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INTERACTION BETWEEN LATTICE DISLOCATIONS AND GRAIN BOUNDARIES IN HIGH PURITY IRON

Fiche cinematographique ONERA n° 1173 (1986)

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The dynamic aspect of the interaction between lattice dislocations and grain boundaries has been investigated by "in-situ" deformation tests in the High Voltage Electron Microscope (H.E.V.M.). These experiments were performed on high purity iron polycrystals with low carbon and phosphorus contents (C : 50ppm , P : 40 to 100 ppm by weight) , both at room temperature and at 620 K . The grain boundaries under investigation are random ones without any prior crystallographic characterization .

During the first stages of deformation at room temperature , three phenomena were revealed :

- the cross-slip of lattice dislocations gliding toward the grain boundary ; in some cases , dislocations were strongly repelled from the grain boundary at a distance of a few micrometers ,
- the role of some grain boundaries as efficient barriers to the propagation of slip : dislocation tangles were built up in narrow zones along the grain boundary leading to the formation of work hardened regions compared to the grain center . These observations are in good agreement with the hardening mechanism which occurs in silicon bicrystals [1] ,
- the absorption and the generation of lattice dislocations : the figure 1 illustrates the different sequences of these phenomena observed near and in a particular grain boundary . Stress concentration was first created in the region A near the triple point before the source might operate (Fig. 1 a). Absorbed and emitted lattice dislocations glide on two slip planes of the same crystal that seem to converge in the grain boundary plane (a/b or c/d) . Then , in the neighbouring region B , initially free of extrinsic dislocations , lattice dislocations entered the grain boundary and became immediately dissociated (e) . Next , a source mechanism similar to the first one operated in the region C .

Glide of extrinsic dislocations was never observed. This remark allows us to put forward the following hypothesis : the observed source mechanism is likely to be the so-called "V-mechanism" which may operate when two slip planes intersect along the grain boundary plane [2] . This process may occur more easily in body centered cubic materials due to the multiplicity of the slip systems . The geometrical condition required to get a "V-mechanism" and the occurrence of dissociation of the incorporated dislocations are two arguments in favor of the speciality of the grain boundary 1/2 (Fig. 1) .

The grain boundary behavior under deformation at high temperature (620K) is characterized by the spontaneous or progressive spreading of extrinsic dislocations. The spreading kinetics may differ from one dislocation to another one in the same boundary. Dislocation motion was never observed . This remark involves that the complete accommodation of extrinsic dislocations in most boundaries never occurs [3].

The most striking observation is the stability of extrinsic dislocations under stress even at high temperature . Most grain boundaries behave as hard components of the microstructure. This behavior may be attributed to the effect of phosphorus which strongly segregates to the grain boundaries in iron and promotes embrittlement . At room temperature , phosphorus may impede intergranular dislocation motion by increasing the friction stress [4] . This effect may be seen as a consequence of the strong bonding between phosphorus and iron and may alternately explain grain boundary embrittlement [5,6]. At elevated temperature , phosphorus segregation may increase the grain boundary diffusion coefficient and thus impede climb of dislocations within the boundary . Dissociation may occur as it just requires short range diffusion but the grain boundary equilibrium state is not reached [3] . Mechanical properties of polycrystals are strongly modified by grain boundary segregation . The grain boundary behaviors under stress investigated by static T.E.M. experiments and calculations are clearly confirmed by the "in situ" H.V.E.M. deformation tests.

Figure 1 : sketch illustrating the absorption and the emission of lattice dislocations which sequentially occur in the grain boundary 1/2 (see text).

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