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Tunneling of Mixed Dumbbells in Al-Zn

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Abstract.— Evidence for the caged mixed dumbbell configuration for the interstitial impurity complex is obtained from the polarization and annealing dependence of the ultrasonic diaelastic and paraelastic response in irradiated aluminum with zinc impurities. From the temperature dependence of the relaxation time, it can be deduced that the complex tunnels between equivalent configurations.

We have irradiated specimens containing 0.5, 0.1, and 0.01 atomic percent of zinc in aluminum at 65 K. A defect with $\langle 111 \rangle$ symmetry is found at 103 K which anneals during the measurement, while another with $\langle 100 \rangle$ symmetry is found at 5 K which anneals at 135 K. The measurements for the 5 K peak provide the first strong experimental evidence for the theoretically much discussed and expected^{1/} caged mixed dumbbell configuration illustrated in Fig. 1. In addition, the surprising

Fig. 1 : Schematic view of the mixed dumbbell configuration in the fcc lattice formed by an undersized impurity (open circle) and an atom of the host lattice (crosses). The dumbbell has six equivalent orientations along the $\langle 100 \rangle$ directions.

result is found that the defect tunnels between the equivalent states. The evidence for the mixed caged configuration arises mainly from the polarization dependence of the diaelastic and paraelastic ultrasonic response of the defect. A large diaelastic effect in C_{44} anneals with this defect, while the paraelastic response occurs entirely in the C' elastic constant, as would be expected for

The evidence for tunneling is obtained by combining ultrasonic attenuation and velocity measurements at 10 and 30 MHz. It is easily shown that the ratio R of $\Delta/\omega\Delta v$, where Δ is the decrement, v is the ultrasonic velocity and ω is the frequency, should be independent of ω for a simple Debye relaxation. Once this test is satisfied, then the ratio R gives the temperature dependence of the relaxation time. The results of such a test are shown in Fig. 2 where R is found to be independent of ω . It is found that the test is satisfied for both

Fig. 2 : Relaxation time τ derived from velocity and attenuation measurements on irradiated Al-Zn peak 1.

0.1 and 0.5% Zn in Al. The relaxation time is found to be Arrhenius at high temperature and independent of temperature between 2 and 4 K, providing strong evidence for tunneling of the complex. The low temperature increase of the decrement shown in Fig. 3 is not a second low temperature peak, but is just due to the expected increase of the relaxation strength while the relaxation time remains frozen.

Measurements have now been made for 0.01% Zn in Al. These are more difficult because the background attenuation due to ultrasonic interaction with conduction electrons becomes very large at low temperature in this case.

Fig. 3 : Annealing of peak in decrement of Al-0.1% Zn peak 1.

References

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