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A STUDY OF THE STABILITY OF IRRADIATION INDUCED POINT DEFECTS ON VARIOUS DISLOCATION CLASSES IN COPPER AND SILVER

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Abstract.— The variation of the Bordoni peaks has been studied in copper and silver during electron irradiation at 110 K and subsequent annealings up to 300 K. It is concluded that the interstitials are stable on the dislocations giving rise to B_2 up to 150 K in the two metals. In copper they can diffuse along the dislocations giving rise to B_1 for temperatures lower than 110 K. The vacancies pin both dislocation classes up to 300 K.

1. **Introduction.**— Internal friction and modulus measurements performed at different temperatures allow the separation of the motion of different classes of dislocations. At very low temperature the geometrical kinks are very mobile and give rise to internal friction, at a higher temperature the Bordoni peaks are usually attributed to double kink formation on different dislocation classes, in copper we have proposed (1) that B_2 is associated to dislocations lying along $\langle 110 \rangle$ and B_1 along $\langle 112 \rangle$.

The interstitials created by electron bombardment are freely mobile at the temperature of stage I, around 45 K in copper and 35 K in silver. The monovacancies migrate during the stage III between 200 and 300 K in the two metals.

To study the stability of point defects on the different dislocation classes in copper and silver we have performed electron bombardments at 110 K and measured the height of the Bordoni peaks and the internal friction and elastic modulus at 9 K during the irradiation and after subsequent annealings at increasing temperatures.

2. **Experimental procedure.**— The apparatus for an automatic measurement of the damping and elastic modulus has been described previously (2) and also the cryostat working between 8 K and 750 K and the irradiation facilities (3).

The samples in form of a dual cantilever foil (resonant frequency of the order of 200 to 400 Hz) are prepared from pure COMINCO copper (99.9999 %) or PURCLA silver (99.999 %), after an annealing around 900 K under high vacuum, they are submitted to a cold work at 10 K by an amount of 0.5 % to 3 % and an annealing at 130 K.

3. **Results.**—

3.1. **Variation of the internal friction during electron irradiation.** After cold work the copper sample exhibits the two Bordoni peaks B_1 and B_2 at 32 K and 65 K. We have already shown (1) the variation of the damping spectra after successive electron bombardments at 110 K. Figure 1 shows the variation of the amplitude of B_1 and B_2 with the electron dose. B_2 decreases continuously while B_1 begins to

increase by 25 % before decreasing ; the modulus anomalies associated with each peak present the same evolution. The modulus defect and the internal friction measured at 9 K after each irradiation decrease continuously.

Fig. 1. Variation of the amplitudes of B_1 and B_2 in a copper sample after electron bombardment to a dose Φ .

After cold work, the silver sample presents the damping spectrum shown in fig. 2.1. with the peak B_2 at 60 K and no peak B_1 , the evolution of the spectra after successive electron irradiations at 110 K is shown in fig. 2, the peak B_2 decreases continuously while the damping and modulus defect measured at 9 K also decrease.

Fig. 2. Internal friction spectra of a silver sample after several irradiations at 110 K with the following doses Φ (e⁻/cm²)

- 1 - before irradiation
 2 - 3.10^{14} 3 - 8.10^{14}
 4 - 50.10^{14} 5 - 160.10^{14}

3.2. Variation of the damping during annealing treatments after irradiation.

We have performed, after the last irradiation at 110 K, isochronal annealings (10 mn) with increasing temperature T_{an} . After each treatment the internal friction and elastic modulus are measured from 9 K up to T_{an} . Fig. 3 shows the internal

friction spectra obtained in the copper sample after each annealing between 120 K and 220 K.

Fig. 3. Internal friction spectra of a copper sample after irradiation at 110 K and subsequent isochronal annealings at increasing temperatures. a) 120 K, b) 130 K, c) 140 K, d) 150 K, e) 160 K, f) 180 K, g) 200 K and h) 220 K.

Fig. 4 shows the variation of the amplitudes of B_1 and B_2 with the annealing temperature. B_1 remains almost constant up to 220 K and then decreases while B_2 increases between 160 K and 220 K and decreases higher temperature.

Fig. 4. Variation of the amplitudes of B_1 and B_2 in a copper sample after isochronal annealings, versus the anneal temperature T_{an} .

Fig. 5 shows the variation of the amplitude of B_2 in the silver sample, it increases between 150 K and 200 K and then decreases between 200 K and 300 K.

Fig. 5. Variation of the amplitude of B_2 in a silver sample after irradiation at 110 K and subsequent isochronal annealings, versus the anneal temperature T_{an} .

4. Interpretation.-

4.1. Interaction between point defects and the dislocations giving rise to B_2 .

The behaviour of peak B_2 during irradiation and subsequent annealings is essentially the same in copper and silver samples and the interpretation is identical for the two metals.

Fig. 1 and 2 show that the amplitude of B_2 decreases continuously during irradiation at 110 K, this usual behaviour is explained by the pinning of the dislocations giving rise to B_2 by the interstitials created by irradiation at 110 K, the loop length between two pinning points decreases.

During successive annealings at increasing temperature, fig. 4 and 5 show an increase in the amplitude of B_2 between 160 and 220 K in copper and 150 and 200 K in silver. Two principal interpretations can be proposed to explain the increase.

- 1) The arrival from the crystal of some defects which can eliminate a part of pre-existing pinning points.
- 2) The elimination by diffusion along the dislocations of the pinning points which are the interstitials created by irradiation at 110 K.

We can throw out the first hypothesis for two reasons : the temperature range 150 to 220 K is too low to correspond to vacancy migration in the metals (4) (5) and in the same range the amplitude of B_1 does not vary. The second hypothesis explains very well the difference in the variations of B_1 and B_2 .

The large pinning observed above 220 K in copper and 200 K in silver is connected to the arrival of monovacancies.

4.2. Interaction between point defects and the dislocations giving rise to B_1 .

Fi. 1 shows that in copper the amplitude of B_1 begins to increase during irradiation for doses up to 2.10^{17} el/cm² and then presents the expected decrease. During the bombardment only the length L between pinning points can vary and all the theories indicate that the damping decreases when L decreases. We conclude that during the beginning of the irradiation at 110 K the interstitials arriving

of the lines can diffuse and annihilate some preexisting vacancy type pinning points. When the dose increases further the interstitials can agglomerate or diffuse to geometrical kinks and if we assume that the agglomerates are stable and firmly pin the dislocations, it is possible to explain the subsequent decrease of B_1 for higher doses.

Fig. 4 shows that during annealing between 110 and 220 K the amplitude of B_1 remains constant, the decrease between 220 and 300 K is associated to a pinning by the monovacancies which migrate during stage III.

5. Conclusion.- These experiments can be explained with the hypothesis that the interstitials are stable on the dislocations giving rise to B_2 (lying along $\langle 110 \rangle$) up to 150 K in copper and silver and then can diffuse along them. In copper the interstitials can diffuse along the dislocations giving rise to B_1 (lying along $\langle 112 \rangle$ for temperatures lower than 110 K. The vacancies pin all the dislocation classes between 200 and 300 K.

6. References.-

- [1] J. Lauzier and C. Minier, this same congress.
- [2] P. Girard, 1980, Thèse Université Scientifique et Médicale de Grenoble.
- [3] J.C. Soulié, J.P. Jodeau, C. Minier and Y. Depierre, 1970, Rad. Effects, 11, 221.
- [4] C. Minier, M. Minier and R. Andreani, 1980, Phys. Rev. B, 22, 28.
- [5] P. Hautajarvi, J. Johansson, A. Vehanen, J. Yli-Kaupila, P. Girard and C. Minier, 1981, Journ. Phys. F, in press.