Magnetic Properties of Pu-H_2

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Introduction

The absence of magnetism in pure Plutonium metal remains an enigma of modern science. Our current understanding suggests that the lack of magnetism is related to femto-second fluctuations of the 5f occupancy. [1] It is known that H doping induces a ferromagnetic ground state, possibly because H borrows electronic density from the Pu ions. [2] Here we explore Pu with extremely low H dopings of 1%. We determine whether such low H doping allows PuH_2 molecules to form, or whether H resides innocuously in the grain boundaries.

Experimental

Solid polycrystalline Ga stabilized Pu-239 samples were first purified at 450°C and then doped with H so that one atomic percent (1 at. %) of the sample is H_2. The sample was encapsulated in a Ti sample holder, and the magnetic properties of the samples were then characterized by use of a Vibrating Sample Magnetometer (VSM) in a Quantum Design Physical Properties Measurement System (PPMS) with a maximum applied magnetic field of 13 Tesla and base temperature of approximately 1.8 K.

Results

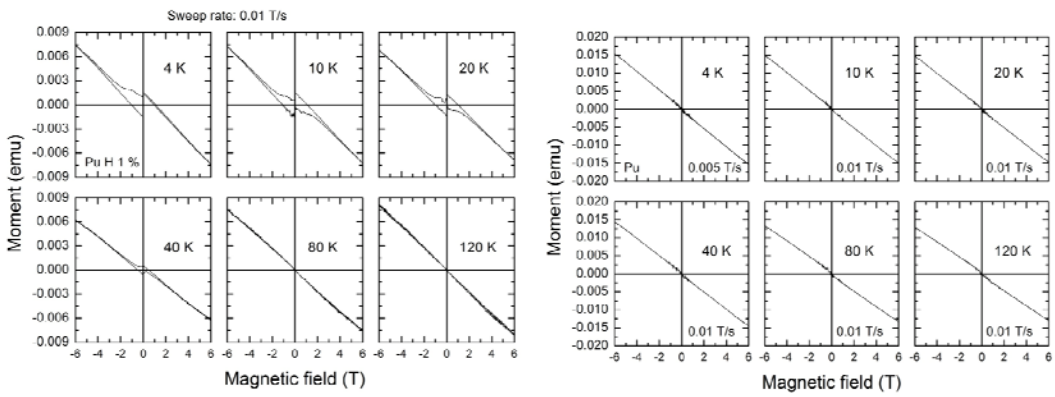

Figure 1 a) Fig. 1 Magnetic hysteresis loops of Ga-stabilized Pu with 1% H_2 doping. b) Magnetic hysteresis loops of the empty sample holder.

We find magnetic hysteresis in the Pu-H_2 sample that is absent in the empty sample holder. The hysteresis is observed at 40 K and below but not in 80 or 120 K traces, which is consistent with previous findings of a ferromagnetic Tc of ~50 K in PuH_2 (depending on the precise H concentration) [2]. Based on the magnitude of the magnetization, all of the H_2 molecules are forming PuH_2. Furthermore, if we assume that magnetic hysteresis is a property of magnetic domain flipping, as is the case for most ferromagnets, then the PuH_2 molecules must be clustering together to allow collective magnetic domain behavior.

Conclusions

Small H_2 dopings in Pu metal allow PuH_2 to form in clusters with magnetic hysteresis and ordering temperatures comparable to macroscopic PuH_2. Thus commercial magnetic measurements are a viable method for detecting small contaminations of H_2 in Pu.

Acknowledgements

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References

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