ANOMALOUS RESISTIVITY OF DILUTE MAGNESIUM-NEODYMIUM ALLOYS*

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Preliminary measurements[1] of the resistances of dilute alloys of magnesium and neodymium (up to 1.3 atomic percent) have resulted in the observation of a remarkable temperature dependence of the extra resistivity $\Delta\rho_T$ due to the alloying.

For temperatures above room temperature the results are in general in qualitative agreement with those on a variety of magnesium alloys published by Salkovitz, Schindler, and Kammer.[2] The atomic resistivity increase, $\Delta\rho_{293}/c$ (where c is the impurity concentration in mole %), equals 1.47 ± 0.37 μohm cm, which lies between the values 0.7 for the monovalent and divalent impurities (Ag, Li, and Cd) and 2.0 for the trivalent impurities (Al and In) as reported by Salkovitz et al. Below room temperature, however, $\Delta\rho_T$ decreases with temperature.

A relatively large drop in $\Delta\rho_T$ below 293°K for the most dilute sample (0.55 at. % Nd, $\Delta\rho_{77}/\Delta\rho_{293} = 0.28$) has led to a further investigation with a sample having smaller neodymium concentration. This sample, for which $\Delta\rho_{293} = 32$ μohm cm, was measured at 4.2°K and at different temperatures between 77°K and 230°K.

At 4.2°K, $\Delta\rho_4/\Delta\rho_{239} = 0.043$ or $\Delta\rho_4 = 0.014$ μohm cm, which represents a large deviation indeed from Matthiessen's rule (which requires that $\Delta\rho$ be independent of temperature). A deviation from this rule is generally observed. Not considering low-temperatures anomalies[3] the temperature-dependent part in $\Delta\rho_T$ is at most of the order 10% of the resistivity increase at room temperature.[4] For the present case, the temperature-dependent part is 95% of the total resistivity increase at room temperature. Using a linear interpolation for the computation of the resistivity for pure magnesium between the values measured at room temperature and 77°K, $\Delta\rho_T$ so found is plotted logarithmically in terms of the ratio $\Delta\rho_T/\Delta\rho_{273}$ against $1/T$ in Fig. 1. This figure strongly suggests $\Delta\rho_T \propto \exp(-\epsilon/kT)$ with $\epsilon \approx 250k = 0.022$ ev. For the temperature region below 77°K the curve has to bend asymptotically to the limit $\Delta\rho_4/\Delta\rho_{293} = 0.043$ as indicated on the left-hand scale in Fig. 1.

Such an exponential relation, which of course has yet to be verified by further measurements, is not easily understood in terms of a usual temperature scattering. One is tempted to consider such a behavior in terms of a diminishing scattering probability with a localized state.

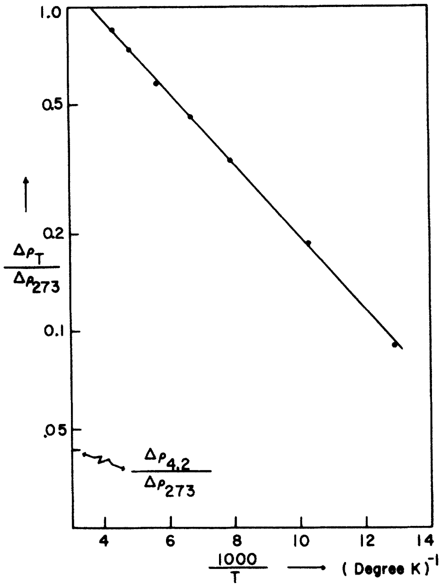

FIG. 1. The ratio $\Delta\rho_T/\Delta\rho_{273} = (\rho_{\text{alloy}} - \rho_{\text{magnesium}})_T/(\rho_{\text{alloy}} - \rho_{\text{magnesium}})_{273}$ for a dilute magnesium-neodymium alloy plotted against $1/T$ in the range $77°\text{K} \leq T \leq 273°\text{K}$.

Also it has to be investigated whether the effect is a particular property of the neodymium impurities in the magnesium. Data published by Hedgcock, Muir, and Wallingford,[5] for example, suggest that a large temperature-dependent part in $\Delta\rho_{273}$ seems to be a more general feature in dilute magnesium alloys. For their Mg-Zn, Mg-Sn, and Mg-Sb alloys, for which the $\Delta\rho_T$ values at 300°K are of the same order as in the present case, it follows from their data for 4.2°K that $\Delta\rho_4/\Delta\rho_{300} \approx 0.15$. It seems, then, that for neodymium impurities the temperature-dependent part in $\Delta\rho_T$ is much larger.

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