PHYSICS

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Figure 1

Figure 1: Figure 1

Figure 2

Figure 2: Figure 2

Abstract

Full Text

PHYSICS

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ON THE NATURE OF THE NONUNIFORMITY OF PLASTIC DEFORMATION OF METALLIC SINGLE CRYSTALS

(Presented by Academician P. A. Rehbinder, 12 IV 1957)

As we have previously shown, the deformation jumps, usually observed during the stretching of zinc single crystals and ranging in magnitude from 0.5 to 20 μ, have a complex structure and are the sum of a series of elementary jumps,

Fig. 1. Small jumps in cadmium: *a* —deformation record, *b* —record of the front of the electrical-resistance jump

occurring in different cross sections of the crystal. An avalanche of elementary jumps is caused by an initiating jump localized in one cross section of the crystal, whose magnitude was estimated at from 700 to 2100 Å ([1],[2]).

Fig. 2. Small jumps in tin: *a* —deformation record, *b* —record of the front of the electrical-resistance jump

The need to investigate elementary shears required a sharp reduction in the inertia of the apparatus and an increase in its sensitivity to 50 Å ([3]). Stretching of single crystals 0.4 to 0.8 mm in diameter made of very

pure (99.99%) zinc, cadmium, tin, lead, and aluminum was carried out under a constant load, somewhat exceeding the yield point, at room temperature. In all cases except aluminum, the change in the electrical resistance of the specimen was recorded simultaneously with the deformation.

In the course of stretching, numerous small jumps from 150–200 Å to 2000 Å, with durations from 1-3 to 30 msec, were recorded for zinc, cadmium, and tin

Figure 3

Figure 3: Figure 3

Figure 4

Figure 4: Figure 4

(Figs. 1 and 2). Occasionally jumps up to 10-15 thousand Å were observed, usually

Fig. 3. Long-duration jumps in tin: *a*—deformation record, *b*—record of the front of the jump in electrical resistance

consisting of several smaller ones. Also recorded (especially for tin, Fig. 3) were considerably less sharply expressed jumps from 1 to 5 thousand Å, with durations of 100-250 msec and more, bordering on what should no longer be called a jump, but rather more or less abrupt inhomogeneities—accelerations of flow with a duration on the order of 1 sec and more. The latter,

Fig. 4. Record of the inhomogeneous deformation of aluminum

along with sharply expressed jumps, on the one hand, and regions of completely homogeneous flow, on the other, occurred both in tin and in zinc and cadmium.

A careful microscopic examination of the deformed crystals established that the observed deformation jumps were caused by slip formation, and not by twinning.

The number of observed jumps increases as their magnitude decreases (at least down to 250-300 Å); the greater probability of the occurrence of small jumps indicates that, apparently, there is no minimum jump magnitude, but one may speak of an upper limit of an elementary slip localized in one slip zone.

In single crystals of aluminum and lead, no clearly expressed jump-like behavior was found. Specimens of spectrally pure aluminum gave,

however, distinct flow inhomogeneities (Fig. 4), resembling prolonged jumps in tin.

These new data on small jumps in various metals confirm the suggestion put forward earlier, in connection with the study of large jumps of up to 20-30 μ in zinc, that the cause of an elementary deformation jump is the breakthrough of an avalanche of dislocations accumulated near some obstacle in the slip plane ([2]). From this point of view, the presence of one or of a predominant slip system is favorable for the preparation of avalanche-type shear formation, both in the hexagonal structure of zinc and cadmium and in the tetragonal structure of tin. The presence of several equivalent slip systems (the face-centered cubic structure of aluminum and lead), however, will not promote the accumulation of an avalanche of dislocations. Indeed, in aluminum and especially in lead, under the same experimental conditions, we did not observe any distinct jump-like behavior.

The deformation jumps and smooth flow observed by us in their dynamics are naturally to be compared with the so-called coarse and fine slip lines ([4]). To explain the occurrence of coarse slip, ideas have been developed concerning the formation of discharge groups near block boundaries, sessile dislocations, inclusions, etc. ([5], [6]).

Such formations, depending on their type, intensity, and character of dissipation, may give rise not only to rapid jumps, but also to less pronounced forms of flow inhomogeneity, which are naturally to be expected even when the conditions for the formation of sharply expressed jumps are unfavorable (the face-centered cubic lattice of pure metals).*

Thus, flow inhomogeneities, along with their most striking manifestation—rapid jumps—should be regarded as a general phenomenon due to the dislocation nature of plastic deformation.

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* Even in the presence of several equivalent slip systems, one may admit the formation and rapid emergence of very small avalanches, which the sensitivity of the apparatus does not yet allow one to detect.

Note: Figure translations are in progress. See original paper for figures.