DISLOCATION BOUNDARIES AND DISCLINATIONS FORMED WITHIN THE CUBE GRAINS DURING TENSILE DEFORMATION OF ALUMINIUM

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INTRODUCTION

The deformation substructure characteristics of f.c.c metals are governed by the corresponding grain orientation [1]. The banded cell block (CB) structures with extended dense dislocation walls (DDWs), corresponding to a majority of grain orientations, have been well described [2]. However, a qualitatively different, roughly equiaxed CB morphology, observed within the cube-oriented grains after tensile deformation of Al and Cu [1], has so far received limited attention. A dislocation/disclination model has been developed [3,4] describing the development of DDWs as a nucleation and growth mechanism, involving propagation of partial disclinations along the pre-existing tangled cells and their immobilisation in CB boundaries.

The aim of the present work was to undertake a detailed investigation of the distinct equiaxed CB morphology, formed within the cube-oriented grains during tensile deformation of aluminium, and to interpret the observations using the dislocation/disclination concept.

EXPERIMENTAL

An AA5005 commercial aluminium alloy was used in the present study. The starting material was in a sheet form with a mean recrystallised grain size of about 60 µm, characterised by a strong cube texture. Tensile specimens, manufactured from the sheet with the tensile axis parallel to a <100> direction, were deformed at a temperature of 250 °C and a strain rate of 2×10^{-4} s^{-1} to true strains of approximately 0.1, 0.3 and 0.5 and water quenched. The cube grain orientations were studied by transmission electron microscopy (TEM).

RESULTS AND DISCUSSION

The initial cube texture remained stable during straining. The substructure evolution within the cube grains was characterised by a gradual development of larger-angle DDWs on a background of tangled dislocation cells [2]. At a strain of 0.1, these walls were at early stages of their formation, often terminating on the tangled cell boundaries without becoming interconnected with the other DDW segments, and divided the grains into loosely-defined CBs (**Fig. 1**). The border lines of terminating planar walls thus separated the regions where grain parts were already misoriented with respect to each other from those where this was not yet the case. Such lines thus represent rotational line defects described by the theory of disclinations [3,4].

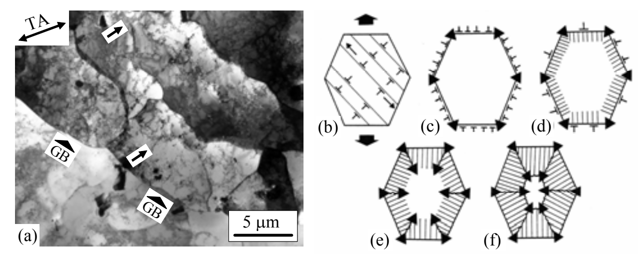

Figure 1. (a) TEM bright field micrograph showing the initial stages of DDW formation in the grain boundary (GB) region at a strain of 0.1 (some of the tips of terminating DDWs are labelled by arrows, TA indicates the tensile axis direction); (b)-(f) Schematic of the progressive grain subdivision into cell blocks through the propagation of partial disclinations during straining.

DDWs appeared to increase their lengths via propagation of the disclination defects across the grain until they impinged on the other walls to form new triple junctions. With increasing strain, cell blocks became better defined (**Fig. 2**) and the density of DDWs progressively increased, which resulted in a gradual decrease in mean CB size (**Fig. 3a**). In parallel, mean misorientation angles across DDWs rapidly increased in value. In contrast, the characteristics of tangled dislocation cells underwent only barely noticeably changes within the strain range studied (**Fig. 3b**). The overall distribution of misorientation angles across DDWs gradually widened with increasing strain (**Fig. 4**).

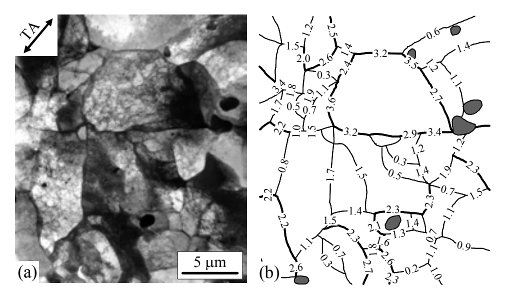

Figure 2. Characteristics of the well-developed DDWs observed at a strain of 0.3: (a) TEM bright field micrograph (TA indicates the tensile axis direction); (b) misorientation map (numbers indicate misorientation angles across DDWs in degrees).

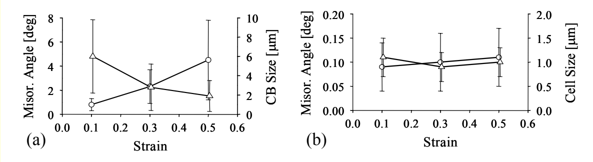

Figure 3. Mean characteristics of the dislocation boundaries as a function of strain: (a) DDWs; (b) tangled cells (open circles and triangles indicate misorientation angle and equivalent diameter values, respectively).

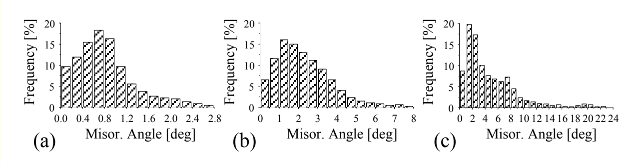

Figure 4. Distribution of misorientation angles across DDWs at strain levels of: (a) 0.1; (b) 0.3; (c) 0.5.

CBs largely remained roughly equiaxed throughout the strain interval used (see **Fig. 2**) and the corresponding DDW arrangements displayed a "random" character, with the walls having complex non-crystallographic characteristics. With increasing strain, misorientations across consecutive DDWs displayed a tendency to become more cumulative. For all the strain levels studied, misorientation axis vectors across DDWs were widely scattered. However, at a strain of 0.5 there was a clear tendency for misorientation vectors corresponding to larger-angle walls to orient themselves approximately perpendicular to the sample tensile axis. At this strain level DDWs showed some preferential alignment at angles 50-60º relative to the tensile axis.

An analysis of the DDW triple junctions was performed for strains of 0.3 and 0.5 according to the method implemented in [4]. Orientation mismatches of about 0.9° and 1.0° were found for the above strain levels, respectively. This appears to indicate the presence of immobile disclination defects in a majority of the above triple junctions [3,4].

CONCLUSIONS

A high degree of freedom in dislocation rearrangement, allowed by the present experimental conditions, resulted in a "random" arrangement of DDWs, which bounded equiaxed CBs and displayed a complex, non-crystallographic character. The dislocation wall characteristics were largely governed by the macroscopically imposed deformation geometry. The present observations appear to support the dislocation/disclination concept, describing the evolution of DDWs as nucleation, growth and immobilisation of partial disclination dipoles.

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