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ON THE INTERNAL FRICTION IN ANTIMONY CAUSED BY UNPINNING OF OVERDAMPED AND UNDERDAMPED DISLOCATIONS

P.P. Pal-Val, V.Ya. Platkov and V.I. Startsev

Physico-Technical Institute of Low Temperatures, Kharkov, U.S.S.R.

Abstract.- It is found and investigated an anomalous behaviour of the amplitude dependent internal friction at temperatures below - 30 K in antimony single crystals of different purity. The results evidence that in this temperature range inertial effects play a dominant role in the process of unpinnig of moving dislocations as a result of their transition from the overdamped to the underdamped state.

1. Introduction.- Generally, the motion of the dislocations through a crystal is treated as a combination of two independent processes: an overcoming pinning centres and viscous motion between them. But recent theoretical [1 to 7] and experimental [8 to 11] investigations provide the evidence of some interdependence between the viscous dislocation motion and the barrier overcoming, especially at low values of the drag coefficient B.

The length of a dislocation segment L and the drag coefficient B are impotant parameters of an influence of the viscousity on the process of the unpinning of dislocations. Therefore it seems resonable to perform investigations in a wide temperature range with the aim of essential change of B [12], and with crystals containing a different number of impurities.

The present paper is dedicated to investigations of the amplitude dependent dislocation internal friction in antimony single crystals of a different purity carried through the temperature range 300 to 6.5 K. The reason for the choice of antimony is that B must decrease in semimetals along the entire range as temperature is lowered, in contrast to typical metals where B in the helium range is determined by the electron drag which is high in magnitude and temperature independent [13] .

2. Experimental results.- The measurements were performed on four series of spesimens of a different purity. The ratio $R_{300}/R_{4.2}$ of electric resistances has served as a criterion of purity. For 1 to 4 series of spesimens this ratio has amounted to 900, 370, 150 and 42,re-

spectively.

For each of the four series the effect of temperature T on the amplitude dependences of the total decrement δ and the modulus defect $\Delta M/M$ has been investigated for the temperature range 6.5 to 300 K. The measurements were carried out by the composite oscilator technique (e.g. [14]), with the frequency of the longitudinal standing waves ~ 38 kHz. The spesimens were oriented so that the wave vector coincided with [001] direction of the f.c.c. rhombohedral unit cell. The maximum strain amplitude ε_0 of oscillations was chosen so as to bring about no irreversible changes in the dislocation structure of the specimens.

The behaviour of $\delta(\varepsilon_0)$ at $30 < T < 300$ K was similar for specimens from all the series, namely the curves $\delta(\varepsilon_0)$ shifted towards higher values of ε_0 as T was lowered (Fig.1).

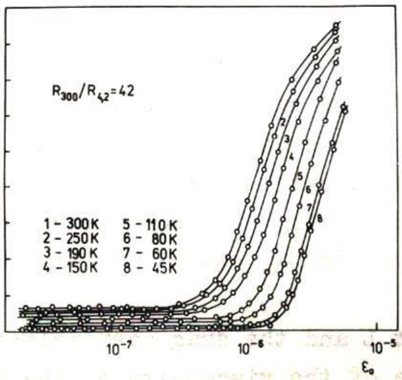
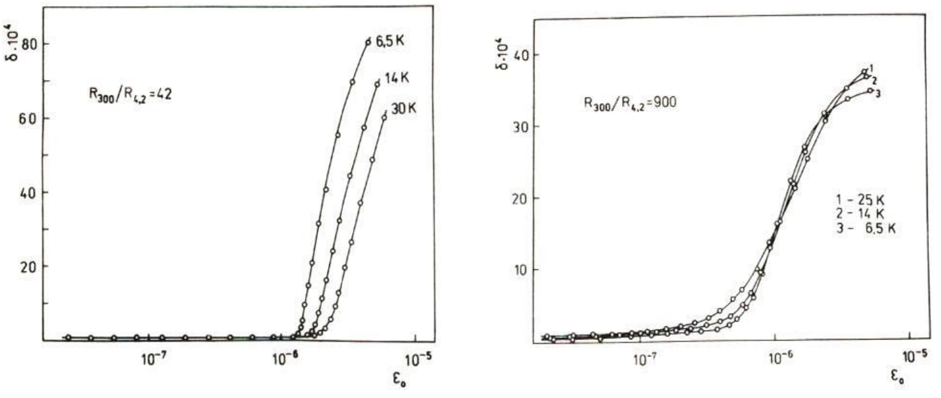


Fig.1

The $\Delta M/M(\varepsilon_0)$ curves showed a similar shift. At further reduction of T (below ~ 30 K) the $\delta(\varepsilon_0)$ and $\Delta M/M(\varepsilon_0)$ curves revealed an anomalous behaviour. In Fig.2a the $\delta(\varepsilon_0)$ curves are given for the spesimens of series 4. As can be seen, the decrease of T is accompanied by a reverse shift of the $\delta(\varepsilon_0)$ curves (i.e. towards lower ε_0) and an anhancement of their slope. Crystals of high purity also showed an anomalous run of the amplitude dependent internal friction in this range of T (Fig.2b). However, the anomaly was of a substantially different type. In pure crystals only a portion of the $\delta(\varepsilon_0)$ curve showed an abnormal shift, namely such one wich corresponded ε_0 much higher than ε_0 of the beginning of the amplitude dependence. Another part of the curve continued shifting towards higher ε_0 as T was decreased.

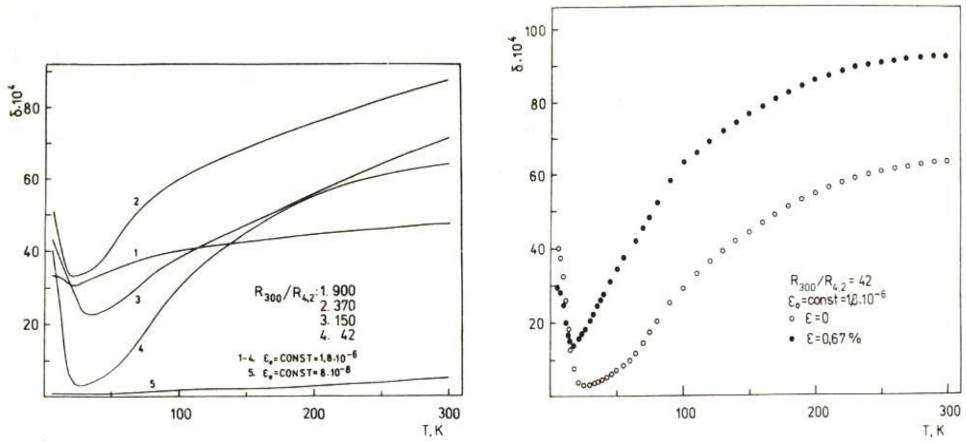
In order to compare the anomalous runs of δ and $\Delta M/M$ reveald by samples of different purity, we have undertaken measurements of the temperature dependences shown by thos values at two fixed amplitudes that corresponded to the amplitude dependent regions.



a) b)

Fig.2

All crystals, both strained and unstrained, demonstrated a monotonic decreasing of amplitude independent decrement throughout the temperature range (Fig.3a). At the same time, the δ (T) and ΔM/M (T) curves showed abnormal runs at T < 30 K in the amplitude dependent region. The anomaly was most pronounced in crystals of the lowest purity and in undeformed crystals.



a) b)

Fig.3

Plastic deformation of the specimens by a four-point bending to 0.6% resulted moreover in a decrease of the temperature the abnormal run of the (T) curves became evident (Fig.3b).

3. Discussion.- In this paper our attention is concentrated at the range below ≃30 K. The shift of the δ (ε_o) and the ΔM/M (ε_o) curves towards lower amplitudes cannot be comprehended in the framework of

the thermally assisted dislocation hysteresis theories [15,16] . The fact that the anomalous run is observed exclusivly in the amplitude dependent region of the $\delta(\varepsilon_0)$ and the $\Delta M/M(\varepsilon_0)$ curves is evidence for the alteration of the mechanism controlling dislocation unpinning from the pinning centres at about 30 K.

A self-consistent explanation to the anomaly observed is provided by the inertial model [3] . According to [3] a dislocation segment can undergo a transition from the overdamped to the undedamped state. The condition for that transition is

$$BL < 2\pi\sqrt{AC} ,$$

where A - the dislocation mass per unit length, C - the line tension of the dislocation.

A similar transition would greatly facilitate overcoming of pinning centres by the moving dislocation [3 to 7] . That transition can be expected at low temperatures due to the considerable reduction in the drag coefficient B [12,17].

The dislocation structure of less pure crystals is characterized by shorter dislocation segments. Hence, the overdamped-underdamped state transition of dislocations occurs at higher B than in crystals of higher purity, i.e. at higher T. Both theory [11] and our tentative data show the magnitude of dB/dT at such T to be much higher than in the low temperature range. As a result all dislocation segments pass to the underdamped state in a narrow temperature range. In this case the abnormal shift the whole of the $\delta(\varepsilon_0)$ and the $\Delta M/M(\varepsilon_0)$ curves is observed (Fig.2a). In purer crystals, characterized by larger dislocation segment length, the transition to the underdamped state occurs at lower temperatures, where dB/dT becoms smaller too. In this case it is possible to observe the transition only of short dislocation segments to the underdamped state. A breakaway of these segments takes place at higher ε_0 . Therefore, in purer samples the abnormal shift of the $\delta(\varepsilon_0)$ curves only in a high amplitude region is observed.

Deformed specimens had larger dislocation segment lengths, than undeformed ones. Hence, the deformation of samples was like the rising of purity of the crystals (Fig.3b).

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