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The mechanism of dislocation mobility in Silicon

1. THE AIM

During Czochralski growth of D.F.Si crystal dislocations happened to appear out of various reasons. From this moment the crystal starts to growth with dislocations, but even in the part which was dislocation-free, dislocations start to appear due to the stress existing in the crystal. In our crystal the length of this part was 5-7 cm.

The aim of our research was, apart from the investigation of the motion of dislocations formade in this way, to examine possibilities of their elimination. The mobility of 60° dislocations in the temperature range of 600--1000° was examined. During this, two cases were considered:

1. when does their manifold intersection occur during the motion of dislocation and
2. when did not the intersection occur during dislocation motion.

2. METHOD

The examination of dislocation motion was carried out by te etch-pits technique. In our samples both the concentration and the distribution of dislocations varied considerably. In the crystal part that was very close to the place of the appearance of dislocations in the crystal, there were about $10^5/cm^2$ of them, laying in all the planes $\{111\}$ (Fig. 1a).

During the motion of dislocations arranged in this way, a great number of intersections take place as well as the formation of hardly movable parts of dislocations. With moving away from the place of the dislocation appearance towards the beginning of the crystal growth, the concentration of dislocations decreased, and at the distance of about 5 cm there were dislocations only in one slip plane $(\bar{1}11)$ and in a very small number (Fig. 1b). During such a distribution of dislocations their intersection did not occured.

Samples for the examination were obtained by cutting the crystal perpendicular on the axis of growth $[111]$ above the place of dislocation appearance;

Fig. 1a. The sample in which dislocations lie in all planes $\{111\}$

Fig. 1b. The sample in which dislocations lie only in planes $(\bar{1}11)$

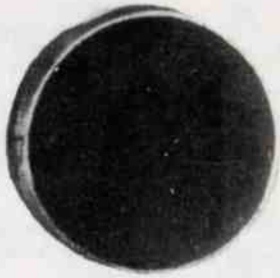


Fig. 2. The sample from Fig. 1a after being heated for 1 h at 900°

Table 1

THE RATES OF DISLOCATIONS MOTION IN THE CASE OF THEIR MANIFOLD INTERSECTIONS

$t^{o}C$	750	800	850	900
$Vs \cdot 10^5$ cm/s	0.7	2.7	24.2	106.4

Table 2

THE RATES OF DISLOCATIONS MOTION WHEN DURING THEIR MOTION NO INTERSECTION OCCURS

$t^{o}C$	600	660	700	750	800
$Vs \cdot 10^6$ cm/s	1.62	8.87	24	55	130

in this way wafers 10-20 mm thick and 40 mm in diameter were obtained. The crystals were obtained by means of the Czochralski method, doped with B and the resistivity was from 7-12   cm.

After etching the wafers, the slips were selected on the samples, and their langths were measured under the microscope. The heating was carried out in Ar atmosphere from 15 min up to 48 h. The temperatures was maintained within the limits of ±5°. After cooling the sample was etched again and its slips were measured.

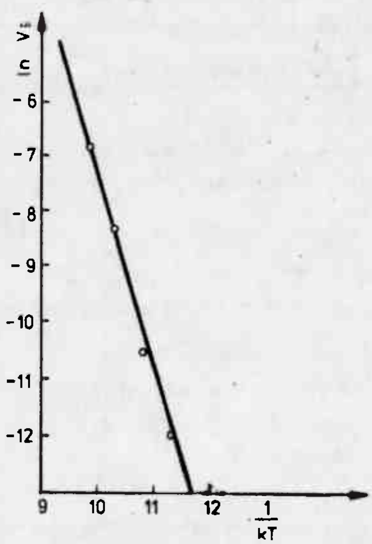
The difference in the slip lengths before and after heating, related to the time unit, were the rate of dislocation motion. Shortening of slips proceeded due to the fact that dislocations moved in the slips $\{111\}$ from the middle part of the crystal towards the periphery.

3. RESULTS

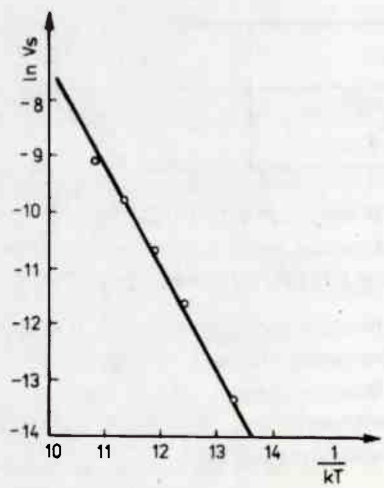
During the first part of our investigation we used the samples in which dislocations were in all planes {111} in the directions of ⟨110⟩. During the motions of dislocations arranged in this way their manifold intersections took place. At 700° the rates were exceptionally low. At 950 and 1000° the dislocation motion rates were very high so the slips completely disappeared already after 15 minutes. For these reasons we were able to determine the rates of dislocation motion only in the temperature range of 750-900°. At each temperature about 20 measurements were carried out, and in Table 1 are given the mean values. In Fig.3. the results are presented graphically, and the activation energy for the dislocation motion was 3.5 eV.

In the second part of our research we measusured the rates of dislocation movement when during their motion no intersection occured. The measurements were performed at temperatures from 600 up to 800°. At temperatures below 600° the rates of dislocation motion were exceptionally low, but at the temperatures above 800° the rates of motions did not essentially differ from the values obtained for the case when dislocations intersected.

In Table II are given the mean values of the dislocation motion rates for this case, and in the diagram (Fig.4) they are graphically presented. The activation energy for dislocation motion in this case ammounts 1.8 eV.



The results from Table 1 presented in system $\ln Vs - \frac{1}{kT}$



The results from the Table 2 presented in system $\ln Vs - \frac{1}{kT}$

4. DISCUSSION AND CONCLUSION

During measuringof the rates of dislocation motion in semiconductors the authors, earlier engaged in this problem, have used the samples in which their intersection did not occured or the number of the intersections were small, and this means that they have determined the activation energy for the dislocation motion by the mechanism of kinks nucleation motion. The obtained values were approximately half less than the activation energy for the selfdiffusion in these materials. The obtained values for Si varied from 2.4 to 1.8 eV. The value of 1.8 eV was obtained when the X-ray topography was used (Kannan and others), so it was possible to observe the separated dislocations in the nearly perfect crystal. For this reason, it is probably the most approximate.

The value of the rates of dislocation motion, we obtained in the first part of our research, are considerably less than the values obtained by other authors, and the activation energy is considerably higher. This event could be expected in regard to quite different conditions for dislocation motion.

The activation energy for self-diffusion E_s in Si doped with B is 3.6 eV, and this is quite near the value that we obtained for the activation energy for dislocation motion of 3.5 eV. On the basis of this it is possible to assume that big jogs, moving non-conservatively, determine the rate of dislocation motion. To prove that the difference in the values we obtained for dislocation motion rates and the activation energy and the value obtained by other authors is the resultsoof the dislocation intersecion during their motion in our experiments, we carried out the second part of our investigations as well. For this investigation we took the samples in which during their motion no dislocation intersection proceeded, as already described. The values obtained in this way agreed well with the values obtained by earlier authors. This gives greated reliability to the conclusion referring to the first part of our research.