Abstract

The present work deals with some of the aspects of microstructure evolution, deformation behavior and related mechanisms of nano-/ultrafine lamellar eutectic composites (UECs). The size effect during micro- and nano-indentation for wide load range of 50 mN - 19.6 N in a series of ultrafine Ti-Fe-(Sn) eutectic comprising of ultrafine FeTi and bcc β–Ti phases with varying lamellae thickness, has been studied. The load dependence microhardness were analyzed using existing models, and has been correlated with the dislocation density, microstructure length-scale, and size effect. The role of individual lamellar phases on the evolution of statistically stored dislocations, geometrically necessary dislocations, and prior deformation on the mechanism of size effect, has been explored. A model has been developed to predict the nano-indentation hardness of ultrafine composites considering the microstructure length scale and size effect. Furthermore, the mechanism of lamellae deformation, microstructural refinement, and phase rearrangement in Ti-Fe-(Sn) UECs upon severe forging have been explored using x-ray diffraction and transmission electron microscopy to reveal the dislocation activity inside the lamellae interior and at the β-Ti/FeTi interface. Nanoindentation studies have been performed to evaluate the effect of forging on the strain rate sensitivity, activation volume in UECs, and to compare them with that of the constituent single phases. The role of dislocation accumulation in the ultrafine lamellae, inter-lamellar sliding, evolution of shear bands, and phase rearrangement, have been discussed using a micromechanical model.

Micrometer-sized γ–Ni dendrite reinforced nanoeutectic matrix (Ni_5Zr and fcc γ–Ni) composites, have been developed in Ni-Zr-(Al). All these composites exhibit very high strength, large compressive plasticity ~25% and strain hardening up to 1780 MPa. The effect of Al addition on the microstructure formation, volume fraction as well as the microstructure length scale of the constituent phases on the mechanical properties, have been discussed. Furthermore, the slip transfers across the β–Ti/FeTi and γ–Ni/Ni_5Zr lamellae interface, have been studied using transmission electron microscopy. A model has been developed to assess the required shear stress for initiating slip/ or cleavage at the eutectic lamellae interface to understand the origin of plasticity in Ti-Fe-(Sn) and Ni-Zr-(Al) UECs.

Keywords: Nano-/ultrafine eutectic alloys, Microstructure, Mechanical properties, Indentation size effect, Microhardness, Nanoindentation, Dislocation, Plasticity.