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Galvanomagnetic Effects in Shock-deformed Iron Alloys

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ABSTRACT

The transverse magnetoresistivity of annealed and shock-deformed Fe, Fe-7·37 wt. % Mn and Fe-30 wt. % Ni was measured as a function of $\mathbf{B}/\rho_0$. The deformed material yields a curve which is in general shifted from the annealed metal. The shift in Fe is due to anisotropic scattering of conduction electrons by dislocations. In Fe–Ni and Fe–Mn the shift can be explained by a shock-induced second-order phase transformation occurring above 90 kbars.

§ 1. INTRODUCTION

RESISTIVITY and magnetoresistivity experiments render information on the effects of lattice defects on conduction electrons (Van Bueren 1967). Defects such as vacancies and interstitials are essentially isotropic scatterers, and will therefore diminish only the free path of the conduction electrons. It is well known that isotropic scattering centres reduce the absolute magnitude of the magnetoresistance, but their presence remains undetected in the Kohler diagram. Kohler (1938) has shown that if scattering of conduction electrons by the lattice can be described by a single isotropic relaxation time τ, then $\Delta\rho/\rho(0)$ will be a function of $H/\rho(0)$ only, where H is the applied field and $\rho(0)$ is the initial resistivity. Magnetoresistance measurements in alloys can provide information concerning the structures of Brillouin zones as well as transformations such as phase changes and precipitation from solid solution.

The Kohler curve is a characteristic of the metal and only by destroying the isotropy of τ are deviations from the Kohler curve obtained. The presence of anisotropic scatterers should show up in the magnetoresistivity of shock-deformed metals, since line defects have been generated with anisotropic strain fields around them (Cottrell 1953). The high density of dislocations is expected to result in a distortion of crystal symmetry. The effects of shock waves on the residual magnetic properties of iron have been investigated by Rose, Villere and Berger (1969). Kressel and Brown (1967) have studied changes in resistivity properties of shock-deformed metals. However, changes in magnetoresistivity characteristics have never been observed in shocked material.

Table 1. Chemical composition of materials investigated (wt. %)

	Mn	Ni	C	O	Cu	Quench temperature
Fe–Mn	7·37	0·0120	0·0015	—	—	900°C
Fe–Ni	—	30·0200	0·0014	0·030	0·010	850°C
Fe	—	0·0015	0·0014	0·025	0·031	—

Note : each metal was analysed for Si, Zr, B, Al, Sn, Nb, Co, Ti, Mo, V—all of which were undetected.

It is the purpose of the present investigation to report our magneto-resistivity studies of polycrystalline Fe, Fe–Mn and Fe–Ni. We have related our experimental results for pure Fe to anisotropic scattering due to the presence of dislocations. The results of Fe–Mn and Fe–Ni have been related to magnetic phase changes and the presence of a high density of dislocations. The alloys studied were prepared using electrolytic iron (99·9 + % purity) whose electrical resistivity at 14°K was found to be about 0·27 $\mu\Omega$-cm. The compositions of the metals studied with initial heat treatment are shown in table 1. It is emphasized that the heat treatment of the Fe–Mn and Fe–Ni alloys resulted in a two-phase structure (α and martensitic α') prior to shock loading. The increase of the total free energy due to shock loading at pressures between 90 and 150 kbars has induced a martensitic ($\alpha \rightarrow \epsilon$) transformation to take place.

§ 2. Experimental Details

The flying plate technique (Duval and Fowles 1963) was used in shock loading, allowing for both the magnitude and geometry of the pressure pulse to be controlled by the driver plate thickness. Table 2 contains the parameters of the shock-loading experiments. The specimens for galvanomagnetic measurements were in the form of thin rectangular samples 1 mm wide, spark cut from a thin foil 3 cm by 3 cm. Prior to shock loading the iron specimens were annealed for ½ hour at 600°C. This produced the desired grain diameter.

Table 2. Shock-loading parameters

Shock pressure (kbars)	Particle velocity (cm/sec)	Driver plate velocity (cm/sec)	Linear strain
90	0·024	0·048	0·0432
150	0·038	0·076	0·0454
300	0·077	0·145	0·0926
500	0·092	0·184	0·1159