THE MOTION OF SOME DISLOCATION SEGMENTS IN GERMANIUM CRYSTALS UNDER LOW STRESSES

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Proceeding from the theoretical premises, in crystals with high Peierls barriers the velocity of short dislocations should be related directly to their length [1-6]. In particular, if the length L of dislocations is small (L < Lcr, but larger than kT/ra), where k is Boltzmann's constant, T is the absolute temperature, a is the distance between neighboring grooves in the relief, r is the acting shear stress, and b is the Burgers vector), the velocity of the dislocations is determined by the probability of formation kink pairs of critical size in the direction of the acting force and is proportional to L:

\[ v = a \cdot I \cdot L. \]  

Here I is the probability of formation of a kink pair per unit time and unit dislocation length. It is generally accepted [7-9] that for germanium crystals under low stresses \( \tau \ll \sigma_b/ab \), where \( \sigma_b \) is the energy of a kink in climbing the barrier associated with a point defect, \( t \) is the mean distance between point defects on the dislocation. The experimental data are, to one extent or another, in agreement with the theory based on the model of thermally activated formation of kinks and their climbing the point-defect barriers [1-3]. Under higher stresses, it is most probable that the dislocation mobility is limited by phonon mechanisms [4-9] and the dislocation velocity must be calculated by using the diffusion theory of kink pairs growing to critical size [4-7]; if possible, the calculations should make allowance for the interaction between dislocations and barriers associated with significant pileups of point defects [5, 6]. In all cases, when short dislocations move as a whole, Eq. (1) should hold, but the probability of formation of kink pairs proves to have substantially differing values when various models are employed. In particular, if the kink mobility is determined by the thermally activated process of the kinks climbing the barriers associated with point defects, according to [1-3] we have

\[ I = I_0 \left( 1 - \frac{E_a}{\gamma ab} - \frac{l_c}{t} \right) \exp \left( - \frac{E_a}{\gamma ab} - \frac{l_c}{t} \right). \]  

Here \( l_c = (a/\gamma ab)^{1/2} \) is the critical width of kink pairs, and \( a = G \frac{b^2}{2} \{(1 + \nu) \cos^2 \varphi + (1 - 2\nu) \sin^2 \varphi \}/8\pi(1 - \nu), \) where G is the shear modulus, \( \nu \) is Poisson's ratio, and \( \varphi \) is the angle between the direction of the dislocation and the Burgers vector. For screw dislocations in germanium, \( a \approx 1 \times 10^{-13} \text{ dyn} \cdot \text{cm}^2 \); for 60° dislocations, \( a \approx 5 \times 10^{-20} \text{ dyn} \cdot \text{cm}^2 \). If we use the diffusion theory of kinks growing to critical size, assuming that the point defects insignificantly change the kink energy \( U(\tau) \), then in accordance with [4, 6, 10] we have

\[ I = I_s = \frac{\nu \gamma}{b^2} \left( \frac{a}{b \ln T} \right)^{1/2} \exp \left[ - \frac{U(\tau)}{k T} \right]. \]

Finally, with allowance for a local change of E, the energy, for a dislocation line near point defects, according to [5, 9] we have

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**LITERATURE CITED**

2. V. N. Lozovskii, Temperature-Gradient Zone Refining [in Russian], Metallurgiya, Moscow (1972).
Fig. 1. Form of dislocation half-loops after being put in the starting position in Ge crystals: D) distance between emergent sloped loop segments on the surface; D₀) length of segment parallel to surface.

Fig. 2. Distribution of displacements of 60° ends of dislocation half-loops as a function of the depths of the half-loops below the crystal surface: T = 400°C; τ = 1.2 kgf/mm²; t = 500 sec; ○) undisplaced dislocations; ●) distances traveled by displaced dislocations.

\[ I = I₀ \left[ 1 + \left( \frac{L_c}{b} \right) \cdot e^{-\frac{E}{kT}} \right]. \]  

where \( c \) is the defect concentration. The expression for \( I₀ \) in Eqs. (2) and (4) is given by Eq. (3).

All of the models calculated can also be used to evaluate \( L_{CR} \), which always, apart from the last case, attains values of centimeters or even meters. Only in the model developed by Petukhov [9] does \( L_{CR} \), for certain values of the parameters, become of the order of magnitude of the mean distance between point defects, i.e., \( L_{CR} \approx l \). Repeated attempts have been made to experimentally verify Eq. (1) and to determine \( L_{CR} \) [11, 12]. The data obtained show that at least for dislocation half-loop diameters greater than 20-30 μm the velocity of the half-loops does not depend on their length. The weak dependence \( v(L) \) observed in [11] on very short half-loops was explained later by the authors by the self-contraction of the ends of small-diameter dislocation half-loops. Thus, as yet there has been no experimental substantiation of the considerations concerning the dependence of the velocity of dislocations in crystals with high Peierls barriers on their length. It may be assumed [13] that the reason for the latter is that dislocations may have on them some sort of "strong" obstacles to the motion of kinks; these obstacles may be, for example, precipitates or impurity jogs observed by x-ray diffraction topography in [16] or jogs formed because of vacancy clusters. The dislocation segments between them move "as a whole," practically independently of the displacement of neighboring segments. Essentially, this case is in conformity with the Petukhov model [9], when \( L_{CR} \) is equal to the mean distance between these strong obstacles. Since the distance between strong obstacles may be microns or tens of microns [14-16],