Novel Techniques for Nanomechanical Characterization

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Due to increased resolution in experimental capabilities and the development of materials at small geometric and microstructural length scales, novel techniques for mechanical characterization at the micrometer and sub-micrometer length scale have been a major focus of many experimental and computational studies in recent years. Perhaps the most widely used nanomechanical characterization technique of the past 20 years is nanoindentation. Conventionally used to make elastic modulus and hardness measurements at depths at the nanometer length scale, this technique has been applied to thin films and bulk structures of various material classes, from hard ceramics to biological tissues. New methodologies beyond nanoindentation have been developed in order to better mimic classical mechanical tests at the micrometer scale, specifically microtensile and microcompression testing. Furthermore, the development of coupling these micro-mechanical measurements to other characterization techniques applied at equivalent length scales has allowed a more comprehensive picture of deformation behavior of materials.

It is not always clear, however, how such techniques can be appropriately applied to outstanding questions within the materials community. Sometimes a new technique becomes popular and is applied to problems without careful examination of the inherent artifacts of the method and the assumptions used in the subsequent analyses. In turn, it is important for the materials community to debate the applicability of such tech-

niques and the interpretation of results, especially in light of observations of new behaviors using these novel methods. Specifically, the overwhelming observation that the behavior of materials in small volumes is often significantly different from their bulk counterparts requires not only an investigation into the mechanisms of small-volume deformation, but also a critical understanding of the measurement itself; geometric and microstructural influences can affect not only deformation mechanisms but also the accuracy and meaning of the measurement. In this spirit, this collection of papers on "Novel Techniques for Nanomechanical Characterization" aims to provide an overview of a set of experimental methods used in small-scale mechanical characterization, to offer advantages and disadvantages of the application of these methods to real materials problems, and to give insight into the future of the field of nanomechanics.

In the first paper, D. Kiener and co-authors describe complimentary methods used in nanoindentation studies in order to more comprehensively investigate mechanisms of deformation within small volumes. Specifically, they describe the use of etch pit techniques for dislocation density measurements, electron back-scattered diffraction measurements for local reorientation characterization, and transmission electron microscopy for direct observation of dislocation processes. Importantly, the authors frame their discussions of these characterization techniques around the widely observed and much debated issue of the indentation size effect.

Next, D.S. Gianola and C. Eberl give an in-depth overview of microtensile testing, addressing the critical questions associated with small-scale

testing regarding sample preparation and handling, accurate application and measurement of small loads and displacements, and the challenges of subsequent analyses of results. Through elegant examples, the authors successfully argue that microtensile testing plays an important role in the understanding of materials at the micrometer or nanometer length scale.

In the final paper, M.D. Uchic, P.A. Shade, and D.M. Dimiduk provide an overview of microcompression testing, a technique which has received a great amount of attention from both experimentalists and modelers alike since 2003, when the authors introduced the method to the materials community. The paper focuses on the mechanisms of plasticity in face-centered cubic metals as investigated with the technique. Through their discussions of both experimental observations and results from dislocation dynamics simulations, they present a mechanistic description for the seemingly universal observation that "smaller is stronger."

While the collection of papers is only a sampling of new experimental micro-mechanical methods, it is my hope that this volume provides the reader with a better understanding of the advances in the field and an appreciation for how such novel techniques can further our knowledge of deformation behavior of materials at small length scales. Additionally, the citation lists provided by the authors provide the interested reader with extensive opportunities for further reading.

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