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Fabrication and application of films and slits with complex surface topography at the subnanometer scale

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The relationship between structure and function is fundamental to nanotechnologies of all dimensionalities, including surfaces, films, and slits with nanoscale vertical dimensions and microscale lateral dimensions. In this presentation, I will describe our use of a focused ion beam to mill such nanostructures into bulk silicon and thin films of silicon dioxide and silicon nitride. This nanofabrication process can resolve vertical features across the nanoscale and into the atomic scale, with lateral features extending across the microscale and into the macroscale. These results establish new limits of dimensional control in these important hard materials. Moreover, this nanofabrication process is highly efficient, enabling rapid prototyping of complex surfaces for practical applications. To demonstrate the utility of such nanostructures, we introduce optical films and fluidic slits with subnanometer surface topography. Optical films, milled in silicon dioxide and silicon nitride, show structural colors as an engineered function. Nanofluidic slits, milled in silicon dioxide and sealed with a soft layer of polysilsequioxane, separate nanoparticles by size exclusion with subnanometer resolution. In this size separation process, an array of nanofluidic slits simultaneously functions as a reference material, allowing characterization of nanoparticles by particle tracking and depth mapping. Analysis of nanoparticle intensity confirms the expected volumetric scaling of dye loading, providing an orthogonal validation of the size separation and characterization mechanism. These applications emphasize subnanometer control over vertical dimensions and demonstrate the potential utility of complex surfaces, films, and slits with subnanometer topography.

Biography:

Samuel M. Stavis is a Project Leader in the Center for Nanoscale Science and Technology (CNST) of the National Institute of Standards and Technology (NIST). He received a B.S.E. in Engineering Physics from the University of Michigan and a Ph.D. in Applied Physics from Cornell University, where he was also a Postdoctoral Research Associate in Biological and Environmental Engineering. In 2007, Sam joined the NIST staff through a National Research Council (NRC) Research Associateship award. In the NIST Physical Measurement Laboratory, he engineered complex nanofluidic devices, advanced single molecule measurement science, and developed microfluidic nanomanufacturing processes. In 2012, Sam joined the CNST, where he leads projects combining nanoscale particles, device technologies, and optical measurements for applications in manufacturing and healthcare. Sam has received two Innovations in Measurement Science awards for the most creative ideas to advance the measurement capabilities of NIST.