

MEASUREMENTS OF RESIDUAL RESISTIVITY OF RAPIDLY
QUENCHED SAMPLES OF Al-Fe ALLOY

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Introduction

The purpose of this paper is to present a survey of the experimental results obtained by residual resistivity measurements on URQ Al-Fe samples. Their comparison with Friedel's theory and with earlier results for dilute alloys will be given also.

For better understanding of this subject we will briefly discuss results of Friedel's theory and their application on Al-Fe alloy. Most electrical properties of pure metals are rather satisfactorily described by the free electron model. When a dilute alloy is made, some localisation of electronic charge must occur around the dissolved atom in order to preserve the electrical neutrality of the conductor. When an atom of transition metal is dissolved as impurity, some "virtual d-bound states" will occur because of their strongly localised d-electrons. This virtual level appears as a resonance for conduction electrons and gives rise to a large residual resistivity (1).

Theory

More quantitative calculation of the resistivity may be carried out in the case of Al base alloys. We will start with standard resistivity formula

$$\rho = \frac{6\pi^2 \hbar}{e^2 \tau \int v dS_F}$$

where v is the electron velocity, and the integration is carried out over the Fermi surface. In the relaxation time expressed by the method of partial waves, phase shifts should satisfy Friedel's sum rule i.e.

$$Z = \frac{2}{\pi} \sum_{l>0} (2l+1) \eta_l$$

where Z is the difference between the number of valence electrons in the host metal atom and the corresponding number in impurity atom. Because the exact shape of the perturbing potential is not known we are not able to calculate different phase shifts. Then we make the following assumption

$$\frac{1}{\tau} = \frac{1}{\tau_d} + \frac{1}{\tau_{n.r.}}$$

where τ_d and $\tau_{n.r.}$ are the relaxation times due to resonant and nonresonant scattering. Assuming that the phase shift with $l = 2$ is the only significant one, it is possible to find the relaxation time for resonant scattering (2). Finally we get for the resistivity due to resonant scattering in f.e.m.

$$\left(\frac{\rho_d}{c}\right)_{f.e.m.} = \frac{\hbar}{10 Z_h e^2 v_F} \sin^2 \frac{\pi Z_d}{10}$$

where concentration c is expressed in at%, Z_h is the number of valence electrons of host metal, and Z_d is the number of d-electrons localised near the transition atom. The value obtained in the case of Al-Fe alloy from this relation is $3.2 \mu\Omega \text{ cm/at\%}$. Experimental results for dilute Al-Fe alloy (up to 0.018 at% Fe) give a value about 1.5 times larger. On the other hand there were no electrical measurements on the supersaturated Al-Fe alloys until recently.

Experimental Procedure

The use of special experimental technique (3) enabled us to perform electrical measurements on URQ Al-Fe samples. The samples were prepared by two different techniques: "spat cooling" technique (4) and by the use of rapidly rotating mill device (5). The concentrations of iron in aluminium were up to 4.2 at%. There was significant difference in the size of samples obtained by different techniques but their thickness was almost the same. Electrical resistance measurements were performed on a large number of samples with different iron concentrations using the standard method of compensation.

Results and Discussion

From the electrical resistance data at 4.2 and 273°K the residual resistivity ratio was computed as $\rho = R_{4.2} / (R_{293} - R_{4.2})$. The dependence of residual resistance ratio with concentration of iron is shown in Fig. 1.

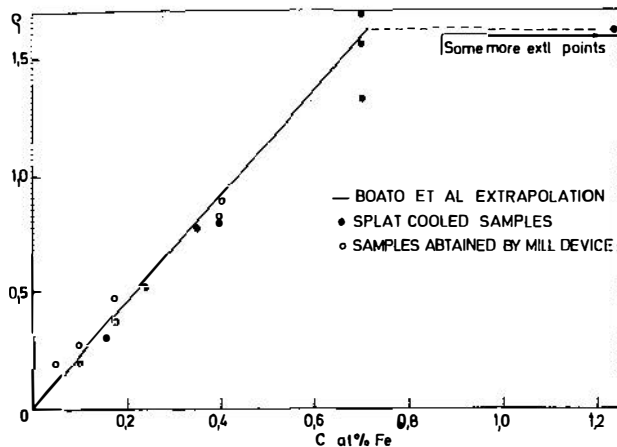


FIG. 1

Residual resistivity ratio ρ versus iron concentration in aluminium. "Splat cooled" samples are marked by black circles and those obtained by mill device by white ones.

The difference in the value of ρ for samples of the same concentration are considered as probably due to slightly different quenching condition, and to a lesser extent to slight variations in iron concentration as well as to the normal measurement errors. This is evident from the fact that the greatest deviation is observed for samples of the highest concentration. Possible linear extrapolation of the results of Boato et al (2) for dilute Al-Fe alloys is shown too. Positive deviation for the samples with low concentrations of iron from this may be attributed to a high concentration of vacancies introduced by URQ (6). On the other hand nearly the same residual resistance ratio for the samples with more than 0.7 at% iron indicates that there we are not dealing with real solid solution.

Conclusions

On the basis of our observations we may conclude that in the concentration region up to 0.7 at% of iron the behaviour of the residual resistance of our samples is the same as for dilute Al-Fe alloys. Such behaviour could be fairly successfully described by Friedel and Anderson theory (7, 8). At the same

time the samples of the same iron concentration obtained by different quenching techniques have essentially the same behaviour.

Acknowledgements

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References

1. G.J. Van den Berg, *Progr. Low Temp. Phys.*, 4 (1968) 194
2. G. Boato, M. Bugo and C. Rizzuto, *Nuovo Cimento*, 45, (1966) 226
3. E. Babić, R. Krsnik and B. Leontić, *J. Phys. E*, 3, (1970) 664
4. P. Duwez and R.H. Willens, *Trans. Met. Soc. AIME*, 227, (1963) 362
5. E. Babić, E. Girt, R. Krsnik and B. Leontić, *J. Phys. E* (to be publ.)
6. E. Babić, E. Girt, R. Krsnik, B. Leontić and I. Zorić, *Phys. Letters* (to be published)
7. J. Friedel, *Suppl. Nuovo Cimento*, 7, (1958) 287
8. P.W. Anderson, *Phys. Rev.* 124, (1961) 41

DISCUSSION :

- P. Duwez : I wonder if the lack of agreement with Friedel's theory above 0.7 at% Fe is really due to the presence of a second phase, , since previous speakers have shown that at least 4 at% Fe could be retained in solid solution.
- B. Leontić : It seems clear that while one appears to have a solid solution even up to, say, 4 at% there is a definite deviation from the Friedel-Anderson model probably due to clustering. Up to 0.7 at% we seem to have the iron rather evenly distributed.
- E. Nagy : Were there any magnetic measurements made on Al-Fe alloys ?
- E. Babić : We have made them . Our results are in agreement with previous results obtained by Sadouc in Orsay. But for magnetic measurements one should take a lot of samples and so you get only a mean value of qualitatively different samples.