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# Indentation size effect in metallic materials in sub-micrometer scale

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## Abstract

Indentation size effect (ISE) is frequently observed in the nanoindentation of metals and alloys, and it is manifested by an increase of hardness with a decreasing penetration depth. This makes it very difficult to compare the values of hardness obtained at different (in particular, small) depths. The classical explanations of this phenomenon are based on the concepts of strain gradient plasticity. In the dimensions where the density of statistically stored dislocations (SSDs) is too low to accommodate the shape of the indenter (i.e., in low penetration depths), geometrically necessary dislocations (GNDs) must be considered. Indentation size effect at shallow indentation depths still remains a challenge as it cannot be correctly described by the Nix–Gao model based on the concept of strain gradient plasticity and geometrically necessary dislocations, which is valid for higher penetration depths. The reasons for this discrepancy may be various, and multiple microstructural factors may play a role at the nanoscale. The effects of several material (e.g., grain size, crystal orientation, pre-deformation) and experimental (e.g., indenter tip radius) parameters on the indentation size effect in sub-micrometer scale were studied. The results on several metallic materials show interesting insight into the deformation mechanisms and the evolution of the plastic zone during the low-depth indentation.

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