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Grain boundary structure intergranular fracture and the role of segregants as embrittling agents*

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There is substantial evidence, from studies of annealed and crept aluminium, which indicates that once a dislocation has entered the boundary region between two grains it dissociates to form several grain boundary dislocations of Burgers vectors determined by the orientation relation between the grains. Subsequent behaviour depends on boundary structure, the dissociation products remaining bunched together in certain boundaries and moving apart in others, indicative of a friction type stress active in the boundary. A simple classification of the different types of boundary, where friction stresses were either high or low, into coincidence and non-coincidence boundaries, however, was not possible.

Here we postulate that an important role of segregation to an interface is to increase the magnitude of the friction stress, thereby restricting the separation of dissociation products. An immediate consequence is that the strain field of these dislocations will remain localized and be of sufficient strength to prevent entry into the boundary region of other oncoming dislocations so producing the essential requirements for a dislocation pile-up. Stresses from such pile-ups can only be relieved by shear in the adjacent grain or decohesion of the interface. Relief of such stresses could be accommodated by emission of dislocations from the grain boundary; but, just as absorption of crystal dislocations in the boundary requires rearrangement and interactions between grain boundary dislocations, so too does such dislocation emission, and thus increased grain boundary friction stress due to segregation will inhibit this process. Segregation therefore favours dislocation pile-up formation and restricts relief of the resultant stresses by emission of dislocations from the boundary, so promoting conditions conducive to stress relief by fracture.

We have tested this hypothesis by measuring the accumulation of dislocations at grain boundaries of embrittled Cu 0.02 % Bi alloy during in-situ testing of specimens in a scanning electron microscope, taking micro-X-ray Kossel diffraction patterns from selected areas in the specimen surface and estimating the dislocation density within that area from measurements of the width of the diffraction lines. The results indeed show that the factors controlling the intergranular fracture path are (1) the degree of dislocation accumulation at the boundary and (2) the orientation relation of the grains across the boundary. For instance, it was a necessary but not sufficient condition for grain boundary fracture that dislocation accumulation at the boundary needed to be high, and secondly, fracture was never observed to occur in the most ordered boundaries, the Σ, 111/60° boundaries, but all $\Sigma\,9$ boundaries, second order twins, that were observed, fractured.

* Extended abstract.