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Magnetic excitations of RNi_2B_2C single crystals with R = Tb and Ho

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Abstract

We present first results of our inelastic neutron scattering experiments on RNi_2B_2C single crystals (R = Tb and Ho) in the most interesting temperature range around the magnetic and superconducting transitions. Here we focus on the magnetic excitations in the energy range from 2 to 20 meV. While there are clear changes in the crystal-electric field excitations between the paramagnetic and the antiferromagnetically ordered ground states for both compounds, no differences are observed between the paramagnetic state and the intermediate magnetically ordered states in $HoNi_2B_2C$.

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The tetragonal rare-earth nickel borocarbides RNi_2B_2C show interesting physical properties, especially the coexistence of superconductivity and long-range magnetic order [1]. To get more insight into both ordering phenomena, informations about phonons and magnetic excitations are of fundamental importance. We present first results of inelastic neutron scattering experiments on RNi_2B_2C single crystals (R = Tb and Ho) in the most interesting temperature range around the magnetic and superconducting transitions.

$TbNi_2B_2C$ shows no superconductivity down to 7 mK [2], but orders antiferromagnetically below T_N = 15 K with the magnetic Tb^{3+} moments aligned along the *a* axis. They are modulated with the propagation vector $\tau = (0.545\ 0\ 0)$ [3,4]. In contrast to $TbNi_2B_2C$, the $HoNi_2B_2C$ compound becomes superconducting below $T_c = 8$ K [5]. Furthermore, the Ho^{3+} moments order antiferromagnetically in a complex manner: At low temperatures the Ho^{3+} moments are aligned along the [1 1 0] direction with a simple antiferromagnetic stacking sequence in [0 0 1] direction with the propagation vector $\tau_1 = (0\,0\,1)$. In the temperature range between 5.2 K and $T_N = 6.8$ K this antiferromagnetic ground state coexists with two additional antiferromagnetic modulations with the propagation vectors $\tau_2 = (0.585\ 0\ 0)$ and $\tau_3 = (0\ 0\ 0.915)$ [4,6,7].

RNi_2B_2C single crystals were grown by the floating zone method using ^{11}B isotope to avoid strong neutron absorption [8]. Pieces with a length of 6 mm for R = Tb and 14 mm for R = Ho were cut from rods with 6 mm diameter. For the inelastic neutron scattering

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experiments the samples were oriented in the (*ac*) scattering plane. The measurements were performed on the three-axis spectrometers 1T1 at Laboratoire Léon Brillouin, Saclay, and BT2 at NIST Center for Neutron Research, Gaithersburg. Standard conditions for investigations with a fixed final energy $E_f = 14.8$ meV were used.

In Fig. 1 two energy scans with fixed wave vector $q = (0.1\,0\,2)$ are shown for $TbNi_2B_2C$ in the antiferromagnetically ordered state at $T = 2$ K and in the paramagnetic state at $T = 30$ K. At $T = 2$ K two strong inelastic peaks are observed at 4.0 and 9.7 meV. An additional weak excitation is present at 12.1 meV. In contrast, at $T = 30$ K the excitations are shifted to energies of 6.7, 8.2 meV for the strong and 10.2 meV for the weak excitations. In addition, the peaks are smeared out. Energy scans at different wave vectors q yield that the peak intensities follow the magnetic form factor of Tb^{3+} moments. Therefore, the observed excitations can be interpreted as crystal-electric field (CEF) transitions. This conclusion is supported by the absence of dispersion. Our results are in good agreement with inelastic neutron scattering investigations of a polycrystalline $TbNi_2B_2C$ sample [9].

Energy scans of the $HoNi_2B_2C$ single crystal yield the spectra shown in Fig. 2. At $T = 2$ K one strong peak at 11.4 meV and one weak peak at 14.2 meV are observed for the antiferromagnetic ground state. Our results agree well with the CEF transitions observed on another $HoNi_2B_2C$ single crystal grown by the flux method [10]. At $T = 5.2$ K the ordered magnetic Ho^{3+} moment is only half of the full ordered Ho^{3+} moment. The two peaks at 11.4 and 14.2 meV (at $T = 2$ K) are shifted to energies of 10.7 and 12.8 meV, respectively. For all temperatures between $T = 5.2$ K and $T = 10$ K the spectra look similar. Both onset-transition temperatures, $T_N = 6.8$ K and $T_c = 8$ K, are in this temperature range. This suggests, that there is no qualitative difference in the CEF states between the intermediate state, characterized by the coexistence of the described three antiferromagnetic modulations, and the paramagnetic state, as well as between the superconducting and the non-superconducting state. This behavior coincides with the temperature dependence of a magnetic excitation at 1.8 meV, which is observed only below 5.5 K on a polycrystalline $HoNi_2B_2C$ sample [11].

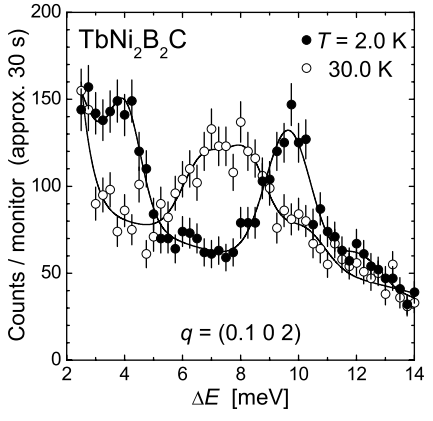

Fig. 1. Low energy excitations of $TbNi_2B_2C$ measured on the three-axis neutron spectrometer 1T1 at Laboratoire Léon Brillouin, Saclay, using a fixed final energy $E_f = 14.8$ meV. The solid lines represent peak fits with Gaussian line shape.

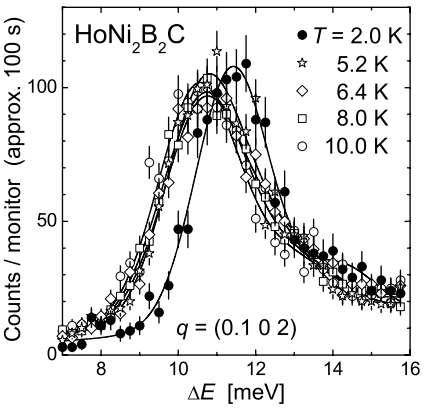

Fig. 2. Low energy excitation of $HoNi_2B_2C$ measured on the three-axis neutron spectrometer BT2 at NIST Center for Neutron Research using a fixed final energy $E_f = 14.8$ meV. The solid lines represent peak fits with Gaussian line shape.

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