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ASPECTS OF DISCONTINUOUS PRECIPITATION REACTIONS IN AG-7.5CU

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Extended Abstract

There are well established models for the progress of discontinuous precipitation (cellular growth) in metal alloys[1,2] including the Tu and Turnbull[3] mechanism and that of Fournelle and Clark[4]. Since the crystallographic orientation of a cellular colony derives from the grain it grows away from, experimental interest in the effects of crystallography on discontinuous precipitation (DP) has centred on how nucleation and growth rates are affected by the misorientation of the initiating grain boundary. Such is the trust in the models that they have been used to measure boundary diffusivities[5]. However there has been little attention paid to the nature of the interface at the reaction front.

Experiments on rolled sheets of sterling silver (Ag-7.5Cu) homogenised for 2h at 1033K, water quenched, and then aged at different temperatures between 523K and 773K showed fine scale discontinuous precipitation with very varied colony habits. Since the internal structure of the colonies was at the limit of the resolution of optical microscopy, the microstructures were examined both optically and by scanning electron microscopy (SEM). Both single seam and double seam morphologies were seen. Some colonies had smooth, bulbous shape, while others were narrow with a smooth reaction front. Jagged colonies, fragmented colonies and completely clean boundaries were also seen. In all cases, the SEM showed that the copper-rich phase took the form of arrays of rods surrounded by the silver-rich phase. In some cases there were two distinct layers in the colony with different spacings between the rods in each. In contrast to conventional discontinuous coarsening, at higher ageing temperatures, the coarser layer was closer to the reaction front, rather than to the initiating grain boundary. In many alloy systems, DP colony sizes are seen to be highly variable within the same specimen and this is usually dealt with by taking an average of the maximum extent of ~40 colonies and applying a stereological correction for sectioning effects. In the current work, prints of high magnification SEM images were used to measure the width of the colonies on each side of > 100 grain boundaries in each of three Ag-7.5Cu samples aged at 523K for 1h, 2h and 3h, giving about 220 measurements per sample. These measurements showed there to be two DP colony populations with distinctly different behaviours: one growing slowly and the other growing very rapidly. In a few cases a fast growing colony completely transformed the grain into which it grew. EBSD was used to study the orientation relationships between the growing colonies and the adjacent grains. EBSD specimens were prepared using standard metallographic grinding and polishing to a 1µm finish followed by light etching in ammoniacal hydrogen peroxide solution to remove preparation induced surface deformation while minimising surface relief. The surface was then lightly carbon coated before examination.

EBSD showed that although many advancing colonies grew with the orientation of the grain away from which it was growing, this did not appear always to be the case. Some colonies appeared to have an inner and an outer layer with different orientations. Within well-developed colonies there was considerable variation in the local misorientation throughout the colony and it

appeared that as the colonies grew there was a build-up of misorientation behind the reaction front. In the as quenched samples the fractions of boundaries identified using the Brandon criterion[6] as being close to as low Σ coincident site lattice (CSL) misorientations were: Σ3 = 21.5%, Σ17b = 0.2%, all others < 0.15%. This is typical of a worked and recrystallised fcc material containing annealing twins. In the material aged for 3h at 523K the commonest boundaries were: Σ3 = 1.5%, Σ5 = 2.9% and Σ29a = 21.5%. In all the samples containing cellular precipitation the predominant CSL boundaries were Σ3, Σ5 and Σ29a. As seen in Figure 1, the Σ3 boundaries (red) were the unchanged twins but the Σ5 and Σ29a boundaries (green) surrounded the fast growing colonies i.e. there were strongly favoured misorientations between the colonies and the grains into which they grew.

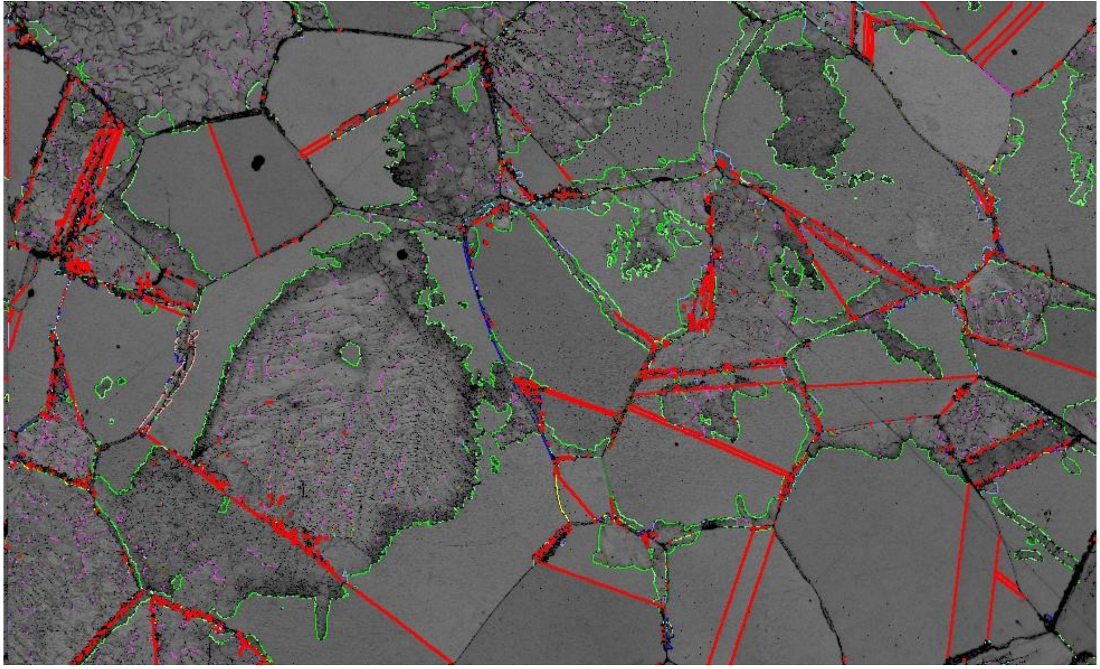

Fig. 1 EBSD map of Ag-7.5Cu aged 1hr at 573K, showing boundaries close to low Σ CSLs (see text for key to colours)

The interfaces between slow growing colonies and the grains into which they grew were often Σ7, Σ13b or Σ19b. Inside well-developed colonies there was a high frequency of Σ41a, Σ13a, Σ25a and Σ37a boundaries.

To investigate whether there might be a displacive element to the transformation, polished homogenised samples were aged at 573K under vacuum and the results will be discussed in the context of the favoured CSL boundaries formed during the cellular transformation.

1 Manna, I., et al. (2001). "Discontinuous reactions in solids." International Materials Reviews **46**(2): 53-9
2 Aaronson, H. I. and C. S. Pande (1998). "A synthesis of mechanisms for initiation of the cellular (or discontinuous precipitation) reaction." Acta Materialia **47**(1): 175-181.
3 Tu, K. N. and D. Turnbull (1971). "Morphology and kinetics of cellular dissolution of the Pb-Sn alloy." Metallurgical Transactions **2**(9): 2509-2515.
4 Fournelle, R. A. and J. B. Clark (1972). "The genesis of the cellular precipitation reaction." Metallurgical Transactions **3**(11): 2757-2767.
5 Monzen, R., et al. (2005). "Initiation and growth of the discontinuous precipitation reaction at [0 1 1] symmetric tilt boundaries in Cu-Be alloy bicrystals." Acta Materialia **53**(4): 1253-1261.
6 Brandon DG (1966) Acta Metall 14:1479