ABSTRACT

Engineering design of essentially all metallic components used in structural applications relies heavily on the framework of continuum plasticity. However, many experiments now show that the plastic flow stress in metals increases in micron-scale material volumes, i.e. “smaller is stronger”. The failure of conventional plasticity is particularly manifest at a crack tip, where infinite toughness can be predicted for realistic material properties. A full understanding of fracture thus requires multiscale modeling, and so our progress at coupling scales from continuum mechanics down to quantum mechanics is briefly reviewed. At the continuum scale, phenomenological strain-gradient plasticity models have emerged to handle size effects but there is no clear physical identification of the actual material length scales controlling size-dependence, in spite of wide speculation. Here, we present a discrete-dislocation/cohesive-zone simulation model and unambiguously demonstrate that the spacing between obstacles to dislocation motion is one dominant material length scale controlling the fracture toughness of plastically deforming metals. With this insight, we propose and validate a new and general “stress gradient plasticity” concept based on the behavior of dislocations in a dislocation “pile-up” at an obstacle under a stress gradient. This model rationalizes our fracture results. Moreover, “stress gradient plasticity” predicts size-effects under many other loading conditions, and predicts size effects in bending and torsion that are in quantitative agreement with experimental data on micron-scale samples of polycrystalline metals.

BIO

Dr. William Curtin received a combined 4 yr. ScB/ScM degree in Physics from Brown University in 1981 and a PhD in theoretical physics from Cornell University in 1986, working on the optical properties of metal nanoparticles and on statistical mechanics theories of freezing. Dr. Curtin then joined the Applied Physics Group at the British Petroleum Research Laboratories (formerly SOHIO) in Cleveland, OH, where he worked on hydrogen storage in amorphous metal alloys, the statistical mechanics of crystal/melt interfaces, and the mechanics of ceramic and composites. In 1993, he joined the faculty at Virginia Tech with a joint appointment in Materials Science & Engineering and Engineering Science & Mechanics. In 1998, Professor Curtin returned to Brown University as a faculty member in the Solid Mechanics group of the Division of Engineering and was appointed the Elisha Benjamin Andrews Professor in 2006.

A current overall theme of Professor Curtin’s research is multiscale modeling of the mechanical behavior of materials, with specific applications to atomistic/continuum models of plasticity and fracture in metals, dynamic strain aging and strengthening in lightweight metal alloys, and fiber composites including carbon-nanotube-based ceramic composites.

Professor Curtin is Director of the Center for Advanced Materials Research at Brown and Director of the NSF Materials Research Science and Engineering Center at Brown. He was appointed as a Guggenheim Fellow in 2005-06 to pursue research on Multiscale Modeling, has published over 160 peer-reviewed journal papers, and has been the Principal Investigator on funded research projects totaling over $22M.

Drinks will be served at 3:45 p.m.