Magnetic Transitions in $CeIrIn_5$

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Abstract

Results are presented on measurements of the magnetization of the heavy fermion superconductor $CeIrIn_5$ at 45 mK and DC magnetic fields up to 45 T. A metamagnetic transition is clearly seen at 29.5 T that is qualitatively similar to metamagnetic transitions reported by other groups. In addition, we also find a second magnetic transition at higher fields that exhibits significant hysteresis and has a pronounced ferromagnetic-like character that has not previously been observed in $CeIrIn_5$.

Key words: Heavy fermions ; Metamagnetic transition ; $CeIrIn_5$

1. Introduction

Recently a new class of Ce based heavy fermion materials was discovered that has become known as the "115s". These materials exhibit a rich variety of behaviors featuring superconductivity interacting with and possibly coexisting with magnetism as well as non-fermi liquid behavior and the possible existence of quantum critical points. The magnetic transitions in $CeIrIn_5$ that we report on here provide important clues that can help to further illuminate the physics behind the behavior of these materials.

2. Experimental

A $CeIrIn_5$ sample grown from flux was placed on a phosphor bronze cantilever magnetometer. This sample and cantilever were loaded into the portable top loading dilution refrigerator and 45 T hybrid magnet at the National High Magnetic Field Laboratory in Tallahassee. All of the data shown here were taken with the dilution refrigerator running at 45 mK. The c-axis of the sample was parallel to the magnetic field for all of the measurements. The same sample and cantilever had been used during a previous run in the portable dilution refrigerator and hybrid magnet with results that were qualitatively the same but had much poorer signal to noise.

It is worth noting that the cantilever magnetometer measures the torque created by the sample in the presence of a magnetic field. The cantilever magnetometer is an extremely sensitive detector of changes in magnetization, but unfortunately can be very difficult to calibrate. Therefore, all the data that we present will not have units for the magnetization.

3. Results

The magnetization of $CeIrIn_5$ from 20 T to 45 T is plotted in Figure 1. In all the traces measured there is a clear increase in the magnetization at 29.5 T. This metamagnetic transition (defined as a sudden increase in the magnetization of the sample under application of an external magnetic field B_{meta}) is qualitatively

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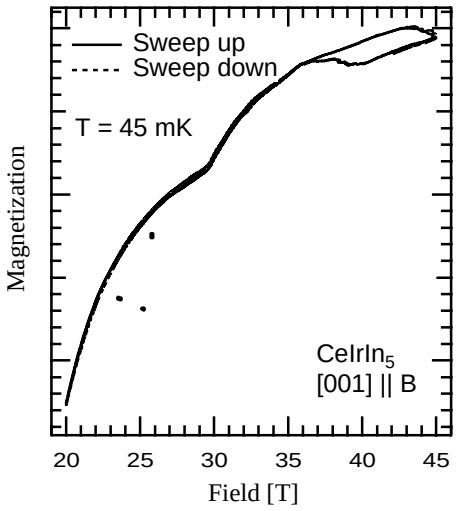

Fig. 1. The magnetization of $CeIrIn_5$ is shown. The solid lines show the magnetization data taken while sweeping the magnetic field away from zero and the dotted lines are data taken while sweeping toward zero. Clearly visible are a metamagnetic transition at 29.5 T and hysteretic behavior at the fields above 42 T.

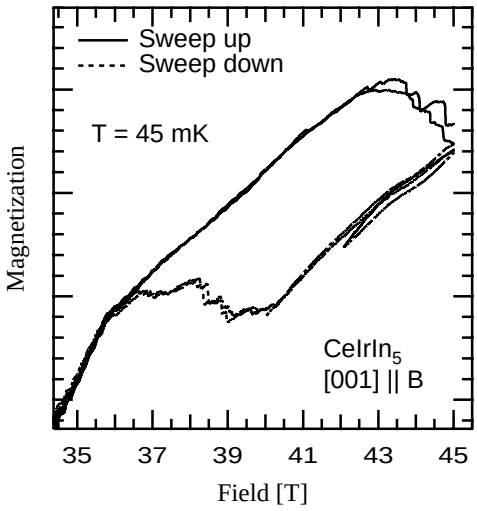

Fig. 2. The high field hysteresis present in $CeIrIn_5$ is shown in detail.

similar to the metamagnetic transition reported previously[1],[2]. Kim *et al.* performing heat capacity measurements also in the 45 T hybrid in Tallahassee, extrapolate from the lowest temperature they measured (1.6 K) to predict a zero temperature transition at $B_{meta} = 26$ T. This is in rough agreement with our results. They also find that this transition is probably a first order transition with a character somewhat similar to the metamagnetic transitions in URu_2Si_2. On the other hand Takeuchi *et al.* measured magnetic susceptibility using pulsed fields found a much higher transition at $B_{meta} = 42$ T.

At 38.7 T we observe another significant change in the magnetization of the sample that clearly has a different character than the metamagnetic transition described above (see figure 2). The slope of the magnetization decreases, then at 42.5 T the magnetization appears to saturate or even decrease slightly. If the field is swept down below 42.5 T, the magnetization retraces itself. However, if the field is swept to 45 T then decreased, the magnetization follows another trace that is parallel to the values during the upsweep. When the field was swept up, after sweeping to 45 T, the trace repeats itself again up to 45 T. During the down sweep, the slope approximates the same slope as when the field was swept up until 40 T is reached at which point the magnetization remains roughly constant until it reaches the initial transition point at 38.7 T. The origin of this ferromagnetic-like behavior is not known, although one may speculate that the two magnetic transitions may arise from the same mechanisms as the two magnetic phases seen by Murphy *et al.* [3] in $CeCoIn_5$.

In conclusion we have presented convincing evidence of two magnetic transitions present in $CeIrIn_5$ at low temperatures. Further measurements on the 115's are planned in order to fully explore the magnetization of these materials and its relationship to the unconventional superconductivity that has been shown to exist in these materials.

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References

[1] T. Takeuchi, T. Inoue, K. Sugiyama, D. Aoki, Y. Tokiwa, Y. Haga, K. Kindo, and Y. Onuki, J. Phys. Soc. Jpn. **70** (2001) 877.

[2] J. S. Kim, J. Alwood, P. Kumar, and G. R. Stewart, Phys. Rev. B **65** (2002) 174520.

[3] T. P. Murphy, D. Hall, E. C. Palm, S. W. Tozer, C. Petrovic, Z. Fisk, R. G. Goodrich, P. G. Pagliuso, J. L. Sarrao, J. D. Thompson, Phys. Rev. B **65** (2002) 100514.