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de Boer, F.R.; Havela, L.; Uwatoko, Y.; Bruck, E.H.; Oomi, G.; Sechovsky, V.

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Effect of pressure on magnetic transitions in UNiGa

V. Sechovský[a], L. Havela[a], F.R. de Boer[b], E. Brück[b], Y. Uwatoko[c] and G. Oomi[c]
[a]Department of Metal Physics, Charles University, Prague, Czechoslovakia
[b]Van der Waals–Zeeman Laboratory, University of Amsterdam, The Netherlands
[c]Department of Physics, Faculty of General Education, Kumamoto University, Japan

The influence of hydrostatic pressure up to 10 kbar on magnetic phase transitions in UNiGa was studied by means of studying electrical resistivity anomalies. The results indicate that the antiferromagnetic interactions along the c-axis of the hexagonal structure are promoted by pressure.

1. Introduction

UNiGa crystallizes in the ZrNiAl-type hexagonal structure. It exhibits a strong uniaxial magnetic anisotropy [1], which is reflected also in the distinct anisotropy of the electrical resistivity [2]. In zero magnetic field and at ambient pressure, collinear antiferromagnetic ordering below $T_N = 38.8$ K is observed. The magnetic phase diagram has been determined by analyzing neutron diffraction results [3,4]. Below T_N, we can find four AF phases (magnetic structures consisting of ferromagnetically coupled basal plane sheets with different + − stacking along the c-axis) separated by magnetic phase transitions at 37.5 (II), 36.1 (III) and 34.8 K (IV). When applying the magnetic field along the c-axis, magnetic structures yielding a net magnetization can be induced above a certain critical field, where a metamagnetic transition takes place. The magnetic phase transitions cause distinct anomalies in the temperature dependence of the electrical resistivity [2,4] as can be seen in fig. 1.

The complicated magnetic phase diagram reflects competing exchange interactions along the c-axis. The aim of the present work is to study the influence of external pressure on these phenomena.

2. Experimental

The single crystal of UNiGa was prepared by the Czochralski technique in a tri-arc furnace. Electrical resistivity was measured in fields up to 2 T at pressures up to 10 kbar using a standard four-probe method in a superconducting solenoid. Hydrostatic pressure was generated using a Cu–Be piston–cylinder device and a 1:1 mixture of kerosene and transformer oil as a pressure transmitting medium. The details of the high-pressure system were reported elsewhere [5].

Correspondence to: V. Sechovský, Department of Metal Physics, Charles University, Ke Karlovu 5, CS-121 16 Prague 2, Czechoslovakia.

3. Results and discussion

Figure 2 shows that the temperatures of all magnetic phase transitions in UNiGa in a zero field are gradually reduced with increasing pressure. Moreover, the dip in $\rho(T)$ is absent at 5 kbar and the monotonous resistivity change between anomalies I and IV indicates that phases 1 and 2 are no more stable (transitions II and III disappear) at higher pressures. In 10 kbar, the

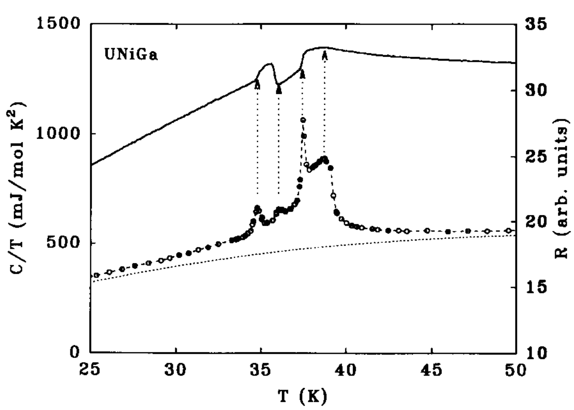

Fig. 1. Temperature dependences of the specific heat divided by temperature (C/T) (open symbols) and of the resistivity ρ for the current$\|$c-axis (full line) in UNiGa in the temperature range of several magnetic phase transitions.

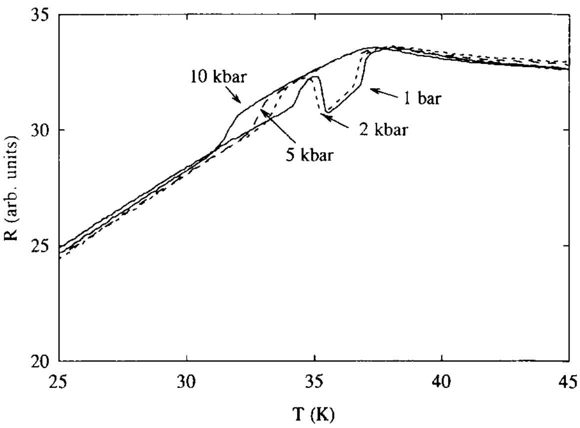

Fig. 2. Temperature dependences of the resistivity ρ (for the current$\|c$-axis) in UNiGa in the temperature range of several magnetic phase transitions measured under different external pressures.

AF phase 3 is established already below the magnetic ordering temperature (37.9 K) and exists down to 32.2 K where it transforms into the low-temperature AF structure – phase 4 (see fig. 3).

When measuring in 0.36 T applied parallel to the c-axis, the phases 1–3 are absent at ambient pressure and the ferrimagnetic phase (+ + −) is present between 35 and 39 K [1]. The external pressure tends to spread the ground state phase 4 to higher temperatures (see figs. 4 and 5). On the other hand, the negative effect on the magnetic ordering temperature is preserved ($\partial \ln T_c/\partial p \simeq -2.5\,\mathrm{Mbar}^{-1}$).

These results can be conceived with the promotion of AF interactions along the c-axis by external pressure. The strengthening of AF interactions due to increasing pressure is also well documented by increasing the critical fields of AF→F (see fig. 6) and

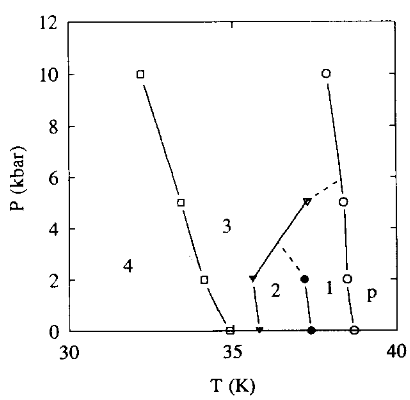

Fig. 3. The p–T magnetic phase diagram of UNiGa in a zero magnetic field.

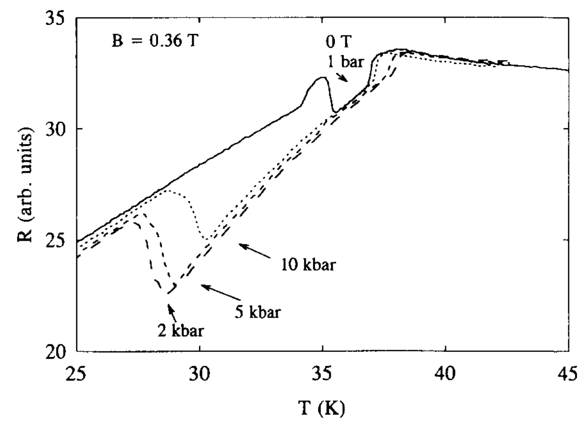

Fig. 4. Temperature dependences of the resistivity ρ (for the current$\|c$-axis) in UNiGa in a magnetic field of 0.36 T ($B\|c$-axis) in the temperature range of several magnetic phase transitions measured under different external pressures.

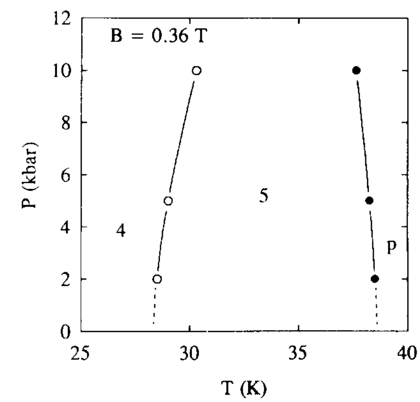

Fig. 5. The p–T magnetic phase diagram of UNiGa in a magnetic field 0.36 T ($B\|c$-axis).

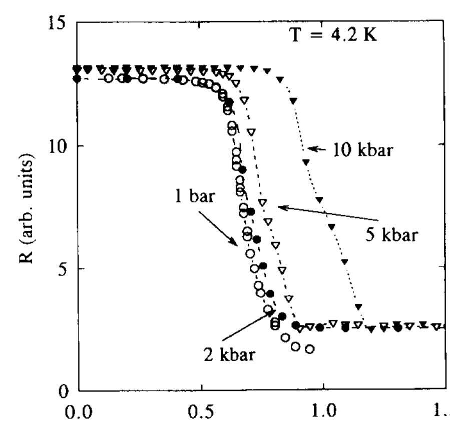

Fig. 6. Field dependences of the resistivity ρ (for the current$\|c$-axis) in UNiGa in the temperature range of several magnetic phase transitions measured under different external pressures.

AF→FI→F transitions with increasing pressure, which were revealed by our $\rho(B)$ measurements at different temperatures.

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References

[1] L. Havela, V. Sechovský, L. Jirman, F.R. de Boer and E. Brück, J. Appl. Phys. 69 (1991) 4813.
[2] V. Sechovský, L. Havela, L. Jirman, W. Ye, T. Takabatake, H. Fujii, E. Brück, F.R. de Boer and H. Nakotte, J. Appl. Phys. 70 (1991) 5794.
[3] P. Burlet, L. Jirman, V. Sechovský, L. Havela, M. Diviš, Y. Kergadallan, J.C. Spirlet, J. Rebizant, E. Brück, F.R. de Boer, H. Nakotte, T. Suzuki, T. Fujita and H. Maletta, in: Proc. 22 Journées des Actinides, Méribel 1992, eds. A. Blaise, P. Burlet and J.M. Fournier, CEN, Grenoble (1992) p. 125.
[4] V. Sechovský, L. Havela, F. R. de Boer, E. Brück, T. Suzuki, S. Ikeda, S. Nishigori and T. Fujita, Physica B 186–188 (1993) 775.
[5] Y. Uwatoko and G. Oomi, J. High Pressure Inst. 29 (1991) 318 (in Japanese).