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JUMP-LIKE MOTION OF DISLOCATIONS IN NaCl CRYSTALS

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Observation of the motion of dislocations in ionic crystals, carried out by means of the method of selective etching on LiF crystals ($^{1-2}$), showed the fundamental possibility of studying the qualitative and quantitative regularities of the motion and generation of dislocations.

The applicability of the method of selective etching for studying the motion of dislocations is determined by the fulfillment of the following necessary requirements:

1) The etch figures correspond to the emergence points of dislocations on the surface of the crystal.
2) The etch figures have a clear faceting that makes it possible to identify dislocations emerging on the surface of the crystal.
3) Etching proceeds sufficiently slowly, which makes it possible to apply the method of successive etching.
4) The tangential rate of selective etching is determined by the presence of a pit (a step-like irregularity) on the surface of the face and, consequently, does not depend on the presence of a dislocation at the place where the surface is etched. The normal rate of selective etching becomes negligibly small in the absence or removal of a dislocation from the place where the surface is etched, which leads to the formation of etch pits with a flat bottom.
5) The ratio of the normal rate of selective etching to the tangential rate at the locations of dislocations is approximately 0.15 (^{3}), which accounts for the clear visibility of the faceting of the pits in reflected light under oblique illumination.

Etching of the emergence points of dislocations on the surface of crystals with glacial acetic acid, proposed by Dzheseckii (^{4}), and with methyl alcohol, proposed by Amelinks (^{5}), presents certain difficulties when studying dislocation motion. By mixing acetic acid with methyl alcohol we succeeded in achieving the desired result—the production of clear pits with a convenient etching time.[*]

A mixture of glacial acetic acid (density 1.045) and anhydrous methyl alcohol (density 0.800) in a ratio of $2:1$ gives good selective etching with an etching time of $5 \div 40$ sec. If etching is carried out with continuous vigorous stirring, the resulting etch figures have a very clear faceting, with a ratio of depth to half-width of ~ 0.15. After etching, the crystal is washed in butyl alcohol and the remaining liquid is blown off the crystal surface with a strong jet of air.

Successive etching also gives good results; however, on the faces of the pyramidal surface of the pits, layers are distinguishable corresponding successive stages of etching (Fig. 1a). When etched for more than 30 sec, the four-sided etch figure gradually turns into an eight-sided one. With further etching the facet becomes blurred.

Some figures after the first etching prove to be flat-bottomed, which corresponds to the etching out of various surface defects (many similar figures are observed on cleavage steps), as well as of dislocations which, in the course of etching, have taken up another position. Good etch figures are observed both on natural crystals of rock salt and on artificial NaCl crystals. The latter, however, are more convenient for investigations because of the lower density of dislocations.

To Rozhanskiĭ s article, p. 804

Fig. 1. Etching of dislocation outlets on the surface of NaCl crystals. **a**—figures of successive etching; on the surface of the pyramid four layers are distinguished, corresponding to the stages of successive etching, 1100×; **b**—jump-like displacement of a screw dislocation, 1700×; **c**—region of a crystal with a series of edge dislocations moving in mutually perpendicular slip planes, 450×; **d**—gliding of a cluster of dislocations toward an obstacle, 450×; **e**—coordinated displacement of a vertical wall of four edge dislocations, 900×; **f**—leaving, by a group of edge dislocations, of an interblock boundary formed from a vertical row of edge dislocations, 900×. $P = 2$ kg/cm^2.

To the article by L. S. Palatnik, p. 821

Fig. 1. Interference reflections (311) of austenite on radiographs obtained from one and the same metastable 12KhN2V steel during heat treatment. **1**—isothermal holding at 1050°; **2–11**—holding at 300°. Time of isothermal holding elapsed before the start of exposure of the photograph: **2**—0 min., **3**—30 min., **4**—120 min., **5**—150 min., **6**—210 min., **7**—240 min., **8**—250 min., **9**—260 min., **10**—270 min., **11**—280 min. All radiographs are enlarged 9 times.

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[*] S. T. Koretskaya took part in selecting the etchant formulation.

Fig. 2. Diagram explaining the displacement of a dislocation corresponding to Fig. 1b. I–IV—schemes of the formation of etch figures at successive stages of dislocation motion; V—graph of dislocation displacement

Figure 1: Fig. 2. Diagram explaining the displacement of a dislocation corresponding to Fig. 1b. I–IV—schemes of the formation of etch figures at successive stages of dislocation motion; V—graph of dislocation displacement

Good etch figures are observed on freshly cleaved surfaces, on crystals that have lain for several days after cleavage along the cleavage plane, and on the surfaces of crystals subjected to prolonged annealing at temperatures up to 200°. The latter makes it possible to study the displacement of dislocations during annealing.

The method of successive etching, developed by Gilman and Johnston (^{1}), can be successfully applied to the study of dislocation motion in NaCl crystals; however, a more convenient method, opening up new possibilities for investigating dislocation motion (^{2}), has proved to be the method of selective etching during deformation. By this method it is possible to establish the kinetics of dislocation displacement. The method of successive etching makes it possible to determine only the initial and final positions of a dislocation in a crystal deformed between two etchings; this method does not make it possible to establish the character of the displacement of the dislocation in the interval between these limiting positions. In continuous etching, the path of motion of a dislocation is traced in the form of successively arranged flat-bottomed pits of decreasing size. The final position of the dislocation is marked by a small pointed pit (Fig. 1b). The depth of the pits is proportional to the time during which the dislocation remains in a given position; the transverse size of the pits is proportional to the time from the arrival of the dislocation at that place to the end of etching. From the determination of the sizes of the etch figures it is possible to establish the kinetics of the displacement of the dislocation, as is shown in Fig. 2.

Fig. 2. Diagram explaining the displacement of a dislocation corresponding to Fig. 1b. I–IV—schemes of the formation of etch figures at successive stages of dislocation motion; V—graph of dislocation displacement.

The arrangement and sizes of the etch figures indicate a jump-like displacement of dislocations under the action of constant shear stresses. Figure 1b shows a region of a crystal with a series of edge dislocations moving in mutually perpendicular slip planes. Figure 1c gives an example of the compression of an accumulation of dislocations against an obstacle and the creation, in front of it, of a nonuniform distribution of dislocations. In a number of regions a coordinated displacement of dislocations interacting with one another is observed. Figure 1d shows the displacement of a vertical dislocation row consisting of four edge

dislocations; moreover, three closely spaced dislocations move completely synchronously, making 8 consecutive joint jumps. The identical arrangement of etch pits for the group of jointly moving dislocations definitely indicates that the etch pits appear at the sites of intermediate stops, and not at random points along the path of continuous motion. The fourth dislocation, somewhat removed from them, makes jumps not synchronously with the first group. Fig. 1e shows a case of joint departure from a vertical dislocation wall of four edge dislocations, with three closely spaced dislocations undergoing a joint synchronous jump-like motion. A simple calculation shows that each jump observed in the micrographs corresponds to a jump-like elongation of the crystal by less than 10^{-2} Å.

The nonuniformity of plastic shear formation, studied in detail for macroscopic deformation and for elementary and composite jumps with magnitudes from 35 μ to 250 Å, is a very general phenomenon caused by the collective motion of large groups of dislocations (6). The observed jump-like motion of individual dislocations indicates that nonuniformity is also characteristic of the elementary acts of plastic deformation and is the most general feature of shear formation in crystals. The nonuniformity of plastic deformation is due to the presence of various distortions of the crystalline structure (vacancies, impurity atoms, inclusions, block boundaries, etc.), which create potential barriers that hinder the free motion of dislocations.

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[1] J. Gilman, W. Johnston, J. Appl. Phys., **27**, 1018 (1956).
[2] W. Johnston, J. Gilman, J. Appl. Phys., **30**, 129 (1959).
[3] J. Gilman, W. Johnston, G. Sears, J. Appl. Phys., **29**, 747 (1958).
[4] B. Jeszenszky, Nature, **181**, 559 (1958).
[5] S. Amelinckx, Acta Met., **2**, 848 (1954).
[6] V. N. Rozhanskii, Usp. Fiz. Nauk, **65**, 387 (1958).

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