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Effect of Pressure on the Internal Friction in Zinc Single Crystals with Twins

In noncubic crystals with internal interfaces as well as in heterophase systems, there arise under high hydrostatic pressure (HHP) tangential stresses, which at $p > p_{crit.}$ relax by generation of fresh dislocations (Zaytsev 1983). All the residual changes of the structure taken together that are observed in noncubic syngony crystals are called the compression anisotropy effects (CAE) (Zaytsev 1977). The study of the CAE's is an important step of investigation of the HHP-induced defect structure of real crystals. Changes of the dislocation structure due to CAE's have been studied more than once (Galkin et al.; Ryumshina; Zaytsev, Ryumshina 1980; Ryumshina, Zaytsev; Ryumshina 1983). Valuable information on the defect structure of a crystal under HHP may be derived from internal friction (IF) tests. This paper reports on a first investigation of the behaviour of zinc single crystals with incoherent twin layers under HHP by high frequency IF.

The test samples measuring 10 × 10 × 15 mm were prepared from a large single crystal of high structural perfection (with the initial dislocation density within $5 \times 10^3 \ldots 5 \times \times 10^4$ cm^{-2}), of 99.997% purity. Single twin layers of thickness 0.02 to 0.04 mm were introduced by cleaving the single crystals under liquid nitrogen. The internal friction was measured by the pulsed ultrasound method with the frequency of the longitudinal oscillations perpendicular to the basal plane equal to 10 MHz. The IF was registered during pressure increase, holding and decrease by an automatic recorder of ultrasound attenuation (Zaytsev, Nosoley). The sample ends were parallel to within 1 μm/cm. The ultrasound attenuation was measured accurate to within ±5%. The pressure alteration rate was within 5 MPa/min, and the pressure-transferring medium was gasoline, both the factors providing hydrostatic conditions.

Figure 1 shows IF as a function of the hydrostatic pressure for zinc single crystals with and without twins. Between 0.001 and 0.4 GPa, ultrasound attenuation in a twin-free monocrystal is seen to change with pressure in a linear fashion. The hydrostatic pressure decrease is attended by reversible change in the attenuation. Thus, in this case the HHP does not cause irreversible structural changes.

In contrast, ultrasound attenuation with increasing pressure in a zinc monocrystal with a twin changes in a nonlinear way, displaying two maxima at about 0.1 and 0.33 GPa. During pressure decrease, there are also two maxima. In this case, however, they are more pronounced. After the atmospheric pressure has been attained, the attenuation magnitude remains larger than initial, i.e. a hysteresis of the IF is observed. This suggests irreversible character of the structural changes induced by HHP.

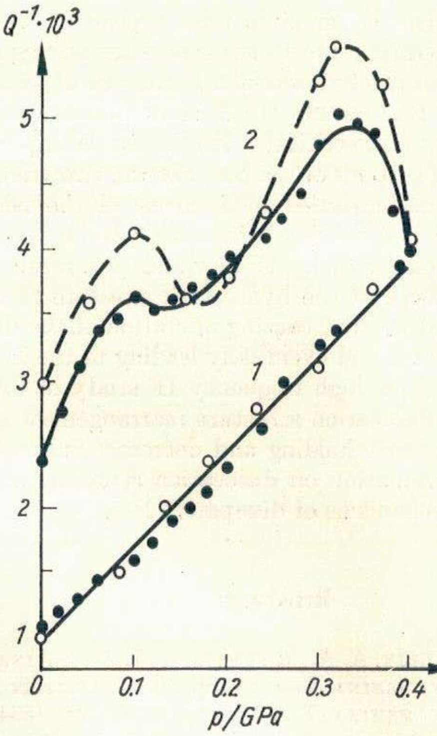

Fig. 1. Ultrasound attenuation as a function of hydrostatic pressure in zinc single crystals without (1) and with twins (2). ● pressure increase, ○ pressure decrease

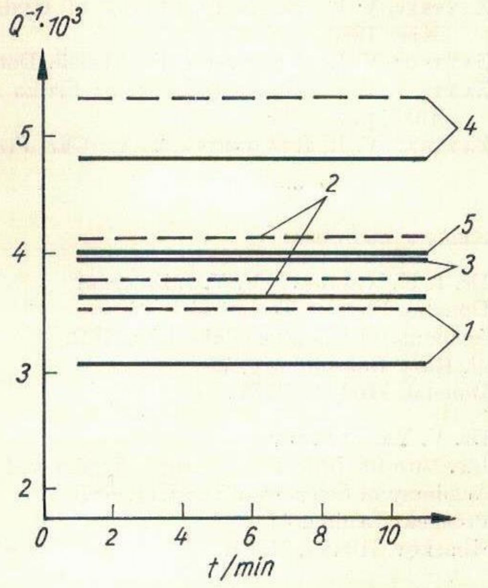

Fig. 2. Typical time-dependences of the internal friction for zinc single crystals with twins at fixed hydrostatic pressure values: 1) 0.04 GPa, 2) 0.1 GPa, 3) 0.2 GPa, 4) 0.3 GPa, 5) 0.4 GPa. The solid lines represent pressure increase, the broken lines pressure decrease

Besides, the time dependences of the IF were measured in twin-containing zinc single crystals under fixed pressures at every other 0.2 GPa, both during pressure increase and decrease. These measurements evidence that in the present pressure range the IF does not depend on the holding time (Fig. 2). Otherwise, every complex-stressed state of the crystal system considered which is realized under HHP has a definite type of the dislocation structure established during the pressure increase before and independent on time in this pressure range.

The IF maxima that appear at 0.1 and 0.33 GPa suggest dislocation structure alteration due to shear stresses arising from HHP at incoherent twin boundaries in anisotropic materials. Estimates of shear components based on the model proposed by RYUMSHINA (1982) show that as the hydrostatic pressure increases, shear stresses attain the critical value first in the slip basal plane of the twin and then in the pyramidal systems of the host crystal. Growth of IF at rising hydrostatic pressure to 0.1 GPa is accompanied by increase of the basal dislocation density within the twin. Its further increase with rising HHP results in interaction of the basal dislocations, reducing their mobility and as a result reducing ultrasound attenuation. Continuing growth of the hydrostatic pressure "switches on" pyramidal systems of slip of the host crystal, causing alteration of the dislocation structure, similar to that described above, and eventually leading to the IF maximum at about 0.3 GPa.

Thus, high frequency IF study of CAE's provides a method to observe processes of dislocation structure rearrangement in materials subjected to hydrostatic pressure increase, holding and decrease. Subsequent investigations are to yield quantitative information on dislocation structure alteration under HHP and throw light on the mechanisms of dissipative loss.

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