Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

Statistical analysis of nanoindentation hardness and pop-in behavior: variation as a characterization tool

Maughan, Michael, mmaughan@gmail.com; Bahr, David, Purdue University, United States

ABSTRACT

Accurate determination of nanomechanical materials properties is required for successful nanoscale materials characterization and subsequent design. Advancements in indentation science have been made in recent decades; however, widely varying nanoindentation hardness and elastic moduli are still currently reported in the literature on nominally similar samples, particularly at small depths or when only a few tests can be carried out in a limited sample volume. The study explores changes in the variation of hardness of platinum tested at five different depths between 50 and 300 nm for three different dislocation densities. Analysis of nearly 1500 indents showed that the coefficient of variation in hardness increases with decreasing dislocation density and sampling volume. Dislocation density plays a critical role in the variation, beyond solely instrumentation uncertainty, and supports a defect-based explanation for the stochastic behavior. The elasto-plastic transition has also been studied from a statistical standpoint. There is substantial research on the first so-called pop-in, however there has been little research concerning muliple pop-in events. Software has been developed for detecting first and subsequent pop-ins from indentation load-depth curves. The analysis of many indentation tests, combined with well-accepted models of deformation evolution allows nanoindentation to be used as a tool for characterizing dislocation density in crystalline materials. Heavily worked materials containing many preexisting dislocations exhibit little or no initial pop-in and no subsequent pop-ins. Alternatively, after annealing to reduce the dislocation content, larger and later pop-ins are exhibited. Other microstructural features such as impurities may be detected. This study additionally explores the transition from staircase yielding to bulk plasticity.