Applied Physics Seminar

Size Matters: Mechanical properties of materials at the nano-scale

Prof. Julia R. Greer – Caltech

Abstract:

A key focus in Professor J.R.Greer's research is the development of innovative experimental approaches to assess mechanical properties of materials whose dimensions have been reduced to nano-scale. One such approach involves the fabrication of nanopillars using Focused Ion Beam (FIB) and micro fabrication approaches. Their strengths in uniaxial compression and tension are subsequently measured in a one-of-a kind in-situ mechanical deformation instrument the SEMentor, which allow for precise control of displacement and loading rates, as well as for simultaneous video capture. In this seminar we will discuss the differences observed between mechanical behavior in two fundamental types of crystals: face-centered cubic (fcc) and body-centered cubic (bcc), as well as of nano-crystalline Nickel and amorphous metallic glasses with nano-scale dimensions. In a striking deviation from classical mechanics, we observe a SMALLER IS STRONGER phenomenon in single crystals manifested by the significant (~50x) increase in strength of as material size is reduced to 100nm. To the contrary, nano-crystalline materials tend to exhibit the opposite trend: SMALLER is SOFTER. Finally, metallic glasses, whose Achilles' heel has always been the occurrence of catastrophic failure at very small strains, exhibit non-trivial ductility when reduced to nano-scale. Furthermore, unlike in bulk where plasticity commences in a smooth fashion, all of these materials exhibit numerous discrete strain bursts during plastic deformation. These remarkable differences in the mechanical response of nano-scale solids subjected to uniaxial compression and tension challenge the applicability of conventional plasticity models at the nano-scale. We postulate that they arise from the effects of free surfaces, leading to the significant differences in dislocation behavior for the case of crystals, grain boundary activity for the case of nano-crystalline solids, and shear transformation zones in metallic glasses and serve as the fundamental reason for the observed differences in their plastic deformation. These mechanisms and their effect on the evolved microstructure and the overall mechanical properties will be discussed.

Biography:

Julia R. Greer received her S.B. degree in Chemical Engineering with a minor in Advanced Music Performance from Massachusetts Institute of Technology (1997) and Ph.D. degree in Materials Science and Engineering from Stanford University (2005). She has also worked at Intel Corporation in a mask micro-fabrication facility (2000-03) and was a postdoctoral fellow at the Palo Alto Research Center, PARC (2005-07), where she studied organic flexible electronics. Greer is a recipient of the Top Young Innovator under 35 Award (TR-35, 2008), the NSF CAREER award (2008), the gold Materials Research Society Graduate Student Award (2004) and American Association of University Women Fellowship (2003). She has been an assistant professor in the Materials Science department at Caltech since summer of 2007, and she is also a concert pianist, with most recent performance of Brahms Concerto No. 2 with the Redwood Symphony.

Tuesday April 21st
4:00pm-5:00pm.
Watson 104

Refreshments will be available in the Watson Lobby at 3:45pm