Magnetic phase transitions in \( \text{NdCu}_2 \) under pressure

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Abstract

The electrical resistivity on a \( \text{NdCu}_2 \) single crystal was measured as a function of temperature, hydrostatic pressure and magnetic field. At ambient pressure, a complex phase diagram with \( T_N=5.86\text{\,K} \) and two spin reorientation temperatures of \( T_{R1}=3.78\text{\,K} \) and \( T_{R2}=3.25\text{\,K} \) is found. Under external pressure, \( T_N, T_{R1} \) and \( T_{R2} \) decrease by increasing pressure, and \( T_{R2} \) vanishes under 9 kbar. In the field dependence of the magnetoresistance, we find anomalies at three metamagnetic transitions, which under pressure are initially shifted to lower values but increase again for pressures beyond 5 kbar.

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\( \text{NdCu}_2 \) crystallizes in the orthorhombic CeCu\textsubscript{2}-type structure and is known to exhibit a complex magnetic (\( B-T \)) phase diagram, arising from the RKKY interaction in the presence of crystal field splitting \cite{1} and other methods \cite{2–6}. In zero magnetic field, there are three different magnetic phases \cite{1}. In all phases, however, the magnetic moments of Nd\textsuperscript{3+} ions are oriented along \( b \)-axis. For field applied along the crystallographic \( b \)-axis at low temperatures, initially three field-induced ferromagnetic phases \( F1-F3 \) were proposed \cite{1}, but later on Sugawara et al. \cite{3} proposed an even more complex phase diagram with 5 or more phases.

We measured the low-temperature electrical resistance on a good-quality single crystal of \( \text{NdCu}_2 \) under hydrostatic pressure up to 10 kbar and in magnetic field up to 18 T for a wide range of temperatures. The electrical resistivity was measured by means of a standard four-probe AC method using the 20-T superconducting magnet at the Pulse Field Facility, NHMFL, Los Alamos National Laboratory. Hydrostatic pressure was created using a Cu–Be pressure cell with mineral oil as a pressure-transmitting medium.

In Fig. 1, the low-temperature behavior of the electrical resistivities for currents applied along \( b \)- or \( c \)-axis are shown for selected pressures up to 9 kbar. At ambient pressure, three anomalies in the resistivity can be distinguished at low temperatures, indicating the Néel transition temperature at \( T_N=5.86\text{\,K} \) and two spin reorientation temperatures at \( T_{R1}=3.78 \) and \( T_{R2}=3.25\text{\,K} \), in good agreement with previous results \cite{3}. For both current directions, application of pressure causes a reduction of the ordering temperatures. In the case of \( i||c \)-axis, \( T_N, T_{R1} \) and \( T_{R2} \) are shifted to lower temperatures with increasing pressure at an approximate rate of \(-0.12, -0.08\) and \(-0.07\text{\,K/kbar} \), respectively. The second spin reorientation temperature \( T_{R2} \) either

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Fig. 1. Temperature dependence of the electrical resistivity at various applied pressures with current (a) parallel to \( c \)-axis and (b) parallel to the \( b \)-axis.

Fig. 2. Field dependence of the electrical resistivity at various applied pressures with an applied magnetic field parallel to the \( b \)-axis.
completely vanishes under 9 kbar or is shifted to temperature less than 2 K (the lowest temperature measured). For current applied along the $b$-axis, $T_{R2}$ vanishes for pressure above 3 kbar, and $T_{R1}$ is initially shifted to a higher value by increasing pressure but decreases again for pressure beyond 5 kbar. $T_N$ is shifted to lower values with increasing pressure at an approximate rate of $-0.09 \text{ K/kbar}$. Rough estimates of the critical pressure $P_C$ for $i||e$-axis and $i||b$-axis are 50 and 65 kbar, respectively.

The 2-K magnetoresistance (MR) curves of NdCu$_2$ for $B||b$-axis for various pressures are shown in Fig. 2. At ambient pressure, three metamagnetic transitions (MTs) are observed at 0.75, 2.42 and 2.88 T. Inspection of MR data in higher temperature region reveals that only two MTs can be observed for $T_{R1}<T<T_N$, while above $T_N$ no transition is found although a negative magnetoresistance effect (likely connected with the short range correlations) persists. The transition fields initially shift to lower values by increasing pressure, but increase again for pressure beyond 5 kbar. At 9 kbar, the second MT transition around 2.42 T vanishes, while the transitions at 0.75 and 3.2 T are still visible. This suggests a new antiferromagnetic (AF) phase between 0.75 and 3.2 T in 9 kbar.

From the anomalies in the resistivity and magnetoresistance of NdCu$_2$, we were able to construct the magnetic phase diagrams for field applied along the $b$-axis at ambient and under hydrostatic pressure of 9 kbar. The results are displayed in Fig. 3. At ambient pressure, the results are in good agreement with the previous result [4,6]. Under 9 kbar, the AF2 and one of the phases F1 or F2 seem to have vanished while all other phase boundaries are shifted to lower temperatures.

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References