Using the nanoindentation to question the impact of hydrogen on the elasticity and plasticity behaviors of pure nickel

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Abstract

The influence of electrochemical hydrogen charging and subsequent room temperature hydrogen desorption on elastic modulus, incipient plasticity (or pop-in) and indentation hardness were investigated in nickel single crystals using a series of nanoindentation tests. The evolution of hydrogen and vacancies contents during the desorption was analysed using thermal desorption spectroscopy and differential scanning calorimetry. Antagonist softening and hardening effects of hydrogen are related and commented on the base of TEM, HR-EBSD observations and Molecular static simulations using embedded-atom method potential. The irreversible reduction of reduced modulus, i.e., softening in the elastic regime, is a result of hydrogen induced vacancy clusters in the surface and subsurface zones due to the hydrogen charging. The analysis of incipient plasticity disclosed the hydrogen-vacancy clusters enhanced lattice friction against the formation of dislocation, which resulted in an increase in the critical load and critical resolved shear stress for the first pop-in. Moreover, the activation volume for the pop-in and dislocation nucleation decreased by the hydrogen intake. From this, it is rational to conclude that the mechanism governing the pop-in in hydrogen charged conditions is the hydrogen-vacancy clusters induced heterogeneous dislocation nucleation on a subsurface.

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