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Effect of pressure on the magnetic phase transitions of UNiGa

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Abstract

Effect of pressure up to 22 kbar on the electrical resistivity of a single crystal of UNiGa has been studied from 4.2 K to room temperature in fields up to 5 T. The magnetic phase diagram is presented as a function of pressure and magnetic field.

UNiGa crystallizes in the hexagonal ZrNiAl-type structure and orders magnetically below 38.8 K. The complex magnetic phase diagram [1] of this compound contains four magnetic phase transitions at 38.8 K (to the antiferromagnetic phase, AF-1, with propagation vector $\boldsymbol{k}=\pm[0, 0, 0.360]$), 37.5 K (AF-2, $\boldsymbol{k}=\pm[0, 0, 1/3]$), 36.1 K (AF-3, $\boldsymbol{k}=\pm[0, 0, 1/8]$, $\pm[0, 0, 3/8]$) and 34.8 K (AF-4, $\boldsymbol{k}=\pm[0, 0, 1/6]$, $\pm[0, 0, 1/3]$, $\pm[0, 0, 1/2]$) in zero field and at ambient pressure [2, 3]. For the magnetic field along the *c* axis, the antiferromagnetic phases AF-1, AF-2 and AF-3 disappear and we obtain the ferrimagnetic phase AF-5 with propagation vector $\boldsymbol{k}=\pm[0,0,1/3]$ above $B=0.2$ T [3]. The magnetic phase transitions are reflected in pronounced anomalies in the electrical resistivity. We present results of electrical resistivity on a UNiGa single crystal as a function of temperature, pressure to 22 kbar and magnetic field to 2 T.

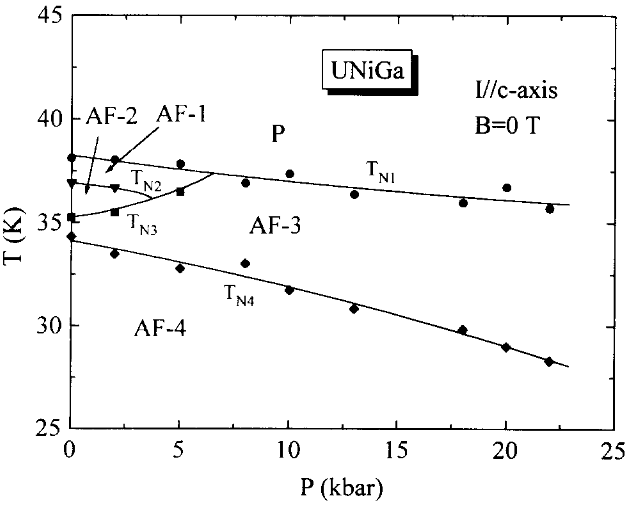

Fig. 1. Magnetic phase transition temperatures of UNiGa as functions of pressure for zero applied magnetic field.

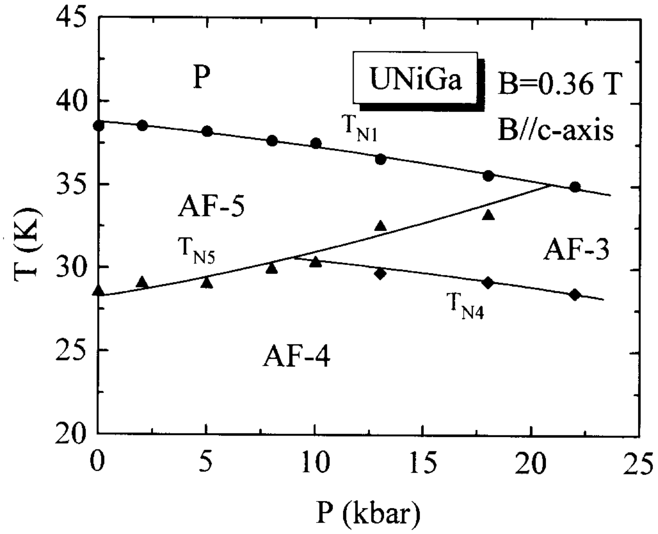

Fig. 2. Magnetic phase transition temperatures as functions of pressure for UNiGa in a 0.36 T magnetic field.

The single crystal of UNiGa was grown by a Czochralski technique in a tri-arc furnace. The electrical resistivity was measured by standard four-probe techniques. Hydrostatic pressure was generated using a Cu–Be pressure cylinder device and was kept constant throughout the experiment. Details of the high pressure apparatus have been described elsewhere [4].

Figure 1 shows the magnetic phase diagram as a function of pressure in zero field determined from electrical resistivity measurements. At 1 bar, there are four antiferromagnetic phases (AF-1, AF-2, AF-3 and AF-4). The AF-1 and AF-2 phases become unstable above 5 kbar on the account of the AF-3 phase. The

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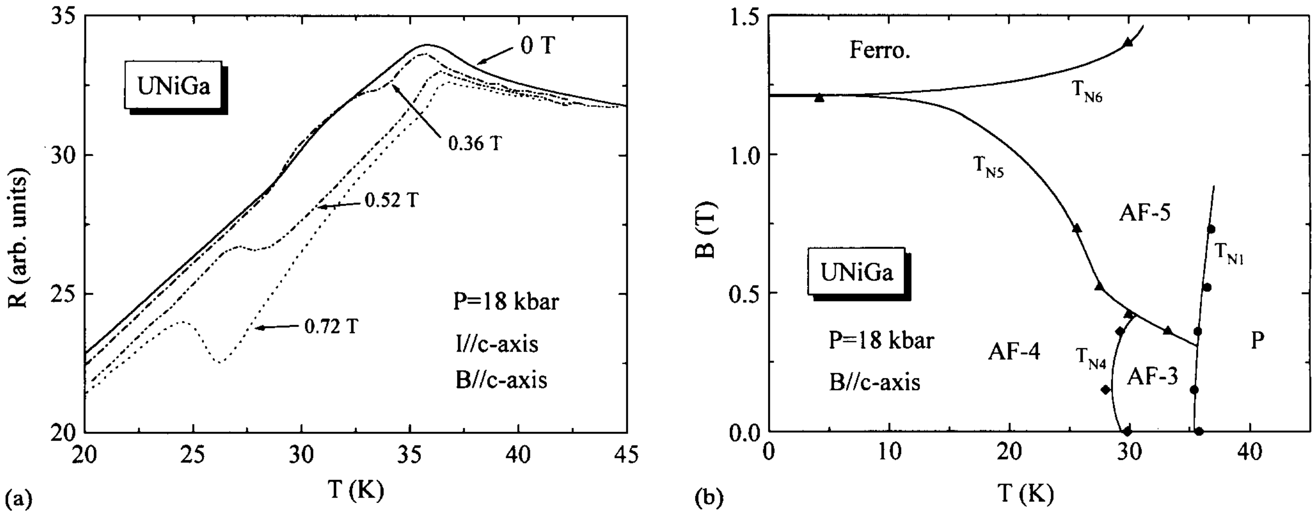

Fig. 3. (a) Electrical resistivity *vs.* temperature at various magnetic fields for a fixed pressure $P = 18$ kbar. (b) Magnetic phase diagram of UNiGa under high pressure. AF-5 is ferrimagnetic with propagation vector $\boldsymbol{k} = [0, 0, 1/3]$.

temperatures T_{N1} and T_{N4} of magnetic transition to AF-3 and AF-4 decrease with increasing pressure to 35.6 K and 27.5 K respectively at 22 kbar.

Figure 2 shows the *T–P* phase diagram for magnetic transitions in a constant magnetic field of 0.36 T applied parallel to the *c* axis. In this field the phases AF-1, AF-2 and AF-3 are absent at ambient pressure. At 1 bar the phases AF-5 and AF-4 are present. Above 10 kbar, phase AF-5 transforms into AF-3 with increasing pressure, as determined by its characteristic resistive signature. The magnetic transition temperature T_{N1} decreases with increasing pressure similar to the zero field curve (see Fig. 1).

Examples of temperature-dependent resistivity curves in various magnetic fields are given in Fig. 3(a) for $P = 18$ kbar. On the basis of the results in Fig. 3(a) we propose a magnetic phase diagram at 18 kbar as shown in Fig. 3(b). The phases AF-5 and AF-4 exist at ambient pressure. With applied pressure, the phase AF-5 becomes unstable and transforms to AF-3. The appearance of a ferromagnetic phase for $B > 1.2$ T is consistent with neutron scattering results at 1 bar [3].

In conclusion, we determined the phase diagram of UNiGa by electrical resistivity measurement under magnetic fields up to 5 T and high pressures to 22 kbar. The diagram is found to be consistent with that obtained by neutron diffraction. The above results can be understood as the promotion of the antiferromagnetic interactions along the *c* axis by external pressure.

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