Study on Polygonization and Recrystallization of Aluminium by Means of Thermal Etching Method (2nd Report). Consideration on Polygonization and Recrystallization.

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I. Polygonization

There are numerous studies on the polygonization of deformed aluminium crystal, but these are chiefly concerned with the stable polygonized sub-boundary. What happens during recovery? This question is very important, neverthless we cannot satisfactorily answer. In particular, the fact that the mechanical strength recovers at low temperature is very important.

Now, the authors showed a lot of micrographs on the polygonization of deformed aluminium crystal by means of thermal etching method in our 1st Report.(1) Generally speaking, the following points should be recalled:—(i) All crystals consist of small crystals of the order of 2000 Å, though they are not distinct but diffuse. (ii) Distinct and sharp polygonized crystal blocks of the order of 2000 A exist near the regions to become the boundary of the recrystalized grains. (iii) Wide grooves of the order of 1μ in width are formed along the polygonized sub-boundary.

Considering from the fine structure of slip bands(2), the deformed crystal seems to consist of small crystal blocks of 200~2000 Å which are jointed by lattice bending layers with each other. Therefore, the formation of these small crystal blocks during recovery is reasonably certain. Especially, at the regions which are destined to become the boundary of the recrystalized grains, the lattice bending is very large in comparison with the other parts and the appearance of distinct polygonized small crystal blocks of 2000Å is very natural.

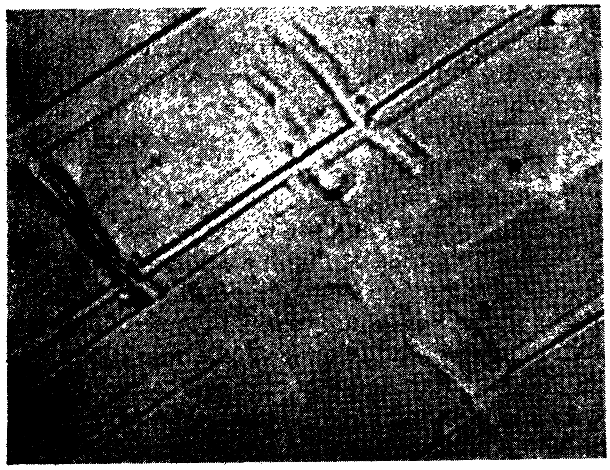

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Fig. 1 Relationship between the sub-boundary and the abnormality of slip band. Single crystal extended 1 percent was rapidly heated to 600°C for 20 min. Sub-boundaries seem to be derived from the distorted region originated at the cross slip.

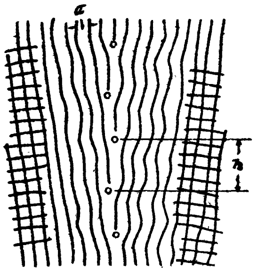

Fig. 2 Dislocation model of sub-boundary. (After Burgers)

In the next place, why is the groove structure, running up to 1 μ in width, formed along the polygonized sub-boundary? An example of such a groove structure formed during polygonization (recovery) is shown in **Fig. 1**. **Fig. 2** represents a diagram of a sub-boundary postulated by Burgers. If the disorientation of neighbouring sub-grains is 1′, then the distance (h) between the dislocations distributed at the sub-boundary layer is about 0.6μ(3) and the lattices between these two dislocations are quasi-continuous. Then the surface energy of such a sub-boundary layer is very small; the groove structure can scarcely be formed by thermal etching. Indeed, we never observe the groove structure after repolishing a crystal having the stable polygonized sub-boundary nevertheless the chemical etching reveals the sub-boundaries. In other words, these groove structures seem to show the transient nature of polygonization.

As mentioned in the 1st Report(1), the groove structure is constructed at the lattice bending region derived from previous deformation. On the other hand, at the lattice bending region, a large stress field is induced by the repulsion of dislocations of same sign on the same slip plane. If such a crystal is annealed, the atomic diffusion (vacancy flow) will become very active, a displacement of dislocation

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(1) K. Shimba and S. Kitazima, Jour. of Japan Institute of Metals, **17** (1953), No. 7.

(2) R. D. Heidenreich and W. Shockley, Bristol Conf., p. 57. A. F. Brown, Nature, **163** (1949), 961. H. Nishimura and J. Takamura, Memoris of the Faculty of Engineering, Kyoto University, 13, **1** (1951).

(3) A. Guinier, Imperfections in Nearly Perfect Crystals. p. 402.

to the direction perpendicular to the slip plane will be accelerated by such a diffusion. On the other word, the probability of neutralization of dislocations of different signs and of the escaping out of the crystalsurface will become very large.

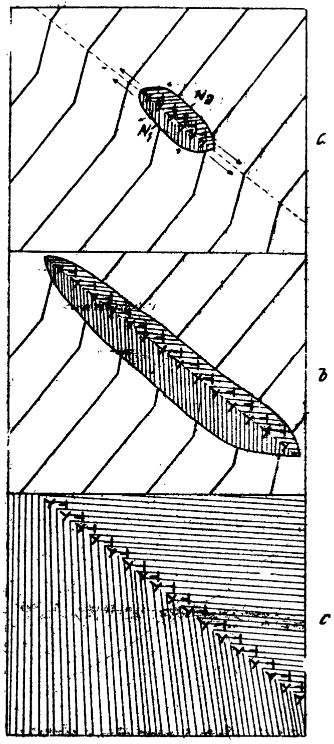
Thus, a lot of excess dislocations trapped at the lattice bending region will nearly disappear and the stable arrangement of remaining dislocations, as shown in Fig. 2 will be built up: the growth of sub-grain is attributable to the disappearance of dislocations in the boundary layer. In other words, the excess dislocations at a weak lattice bending region will perfectly disappear but some of those at a boundary of deformation band will probuce stable sub-boundaries without disappearance. The recovery of mechanical strength at lower temperature may be explained by the disappearance of a portion of trapped dislocations which seem to play a great part of work-hardening.

II. Recrystalization

The authors mentioned in our 1st Report$^{(1)}$ that the boundary of the recrystalized grain was constructed near he region where the lattice bending was very large. On the other hand, as the polygonization exactly occursat the lattice bending region, at the shevere lattice bending region where change of the boundary of the recrystalized grain the very active polygonization should occur. According to the measurment of specific heat during the recovery$^{(4)}$, there is no abnormality in the temperature at which the recrystalization seems to begin. Judging from these facts, the recrystalization seems to be connected with the polygonization: the nucleation in recrystalization seems to be same as the polygonization. The lattice bending region becoming the boundary of a recrystalized grain can not be stabilized by formation of a single row of dislocations, as shown in Fig. 2, but by the formation of complex row of dislocations, † as showen in Fig. 3 c.

If a strongly deformed crystal is annealed, firstly the excess dislocations at and near the boundary of a deformation bandrearrange themselves stably by formation of row of dislocations with a lot of dislocation branches i. e. a boundary of he recrystalized grain is locally formed, as shown in Fig. 3 a. At the same time, the two small crystal blocks (nuclei) on both its sides receive alarge disorientation respectively, because the curvature of lattice bending at the region where the neuclei are formed is large. Thus, these small crystal blocks grow along the lattice bending region by deliverance of the large disorientation and the active diffusion derived from large stress field mentioned above.

Fig. 4 shows an abnormally by deep etching by Lacombe's reagent at the vicinity of a boundary of a recrystalized grain (A B) built at a boundary of a



(a) Nuclei (N$_1$ and N$_2$) are formed at bot des. of a boundary of a deformation band. The crystal boundary separating two nuclei is formed b a kind of polygonization. Length of arrows represents growing velocity at various surface points of growing nuclei.
(b) Growing velocity of nuclei along a boundary of deformation band is very great respectively.
(c) The boundary of therecrystalized grain.
Fig, 3 Relationship between the growth of neucleus and boundary of the recrystalized grain.

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(4) Suzuki, Sci. Rep. Res. Inst. Tohoku University A-Vol. 1 (1949), No. 3.

* All the boundaries of recrystalized grains do not alwayes coincide with the lattice bending region induced by deformation, because the grain boundary migrates the toward stabler positions during annealing.

† This Complex Raw is Never Stable one.

deformation band. What is very important in this micrograph is the deep etching at the another boundary (CD) and in the inner part of a deformation band, though CD is not a recrystalized grain boundary.

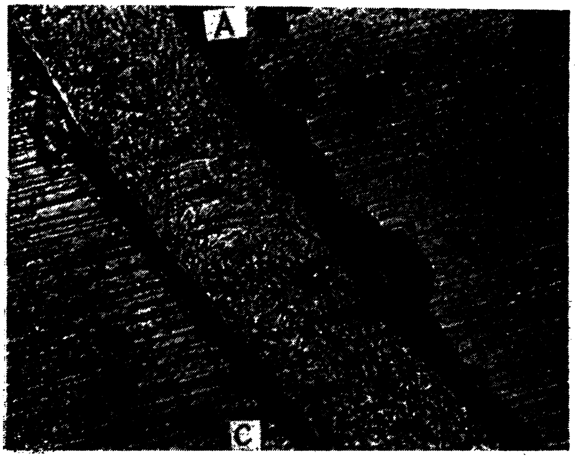

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Fig. 4 Abnormally deep etching by Lacombe's reagent at and near the boundary of as recrystalized grain. AB and CD are the bouudaries of a deformation band before annealing. AB is a boundary of a recrystalized grain hut not C D.

Such an abnormally deep etching seems to be due to the existence of some dislocations which constructed the boundary layers of small crystal blocks in an early stage of recrystalization (polygonization), as shown in Fig. 4~10 in the 1st Report, Part A(1). This abnormal deep etching will be explained by diffusion of impurity atoms to the dislocation centers during the recovery (polygonization). If the boundary of the recrystalized grain is constructed by collision of some growing nuclei, the abnormal deep etching cannot be explained satisfactorily because (i) it is very doubtful whether the front surface of a growing crystal is able to spread out while pushing or pulling the impurities and (ii) the lattice distortion derived from the dislocations constructing a grain boundary extends only within a few atomic layers so that the abnormal etching in Fig. 4 is not explained.

In this way, in the intrinsic sense, the boundary of a recrystalized grain(nucleus) should be built up at the lattice bending region, though we do not distinctly catch such a relation in every case owing to the grain boundary migration and grain growth.

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