Transmission Electron Microscopic Observations of the Microstructure of the Superalloy Inconel, MA 6000 E

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LOOKING AT SALT

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Sodium chloride (NaCl) occurs, all over the world, in two basic forms:
--in seas/oceans in solution (∿2.5%)
--in subterranean salt formations.
In the eastern part of The Netherlands (Twente) the subterranean salt is made via solution-mining which is, after purification, crystallized by evaporation. Other winning and crystallization processes are the evaporation of sea water and the mining of rock salt.

The basic salt (mother) and the crystallization process (father) have a great influence on the construction of the crystals and, with that, on the specific characteristics of the salt. Parameters are: habitus of the salt crystals, the crystalline construction and impurities.

THE INFLUENCE OF IMPURITIES ON THE STRUCTURE OF GRAIN BOUNDARIES

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To study the influence of impurities on the structure of grain boundaries Au bicrystals were made by joining together two single crystals. In this way bicrystals with low-angle boundaries and near-coherent twin boundaries were prepared. On one of those crystals a known amount of impurity, several atom layers in thickness, has been deposited. The preparation was completely carried out under high vacuum conditions, in order to avoid unknown impurity segregation on the crystal surfaces.

Bicrystals containing impurities in the grain boundary are heated in-situ in a transmission electron microscope (TEM). Energy-dispersive X-ray microanalysis shows an inhomogeneous distribution of the impurity layer after annealing. From electron diffraction it was observed that in some cases thin intermetallic compounds (e.g. $AuSb_3$) have formed at the grain boundary. The following effects of impurities were observed. First of all, it was found that relaxation at the grain boundary, as judged by the appearance of dislocation networks, takes place at a higher temperature than in clean grain boundaries. Relaxation also depends on the thickness of the impurity layer. Next it was observed that for some impurities (e.g. Co) the dislocations in the grain boundaries are very irregularly spaced.

MIGRATION OF NEAR CSL BOUNDARIES IN Au BICRYSTALS

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A low-angle (111) twist boundary in a Au bicrystal was investigated by TEM. During annealing at 200°C a hexagonal network of screw dislocations with $a/2\langle 1\bar{1}0\rangle$ Burgers vectors appeared. Due to grain boundary migration, this low-angle boundary and a parallel coherent twin boundary merged in some areas to form a near-coherent twin boundary. Here, a regular six-star pattern was found, consisting of three sets of screw dislocations with Burgers vectors of the type $a/6\langle 11\bar{2}\rangle$. Extra spots were found in the diffraction pattern corresponding to the reciprocal unit cell of the observed network.

$(1\bar{1}0)$ tilt boundaries were found to separate areas in the grain boundary with different misorientations from $\Sigma = 3$. The dislocation structure of the three intersecting boundaries was analyzed in detail.

During subsequent annealing at temperatures between 200 and 500°C, two processes were studied: migration of the $(1\bar{1}0)$ tilt boundary and surface diffusion. The latter process causes local thinning of the bicrystal which results in the disappearance of the grain boundary.

TRANSMISSION ELECTRON MICROSCOPIC OBSERVATIONS OF THE MICROSTRUCTURE OF THE SUPERALLOY INCONEL, MA 6000 E

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The superalloy Ma 6000 E is a Ni-base alloy developed for high creep resistance at intermediate as well as at high temperatures. The alloy has a complex composition being strengthened with several solid solution additions, γ' precipitates for intermediate temperature strength and inert yttria for extreme elevated temperature creep resistance. The volume fraction of the γ' (Ni_3Al) precipitates is approximately 50% and their size about 0.2 μm in diameter. The yttriumoxide (Y_2O_3) volume fraction is 2.9% with an average particle size of 28 nm.

Precipitates in an as received sample, deformed in tension to rupture at 760°C, are identified with an energy-dispersive X-ray system (EDS). Dislocation structures are studied using a 200 kV transmission electron microscope (JEM 200 CX). It is expected that dislocations bypass the yttriumoxide particles by looping, whereas γ' precipitates can be bypassed either by looping or shearing. With increasing temperature dislocations will tend to climb rather than form coplanar Orowan loops around the particles. The experimental results are compared with predictions based on a model calculation for the critical particle diameter where cutting is taken over by looping.

THE INTERACTION BETWEEN DISLOCATIONS AND PRECIPITATES IN Al-Li ALLOYS STUDIED BY TEM

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The basic strengthening mechanism of aluminium-lithium alloys is due to the formation of coherent δ' precipitates (ordered Li_2 phase Al_3Li). The addition of Li to Al results in a reduction of density and an increased modulus of elasticity compared with conventional aluminium alloys. Consequently, the development of Al-Li alloys is highly desirable for structural applications, especially in aerospace industry.

In this paper, a transmission electron microscopic study of the mechanism of dislocation motion in Al-2.2 wt% Li is presented. TEM micrographs were taken using a JEM 200 CX operating between 120 and 160 keV.

In order to obtain precipitates of different size, ageing times were varied from 1 hr to 115 hrs, and the ageing temperatures ranged between 200 and 245°C. Particle size distribution and volume fraction were determined using stereo-transmission electron microscopy. The increase in yield stress as a function of the experimentally determined particle size distribution and volume fraction can be predicted based on theoretical models.

FROM BLANK TO CAN-- THE ORIGIN AND GROWTH OF THE MORPHOLOGY OF THE WALL OF A DWI CAN

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An extensive study of the morphology of the wall of the two-piece drawn and wall-ironed (dwi-) can has been made by both SEM and EPMA. Both the topography and the distribution of tin on the inner and outer sides of the wall could be logically explained as a product of the various stages in the forming process of the can. It is suggested that the mechanical properties of the steel base and those of the coating material have a strong influence on the resulting properties of the can wall.

SOME APPLICATIONS OF ELECTRON MICROSCOPY IN THE AIRCRAFT INDUSTRY

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Important applications of electron microscopy in the aircraft industry are the characterization of surfaces after chemical pretreatments and the study of fracture surfaces of aircraft parts. Transmission electron microscopy was used to study the structure of