HIGH PRESSURE APPARATUS FOR TRANSPORT PROPERTIES STUDY
IN HIGH MAGNETIC FIELD

F. HONDA and V. SECHOVSKÝ

Department of Electronic Structures, Charles University, 121 16 Prague 2,
The Czech Republic
E-mail: sech@mag.mff.cuni.cz

O. MIKULINA and J. KAMARÁD

Institute of Physics, Academy of Sciences of CR, 182 21 Prague 8, The Czech Republic
E-mail: kamarad@fzu.cz

A. M. ALSMADI and H. NAKOTTE

Physics Department, New Mexico State University, Las Cruces, NM88003, USA
E-mail: hnakotte@nmsu.edu

A. H. LACERDA

National High Magnetic Field Laboratory, LANL, MS E 536 Los Alamos, NM87545, USA
E-mail: lacerda@lanl.gov

We have designed a high pressure apparatus for measuring electrical-transport properties at
low temperatures, high magnetic field and hydrostatic pressure up to 10 kbar. Details of the
high-pressure cell and an exemplary study on UNiAl are described and discussed briefly.

1 Introduction

The measurement of physical properties of solids in multi-extreme conditions, under
high-pressure, low temperature and high magnetic field, occupies attention in many
fields of science and engineering. At multi-extreme conditions, the relationship of
atom configuration and electronic structure can be tested and, moreover, there is a
chance that some induced exotic electronic states can become a seed of new
phenomena. Here, we describe the design and operation of the high-pressure
apparatus for electrical-transport properties measurements under hydrostatic
pressure to 10 kbar and magnetic field to 20 Tesla at low temperatures. We will
discuss recent results of relevant pressure measurement of the electrical resistivity
of the UNiAl single crystal.
2 Experimental procedure

The schematic picture of hydrostatic high-pressure CuBe cell, which we designed and build for the 20-T superconducting magnet at the Pulse Field Facility, NHMFL, LANL, is shown in Fig.1. This clamped high-pressure cell can be put into the $^4$He cryostat with 20-T superconducting magnet. The sample (4) is placed in a chamber with inner diameter of 7 mm and height of 30 mm. The chamber is filled by a liquid pressure transmitting medium (mineral oil). The sample space is closed by piston (2) and obturator (10) and sealed by rubber (3) and copper (9) sealing rings. Copper wires are sealed by epoxy resin in the obturator for measuring the electrical resistance of two samples and manganin manometer (5) by standard AC four probe method. For the electrical-transport studies, we typically use gold or copper wires of 50 μm in diameter which are glued by silver paste on the surface of the metallic samples to ensure reliable electrical contacts even under the extreme conditions.

Figure 2: Pressure variation of $\Delta P=P(T)-P_{RT}$, ($P_{RT}$=10 kbar) inside the pressure cell with respect to temperature.

Due to different thermal expansion of the pressure medium and the CuBe bronze, the pressure inside the clamped cell decreases with decreasing temperature. The actual pressure at any given temperature is determined by measuring the
electrical resistance of a manganin wire. The pressure coefficient of the manganin resistance is almost constant (+ 2.465×10^{-3} \text{kbar}^{-1}) for the temperature range of interest (1.5-300 K), and the measured change of pressure as a function of temperature with mineral oil as a pressure medium is shown in Fig. 2. Pressure decreases gradually of about 2.6 kbar as the cell filled by mineral oil is cooled from room temperature to 50 K. For temperatures below 50 K, any further pressure decrease is practically negligible. Compared to mineral oil as a pressure medium, a substantially large pressure decrease of about 4 kbar was found if Fluorinert FC-77 is used (see Fig.2).

Next, we present an exemplary study on UNiAl at multi-extreme conditions using the high-pressure apparatus described above.

3 Magnetoresistance of UNiAl at high pressures

UNiAl belongs to isostructural UTX (T = transition metal, X = p-electron metal) compounds crystallizing in the hexagonal ZrNiAl-type structure. UNiAl is an itinerant 5f-electron antiferromagnet with $T_N = 19.3$ K. At low temperatures, this material undergoes a metamagnetic transition to a high-field ferromagnetic state for magnetic fields applied along the c-axis, and $B_c = 11.35$ T at 1.7 K. We measured low temperature electrical resistance on single crystalline UNiAl under hydrostatic pressures to 10 kbar and in magnetic field to 18 T in a wide range of temperature in order to clarify the effect of pressure onto the electronic structure in this material.

The temperature dependence of the electrical resistance, $R$, of UNiAl at 0 kbar and 10 kbar is displayed in Fig.3. At ambient pressure, $R(T)$ in 10 T ($< B_c$) shows anomaly around $T_N$, and it can be ascribed to a magnetic scattering due to strong antiferromagnetic (AF) correlations. The resistance anomaly around $T_N$ is sharpens with increasing magnetic field until reaching $B_c$, above which $R(T)$ decreases monotonically with decreasing temperature. UNiAl exhibits giant magnetoresistance (GMR) effects at the metamagnetic transition. At 1.5 K, the GMR effect is as large as 80%. On the hand, large magnetoresistance effects were found to exist also well
above $T_N$ (ex. 14% GMR at 30 K, 18 T), which supports the idea that AF correlations are suppressed by an applied magnetic field.

Under hydrostatic pressure of 10 kbar (room-temperature value), we find that the anomaly at $T_N$ broadens and shifts to the lower temperature which is in good agreement with previous data.\textsuperscript{3,4} Compared to the ambient-pressure results, the GMR effect in the antiferromagnetic and paramagnetic states were found to be somewhat reduced. Thus, we speculate that AF correlations are suppressed by increased $f$-$d$ hybridization due to pressure, and a detailed analysis is in progress.

We have constructed a high-pressure apparatus that can be used with a large superconducting magnet. As an example, the resistivity of the single crystals of UNiAl has been measured under multi-extreme conditions (high pressure, high magnetic field, low temperature).

To better understand the nature of the magnetic correlations under pressure in this material measurements at higher pressure (to 30 kbar) and lower temperatures (down to 20 mK) are now under development.

This work is partly supported by the Grant Agency of the Czech Republic (grant number: D202/01/D045). The work was also supported by a grant from NSF (grant number: DMR-0094241). Work at the National High Magnetic Field Laboratory in Los Alamos was performed under the auspices of the NSF (INT-9722777), the US Department of Energy and the State of Florida.

References