Electric transport properties of a Ni-Mn-In alloy subjected to external stimuli

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Introduction:

Ni-Mn-In is an alloy mostly known as a prospective multicaloric material capable of a large modification of its structure and physical properties in response to magnetic, thermal or pressure stimuli. A study of transport properties in Ni-Mn-In alloys was designed to gain versatile information concerning the evolution of the electron spectrum during the transition between austenite (AP) and martensite (MP), the scattering mechanisms as well as the type, density and mobility of carriers in these structures. In addition, the effect of hydrostatic pressure on the transport properties at the martensitic transformation was investigated.

Methods:

The $Ni_{45.4}Mn_{40}In_{14.6}$ alloy was fabricated by induction melting in an argon atmosphere. The sample used for the resistivity, Hall effect (PPMS, Quantum Design) and magnetization (MPMS, Quantum Design) measurements featured a rectangular cross section of 2.17 mm x 0.72 mm x 0.35 mm. Simultaneous determination of longitudinal and Hall resistivities was performed by six terminal method using spot-welded 25 μm gold wires at different pressures in double-layered CuBe/NiCrAl piston-cylinder pressure cell. The ordinary and anomalous Hall constants (OHC and AHC) were determined from Hall resistivities and magnetization.

Results:

Figure 1. Temperature variation of Hall resistivity at different hydrostatic pressures

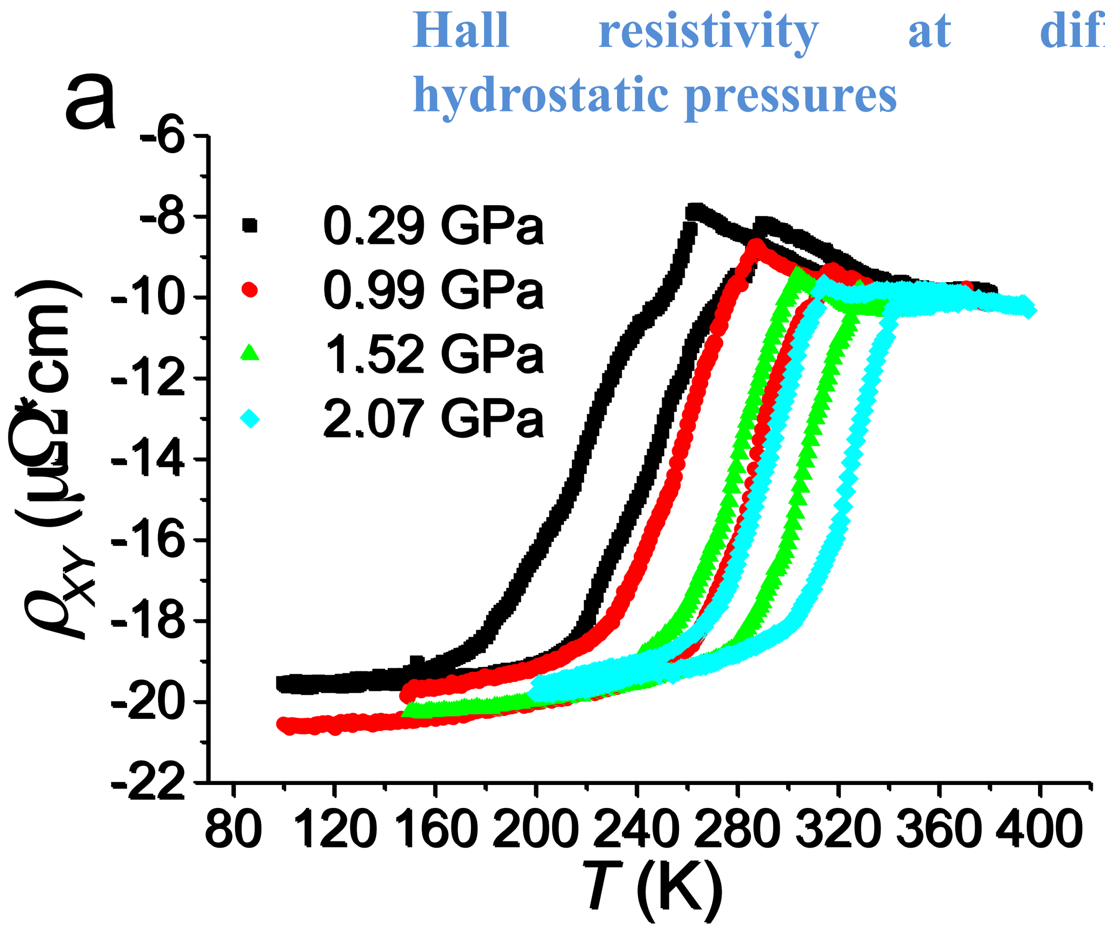


Figure 2. Temperature dependences of longitudinal resistivity in $Ni_{45.4}Mn_{40}In_{14.6}$ at different hydrostatic pressures. The inset shows the variation of the martensite start temperature with pressure.

dT/dP = 29 K/GPa

$dT/dP = \Delta V/\Delta S$

$\Delta V \sim 0.09\%$

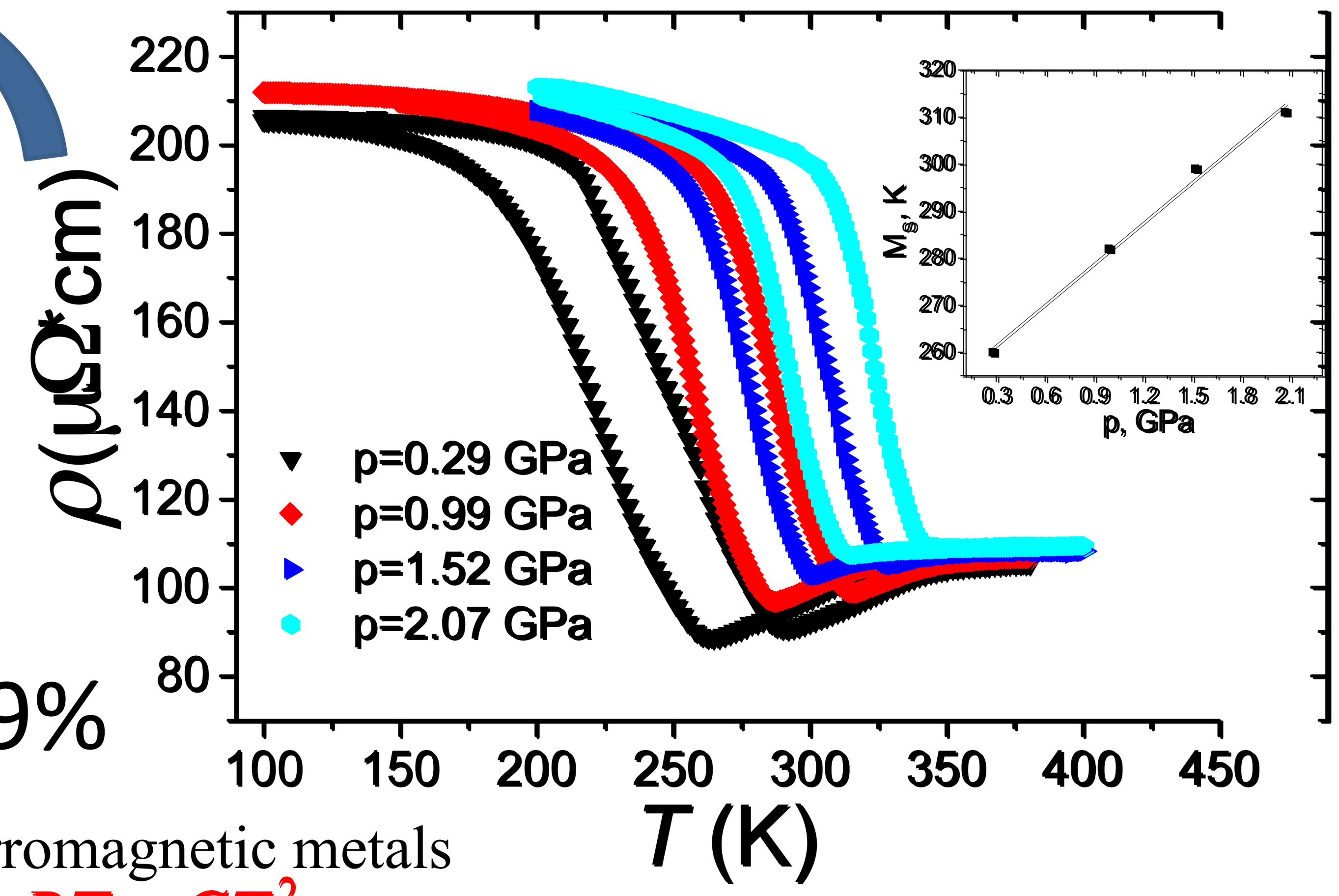
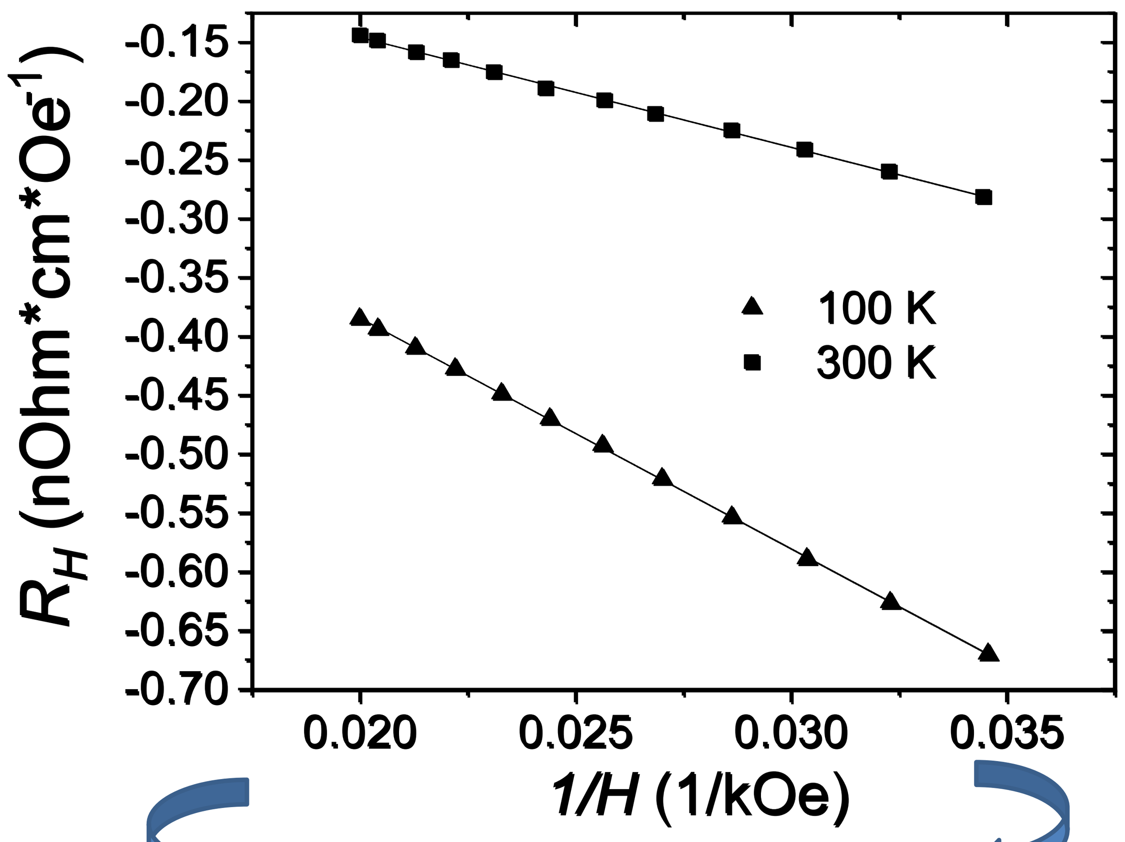


Figure 3. Hall resistivity of $Ni_{45.4}Mn_{40}In_{14.6}$ alloy per magnetic field unit as a function of reciprocal magnetic field at martensitic and austenitic temperatures fitted to a linear function to find OHC



INTERCEPT → R_0 (OHC)

SLOPE → R_{an} (AHC)

$n=1/R_0e$

$\mu=1/en\rho$

	R_0, Ω·cm/Oe	n, m^{-3}	μ, m^2/V·s	R_{an}, Ω·cm/Gs
AP, 300 K	4.1×10^{-11}	1.5×10^{27}	4.3×10^{-3}	-2×10^{-9}
MP, 100 K	8.2×10^{-12}	7.7×10^{27}	4×10^{-4}	-12×10^{-9}

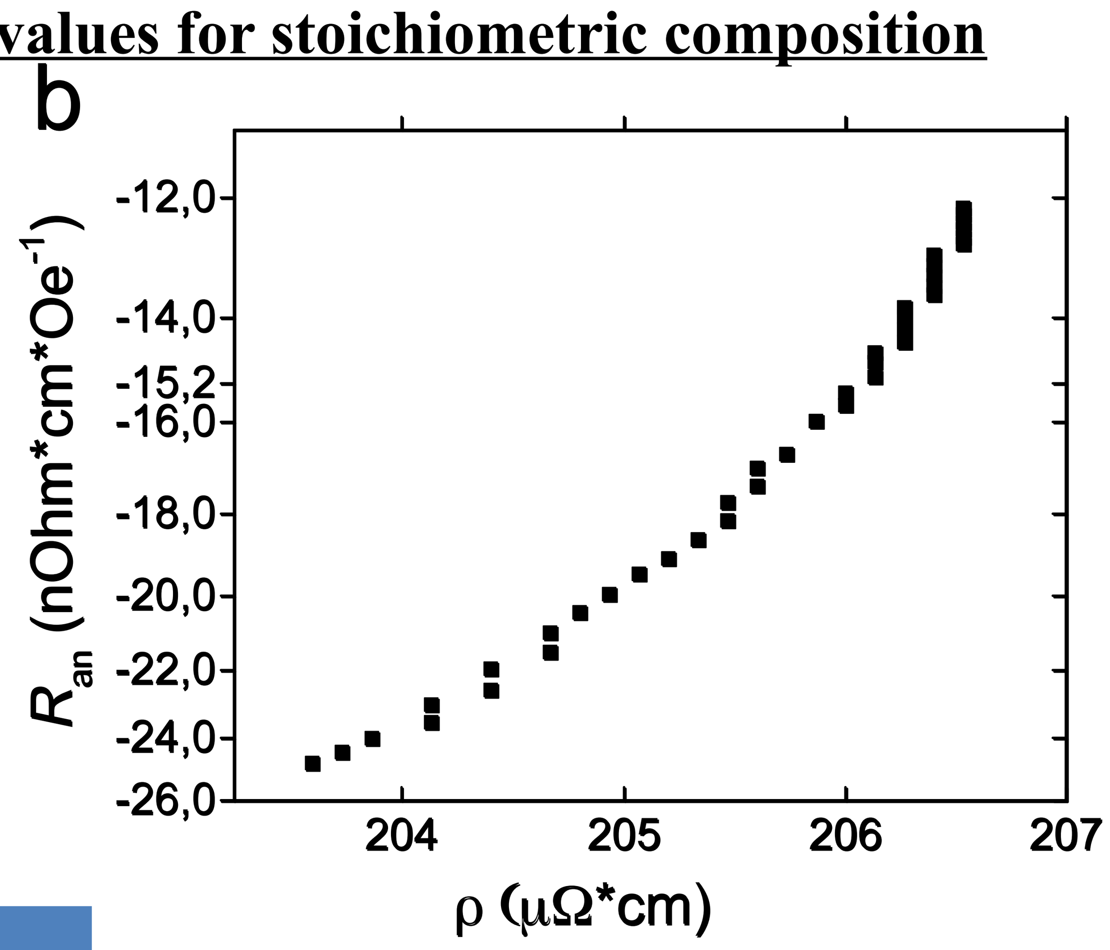
The electrical resistivity, ρ, of ferromagnetic metals

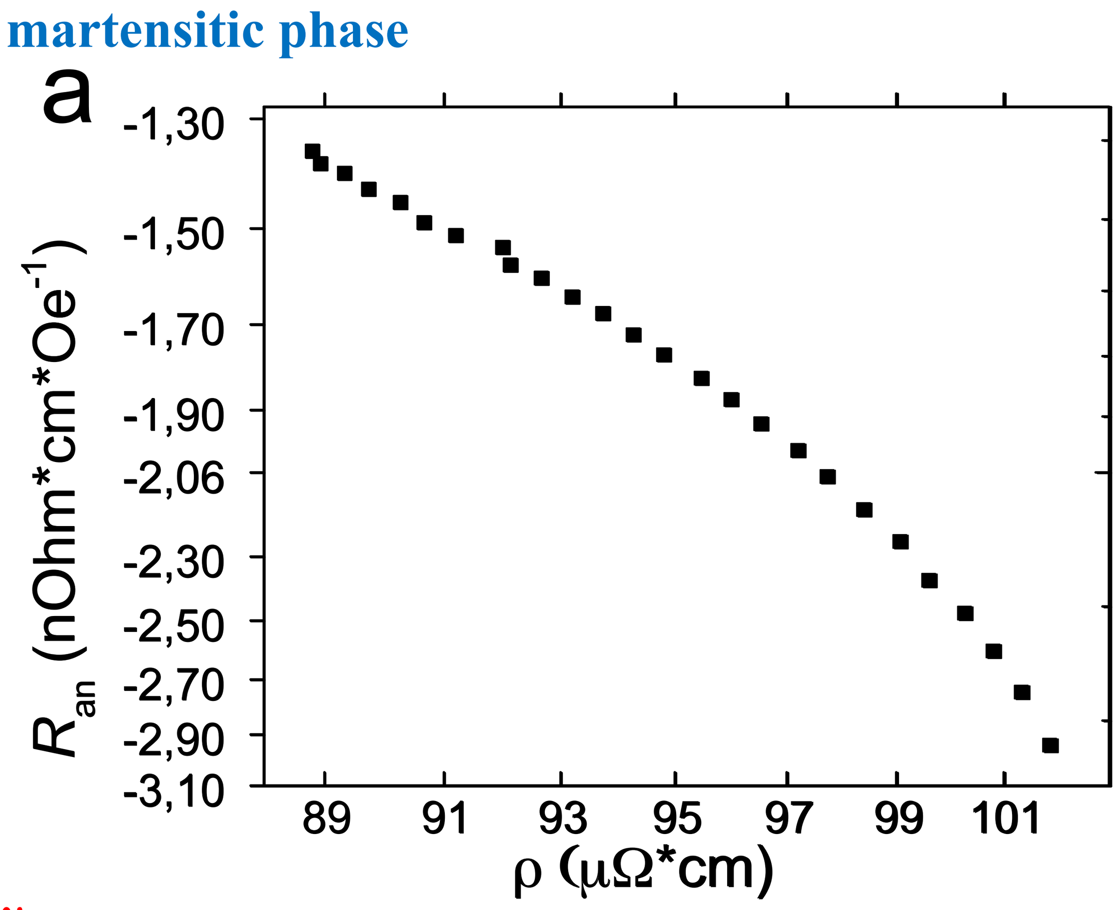
$$\rho = \rho_{res} + \rho_{ph} + \rho_m = A + BT + CT^2$$

- electron (hole) scattering by impurities and crystal imperfections
- scattering by phonons
- scattering by magnetic fluctuations

Fitting the temperature dependent resistivity (Fig.2) gives: $\rho_{ph} \sim 9$ μΩ·cm, $\rho_m \approx 44$ μΩ·cm, $\rho_{res} \approx 51$ μΩ·cm , **ρ_m is very close to theoretically predicted and experimental values for stoichiometric composition**

Figure 4. Relationship between longitudinal resistivity and AHC for the $Ni_{45.4}Mn_{40}In_{14.6}$ alloy in (a) the austenitic phase and (b) the martensitic phase





$$R_{an} = a\rho^{\gamma}$$

3 main mechanisms of AHE

- Intrinsic, **γ = 2**
- Side jump, **γ = 2**
- Skew scattering, **γ = 1**

But here γ~5.6!

- inhomogeneous magnetic structure in MP
- Closeness to T_C in AP

Conclusions:

- **Analysis of the temperature variation of resistivity for the selected pressure yielded thermal, magnetic and residual contributions to the resistivity of the austenitic phase The larger relative contribution of residual resistivity is explained by compositional disorder caused by excess Mn atoms.**
- **Application of hydrostatic pressure resulted in a twofold rise of the Hall resistivity in the vicinity of M_S due to pressure-induced MT. The holes are the main current carriers in the $Ni_{45.4}Mn_{40}In_{14.6}$ alloy. AHC demonstrated negative values over the whole temperature range of measurement while its magnitude in martensitic phase is almost order higher than in austenite.**
- **The unusual correlation between the Hall and the longitudinal resistivities can not be explained either by any of three main contributions into AHR or by combining them because of inhomogeneous magnetic structure of MP and the closeness to the Curie temperature in the austenitic phase.**