ORIENTATION, TEMPERATURE AND STRAIN RATE EFFECTS IN DEFORMATION TWINNING OF MAGNESIUM

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Deformation twinning (DT) has a very important role in accommodating plastic deformation in hexagonal close packed (HCP) metals due to their limited number of easy slip systems. Unfortunately, DT is also known to be associated with a lack of ductility and high residual stresses, which can lead to cracking, affecting the industrial applicability of these metals and making them only partially competitive compared to other light metal alloys. Despite decades of research on DT, many questions remains open about their exact nucleation and propagation mechanisms and their associated defects and stresses in the material. Focusing the study on the $\{10\bar{1}2\}$ twin mode, we performed in situ tensile and compression tests at the micron-scale on suitably oriented single crystal pure magnesium over 7 order of magnitude of strain rate (from 10^{-4} to 500 s^{-1}) and at different temperatures (from 293 to 573 K). 3D HR-EBSD is used to characterize the shape of the twins as well as the distribution of the residual stresses and the geometrically necessary dislocation (GND) inside the deformed volume of the material. TEM is used to characterize the activated dislocations and twin plane features for the different deformation conditions.

The results show that unconventional twin morphologies form at high strain rate, which can't be explained by simple considerations of twinning shear. Activation of pyramidal slips is shown to assist twin formation and propagation leading to an invariant twin plane with an $(\bar{1}\bar{1}23)$ orientation rather than the conventional $(0\bar{1}12)$ one [1]. Under shock compressions, the twin plane is mainly composed of basal/prismatic serrations across which a parent-twin lattice misorientation of 90° is established. At high temperature (above 423 K) and low strain rate (< 100 s^{-1}), no twin is observed and the plasticity is only accommodated by slip, while at higher strain rates, DT is again observed. All these results show that DT in magnesium is strongly time and temperature dependent, which has consequences in the strain hardening and to the response of the materials to shock.

[1] N.M. della Ventura, A. Sharma, M. Jain, S. Kalácska, T.E.J. Edwards, C. Cayron, R. Logé, J. Michler and X. Maeder: Evolution of Deformation Twinning Mechanisms in Magnesium from Low to High Strain Rates. Accepted for publication in Materials & Design.