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MULTISCALE CHARACTERIZATION OF THE MICROMECHANICS OF PURE Mg

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An important limitation of wrought (rolled and extruded) Mg alloys is their inherent strong mechanical anisotropy, a consequence of their hexagonal closed- packed (hcp) lattice. Several reasons contribute to this effect. First, at room temperature, the critical resolved shear stresses (CRSSs) of basal and non-basal slip systems have very different values, spanning several orders of magnitude; second, twinning, a very common deformation mechanism in these materials, exhibits a pronounced polarity, i.e. its activation is dependent on the relative orientation between the c-axis and the applied stress; finally, both hot and cold deformation processing textures are often quite sharp and the way the activation of different slip systems is influenced by the local texture and grain boundary network is not clear. Together, these factors lead to a dependence of the dominant deformation mechanisms on the texture, grain size, testing mode (tension or compression) and the testing direction, resulting in large differences in yield stress values and strain-hardening responses.

In this work, we adopt a multiscale characterization strategy to unravel the micromechanisms of pure Mg. First, we present a coupled experimental and simulation study on the nanoindentation of pure Mg at different temperatures to determine the critical resolved shear stress evolution of the different slip systems at the single crystal level [1-3]. For this, several indentations were performed at temperatures between RT and 300 °C in individual grains of a polycrystalline sheet of pure Mg with different crystallographic orientations. The deformation profile and the microstructure around the indents was analyzed by atomic force microscopy (AFM) and electron backscatter diffraction (EBSD), to determine the CRSS of the different slip systems without grain boundary effects.

EBSD assisted trace analysis during in-situ SEM mechanical testing of cold-rolled polycrystalline Mg sheets was then used to account for the role of the local microstructure, such as the local texture and grain boundary network, on the activation of the different deformation modes, In particular, it was found that, with decreasing grain size, at room temperature, a clear transition from non-basal to basal-slip dominated flow takes place under tension [4] and a transition from twinning to basal slip takes place under compression [5]. On the other hand, a similar transition from twinning to basal slip takes place with increasing temperature and decreasing strain rate [6]. The emergence of basal slip as a dominant mechanism is shown to be due to increasing levels of connectivity between favorably oriented grains, which facilitate slip transfer across grain boundaries.

This study emphasizes the complexity of the micromechanics of pure Mg, where the activation of different deformation modes is strongly affected, not only by their single crystal CRSS levels, but also by the local grain boundary networks and local texture emerging from processing.

References

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