ME DEPARTMENTAL SEMINAR
Friday, February 25, 2005
1:00pm – 2:00pm
2233 GG BROWN

Professor Taher Saif
Mechanical & Industrial Engineering
University of Illinois at Urbana-Champaign

"Mechanical Behavior of Nano-grained Thin Metal Films"

Abstract:

Thin metal films are extensively used in electronics and micro/nano mechanical systems. These nano scale metal structures are typically poly crystalline in nature with abundant grain boundaries. The fundamental role of size scale in determining the thermomechanical properties of nano metallic structures is not yet fully understood, a study that is challenged by the limitations of the instrumentation that allows testing nano scale specimens. We have developed a new micro mechanical experimental method to study the stress-strain response of free standing thin metal films with thickness 20 nm or higher, in-situ in TEM and SEM. We employed the microinstrument to study Aluminum and gold films with thicknesses of 30-400nm, and with the corresponding grain sizes of 10-200nm. We find, as grain size decreases, (1) elastic modulus decreases, (2) metals show non-linear elastic response with small plastic deformation, and (3) yield stress increases, reaches a maximum value and then decreases with further decrease of grain size. In-situ observation of Al samples shows little dislocation activity in grains with size 100nm or less even at high stresses, which point to a grain boundary based mechanism for nano grained metal deformation. It appears that there is a shift of the deformation mechanism as grain size decreases: at small grain size, dislocation slip ceases to operate and deformation is contributed by grain boundary mechanisms, whereas as grain size increases, dislocation dynamics overwhelms the grain boundary mechanisms. At the transition size, where the grains are small so that dislocation dynamics is energetically unfavorable, but not small enough for grain boundaries to assist in deformation, metal may show highest strength. For Al, this critical grain size seems to be around 50 nm from our experimental observations, close to 20-30 nm predicted by theory. Below this transition size scale, metals become softer and they lose strain gradient strengthening due to lack of dislocations.

If time permits, I will briefly discuss an ongoing project: guided self-assembly of nano channels and wires.