NANO HIGHLIGHT
Manufacturing with Nanoparticle Beams and Sprays

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PIs: **S. L. Girshick**, **T. Dumitrica, W. W. Gerberich, D. J. Norris and P. H. McMurry**
University of Minnesota, Minneapolis, MN

We have developed a novel approach to evaluating the mechanical properties of nanostructured material, and have used this to characterize the Young's modulus of nanoparticle films that we deposit using hypersonic plasma particle deposition [1]. A focused ion beam (FIB) is used to mill out doubly-clamped beams from the nanoparticle deposits, as seen in Fig. 1 for a deposit composed of silicon nanoparticles. The doubly-clamped beam is then probed with a nanoindenter, which provides load-deflection measurements that are used to evaluate the Young's modulus, a key measure of a material's elasticity. To our knowledge this is the first time that such a method has been used for determining the mechanical properties of nanoparticulate composites.

The beam is created by making wedge-shaped cuts on either side of the area of interest, followed by a freeing cut into the resulting "wall" of material. These beams are typically about 40 μm long with cross-sections measuring a few μm on each side. Next a nanoindenter is used to flex the beam at its center using closed-loop displacement-controlled loading. The Young's modulus of the beam is calculated using standard linear beam theory relating load to deflection. For beams milled from films composed of silicon nanoparticles with diameters in the range 5 to 20 nm, the load-displacement curves (Fig. 2) show remarkably elastic behavior through multiple loadings at several different strain rates. The Young's modulus of Beam 1 was determined to equal approximately 360 GPa, compared to about 150 GPa for conventional silicon.

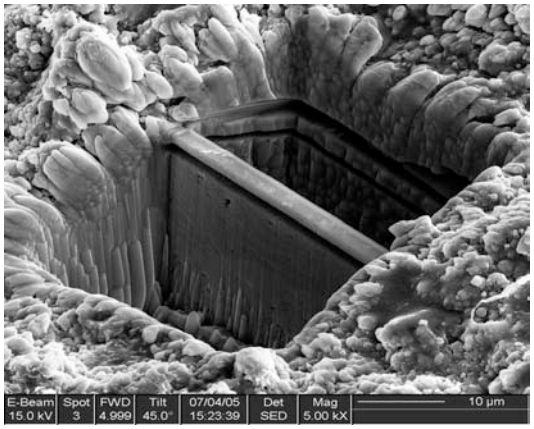

Figure 1. FIB-milled double-clamped nanoparticulate silicon beam. The material surrounding the milled-out trench is gallium deposited by the focused ion beam.

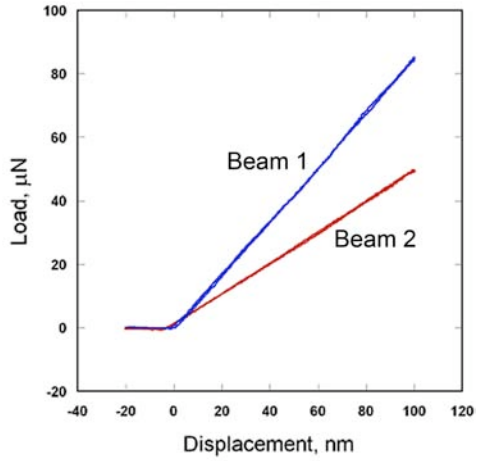

Figure 2. Load-displacement curves of two beams composed of silicon nanoparticles. The different slopes are due to the different geometries of the two beams.

References

[1] J. Hafiz, R. Mukherjee, X. Wang, M. Marshall, R. D. Twesten, M. Cullinan, J. V. R. Heberlein, P. H. McMurry and S. L. Girshick, "Effect of process parameters on the properties of Si-Ti-N nanostructured coatings," *Surf. Coat. Technol.*, in press; available online Oct. 17, 2005.