Journal of Applied Mechanics and Technical Physics, Vol. 42, No. 3, pp. 516–517, 2001

MAGNETOPLASTIC EFFECT UPON TWINNING OF BISMUTH SINGLE CRYSTALS

O. M. Ostrikov

UDC 669.76:548.24

The effect of the magnetic field on the twinning of bismuth single crystals is studied. It is shown that a 1 T *magnetic field contributes to an about twofold increase in the length and number of twins that appear near an external-stress concentrator.*

At present much attention is paid to the study of the magnetoplastic effect [1–5]. Experimental studies are performed mainly on ion crystals. At the same time, the need arises to construct mathematical models of the phenomena observed upon deformation of crystals in a magnetic field. This problem has not been treated comprehensively in the literature and, as was noted by Golovin et al. [6], the mechanism of the effect of the magnetic field is not completely clarified. In particular, Golovin and Morgunov [7] regard the increase in the plasticity of crystals as a result of the dynamic equilibrium in a system of dislocations and stoppers. It is the opinion of the authors of [4, 8, 9] that the most probable reason for crystal plasticization in the magnetic field is the effect of the magnetic field on the frequency of singlet–triplet transitions in the radical pairs formed by radicals belonging to a point defect and dislocation. As a result of the action of the magnetic field, the binding energy of a defective dislocation decreases.

The study of the effect of the magnetic field on twinning-induced plastic deformation, which is different from sliding by a large number of partial Shockley dislocations is of interest. Therefore, in the case of twinning, the influence of the magnetic field on the interaction between dislocations is significant.

The goal of the present work is to study the magnetoplastic effect upon twinning of bismuth crystals.

Experimental Technique. As a model material suitable for studying the twinning, bismuth was used because its low melting point makes it possible to grow its single crystal without special equipment. The bismuth single crystals have a strikingly expressed cleavage and, hence, the spallation surface along the cleavage plane does not require additional processing for microscopic studies.

In the present work, the bismuth single crystals were grown by the Bridgman method from a raw material containing 99.999% of bismuth. The $4 \times 5 \times 10$-mm specimens were spalled from the $5 \times 10 \times 50$ mm single crystals along the cleavage plane (111). The initial densities of the basis dislocations of the resulting and pyramidal specimens, which were found by the method of selective etching, are 10^5 and 10^3 cm^{-2}, respectively.

Deformation of the specimens was performed by means of a PMT-3 device. As a concentrated load, a diamond Vickers pyramid was used. To study the effect of the magnetic field on the twinning of bismuth single crystals, the (111) surface of the single-crystal specimens was deformed under the action of a magnetic field of up to 1 T. The magnetic-field direction was perpendicular to the action of loading.

The geometrical parameters of the twins were measured by means of the eyepiece-micrometer of a PMT-3 microscope. The number of twins appearing in the indention of an indenter was controlled.

Experimental Results and Discussion. Figure 1 shows experimental results obtained for the effect of the magnetic field on the twinning of bismuth single crystals. It follows from the dependences of the maximum length of twins L_m on the load P that a magnetic field whose magnitude is up to 1 T exerts a strong effect on the formation of mechanical twins near the stress concentrator. Under the action of the magnetic field, the maximum length of the twins formed in the indention of an indenter is larger compared to the case of crystal deformation in the absence of a magnetic field.

Sukhoi State Technical University, 246746 Gomel', Belarusia. Translated from Prikladnaya Mekhanika i Tekhnicheskaya Fizika, Vol. 42, No. 3, pp. 159–161, May–June, 2001. Original article submitted January 27, 2000; revision submitted October 17, 2000.

 0021-8944/01/4203-0516 $25.00

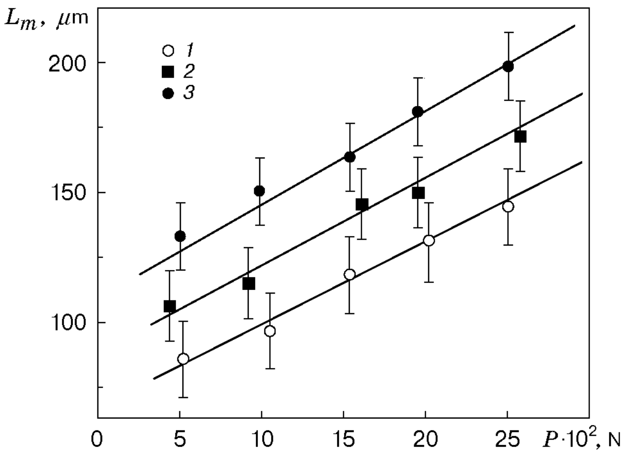

Fig. 1. The maximum length of twins L_m versus the load on the indenter P upon deformation in the absence of a magnetic field (points 1) and in the presence of the 0.5 and 1 T magnetic fields (curves 2 and 3, respectively).

One can assume that the increase in twin length is connected with the magnetic field-induced mobility of twinning dislocations. This is due to the fact that, probably, the magnetic field activates splitting of the full dislocations participating in plastic deformation into partial twinning dislocations, which, in turn, rises the density of twinning dislocations at the twinning boundaries, increasing the repulsive force between the indicated dislocations. The interaction between the twinning dislocations in a magnetic field results in an increased length of the twins.

The assumption that the magnetic field activates the splitting of full dislocations into partial twinning ones is supported by the results of experiments in which an increase, on average, by a factor of 2.3 in the number of twins appeared in the indenter indention was observed. The growth of the number of twins is connected with the increase in the number of sources of twinning dislocations. Since these sources are mainly the agglomerates of full dislocations split during plastic deformation into twinning dislocations, the effect of the magnetic field on the process of dislocation splitting seems to be quite possible.

Thus, the effect of a magnetic field of up to 1 T on the twinning of bismuth single crystals has been studied for the first time. It has been shown that the magnetic field contributes to the increase in the length and number of twins.

REFERENCES

1. Yu. I. Golovin, R. B. Morgunov, and S. E. Zhulikov, "Kinetic features of the motion of dislocations in ion crystals stimulated by the pulse of a magnetic field," *Izv. Ross. Akad. Nauk, Fiz.*, **61**, No. 5, 965–971 (1997).
2. A. A. Urusovskaya, V. I. Al'shits, A. E. Smirnov, and N. N. Bekkauer, "The effect of the magnetic field on the yield point and macroplastic kinetics of LiF crystals," *Pis'ma Zh. Éksp. Teor. Fiz.*, **65**, Nos. 5/6, 470–474 (1977).
3. Yu. I. Golovin and R. B. Morgunov, "The effect of a constant magnetic field on the plastic-flow rate of NaCl : Ca single crystals," *Fiz. Tverd. Tela*, **37**, No. 7, 2118–2121 (1995).
4. V. I. Al'shits, E. V. Darinskaya, and E. A. Petrzhik, "In situ study of the magnetoplastic effect in NaCl crystals by the method of continuous etching," *Fiz. Tverd. Tela*, **33**, No. 10, 3001–3010 (1991).
5. V. I. Al'shits, E. V. Darinskaya, T. M. Perekalina, and A. A. Urusovskaya, "The motion of dislocations in NaCl crystals under the action of a constant magnetic field," *Fiz. Tverd. Tela*, **29**, No. 2, 467–471 (1987).
6. Yu. I. Golovin, R. B. Morgunov, and V. E. Ivanov, "Thermodynamic and kinetic aspects of softening of ion crystals by a pulsed magnetic field," *Fiz. Tverd. Tela*, **39**, No. 11, 2016–2018 (1997).
7. Yu. I. Golovin and R. B. Morgunov, "Influence of a constant magnetic field on the macroplastic-flow rate of ion crystals," *Pis'ma Zh. Éksp. Teor. Fiz.*, **61**, No. 7, 583–586 (1995).
8. Yu. I. Golovin, R. B. Morgunov, and S. E. Zhulikov, "Influence of a constant magnetic field on overcoming of short-range obstacles in LiF single crystals by dislocations," *Fiz. Tverd. Tela* **39**, No. 3, 495–496 (1997).
9. M. I. Molotskii, "Possible mechanism of the magnetoplastic effect," *Fiz. Tverd. Tela*, **33**, No. 10, 3112–3114 (1991).