gayle Duncan visited from Univ. of Abertay Dundee, Scotland through the Summer Undergraduate Research Program. Along with undergraduate student Natalie Villani, Gayle developed a novel approach to indent living cells by one-millionth of a meter while simultaneously measuring the movement of intracellular structures.

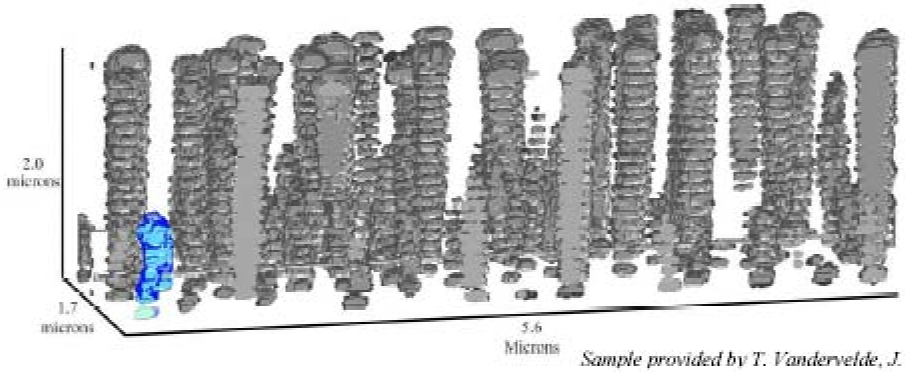


Cell structure before (red) and after (green) indenting with a glass microneedle (Duncan and Villani).



3-D projection of cytoskeletal structure and nucleus. Time-lapse images reveal adhesion and structural dynamics in response to extracellular force.

Three Dimensional Reconstruction of Nanostructured Systems ***(A. Kubis, R. Hull)***



Sample provided by T. Vandervelde, J. Bean

Small clusters or “quantum dots” can form during growth of dissimilar semiconductor materials These nanostructures can potentially be used as individual elements of advanced nanoelectronic systems. Control of the placement of the quantum dots is key to the development of prototype devices. If successive layers of quantum dots are grown, they evolve into more regular arrays. This is due the interactions of strain fields – i.e. crystal distortions - between each layer of dots. In this work we are growing germanium quantum dots separated by silicon spacer layers. While experimental studies of this process have been previously published, they utilized two dimensional imaging techniques that provided only limited views of the full three dimensional array of dots. Here we have applied new focused ion beam tomographic imaging methods to reconstruct the full three-dimensional distribution of germanium quantum dots. In the image above, only the germanium quantum dots are shown, the surrounding silicon matrix being omitted for clarity. Processes such as the detailed evolution of the quantum dot columns, competitive growth, and creation or annihilation (for example the dot column colored in blue) of quantum dot columns can be observed and understood. In parallel, MRSEC research groups under Bill Johnson at UVA and John Lowengrub at UC Irvine are developing three dimensional elastic continuum modeling techniques to further understand these processes.

Societal and Ethical Dimensions of Nanotechnology: Summer REU 2003, UVa

In fulfillment of program requirements, each MRSEC summer REU student enrolls in a nanotechnology ethics course, STS 300. The course was designed by Carolyn Vallas and James Groves, the Co-PI's of the program. Rosalyn Berne selected and taught the material (Spring 2003) exclusively for ten students enrolled in the MRSEC-REU Program. Students explore the societal dimensions of new technology through a combination of readings and discussions. They relate their individual research experiences, using actual case studies from MRSEC faculty, to examine the societal and ethical implications of nano technology research. The course provides students with a greater understanding of the implications of their research. All enrolled students receive two university credits.

Rosalyn Berne, PhD.
Assistant Professor, Science Technology And Society selected the reading material For the course.

Student's Comments:
Adam DiNardo, a 2003 summer REU student from Pennsylvania State University, indicated that the course stimulated a new perspective in his thoughts about conducting research.

The NANO Revolution - "Nanotechnology will change our world"*(J. Fitz-gerald, R. Hull, P. Norris, C. Vallas)*

The Center for Nanoscopic Materials Design recently completed a fast-paced 7 minute video introducing middle and high school students to nanotechnology. As part of the Center's education program, faculty members Jim Fitz-Gerald, Carolyn Vallas, Robert Hull, and Pamela Norris use the video's multimedia environment to provide students with an insight into the scale, complexity, and opportunities associated with nanotechnology. Professor Hull describes how micro and now nanotechnology is enabling the electronics revolution while Professor Norris exposes students to the wonders of aerogels.
Using some of the advanced electron microscopy facilities at the University of Virginia, the video also helps students understand the scale of nano, providing them with a glimpse of familiar objects such as a leaf, a human hair, and a space shuttle insulation tile, but at an unfamiliar scale – the nanoscale. The video is currently being distributed to high school groups in Virginia and beyond, and students are being encouraged to consider how nanotechnology could impact their lives.