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TEM-STUDIES OF THE DISLOCATION STRUCTURE IN A γ/γ' Ni-BASED SUPERALLOY

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Superalloys which have the long range ordered structure L1₂, raise considerable scientific and technical interest. The increase of the hardening and the improvement of the mechanical properties at elevated temperatures open a wide field of applications.

The explanation for the increase of the critical resolved shear stress with increasing temperature which was proposed by Kear and Wilsdorf [1] is generally accepted in the literature. The mechanism is based on the fact that screw superlattice dislocations can be locked by the cross slip from (111) planes where they are mobile to (010) planes where the screws are assumed to be sessile. The driving force for this cross slip is the anisotropy of the antiphase boundary (APB) energy and the condition is $\gamma_{(111)}/\gamma_{(010)} > \sqrt{3}$, where $\gamma_{(111)}$ and $\gamma_{(010)}$ are the APB energies on (111) and (010) planes, respectively. Yoo [2] modified this condition by taking both the anisotropy of the ABP energy and the torque term of the elastic interaction force into account which leads to the result: $(1+f\sqrt{2})\gamma_{(111)}/\gamma_{(010)} > \sqrt{3}$, where the factor f arises from elastic anisotropy. Yamaguchi, Paidar, Pope and Vitek [3] showed with computer simulations that the cores of the unit dislocations of a screw superlattice dislocation are spread on (111) planes. The fact that no spreading of the cores is expected to occur on the (010) cross-slip planes explains the locking of the screws on these planes. To explain the temperature and orientation dependence of the flow stress Takeuchi and Kuramoto [4] assumed that the number of locked segments is controlled by thermal activation and by the shear stress acting on the (010) cross-slip plane. Paidar, Pope and Vitek [5] proposed a refined model taking into account the atomistic details of the cross-slip event (Escaig-effect), and their calculations agree well with the macroscopical mechanical data. A specific microstructure of the locks is predicted by this theory and it is stated that the width of the segments which are cross slipped on (010) is very narrow (only $b/2$ or b wide, where b is the Burgers vector). It is also concluded from this model that ordinary cross slip onto (111) planes should not occur at all. The aim of this paper is to investigate the cross-slip behaviour of the screw superlattice dislocations and to analyse their different modes of dissociation.

Single crystals of CMSX-2, a Ni-based superalloy, are investigated and the results obtained by transmission electron microscopy (TEM) methods are presented in this paper. The material was heat treated and provided by the Department of Metallurgical Engineering and Material Science of the University of Pittsburgh. The heat treatment was performed in two steps. A complete solution was achieved by annealing for 3 hours at 1315°C. Afterwards the samples received a precipitation heat treatment of 16 hours at 1015°C (air cooled) and a supplementary heat treatment of 48 hours at 850°C (air cooled). A homogeneous distribution of

cuboidal shaped γ' particles of 0.7 to 1.0 μm which have a volume fraction of about 75% results from this heat treatment. The samples were oriented for single slip and deformed in compression up to 15% resolved shear strain. The deformation was carried out at room temperature. A rather high critical resolved shear stress of 420 MPa and a fairly low work-hardening rate of 70MPa result from the stress strain curves.

For the TEM investigation the specimens were cut parallel to (111) and (010) planes, respectively, and thin foils were prepared by standard electropolishing techniques. A very high dislocation density is observed in the γ phase whereas in the γ' particles only a few superlattice dislocations with screw character were found in the foils cut parallel to (111) planes. The weak beam method of TEM was applied to analyse the screws, and tilting experiments of the foils cut parallel to (010) show that the screws are dissociated either on (111), (111) or (010) planes which indicates that most of them form Kear-Wilsdorf locks. The dissociation width of the screws on the cube (010) planes is about 4 nm which corresponds to about 20b. (It should be mentioned that a similar study has been carried out in L1₂ ordered Ni₃Fe [6].) These extended Kear-Wilsdorf locks and the segments which cross slipped on the (111) planes are in contradiction to the model proposed by Paidar, Pope and Vitek [5]. However, preliminary results show that the mechanical properties are mainly determined by the glide of unpaired dislocations in the γ phase and that the γ' particles act as hard precipitates. Therefore it is expected that the superlattice screw dislocations which are observed in the γ' phase have only a weak influence. To elucidate the importance of the screw superlattice dislocations with respect to the mechanical properties at elevated temperatures further investigations are in progress.

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