Supplementary Materials

Enhanced strength and ductility of high-entropy alloy via dislocation-mediated heterogeneous martensitic transformation

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Strengthening contribution

In the partially recrystallized $Fe_{40}Co_{20}Cr_{20}Mn_{10}Ni_{10}$ (at. %) high-entropy alloys (HEAs), the yield strength (σ_y) can be expressed as the sum of multiple strengthening effects of lattice friction stress (σ_0), grain boundary strengthening (σ_{gr}) and dislocation strengthening (σ_{dis}), as follows:

$$\sigma_y = \sigma_0 + \sigma_{gr} + \sigma_{dis} \tag{1}$$

By plotting the Hall-Petch relation, the contribution of σ_0 is 140 MPa[1]. And grain boundary strengthening can be described as[2]:

$$\sigma_{gr} = f_{RX} k/\sqrt{d} + f_{NRX} k/\sqrt{d} \tag{2}$$

where $f_{RX} =$ 74% is the volume fraction of the recrystallized regions, $f_{NRX} =$ 26% is the volume fraction of the recrystallized regions, k = 564 MPa·μm$^{1/2}$ is the Hall-Petch coefficient[1], and d = 2 μm is the grain size of the recrystallized regions. Thus, the strength provided by grain boundary is 324 MPa.

The dislocation strengthening is represented by the Taylor hardening law[3]:

$$\sigma_{dis} = M\alpha Gb\sqrt{\rho_{dis}} \tag{3}$$

where M = 3.06 is the Taylor factor, α = 0.2 is a constant, G = 76 GPa is the shear modulus, b = 0.26 nm is the magnitude of the Burgers vector, and ρ_{dis} is the dislocation density, which can be expressed as[4]:

$$\rho_{dis} = 2\theta/\mu b \tag{4}$$

where θ = 0.43 is the misorientation angle measured from kernel average misorientation maps and μ =10^{-5} m is the unit length. Based on the calculated dislocation density of ρ_{dis} = 3.3×10^{14} m^{-2}, the strengthening effect of dislocations (σ_{dis}) is evaluated as 219 MPa. The theoretically predicted σ_y = 683 MPa agrees well with the measured yield strength of 684 MPa.

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