Nanoindentation study of dislocation-based plasticity and crack formation in oxides

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In light of the rising topic of dislocation-based functionality of oxides, the dislocation-based mechanical behavior, for instance, dislocation plasticity and potentially crack formation induced by dislocations is also drawing increasing attention. Dislocations are line defects and the main carrier of plastic deformation. Understanding the dislocation-based mechanics in oxides can play a critical role in assessing the materials' mechanical and operational reliability.

In this work, we present an approach to evaluate the incipient dislocation plasticity and crack formation using nanoindentation. In addition, the concept of "defect chemistry engineering" is proposed for the first time, based on which the dislocation plasticity of the oxide crystals can be tuned, as will be demonstrated in single-crystal $SrTiO_3$. Two methods, i.e., via stoichiometry change of the Sr/Ti ratio, and by reduction treatment to increase oxygen vacancy concentration, have been validated to modify the dislocation nucleation and dislocation motion based on the nanoindentation study. These are both keys to dislocation plasticity. Furthermore, a unique size effect for brittle oxides, in comparison to metals, has been identified. Under a critical indenter tip radius, the plastic deformation in brittle oxides under the indenter tip will be purely governed by dislocations without crack formation.