HOW BIG SHOULD YOUR NANOINDENTATION BE? THE IMPLICATIONS OF INDENTATION SIZE IN ASSESSING THE PROPERTIES OF COMPLEX STRUCTURES.

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Drivers for testing small volumes of materials for assessing the mechanical properties are either (1) the sample you want to test is very small in the first place, such as measuring the hardness of a wear resistant coating which is in thin film form or (2) you can well-characterize a small volume or the small volume has some spatially distinct feature, such as probing properties near a grain boundary, or in two phase systems. Small scale mechanical testing using instrumented indentation generally requires minimal sample preparation and has high spatial fidelity, but creates complex loading states as opposed to uniaxial or biaxial applied stress methods. However, the ease of use and wide range of samples which are amenable for indentation testing has made this a common tool both for experimental assessment studies and for experimental validation of providing comparisons to simulations and predictions of mechanical properties.

This presentation will focus on two systems of interest that exemplify the ways instrumented indentation can be used to extract information regarding material properties and structures. First, for a case where samples are small, an experimental study of the elastic and plastic deformation mechanisms and fracture in small molecular crystals will be presented. Energetic and pharmaceutical materials are often non-cubic molecular crystals with complex polymorphs that exhibit brittle mechanical behavior, making machining test samples difficult. Nanoindentation has been used to assess properties of large (mm’s) crystalline forms, but to grow large crystals requires processing conditions which are non-typical for industrial growth conditions. Testing sub-mm crystals, and accounting for orientation effects, will be shown and validated versus large crystals. Of particular interest is determining the size of indentations required to extract information regarding elastic properties as well as the limit for onset of fracture. By using two materials with very similar elastic properties but different fracture behavior (ioxuridine, a pharmaceutical; and HMX, and explosive), the importance of size in testing tablets and plastic bonded molecular crystals is emphasized.

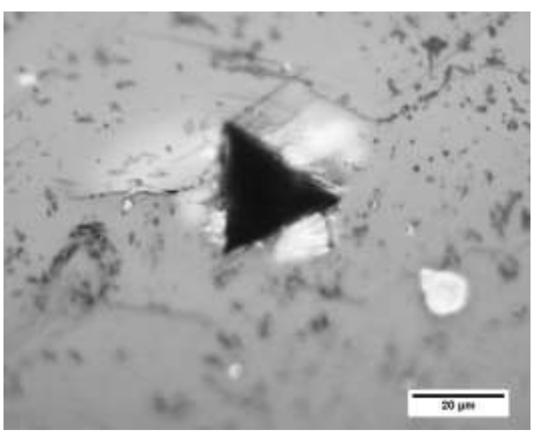

Figure 1 – Idoxuridine indented at 200mN showing slip, pile-up, and fracture

The second system of interest is metallic materials, with sparse defects, two phase structures, and residual stress gradients. The effects of dislocation density on both yield behavior and subsequent plastic deformation, and the ability to probe spatially varying properties will be evaluated. Of particular interest will be the use of indentation systems to extract residual stresses in graded structures. The localized properties of particular grains and particular locations will be compared to broad x-ray measurements of stress, and while averages compare to the full field measurements, the local variations can be significant, with stress variations of over 25%.