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Plastic deformation mechanisms of extruded Zn–0.2Mn alloy analyzed by in-situ SEM/EBSD and micropillar compression

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Abstract

Extruded Zn–0.2Mn alloys exhibit excellent potential for biodegradable implant applications; however, the role of Mn in controlling deformation mechanisms remains insufficiently understood. In this work, the evolution of plastic deformation in an extruded Zn–0.2Mn alloy was investigated by in-situ tensile testing inside a scanning electron microscope (SEM), combined with slip-trace analysis and electron backscatter diffraction (EBSD) at multiple strain levels. The alloy exhibits a strong basal texture and a high initial volume fraction of {10-12} compression twins which form during extrusion. From the onset of plasticity, deformation is accommodated predominantly by ⟨a⟩ basal slip, grain-boundary sliding (GBS), and twinning/detwinning, while twin transfer is also evident across boundaries where GBS occurs. Limited activity of ⟨c+a⟩ pyramidal II slip is observed even at early strain levels. At later stages, basal slip is also activated within twin domains when the local basal Schmid factor is sufficiently high. With increasing strain, extensive formation of {1012} compression twins occurs in grains with favorable twinning Schmid factors, while simultaneous detwinning is activated in grains with negative twinning Schmid factors. To quantify the effect of Mn in solid solution on the critical resolved shear stresses (CRSS) of the active deformation modes, single-crystal micropillar compression tests were performed on pillars with different crystallographic orientations. The results show that the CRSS for {10-12} twinning in Zn–0.2Mn is reduced compared to pure Zn, indicating a softening effect associated with Mn addition, while the CRSS values for basal and $\langle a+c \rangle$ pyramidal slip remain comparatively less affected. Density functional theory (DFT) calculations further reveal a strong dependence of the twin-boundary energy on Mn concentration in solid solution, providing a physical basis for the experimentally observed ease of twin nucleation and detwinning.

Keywords:

Zinc based biodegradable alloys in situ SEM/EBSD Micropillar compression Deformation mechanisms