Ascertaining the plastic deformation mechanisms of polycrystalline Zn and Mg through in situ HRDIC and EBSD

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Abstract

Hexagonal close-packed (HCP) metals, such as Mg and Zn, accommodate plastic deformation through different mechanisms that depend on c/a ratio of the HCP lattice as well as on the loading conditions (temperature, strain rate) and texture. They include dislocation slip along different slip systems (basal, prismatic and pyramidal, pyramidal), twinning across different planes ({10-12} and {10-11} as well as double twinning), grain boundary sliding and recrystallization. Moreover, their dominant mechanism also changes during deformation and may be different at the onset of yielding, during strain hardening region or after the maximum strength, when the deformation is localized. This information is relevant to design microstructures with improved mechanical properties (yield and ultimate tensile strength and ductility) but can only been obtained through in situ mechanical tests in which the deformation processes are monitored through electron back-scattered diffraction (EBSD) and high-resolution digital image correlation (HRDIC). In order to ascertain the activation of the different plastic deformation mechanisms, tensile tests were carried out within the scanning electron microscope in pure Zn and Mg samples manufactured by extrusion. Both materials exhibited a weak basal tetxure. Mechanical tests were stopped at different strain levels and the sample surfaces were analyzed by means of EBSD and HRDIC. In the case of Mg, deformation was accommodated by basal slip and {10-12} tensile twins, while traces of non-basal slip were not found due to the high critical resolved shear stress necessary to activate them. It was found that deformation of Mg was very heterogeneous, that the global Schmid factor was not suitable to predict the active basal slip system in 50% of the cases while no relation was found between the twinning Schmid factor and twin nucleation. Most twins were nucleated at grain boundaries and triple junctions and the active twin variants were found to be related with the angle between the twin shear strain and the grain boundary trace of the surface. The mechanical tests of the Zn samples revealed that initial plastic deformation was mainly accommodated by basal although pyramidal slip was also found in selected grains. {10-12} compression twins appeared at larger strains and the active twin variant followed the Schmid law, indicating that plastic deformation was more homogenous. Finally, grain boundary sliding was also detected at higher strains.

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