Abstract

The strategy to design low stacking fault energy (SFE) eutectic $CoCr_{1.3}FeNi_{0.7}MnNb_x$ (x = 0.3-0.45) high entropy alloy (EHEA) and to enhance the properties through thermomechanical treatment have been systematically explored. EHEAs comprising of ultrafine lamellae of low SFE (SFE = 11 mJ/m^2) face-centered cubic (FCC) and Fe_2Nb-type hexagonal-closed pack (HCP) Laves phase (C14-type) have been synthesized at cooling rates of 2.5–10 K/s (arc melted ingots, AMIs) and 4.2×10^2 K/s (suction cast bars, SCBs). The effect of cooling rate on the microstructure evolution, their refinement and mechanical properties has been explored and are correlated with Nb addition, interlamellar size (λ_e), dislocation density (ρ_d), and twin density (ρ_t). Systematic investigation revealed that the phase interface strengthening, solid solution strengthening, and twin boundary strengthening play critical roles in providing the high strength (σ_y) up to 1.35 GPa along with 20% plastic strain (ε_f). The stress-strain curves and post-deformation analysis using transmission electron microscopy confirmed that the concurrent evolution of dislocations, deformation twins, and their mutual interactions, which are solely responsible for the large strain hardening (n = 0.27) at multiple stages during plastic deformation. The impact of thermo-mechanical processing on the microstructure evolution and mechanical properties of AMI EHEAs using cold forging and subsequent annealing have been investigated. The refinement of the microstructure, formation of dislocation substructure (ρ_d = 1.5×10^{15}/m^2), thermally stable deformation twins (ρ_t= 7.8×10^6/m), and controlled precipitation of σ-phase (5 vol.%) reduce the mean free path (Λ) for dislocation glide and provide a good combination σ_y = 1389-1537 MPa and ε_f = 11%-13%. The stain rate jump test and the nanoindentation have been carried out at room temperature to investigate the effect of processing conditions on the rate sensitivity (m = 0.0106-0.0111) and activation volume (V^* = 28b^3-41b^3), which suggest that the deformation kinetics is mainly governed by the dislocation interactions with the ultrafine lamellae interface and the twin boundaries. The potential of warm-rolling to further tune the microstructure, and mechanical properties have been investigated. The present investigation further explore the effect of low SFE on the nucleation of twins/ or dislocations in the lamellar phase using various models. Theoretical calculations have been presented considering Stroh's pile-up model to establish the evolution of deformation bands and transfer of slip across the lamellae interface.

Keywords: Nano-/ultrafine eutectic microstructure, High entropy alloys, Stacking fault energy, Deformation twinning, Dislocation, Strengthening, Thermo-mechanical treatment.