Journal of Magnetism and Magnetic Materials 104–107 (1992) 19–20
North-Holland

Magnetic and transport properties of UNiGa

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The electrical resistivity of UNiGa is strongly anisotropic and displays a dramatic decrease in magnetic fields above the metamagnetic transition. The negative $d\rho/dT$ observed above T_c can be attributed to AF correlations.

UNiGa belongs to the group of UTX compounds crystallizing in the hexagonal ZrNiAl-type structure. Magnetization measurements have indicated [1] an antiferromagnetic ground state whereas magnetic ordering with a net magnetization was observed at higher temperatures and/or in magnetic fields larger than a critical field B_c ($\simeq 1$ T). The related magnetic phase transitions are accompanied by distinct anomalies in the magnetization and also in the electrical resistivity [2]. The huge uniaxial anisotropy allows a description of the magnetism in UNiGa in terms of the Ising model with the U magnetic moments oriented along the hexagonal axis.

Preliminary neutron-diffraction experiments [3,4] indicate a low-temperature antiferromagnetic structure with a $6c$ periodicity [5]. Here, we report on electrical-resistivity measurements on a UNiGa single crystal in various magnetic fields.

The single crystal described in ref. [1] has been used for the present study. The $\rho(T)$ curves for two directions of the current $i \parallel c$ and $i \perp c$ (the low temperature part is shown in figs. 1b and 1c, respectively, in comparison with the $M(T)$ behaviour in fig. 1a) demonstrate the pronounced anisotropy of charge transport. The $\rho(T)$ curve for $i \parallel c$ at high temperatures is flat whereas an upturn develops with decreasing temperature below 80 K in zero magnetic field (see also fig. 2). This anomalous behaviour appears in the same temperature range as the deviation of $\chi(T)$ from the Curie–Weiss law [1] and can be suppressed by a sufficiently large magnetic field $B \parallel c$ (fig. 2). The still pronounced S-shape of the $M(B)$ curves observed in this temperature range indicates the existence of antiferromagnetic correlations, which may be responsible for the enhanced electrical resistivity. This explanation is corroborated by the regular resistivity behaviour (positive $d\rho/dT$) for the electric current within the ab-plane, where ferromagnetic correlations can be expected [5].

The magnetic phase transitions at $T_c = 38$ K (P → Ferri) and $T_N = 35$ K (Ferri → AF) are expressed in the electrical resistivity by a cusp and a minimum in

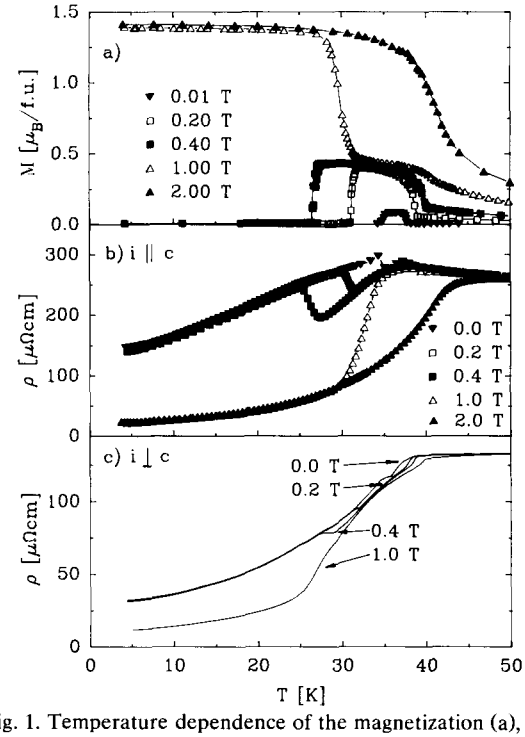

Fig. 1. Temperature dependence of the magnetization (a), the electrical resistivity for $i \parallel c$ (b) and $i \perp c$ (c) of the UNiGa single crystal in various magnetic fields $B \parallel c$.

$\rho(T)$, respectively [5]. The anomalies are much more pronounced for $i \parallel c$. The sharp discontinuity in $\rho(T)$ below T_N is reminiscent of the effect observed at the F → AF transition in $Ce(M,Fe)_2$ for M = Co or Al [6].

Dramatic changes of the electrical resistivity and the magnetization induced by magnetic fields $B \parallel c$ are seen in fig. 1. The anomaly connected with T_c is slowly shifted to higher temperatures whereas T_N is rapidly reduced. The discontinuity in $\rho(T)$ below T_N becomes gradually enhanced. For magnetic fields, in which the AF ordering is already absent, the resistivity behaviour resembles that found in ferromagnets. The residual

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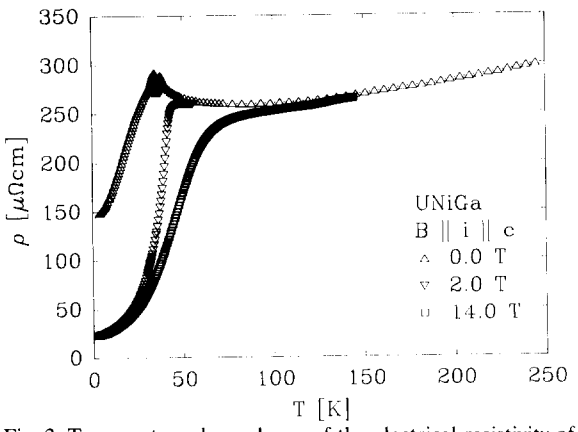

Fig. 2. Temperature dependence of the electrical resistivity of the UNiGa single crystal in $B = 0$, 2 and 14 T for $i \parallel B \parallel c$.

resistivity is then strongly reduced with respect to the value at the magnetic ordering temperature, $\{\rho(T_c) - \rho(0)\}/\rho(T_c) \simeq 90\%$ for both directions of the current.

Such a large effect is expressed by the precipitous drop in $\rho(B)$ at the metamagnetic transition found in $M(B)$ for $B \parallel c$ (fig. 3). The temperatures $T = 4.2$, 28, 34.5 and 40.6 K represent three of four characteristic regions:

(a) $T < 20$ K; a "simple" metamagnetic transition converts the AF phase directly to the F phase.

(b) $25 < T < 35$ K; the transition consists of two steps connected with AF → Ferri → F transitions.

(c) $35 < T < 38$ K; the Ferri state (AF state with a net magnetic moment) exists in zero field and the F state is reached in one single transition.

(d) $T > 38$ K; a still considerable decrease of ρ reflects the suppression of the upturn in $\rho(T)$.

The $\rho(T)$ curves remain unchanged in magnetic fields $B \perp c$ (≤ 1.5 T), which documents that the resistivity variations found for $B \parallel c$ are driven by magnetization changes.

The impact of antiferromagnetic ordering on the electrical resistivity is generally ascribed to gapping of the Fermi surface due to the occurrence of magnetic superzones [7]. However, in such a case the resistivity for the current perpendicular to the propagation vector of the AF structure is expected to remain nearly unaffected, which is not observed in UNiGa. We are, moreover, aware of an almost field independent γ-value [8], which makes interpretations in terms of any band-gap approach questionable.

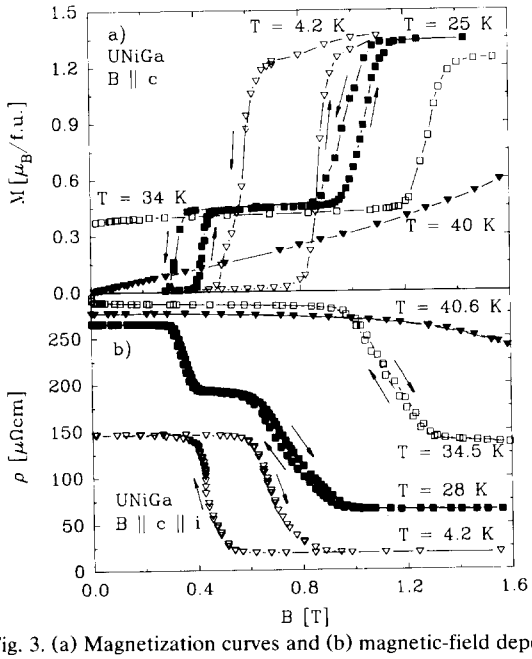

Fig. 3. (a) Magnetization curves and (b) magnetic-field dependence on the electrical resistivity of the UNiGa single crystal at various temperatures for $B \parallel c$ and $i \parallel c$.

This work is part of the research program of the "Stichting voor Fundamenteel Onderzoek der Materie (FOM)", which is financially supported by the "Nederlandse organisatie voor Wetenschappelijk Onderzoek (NWO)". The work of V.S. was kindly supported by the Japan Society for Promotion of Science.

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