ANOMALOUS MAGNETORESISTANCE OF HYDROGEN – DOPED $Zr_{0.67}Ni_{0.33}$ METALLIC GLASS

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Magnetoresistance of liquid quenched $Zr_{0.67}Ni_{0.33}H_x$ $(0 < X < 0.7)$ metallic glasses has been measured at low temperatures and in magnetic fields up to 6.5 T. The results show positive magnetoresistance which decreases with hydrogen concentration. Anomalous magnetoresistance can be accounted for in theoretical models of weak localisation in the presence of strong spin-orbit scattering and quenched-in superconducting fluctuation.

Weak localization and electron-electron interaction effects in three-dimensional disordered sistems have been observed recently in several metallic glasses.[1–4)] Magnetoresistance data were interpreted using the spin-splitting interaction theory[5)] and the localization theory[6, 7)] modified to include spin-orbit interaction. In this paper, we report the results of magnetoresistance on a number of hydrogen doped $Zr_{0.67}Ni_{0.33}$ metallic glass samples.

The samples were cut from ribbon produced on a single -roll spinning wheel apparatus in reduced argon atmosfere, and electrolitically doped with different concentrations of hydrogen[8)]. The content of absorbed hydrogen was determined using a previously established relationship between the gain in resistance and volumetrically determined hydrogen concentration[8)].

Magnetoresistance was measured by an AC method using a superconducting magnet in fields up to 6.5T. The samples were mounted on an orientable holder to obtain results in a transverse and a longitudinal field. We found anomalous magnetoresistance that is independent of magnetic field direction and 10^4 times greater than the expected normal magnetoresistance. A small normal magnetoresistance is a consequence of the small value $\omega_c\tau_0$ (ω_c = He/m is cyclotron frequency and τ_o is elastic scattering time) in these materials compared with crystalline ones. The results are plotted as a function of $H^{1/2}$ at 4.2K in Fig. 1, for $Zr_{0.67}Ni_{0.33}H_x$ $(0 \leqslant X\ 0.7)$ alloys. The magnetoresistance slopes are lowered with increasing hydrogen concentration and the saturation is shifted to lower fields.

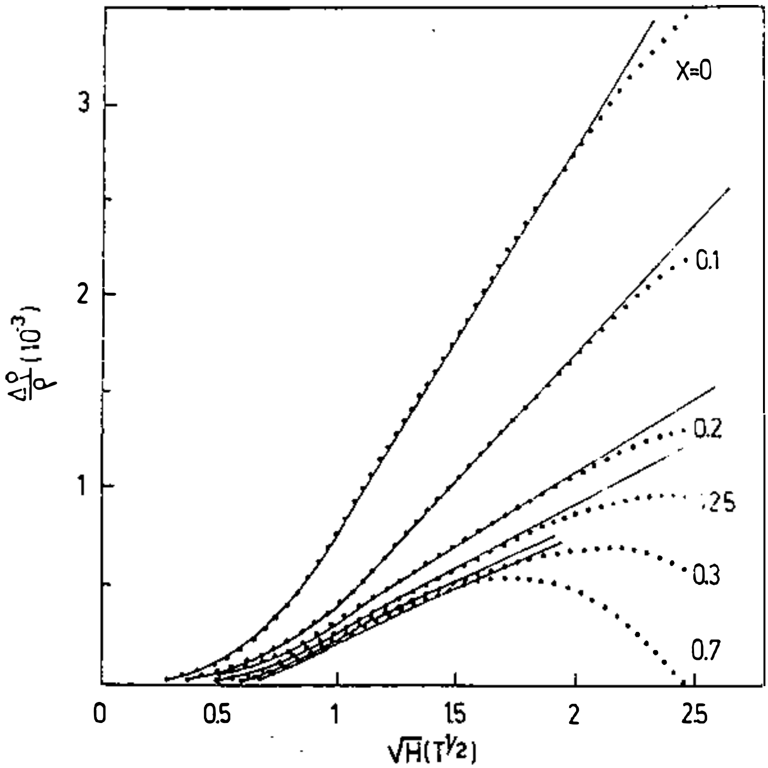

Fig. 1.
Magnetoresistance of $Zr_{0.67}Ni_{0.33}H_X$ at 4.2. Dots are experimental results. Lines are calculated from Eq. (1)

The data were analised using a model due to Altsuler et al.[6]. The quantum corrections to the magnetoresistance of a three-dimensional sistem in the presence of spin-orbit scattering and superconducting fluctuations are given by:

$$\frac{\Delta\rho}{\rho} = \rho \frac{e^2}{2\pi^2\hbar} \left(\frac{eH}{\hbar}\right)^{1/2} \left\{\left[\frac{1}{2} + \beta\right] f_3 \left(\frac{H}{H_i}\right) - \frac{3}{2} f_3 \left(\frac{H}{H_{so}}\right)\right\} \tag{1}$$

where

$$H_i = \frac{\hbar}{4eD\tau_i} \; ; \; H_{so} = \frac{\hbar}{4eD} \left(\tau_i^{-1} + 2\,\tau_{so}^{-1}\right); \; D = \frac{1}{3} \nu_F \tau_o$$

D is diffusion constant and τ_o, τ_i, τ_{so}, are the electron relaxation times for elastic, inelastic and spin-orbit scatterings respectively. The function $f_3/x/$ is given in ref. 6 and its asymptotic forms are:

$$\begin{aligned} f(x) &= x^{3/2}/48 && \text{for } x \ll 1 \\ f(x) &= 0{,}605 && \text{for } X \gg 1 \end{aligned} \tag{2}$$

The factor β corresponds to the so called Maki-Thompson corrections which are well known in the theory of fluctuational superconductivity[9]. It is tabulated in ref. 10 as a function of g which is in a low field limit given as:

$$g^{-1} = -\ln(T/T_c)$$

The solid curves fitted to the experimental data in Fig. 1 are calculated from the relation /1/. The values of β at 4.2K as determined experimentally by fitting rel. /1/ to the data are plotted as a function of dopant concentration in Fig. 2. The value of β is found to decrease sharply with increasing X and to level off as X exceeds about 0.4. This is in agreement with our earlier results[8] which showed the lowering of superconducting transition temperature by the dopant. The best fit curves in Fig. 1 give values of D, τ_o and H_{SO} which decrease with the increase of hydrogen concentration.

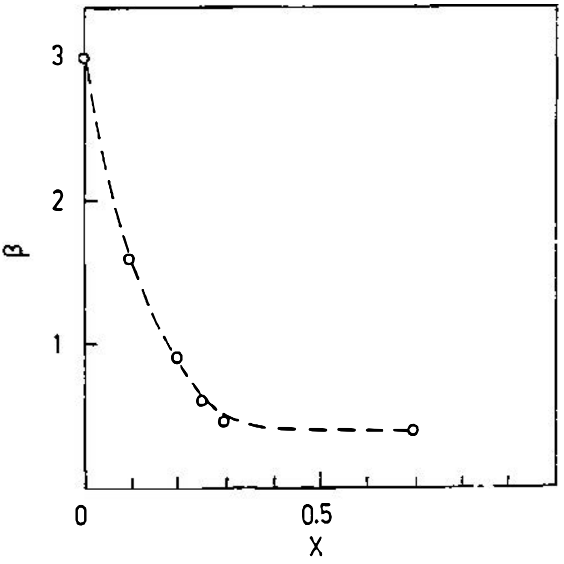

Fig. 2.
Parametar β ploted as a function of hydrogen concentration (x)

This can be taken as evidence that hydrogen enhances localisation by providing additional centres of quasy-elastyc scattering thus reducing the effective electron diffusion constant. Soft X-ray spectroscopy results[11] show that the hydrogen atom occupyes preferentially tetrahedral siets surrounded by four Zr-atoms and hybridizes with the Zr d-band. Since most of the spin-orbit scattering occurs at Zr siets, the hydrogen reduces the effective spin-orbit contribution to the magnetoresistance.

The present data show that hydrogen is a good atomic probe to study quantum interference at defects in highly disordered systems.

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