Investigation of Magnetism in UNi_2Ge_2 by Using X-ray Resonant Exchange Scattering

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Introduction

The experiment described in this activity report was carried out to establish the feasibility of x-ray resonant exchange scattering at the uranium M_4 absorption edge (E_{M4} = 3.725 keV) and M_5 absorption edge (E_{M5} = 3.55keV) at the Midwest Universities Collaborative Access Team (MU-CAT) sector 6 insertion device beamline at APS.

Methods and Materials

The sample, a single crystal of UNi_2Ge_2, was chosen because of its magnetic properties, namely a high Néel temperature T_N of 77K and a large effective moment μ_{eff} of ≈3.05 μ_B [1]. Single crystals of UNi_2Ge_2 were grown at Ames Laboratory by using a high-temperature flux technique [2]. The crystals are shaped as platelets, with the ***c*** axis perpendicular to the surface. For this magnetic x-ray diffraction experiment, the cleanest sample, without noticeable flux inclusions from the growth process, was chosen. The mosaic was measured to be 0.023° at the (008) reflection at 17 keV.

The experiment was carried out at the 6-ID undulator beamline at MU-CAT sector 6. A liquid-nitrogen-cooled, double-crystal Si(111) monochromator selects the photon energy. A 700-mm-long, bent, ultralow-expansion-glass mirror was set to vertically focus the beam at the sample and suppress the higher-order harmonics by about three orders of magnitude. A 300-mm-long Zerodur® mirror was used to further reduce the higher-order harmonics contamination.

The sample was mounted on a copper rod and encapsulated in a Be dome with He exchange gas to enhance thermal stability. The single crystal was oriented with the (*h*0*l*) zone in the scattering plane on the cold finger of a closed-cycle refrigerator.

Results

The crystal structure is *I*4/*mmm*, for which $h + k + l = 2n + 1$ reflections are forbidden. During the course of the experiment, intensity was systematically observed on forbidden reflections above T_N. This can be explained by intermixing of the Ni and Ge sites in the crystal, which would break the symmetry of the structure. Further investigation of this observation is under progress.

At the uranium M_4 edge E = 3.725 keV, the intensity of the forbidden (003) reflection shows temperature-dependent behavior. At 100K, above the T_N, the peak intensity of the reflection is about 9,350 counts/s. Upon cooling, the intensity remains constant until 77K, where it starts to increase up to 14,500 counts/s at 10K. At the same time, the peak intensity of the (002) reflection remains constant upon cooling.

Figure 1 shows the integrated intensity of the (003) reflection as a function of temperature. Long-range antiferromagnetic ordering, characterized by a wave vector of τ = (001), was observed at both uranium M_4 and M_5 edges below the T_N of 77K, consistent with the dc susceptibility measurements and previously reported neutron data [1, 3]. The energy profiles of both (002) and (003) are depicted in Fig. 2. The integrated intensity clearly shows a different behavior when the energy is scanned through the uranium absorption edge for the pure (002) charge and the magnetic (003) reflections. A model that includes the charge contamination on the forbidden reflections is being developed in order to understand these energy profiles.

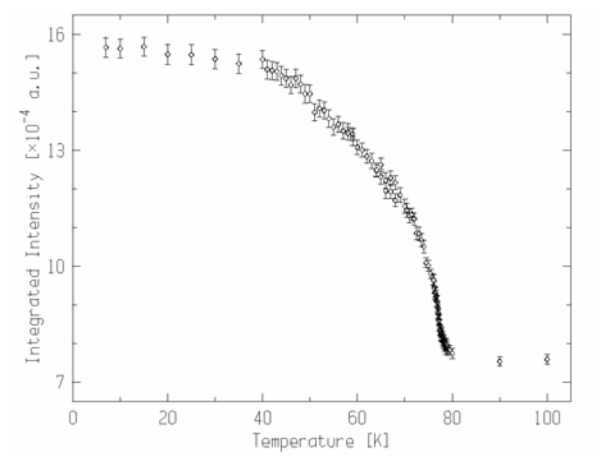

FIG. 1. Integrated intensity of the (003) reflection of UNi_2Ge_2 as a function of temperature at the uranium M_4 edge E = 3.725 keV.

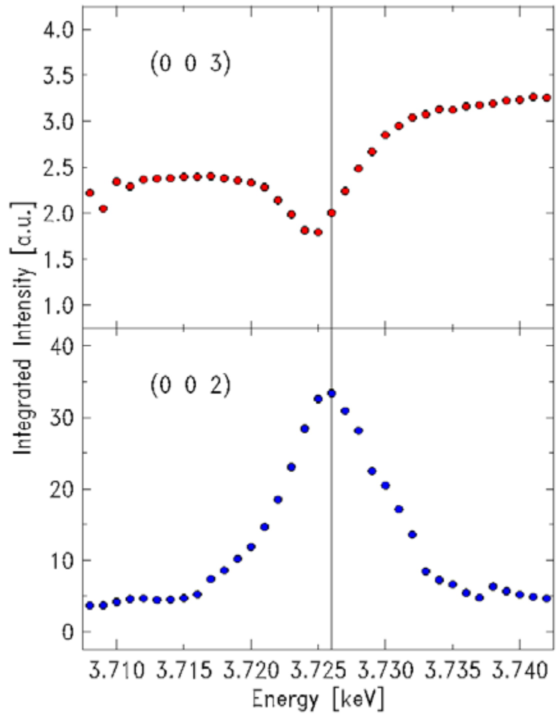

FIG. 2. Integrated intensity of the (003) (upper panel) and (002) (lower panel) reflections of UNi_2Ge_2 as a function of energy across the uranium M_4 edge in the low-temperature magnetic phase.

Because of the low energy of the edges, optimization of the flux in front of the sample is crucial. From an experimental point of view, further progress can be made to reduce the amount of absorption by air, Kapton®, and beryllium windows in order to study other uranium compounds with weaker magnetic interactions.

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