Magnetic Order Studies of $ErNiAl_4$

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Specific heat measurements on $ErNiAl_4$ show a phase transition at 5.8(1) K. Magnetisation data confirms the low temperature phase is antiferromagnetic in nature, while neutron powder diffraction data suggests an incommensurate structure similar to the intermediate magnetic phase of $TbNiAl_4$.

1. Introduction

The intermetallic series RNiAl$_4$ (R = rare earth) exhibits intriguing magnetic properties. For the compounds with R = Pr, Tb and Gd there are at least two magnetic phase transitions as a function of decreasing temperature, including an incommensurate magnetically ordered phase (e.g. [1-3] and references therein). In addition, the low temperature magnetisation of $TbNiAl_4$ exhibits two transitions as a function of applied magnetic field [4]. The choice of rare earth is crucial in determining the magnetic anisotropy. The Kramers ion Nd in $NdNiAl_4$ orders along the *b*-axis, perpendicular to that of neighbouring non-Kramers $PrNiAl_4$ which orders along the *a*-axis. Furthermore $NdNiAl_4$ does not show any sign of a second magnetic phase to the lowest temperatures.

We report here on a study aimed at improving the understanding of the systematics of the RNiAl$_4$ series. Heat capacity and magnetisation are recorded for $ErNiAl_4$ as a function of temperature. Neutron powder diffraction at approximately 5.8 K that shows magnetic order.

2. Sample preparation

The $ErNiAl_4$ compound was synthesised by repeated argon arc melting of stoichiometric amounts of 99.9% Er together with 99.99% Ni and Al. The resulting ingots were annealed for seven days at 1300 K wrapped in tantalum foil under vacuum. The resulting material was checked for impurity phases by powder x-ray diffraction (XRD). Magnetisation measurements were made using a SQUID magnetometer in applied magnetic fields up to 7 T and in the temperature range from 2 to 300 K. The specific heat was measured in zero magnetic field using the relaxation method on a Quantum design PPMS system.

The powder specimen for neutron diffraction was prepared by grinding a number of ingots. Neutron powder diffraction data were collected using the MRPD at the HIFAR reactor, Lucas Heights. Use of a closed cycle refrigerator allowed these measurements for temperatures down to a nominal base temperature of 5 K. At base temperature, the two thermometers, top and bottom of the specimen read 5.4 K and 6.1 K respectively. We have assigned an average temperature 5.8 K for this run. Data were analysed using Rietica [5] and FullProf [6], the latter allowing for refinement of magnetic structures.

3. Results

3.1 Specific heat and magnetisation

Specific heat data, collected down to 2 K, is shown Fig. 1 and feature a single significant peak corresponding to a single magnetic transition at 5.8(1) K. This result is suggestive of only two magnetic phases, much like the other Kramers ion system, $NdNiAl_4$. The magnetisation data of Fig. 2 also support the case for a transition at 5.8 K, and suggest that the lower temperature phase is likely antiferromagnetic.

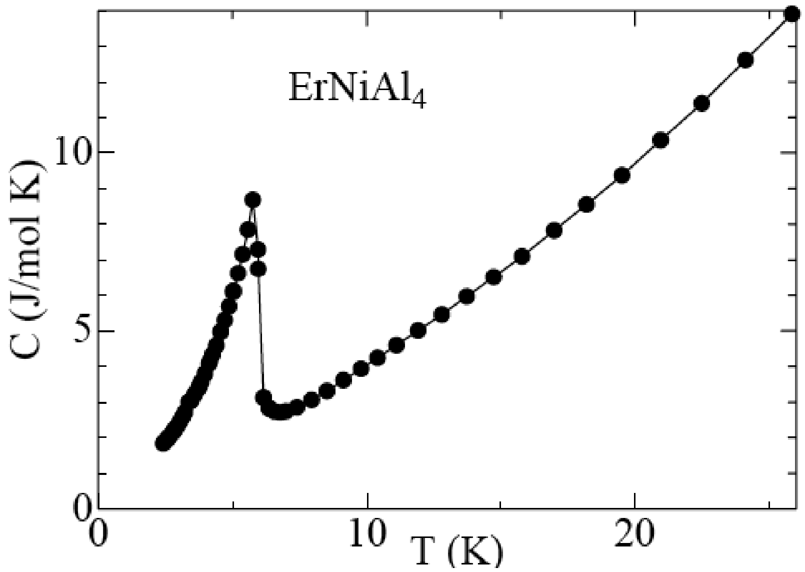

Fig. 1. Specific heat measurement for $ErNiAl_4$ in zero magnetic field.

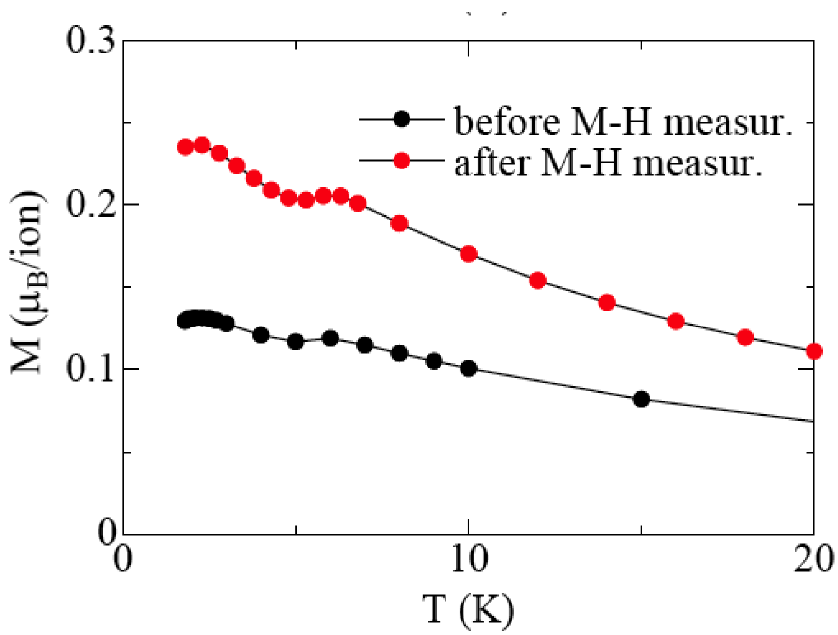

Fig. 2. Magnetisation measurements for ErNiAl4 powder, collected at 0.1 T applied magnetic field, before and after exposing the sample to a high magnetic field (7 T).

3.2 Neutron diffraction

Neutron diffraction data collected at 10 K showed structural peaks only and could be fitted with structural parameters much as for $TbNiAl_4$ [2]. However data collected at the nominal base temperature of the cryostat, average sample temperature approximately 5.8 K, shows the onset of magnetic order. This lowest temperature data, shown in Fig 3, has been fitted using Fullprof to reveal incommensurate magnetic order. A propagation vector of τ = ($h_\tau k_\tau l_\tau$) = (0.191 1 0.015) is assigned with the moments in an antiferromagnetic configuration along the *b* axis. This structure is similar to the incommensurate (intermediate) phase of $TbNiAl_4$, for which τ = (0.171 1 0.038) was assigned [2].

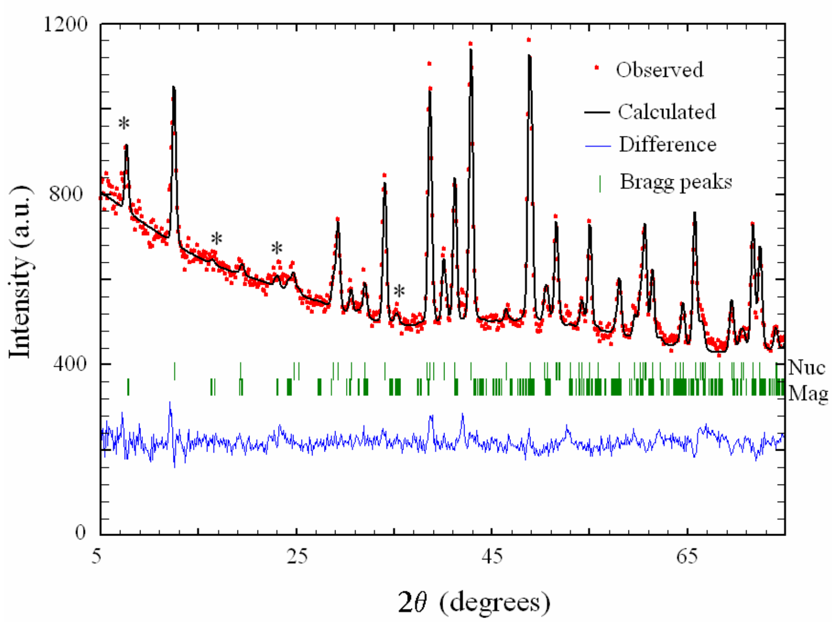

Fig. 3. Neutron diffraction data for ErNiAl4 powder, collected in zero applied magnetic field and at a sample temperature close to 5.8 K. The Fullprof refinement suggests incommensurate magnetic order (starred peaks).

In conclusion, the specific heat measurement suggests that $ErNiAl_4$ has a single phase transition, like $NdNiAl_4$, and the neutron diffraction data reveal a low temperature incommensurate magnetic order such as seen in the intermediate temperature phase for $TbNiAl_4$. Further definitive neutron powder diffraction measurements at lower temperatures will be possible with the OPAL reactor's new suite of instruments.

Acknowledgments

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