

Tailoring Structure and Mechanical Properties of Multicomponent Alloys

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Designing multi-scale heterostructures by taking lessons from nature provides a promising strategy for achieving excellent strength-ductility synergy in metals and alloys. The achievement of this goal usually requires intricate multi-step thermomechanical processing, but this is still a challenge with cast alloys rather than wrought ones. This talk presents some routes for solving this problem, focusing on medium and high entropy alloys (MEAs/HEAs) and eutectic high entropy alloys (EHEAs) subjected to different processing routes for property optimization.

For example, the cast $\text{Cr}_{30}\text{Fe}_{30}\text{Ni}_{30}\text{Al}_5\text{Ti}_5$ (at.%) MEA exhibits a hierarchically heterogeneous structure involving precipitates at multiple length-scales. Microscale body-centered-cubic (BCC) grains are dispersed throughout a continuous face-centered-cubic (FCC) structural framework. Coherent L_{12} nanoparticles form in the FCC matrix, while abundant nanoparticles with hierarchical dimensions (i.e., of η , B2, and η/L_{21} phases) precipitate inside the BCC grains. The synergistic interactions between dislocations and multiscale precipitates which induce massive dislocation networks and stacking faults result in stable strain-hardening behavior, endowing the alloy with an exceptional combination of strength and ductility without the need for homogenization and complex processing. These features surpass known cast high and medium entropy alloys and offer implications for developing new high-performance cast multicomponent alloys.

Further property tuning and optimization can be achieved through thermo-mechanical processing, including deep cryogenic treatment and tempering or through severe plastic deformation via equal channel angular pressing (ECAP) or high-pressure torsion (HPT) – both for initially single-phase materials or for eutectic alloys via tuning grain sizes, grain boundary structures, dislocation networks and interactions, and precipitates, further allowing to tailor the mechanical properties. This may also involve transformation or twinning-induced plasticity (TRIP/TWIP) mechanisms helping or governing the deformation characteristics. In all cases hierarchical heterogeneous structures are achieved that help to create high-strength yet ductile materials with improved crack resistance and fatigue performance.

This talk will present recent results and examples for different MEAs, HEAs and EHEAs for optimizing microstructures and mechanical properties of multicomponent alloys through different processing routes.