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THE INFLUENCE OF NEUTRON IRRADIATION ON THE ELECTRICAL RESISTIVITY OF THE AMORPHOUS Fe-Ni-B SYSTEM[1])

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The effect of the increase of electrical resistivity of amorphous $Fe_{60}Ni_{20}B_{20}$ and $Fe_{40}Ni_{40}B_20$ alloys is explained with the help of the T-matrix formulation of the extended Ziman theory.

В работе на основе Т-матричной формулировки расширенной теории Займана дано объяснение увеличения электрического удельного сопротивления образцов аморфных сплавов Fe-Ni-B после их облучения нейтронами.

I. EXPERIMENTAL PROCEDURES

Thin ribbons of the amorphous alloys were prepared by rapid quenching from the melt using the oneroller technique. In general the ribbons were 30 μm thick and 1.5 mm wide. The neutron irradiation was performed in a nuclear reactor at Řež. The fast neutron doses ($E > 1$ MeV) were $5 \,.\, 10^{17}$ n/cm^2 and 10^{18} n/cm^2, respectively. The temperature of irradiation was slightly above room temperature. Resistivity measurements were carried out in a helium cryostat using a standard ac four terminal bridge method. The absolute resistivity values determined from directly measured dimensions of the samples were accurate to about 5 %. The relative error in the resistivity measurement was ≈ 10 ppm.

II. THEORY AND DISCUSSION

The electron microscope photographs of the amorphous system $Fe_{40}Ni_{40}B_{20}$ show after irradiation regions of varying brightness: light and dark regions — Fig. 1. The amorphousness before and after irradiation was checked by X-ray diffraction. The macroscopis change of density is negligible ($\Delta\bar{\varrho} \approx 0.5$ %) [1].

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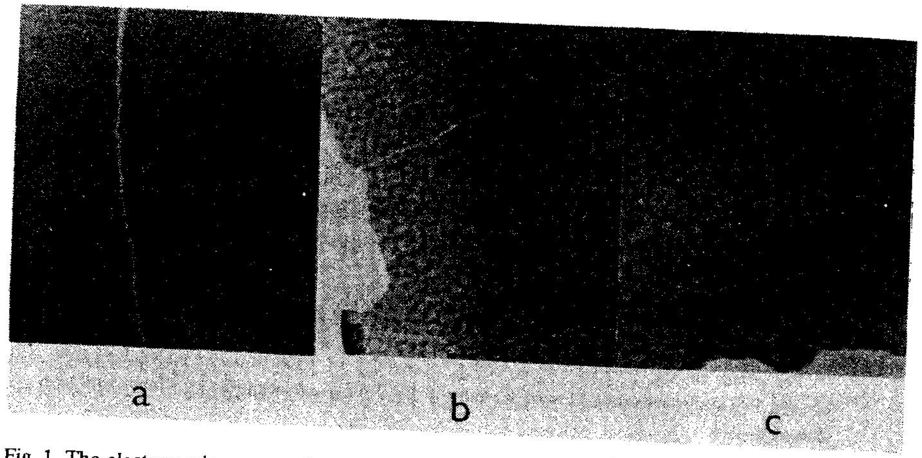

Fig. 1. The electron microscope photographs of the amorphous $Fe_{40}Ni_{40}B_{20}$ alloy. A — not irradiated, B — irradiated with the fluence $5 \cdot 10^{17}$ n/cm^2, C — 10^{18} n/cm^2.

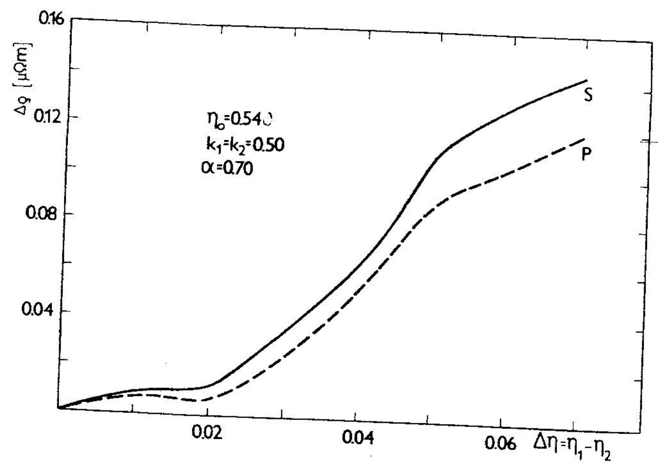

Fig. 2a

We shall assume a varying density in the light and the dark regions and do not consider the concentration fluctuations. In [2] there has been calculated the structural part of electrical resistivity of the model amorphous $Fe_{80}B_{20}$ alloy by means of the T-matrix formulation of the extended Ziman theory [3] as a function of the packing density parameter η and the $\alpha \leqq 1$ ratio of hard spheres [4]. The ternary system Fe-Ni-B can be treated like a quasibinary system Fe-B because we consider the structural contribution of the electrical resistivity only.

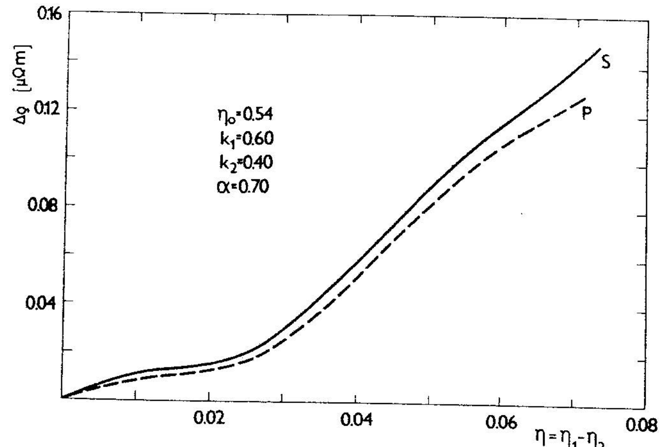

Fig. 2b

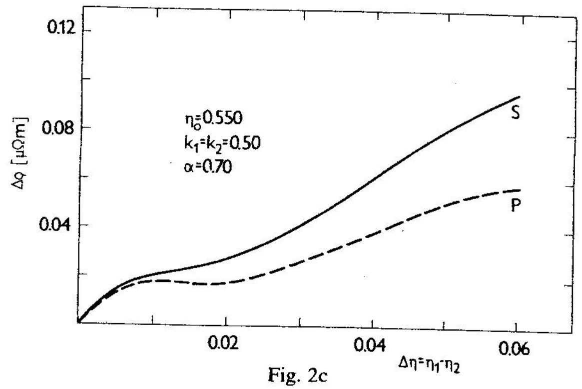

Fig. 2c

Let η_0 be the packing density parameter of a homogeneous amorphous structure (before irradiation) and η_1, η_2, k_1, k_2 are the packing density parameters of the inhomogeneous structure (after irradiation) and the concentrations of the regions, respectively. Then we easily obtain

$$\frac{k_1}{\eta_1} + \frac{k_2}{\eta_2} = \frac{1}{\eta_0}. \tag{1}$$

The resulting resistivity $\varrho(\eta_1, \eta_2, \alpha)$ of the inhomogeneous amorphous structure is assumed to be between $\varrho_p(\eta_1, \eta_2, \alpha)$ and $\varrho_s(\eta_1, \eta_2, \alpha)$, where

$$\frac{1}{\varrho_p(\eta_1, \eta_2, \alpha)} = \frac{k_1}{\varrho(\eta_1, \alpha)} + \frac{k_2}{\varrho(\eta_2, \alpha)} \tag{2a}$$

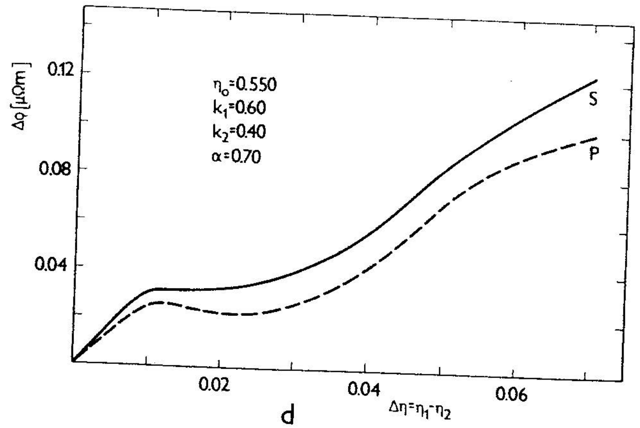

Fig. 2. The change of the electrical resistivity $\Delta\varrho(\Delta\eta, \alpha) = \varrho_{s,p}((\eta_1, \eta_2, \alpha) - \varrho(\eta_0, \alpha)$ as a function of the packing density parameter difference $\Delta\eta = \eta_1 - \eta_2$, $\varrho(\eta_0 = 0.55, \alpha = 0.70) = 1.10\ \mu\Omega m$. $\varrho(\eta_0 = 0.54, \alpha = 0.70) = 1.03\ \mu\Omega m$.

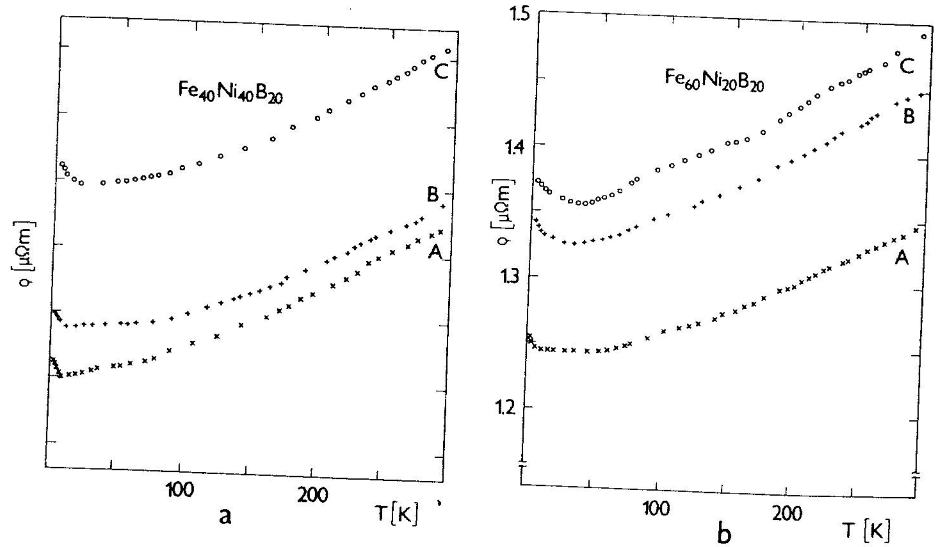

Fig. 3. The temperature dependence of the electrical resistivity of the amorphous Fe-Ni-B system. A — not irradiated, B — irradiated with the fluence $5 \,.\, 10^{17}$ n/cm^2, C — 10^{18} n/cm^2.

$$\varrho_s(\eta_1, \eta_2, \alpha) = k_1\varrho(\eta_1, \alpha) + k_2\varrho(\eta_2, \alpha) \tag{2b}$$

and

$$\varrho_p(\eta_1, \eta_2, \alpha) \leqq \varrho(\eta_1, \eta_2, \alpha) \leqq \varrho_s(\eta_1, \eta_2, \alpha)\,. \tag{3}$$

The change of the electric wave vector on the region boundaries is usually $\Delta k \sim 2\pi/a \approx 0{,}003\ \mathrm{nm}^{-1} \ll 2k_F$ (a is a dimension of regions ≈ 20—35 nm) therefore we do not consider the contribution to the electrical resistivity on the scattering of the regions. Fig. 2 shows the change of the electrical resistivity $\Delta\varrho(\Delta\eta, \alpha) = \varrho_{s,p}(\eta_1, \eta_2, \alpha) - \varrho(\eta_0, \alpha)$ as a function $\Delta\eta = \eta_1 - \eta_2$ for the typical values α, k_1, k_2 of the amorphous Fe-Ni-B system. The temperature dependence of the electrical resistivity of the amorphous Fe-Ni-B system before and after irradiation is shown in Fig. 3. From our model we can suppose that with the increasing dose of irradiation there increases the density difference between regions.

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