Study of $H$-$T$ Phase Diagram of ErNi$_2$B$_2$C

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Abstract

A field dependence of magnetization of ErNi$_2^{11}$B$_2$C at 1.8 K with a field parallel to the $b$ axis indicates that three phase transitions occur at 0.6, 1.1 and 1.9 T. In the present study, we performed a neutron diffraction measurement and determined a detailed magnetic structure in a phase at 1.9 K and 0.85 T. Accompanied by odd number higher order peaks there appear strong SDW magnetic peaks with $\mathbf{q} = \frac{4}{7} \mathbf{a}^*$, indicating that the size of the magnetic unit cell is $7a \times b \times c$.

Key words: weak ferromagnetism; superconductivity

Superconductivity and ferromagnetism are conventionally considered as antagonistic states, because superconductivity collapses when an external magnetic field is applied. However, it is theoretically predicted that superconductivity can coexist with ferromagnetism as far as an internal magnetic filed ($H_{\text{int}}$) mediated by the ferromagnetism is lower than the critical magnetic field[1]. In particular, for type II superconductors, the theory predicts that a spontaneous vortex phase may exist if $H_{\text{int}}$ further satisfies a following inequality, $H_{c1} < H_{\text{int}} < H_{c2}$, where $H_{c1}$ and $H_{c2}$ are lower and upper critical magnetic field, respectively[2–4].

ErNi$_2$B$_2$C is the first material in which coexistence of weak ferromagnetism and superconductivity was microscopically confirmed by neutron scattering techniques [5–7]. Previously we determined a weak ferromagnetic structure at 1.4 K in zero-field, which has a unit cell with $20a \times b \times c$[8]. To study details of the $H$-$T$ phase diagram of this material, we further performed magnetization and neutron diffraction measurements with a field applied parallel to the $b$ axis. In this paper, we shall report the magnetic structure in a phase at 1.9 K and 0.85 T.

Single crystals of ErNi$_2^{11}$B$_2$C were grown by the floating zone method. To reduce neutron absorptions by $^{10}$B, the $^{11}$B isotope was used. A superconducting transition temperature ($T_c$), a Néel (SDW) temperature ($T_N$) and a weak ferromagnetic transition temperature ($T_{\text{WFM}}$) of our pre-annealed sample are 8.6, 6.0 and 2.75 K, respectively. Magnetization measurements were performed with a Quantum Design MPMS SQUID magnetometer. Neutron diffraction measurements were done with a triple axis spectrometer GP-TAS (4G) installed in the JRR-3M at JAERI, Tokai. Neutrons with $k_i = 2.57\, \text{Å}^{-1}$ were used. In the present study, an external magnetic field was applied along the $b$ axis.

In Fig. 1(a) is depicted a magnetization curve ($M(H)$ curve) observed at 1.8 K. Three jumps at 0.6, 1.1 and 1.9 T indicate three phase transitions take place at respective fields. From this curve, a saturation moment
A neutron diffraction profile observed along the (h00) direction at 1.9 K and 0.85 T. The number of magnetic peaks with positions of Er atoms. The size of the magnetic unit cell in this phase is seven times larger than the crystal unit cell along the a axis and that one from seven Er spins contributes weak ferromagnetism. The structure gives a net moment of 1.1 \( \mu_B/Er \) which is consistent with the magnetization data.

### References


