Unravelling hydrogen effects on elasticity and plasticity mechanisms in nickel single crystal using nanoindentation

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One of the fundamental aspects of hydrogen embrittlement is based on the impacts of the hydrogen on the elementary mechanisms of plasticity [1]. Though it is well known that the solute hydrogen deteriorates ductility of nickel, there are antagonistic aspects in the hydrogen effects on the plasticity, i.e., hydrogen induced hardening as well as softening in metallic materials [1-4], these effects may reflect an implication of hydrogen on the modification of the elasticity behavior. In this work, the impact of hydrogen on elastic modulus, elastoplastic transition (pop-in) and indentation hardness were investigated in nickel <100> single crystal using nanoindentation tests. The indented surfaces were analyzed by SEM-FIB, EBSD and TEM to characterize the development of dislocation structures and any other defects and hence to establish the hydrogen-plasticity correlation. Hertz theory is used to model the elastic regime and Oliver and Pharr model was used to analyze the elastoplastic regime of the nanoindentation load-displacement curve. Hydrogen induced impact on maximum shear stress to activate dislocations, hardness and elastic modulus was observed. A reduction in elastic modulus (i.e., softening in the elastic regime) with hydrogen absorption and an incomplete recovery of elastic modulus with hydrogen desorption disclose the influence of hydrogen induced vacancy clusters on elasticity. On the other hand, the increase in pop-in load and indentation hardness with hydrogen absorption indicating a hardening behavior in the plastic regime resulting from the interaction of interstitial hydrogen with dislocations.

Keywords: Hydrogen, Nickel, Nanoindentation, Plasticity, Elasticity, Dislocation.

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