THE ANOMALOUS HALL EFFECT IN AMORPHOUS $(FeCoNi)_{78}B_{12}Si_{10}$ ALLOYS

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Abstract:

The Hall resistivity and electrical resistivity of amorphous ferromagnetic $(FeCoNi)_{78}B_{12}Si_{10}$ *alloys have been measured from 77 to 420K. A continous increase of the anomalous Hall coefficient* R_s *with temperature has been observed.* R_s *varies as* ρ^n *where n ranges from 4 for Co-rich alloys to 2 for FeNi alloys.*

One of the characteristic features of amorphous ferromagnetic alloys, as compared to the crystaline ones, is large anomalous or spontaneous Hall effect. This is a direct consequence of the high resistivity of these alloys. It is generally accepted[1,2] that in strongly disordered transition metal alloys the main contribution to the anomalous Hall effect comes from the side-jump mechanism (proposed by L. Berger[3]) that leads to ρ^2 dependence of the anomalous Hall coefficient R_s. The experimental confirmation of this dependence is somewhat difficult in amorphous alloys because relative changes of resistivity and R_s are very smalll. Therefore very accurate determination of R_s is required in order to deduce the correlation between R_s and ρ. Here we report this correlation for $Fe_xCo_{78-x}B_{12}Si_{10}$ $(0 \leqslant x \leqslant 78)$ and $Fe_xNi_{78-x}B_{12}Si_{10}$ (x = 23, 39 and 55) alloys.

The Hall resistivity ρ_H (in magnetic field up to 0.8T) and electrical resustivity have been measured from 77 to 420K. All our alloys are ferromagnetic with the Curie temperatures above 420K except $Fe_{23}Ni_{55}B_{12}Si_{10}$ alloy whose T_c is at 410K. The details concerning the sample preparation and the measurement technique were the same as reported earlier[4,5].

The Hall resistivity as a function of magnetic induction B for two alloys at three different temperatures is shown in figure 1. We note the small but significant increase in the initial slope of ρ_H vs B curves for increasing temperatures. The general behaviour of ρ_H for our alloy system as a function of magnetic field and temperature is shown in the inset to the figure 1. The initial slope increases with temperature but the higher field value decreases because of the decrease in the saturation magnetisation.

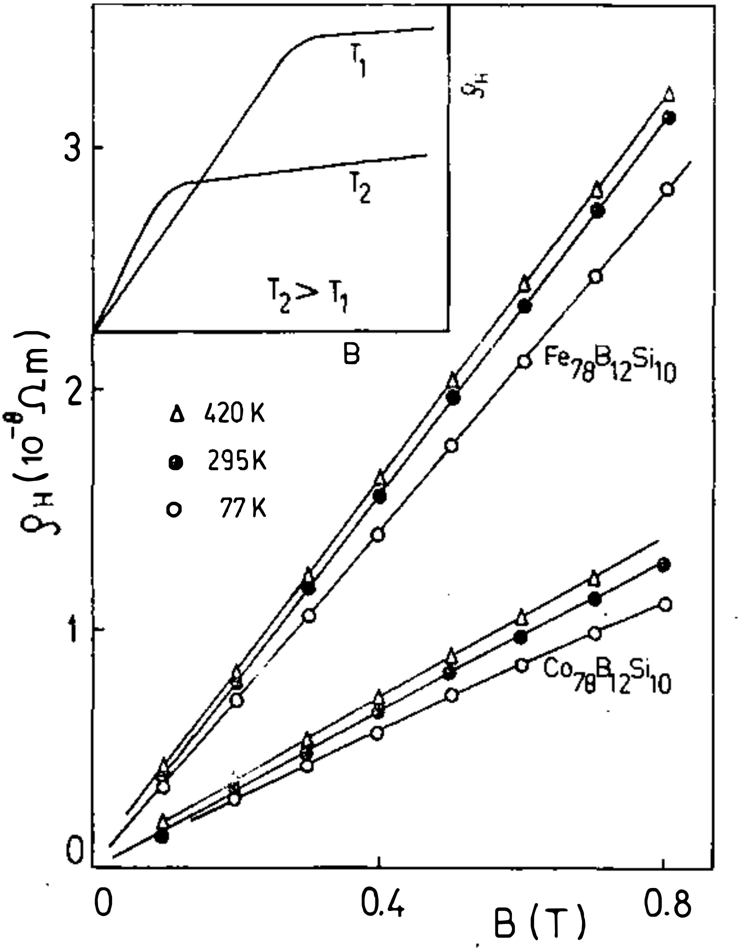

Figure 1.
The Hall resistivity as a function of magnetic field at three different temperatures

The initial slopes of ρ_H vs B curves for all our alloys are of the order $10^{-8} m^3 A^{-1} s^{-1}$. At the same time the normal Hall coefficient is expected to be equal to or lower than the free electron value[6,7] i.e. to be of the order $10^{-10} m^3 A^{-1} s^{-1}$. Hence we neglect the normal Hall coefficient and take $R_s = (\Delta\rho_H/\Delta B)_{B\to 0}$ as in ref. 5. The concentration dependence of the anomalous Hall coefficient for our alloys at 77K is shown in figure 3. We note that our values for $Fe_xCo_{78-x}B_{12}Si_{10}$ alloys are close to R_s values for $Fe_xCo_{80-x}B_{20}$ amorphous alloys reported by O'Handley[8]. It would be misleading however to correlate R_s and ρ for different alloys from our system because the differences in the band structure may influence R_s more than the resistivity does.

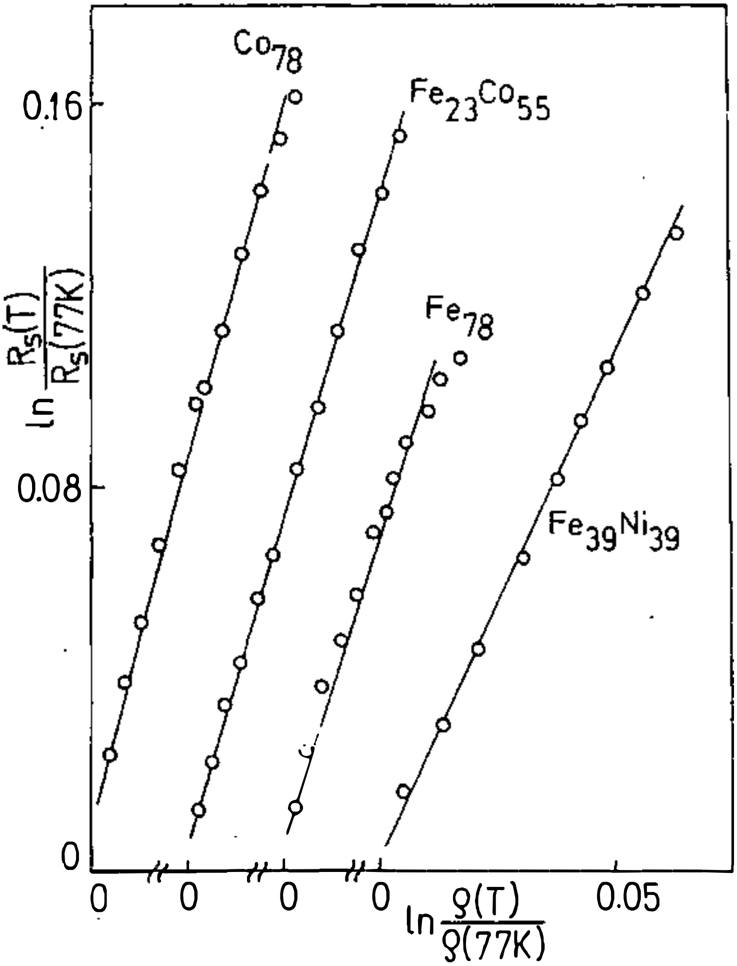

Figure 2.
Relative change of the anomalous Hall coefficient vs relative change of resistivity

We found that in all alloys R_s smouthly increase with temperature. The relative increase of R_s was about 10%. The behaviour in $Fe_{23}Ni_{55}B_{12}Si_{10}$ alloy and previously published data$^{4,5)}$ indicate that the anomalous Hall coefficient practically does not change on passing through T_c. However the tendency of R_s to saturate with temperature in Fe-rich alloys is observed.

In order to obtain the correlation between R_s and ρ we ploted 1n $(R_s(T)/R_s(77K))$ vs $\ln(\rho(T)/\rho(77K))$ as in figure 2. With the exception of Fe-rich alloys the variations of R_s wuth ρ can be well described by a power law $R_s \sim \rho^n$. The values for n are ploted in figure 3. If we take into account the problems mentioned before we can say that the results presented confirm (except for Co-rich alloys) predicted ρ^2 dependence of R_s. It would be premature however to state that Co-rich alloys violate the predicted$^{3)}$ behaviour. There is a possibility that in Co-rich alloys magnetisation has an anisotropy which va-

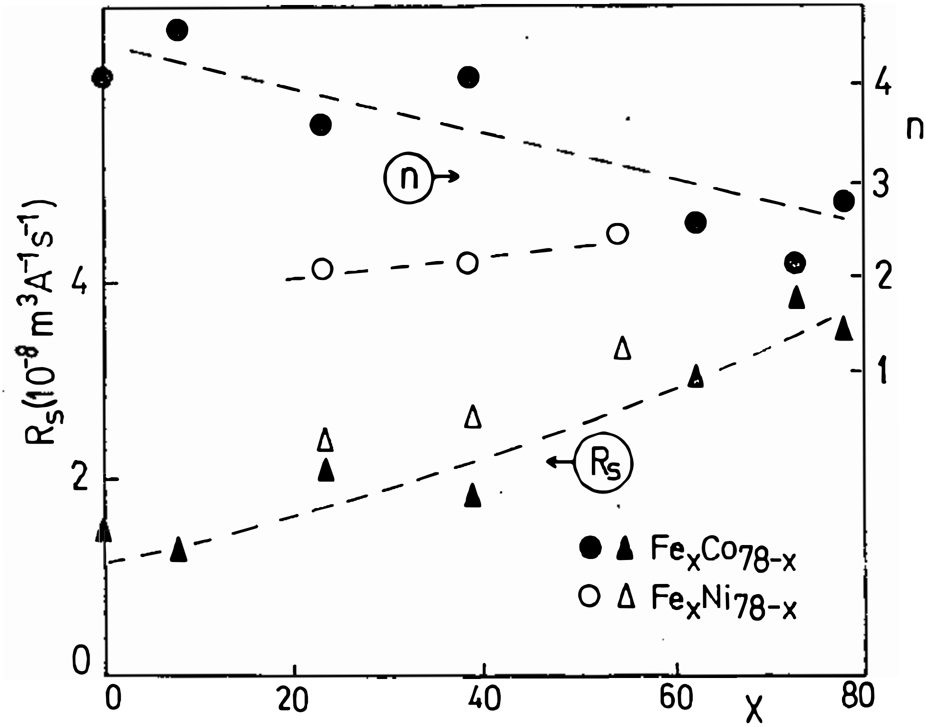

Figure 3
The concentration dependence of the anomalous Hall coefficient and exponent n from $R_s \sim \rho^n$ variation

ries with temmperature and can not be neglected. If this is the case than the proper determination of temperature dependence of R_s would require the knowledge of the temperature dependence of anisotropy. However accurate determination of a change in the magnetisation anisotropy with temperature is rather difficult and hence has to be left for the future.

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