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Probing Nanoscale Damage Gradients in Irradiated Metals using Nano-mechanical Test Techniques

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ABSTRACT:

Materials with modified surfaces – either as a consequence of a graded microstructure, or due to an intentional alteration of the surface – are of increasing interest for a variety of applications ranging from enhanced wear and corrosion resistance, superior thermal and biomedical properties, higher fracture toughness, and reduced stress intensity factors etc. Quantifying the resulting property gradations poses a significant challenge, especially when the changes occur over small (sub-micrometer) depths, such as during ion-irradiation. The first half of this presentation will focus on a novel indentation approach which, together with the corresponding local structure information obtained from electron backscatter diffraction (EBSD), allows us to probe nanoscale surface modifications in solid materials and quantify the resulting changes in its mechanical response. Using tungsten as a specific example we discuss the capabilities of spherical nanoindentation stress-strain curves, extracted from the measured load-displacement dataset, in characterizing the elastic response, elasto-plastic transition, and onset of plasticity in ion-irradiated tungsten under indentation, and compare their relative mechanical behavior to the unirradiated state.

Time permitting we will also use a series of examples to show the capabilities of our nanoindentation techniques in (a) characterizing the local indentation yield strengths in individual grains of deformed polycrystalline metallic samples and relating them to increases in the local slip resistances, (b) correlating the stored energy differences of individual grains to their Taylor factors as a function of imposed cold work, and (c) understanding the role of interfaces (grain boundaries) in the deformation of a polycrystalline sample.

The second part of this presentation will focus on alternate testing techniques of miniaturized structures at these lower (micro-to- nanometer) length scales. In particular we look at utilizing a combination of nanoindentation, in-situ SEM compression testing of micro-pillars, and the recently developed in-situ SEM fracture toughness testing of 3 point bend micro-beams on multilayered nano-composites to evaluate their deformation mechanisms. These two-phase nanolayered composites have individual layer thicknesses varying from microns down to 1-2 nm, where one of the constituent phases has low ductility (such as a metal-ceramic Al-TiN, Cu-TiN, or an hcp-bcc Mg-Nb nanocomposite), with the final goal of enhancing both the strength and ductility of the system.

BIOGRAPHY:

Prof. Siddhartha (Sid) Pathak is an assistant professor in the Chemical and Materials Engineering department at the University of Nevada, Reno (UNR) since Fall 2015. Before joining UNR he was a Director's Postdoctoral Fellow 2012-2015 at Los Alamos National Laboratory (LANL), and a Keck Institute Postdoctoral Fellow at Caltech (2010-2012). His research interests are in the field of nanomechanics, particularly in developing novel experimental test strategies for mechanical testing of nano-structured materials. He has co-authored >55 peer reviewed articles and 2 book chapters in various scientific journals. He has received numerous scientific awards based on his work including the 2017 TMS Young Leaders Professional Development Award, one of the 2019 Top UNR Researchers for his university, as well as the 2019 DARPA Young Faculty Award.