Low-cycle fatigue behavior and deformation mechanisms of a dual-phase $Al_{0.5}CoCrFeMnNi$ high-entropy alloy

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High-entropy alloys (HEAs) have drawn tremendous scientific interest due to their excellent combination of mechanical properties. Among them, dual-phase HEAs have shown higher strength and better high-cycle fatigue resistance compared to single-phase face-centered cubic (FCC) HEAs, with their low-cycle fatigue (LCF) behavior yet to be addressed.

Here, we uncover the peculiarity of the LCF response of a dual-phase $Al_{0.5}CoCrFeMnNi$ HEA (having FCC matrix with embedded body-centered cubic (BCC) precipitates) by comparing to FCC CoCrFeMnNi model HEA. Fatigue results indicate that, despite having lower ductility, $Al_{0.5}CoCrFeMnNi$ demonstrates higher cyclic stress resistance, meanwhile maintaining comparable cyclic strain resistance at low-to-medium strain amplitudes (0.3% and 0.5%). Microstructural investigations revealed dislocation slip as the main deformation mechanism for $Al_{0.5}CoCrFeMnNi$, which changes from planar-slip to wavy-slip with increasing strain amplitude. The enhanced cyclic stress resistance of $Al_{0.5}CoCrFeMnNi$ is related to precipitation hardening and improved solid solution strengthening compared to CoCrFeMnNi. Meanwhile, their comparable cyclic strain resistance is ascribed to their similar deformation mode, which further suggests that minor addition of Al to Co-Cr-Fe-Mn-Ni system introduces no significant change in stacking fault energy. Lastly, by comparing to previously reported dual-phase $Al_{0.5}CoCrFeNi$ and FCC CoCrNi alloys, this work not only advances understanding of deformation mechanisms of dual-phase HEAs, but also offers strategies to optimize fatigue resistance of HEAs.

Keywords: High-entropy alloy; Dual-phase; Low-Cycle Fatigue; Transmission electron microscopy; Dislocation structure.