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PLASTICITY SIZE EFFECTS IN FREESTANDING THIN FILMS: EXPERIMENTS AND MODELING

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Abstract. Over the past decade, there has been a substantial thrust to reduce the size of electronic and electromechanical systems to the micron and sub-micron scale by fabricating devices out of thin film materials. Successful device development requires a thorough understanding of material mechanical properties as a function of device characteristic dimension. At this scale, specimen geometry and dimensions are similar in size to the material microstructural features. We present a new *on-chip* membrane deflection experiment specially designed to investigate material elastic behavior, plasticity (including size effects in the *submicron* regime), and fracture. The study examines *plasticity size effects* in freestanding fcc thin films in the *absence of macroscopic strain gradients.* Experimental results including transmission electron microscopy will be presented to demonstrate that indeed strong plasticity size effects exist and to highlight their possible sources.
Current shortcomings of plasticity theories at the submicron scale motivated us to examine a multiscale modeling approach to capture the aforementioned size effects. Our modeling is twofold. Firstly, *3D Discrete Dislocation Dynamics mesoscopic simulations* are carried out using the software PARANOID[+] to understand qualitatively dislocation-dislocation, dislocation-film surfaces, and dislocation-grain boundary interactions in freestanding films. Secondly, a *grain level FEM model* based on Crystal Plasticity is used to take into account initial grain orientations and texture in a representative volume element (RVE) of the tested films. The geometry of the RVE is based on polyhedrons obtained by Voronoi tessellations. A criterion based on discrete dislocation dynamics results is incorporated into the crystal plasticity continuum model and used to describe the onset of plasticity in each grain. The efficiency of this modeling strategy will be discussed.

H.D. Espinosa, B.C. Prorok and B. Peng, "Plasticity Size Effects in Freestanding Submicron Polycrystalline FCC Films Subjected to Pure Tension," *Journal of the Mechanics and Physics of Solids*, Vol. 52, pp. 667–689, 2004.

H.D. Espinosa, B.C. Prorok, and M. Fischer, "A Methodology for Determining Mechanical Properties of Freestanding Thin Films and MEMS Materials," *Journal of the Mechanics and Physics of Solids*, Vol. 51, No. 1, pp. 47-67, 2003.