THE EFFECT OF DOUBLE TWINNING ON THE DUCTILITY OF MAGNESIUM ALLOYS

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INTRODUCTION

Compression along the c-axis of the h.c.p. unit cell leads to the least ductility in Mg single crystals. This makes cold thinning operations of Mg sheet products, characterised by strong basal textures, very difficult. C-axis contraction can be accommodated by {10-11}/{10-13} “compression” twinning and {10-11}/{10-13}-{10-12} double twinning.

The aim of the present work was to study the compression twin formation mechanisms and their effects on the ductility in Mg alloy polycrystals, subjected to tensile deformation performed approximately perpendicular to the grain c-axes.

EXPERIMENTAL

An AZ31 (3wt.%Al-1%Zn) Mg alloy was used in a form of hot rolled plate with fully recrystallised microstructure. The grain c-axes were largely distributed around the plate normal direction. Tensile testing was performed parallel to the plate rolling direction at room temperature using a strain rate of 0.01 s^{-1}. TEM and EBSD techniques were used for the microstructural study and constitutive modelling was performed to rationalise the experimental findings.

FRACTURE CHARACTERISTICS

Tensile specimens displayed ductile failure with voids forming along the shear zones (bands) containing {10-11} compression twins and {10-11}-{10-12} double twins (**Fig. 1**).

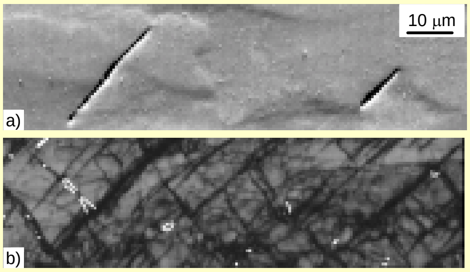

Fig. 1. Samples tested to failure: (a) Secondary electron image showing voids; (b) EBSD Kikuchi band contrast map showing shear zones and {10-11}-{10-12} double twin boundaries in white.

DISLOCATIONS

TEM investigation, including determination of the Burgers vectors (**b**) of slip dislocations, revealed that dislocation glide occurred largely via basal slip with **b** = 1/3<1-210> (**Fig. 2**).

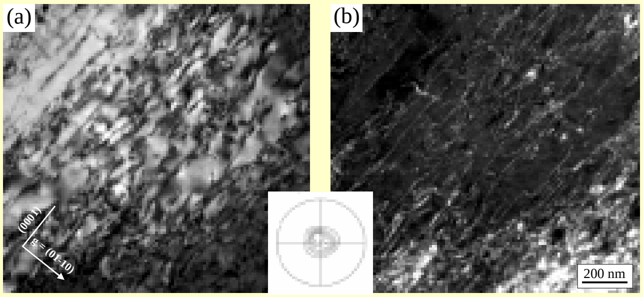

Fig. 2. TEM analysis of the slip dislocations within a deformed grain: (a) Bright field image; (b) Weak-beam dark field image (zone axis is close to [2-1-10], diffraction vector **g** = (01-10)). The insert shows the sample basal pole figure (tensile axis is horizontal) with intensity levels of 2,4,6.. times random.

TWINNING CHARACTERISTICS

A majority of the observed twins displayed misorientations close to 38°/<1-210>, consistent with the {10-11}-{10-12} double twinning (**Fig. 3**). The corresponding interface planes were approximately {30-34}. Some {10-11} twins, or twin segments, with misorientations of about 56°/<1-210> were also present. {10-13} twins (64°/<1-210>) or {10-13}-{10-12} double twins (22°/<1-210>) were found only rarely.

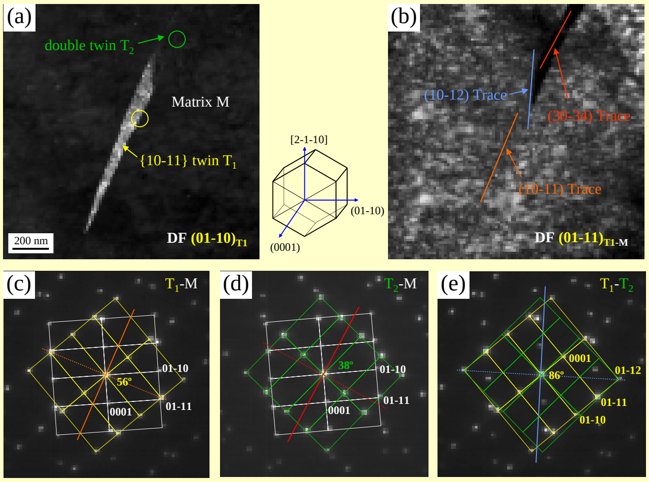

Fig. 3. TEM analysis of {10-11}-{10-12} double twinning: (a),(b) Dark field images obtained using $(01\text{-}10)_{T1}$ and $(01\text{-}11)_{T1\text{-}M}$ reflections, respectively; (c),(d) SAD patterns from the matrix M and twins T_1 and T_2, respectively (zone axes [2-1-10]); (e) Superimposed SAD patterns from the T_1 and T_2 twins.

CONSTITUTIVE MODELLING

The double twin reorientation leaves the basal plane in a position significantly more favourable for slip under continued loading compared to the parent grain (**Figs. 4a, 4b**).

A constitutive model based on double twinning has been developed. Assuming “soft” double twins, it is able to predict the onset of the observed macroscopic work softening (**Fig. 4c**), which eventually leads to strain localization and failure.

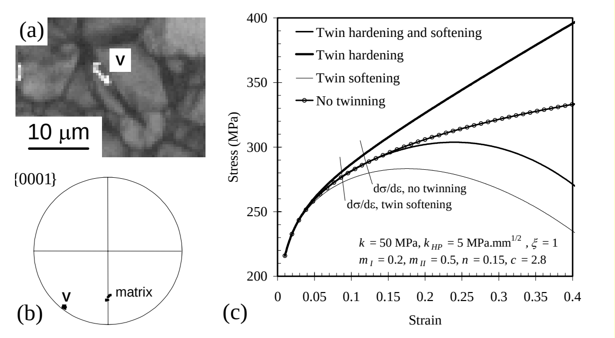

Fig. 4. (a) EBSD map with a {10-11}-{10-12} double twin (white); (b) Basal pole figure (tensile axis is horizontal); (c) Predicted effect of twin hardening and softening on the overall flow behaviour.

CONCLUSIONS

Both the experimental and modelling results have indicated that the formation of {10-11}-{10-12} double twins caused early shear failure of the AZ31 alloy due to the combined effects of strain softening of the continuum and localised void formation.