PROBING THE FUNDAMENTAL SIZE DEPENDENCE OF HARDNESS AND YIELD STRENGTH BY NANOINDENTATION

JENNETT Nigel M, HOU Xiaodong

National Physical Laboratory, NPL Materials, Teddington, United Kingdom, EU

Abstract

The base-line assumption in engineering is that material properties are size independent. However, it is well-known that changes in microstructure dimension (grain size) or in dislocation density (spacing) result in the Hall-Petch and forest work-hardening effects respectively. Similarly, smaller indents are harder and this ‘indentation size effect’ remains after correcting for the geometrical error in contact size in conventional hardness scales. In short, there is a physically real, length-scale dependence in dislocation-based plasticity. Size effects increase as test and structure sizes become smaller - strength enhancement is often proportional to an inverse square root of dimension. This is not just an awkward complication for obtaining comparability in measurement (although it is), but also a technological opportunity for enhancing material performance (by an order of magnitude).

Previously, Jennett et al. (2009 Applied Phys. Lett. 95:123102) showed that it is length (not volume or surface-to-volume ratio) that drives these size effects. Hou et al. (2008 J. Phys. D: Applied Physics 41(7):074006) showed that indentation size and grain size effects combine rather than superpose.

This talk will show how length-scale contributions from grain size, contact plastic zone size, and dislocation density (average mean-free-path) in a material, may be combined to predict macroscopic strength using a modification of Conrad’s Slip distance theory (Hou & Jennett 2012 Acta Mater. 60:4128). This combination is demonstrated using results from uniaxial compression testing and nano-indentation (using a judicious choice of indenter geometry) on a range of materials from single crystal to nano-crystalline materials.

Keywords: Definition, methods of measuring and testing, norms, new methods and approaches to characterization of nanomaterials

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