

INDIUM DIFFUSION ALONG INTERPHASE TWIST BOUNDARIES Sn-Ge

B.B. Straumal, B.S. Bokstein, L.M. Klinger, L.S. Shvindlerman
Institute of Solid State Physics, Academy of Sciences of
USSR, Chernogolovka, 142432, USSR

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Interphase diffusion in solids is a particularly intriguing and practically important process defining properties of commercial materials. But there seem to be few data regarding interphase diffusion and no data on single interphase boundaries.

The results obtained from studies of single grain boundary diffusion [1] and direct measurements of surface tension of single interphase boundaries in Sn-Ge [2] enable one to believe that the diffusion parameters will be dependent of the boundary crystallography. Such orientation dependences of the diffusion parameters may be studied correctly only on single, equilibrium interphase boundaries with preassigned crystallographic parameters. The present work is the first investigation of this kind. A series of bicrystals of Sn-Ge with $\langle 001 \rangle$ twist boundaries has been grown using our original technology. Crystallographic parameters of the bicrystals were predetermined within $\pm 30'$. Misorientation angle φ varied between 0° (when $\langle 100 \rangle$ directions in Sn and Ge are parallel) and 45° with a step of $1,5-2^\circ$.

The orientation dependence of parameters of indium diffusion along these boundaries has been studied. The surface tension of these boundaries we have already measured before [2]. The magnitude of product $D'\delta$ (D' is the boundary diffusion coefficient, δ is the boundary width) was measured using the Fisher formula. In this case it was taken into account, that the bulk diffusion flow in germanium could be neglected ($D \sim 10^{-31} - 10^{-33} \text{ cm}^2/\text{sec}$). Diffusion measurements were done with an electron microprobe analysis. The technique is being discussed in detail in [3].

Fig. 1 gives the dependences of the product $D'\delta$ on the misorientation angle φ for four temperatures: 40, 80, 120 and 160°C . The dependences obtained are nonmonotone. The positions of the maxima comply well with those of special interphase boundaries. By analogy with special grain boundaries, the misorientation angle of "special" interphase boundaries correspond to boundaries with a high density of coincidence sites. Such boundaries are known to exhibit a low surface tension [2]. So far it has been assumed that the special boundaries must possess a lower diffusion permeability compared other boundaries. This opinion was mainly based on data for zinc diffusion along grain boundaries in aluminium [1]. In those experiments angles for the diffusion coefficient maxima corresponded with those for special boundaries. From this viewpoint the behaviour of interphase boundaries and grain boundaries differs sharply.

Fig. 2 and 3 exhibit, respectively, the orientation dependences of activation energy and preexponential factor of indium diffusion along interphase boundaries Sn-Ge. Maxima on these dependences comply strictly with the positions of special phase boundaries. Note, that these dependences are the same as in the case of grain boundaries special misorientations are in line with the maxima of activation energy and the preexponential factor [1].

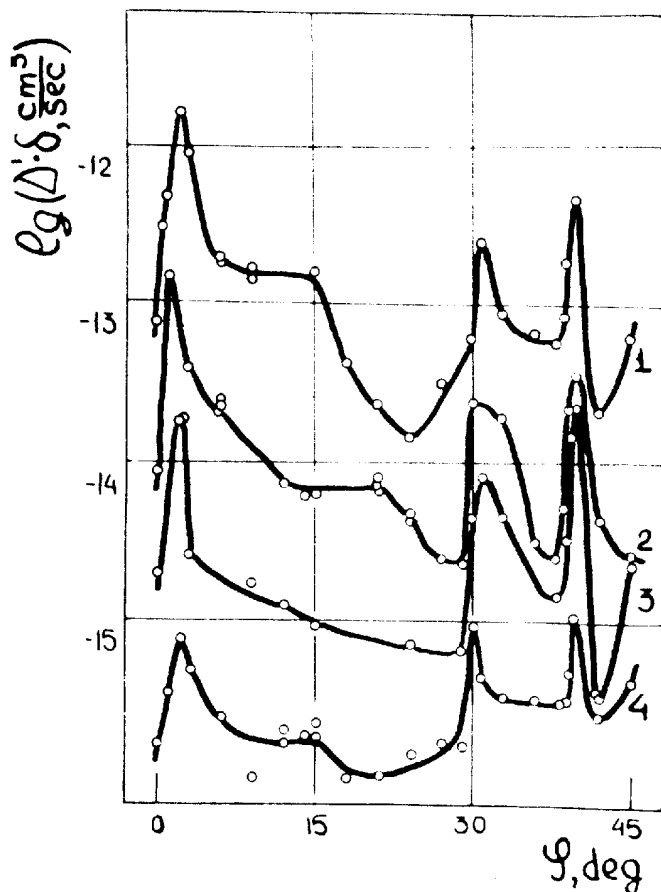


Fig.1. Dependence of the product $D'\delta$ (D' - the coefficient of the boundary diffusion in indium; δ - the boundary width) on the misorientation angle φ for twist phase boundaries $\langle 001 \rangle$ in Sn-Ge 1-160°C, 144 hs; 2-120°C, 362 hs; 3-80°C, 290 hs; 4-40°C, 1366 hs.

Apart from other boundaries, a distinguishing indication of special phase and grain boundaries is higher values of activation energy and of the diffusion preexponential factor. In our case, the value of the diffusion activation energy along special phase boundaries lies in the range 0,4-0,8 E (E is the bulk diffusion activation energy, $E=52,9$ kJ/mol in the temperature range 40-160°C).

In our experiments there is observed a linear dependence of the diffusion activation energy to the logarithm preexponential factor (Fig.4):

$$\ln D'_0 = a + bE$$

This means that curves $(\ln D'_0 = f(T_c))$ for all the boundaries intersect at the same point, at T_c equal to 20°C in our case. Thus, our diffusion measurements were carried

out above the compensation temperature T_c (see Fig. 5) while the diffusion along grain boundaries in aluminium was studied below the compensation temperature ($T_c \approx T_m$ in the case of aluminium). This enables one to understand why the orientation dependences $D'\delta(\varphi)$ for phase boundaries and grain boundaries differ in behaviour in spite of their similar character with respect to the orientation dependences $E(\varphi)$.

Thus, values of diffusion parameters of single phase boundaries have been obtained for the first time. The maxima of the diffusion coefficient as well as those of the activation energy and preexponential factor are shown to comply with the positions of the special interphase boundaries. The positions of the special twist phase boundaries $\langle 001 \rangle$ Sn-Ge are close to those of the special grain boundaries $\langle 100 \rangle$.

References

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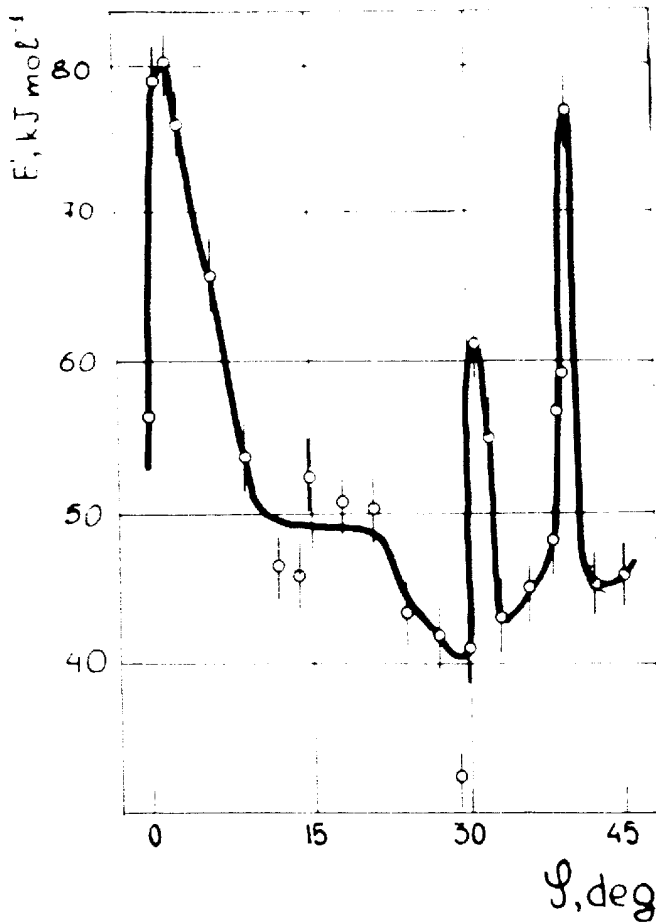


Fig. 2. The dependence of the activation energy E of the indium diffusion on the misorientation angle φ for the twist phase boundaries $\langle 001 \rangle$ in Sn-Ge.

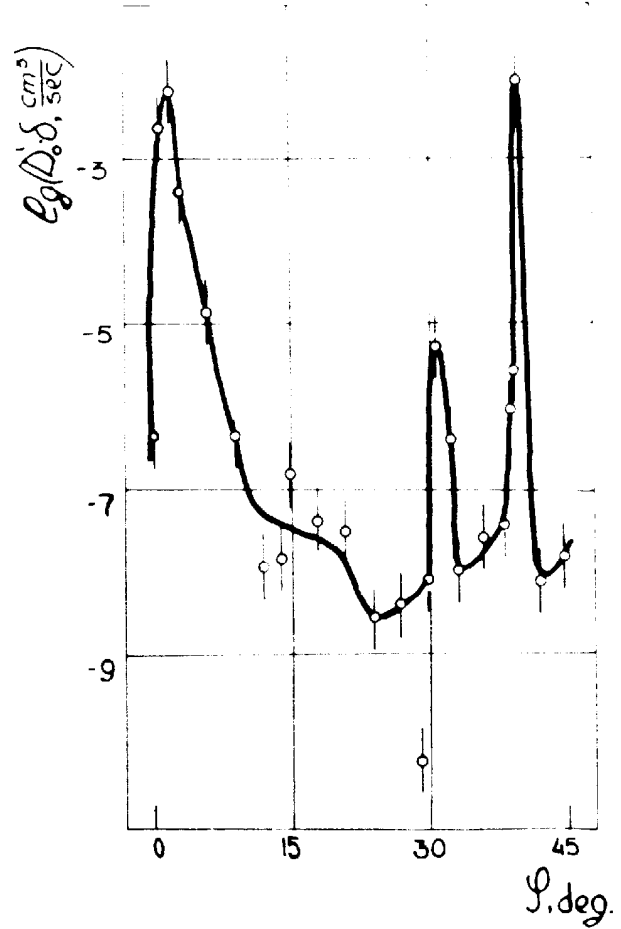


Fig. 3. The dependence of the preexponential factor $D_0 \delta$ on the misorientation angle φ for the indium diffusion along the twist phase boundaries $\langle 001 \rangle$ in Sn-Ge.

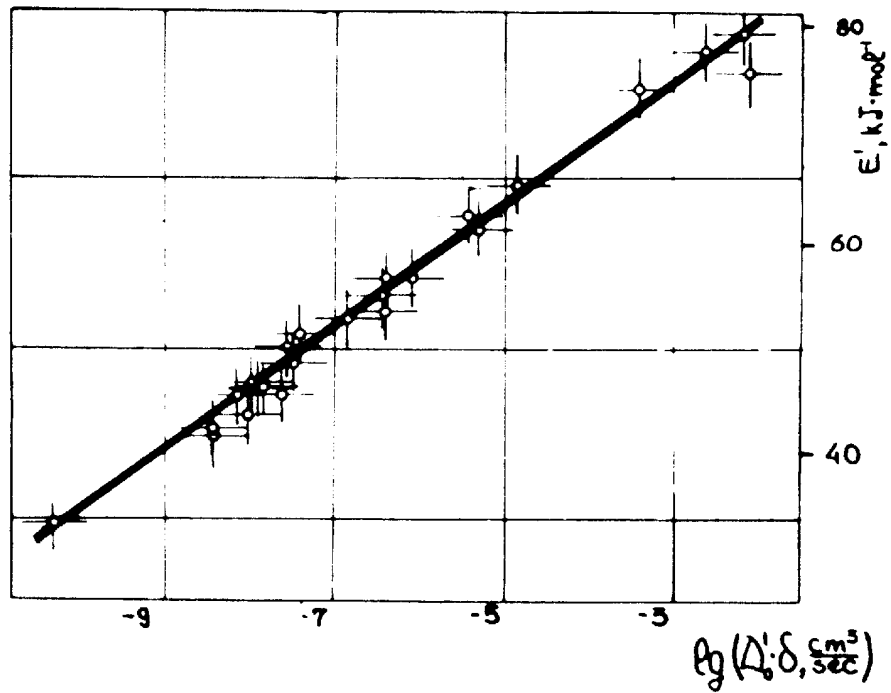


Fig. 4. The dependence of the activation energy E' on the preexponential factor $D_0\delta$ for the indium diffusion along the twist phase boundaries $\langle 001 \rangle$ in Sn-Ge.

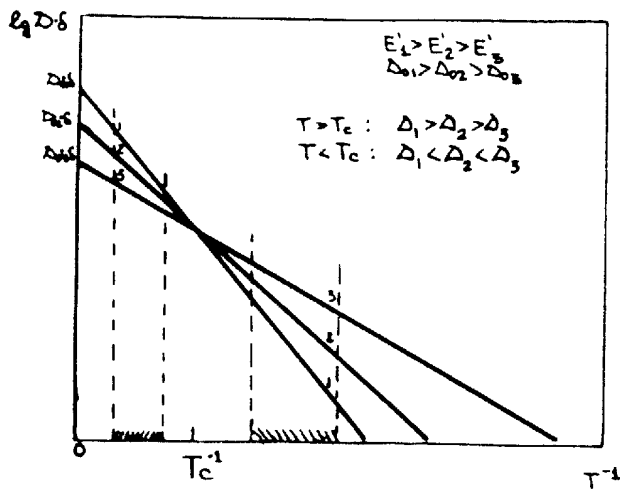


Fig. 5. The positions of temperature regions of the diffusion parameter measurements along grain boundaries in Al and along the Sn-Ge phase boundaries in relation to the compensation temperature.