Strong Enhancement of the Critical Current at the Antiferromagnetic Transition in $ErNi_2B_2C$ Single Crystals

M. Weigand, L. Civale, F.J. Baca, Jeehoom Kim, B. Maiorov (Materials Physics and Applications Division, Los Alamos National Laboratory) S.L. Bud'ko, P.C Canfield (Ames Laboratory, US DOE and Department of Physics and Astronomy, Iowa State University, Ames)

Introduction

As promising as superconductivity is, the entrance of magnetic flux lines (vortices) that occurs when a magnetic field **H** is applied is a big setback for applications. This is because when an electrical current *J* is applied, vortices move and energy is dissipated. This movement can be arrested by non-superconducting defects that pin vortices by lowering the system energy. The interaction between vortices and the pinning centers has been studied extensively for decades, focused mainly on the so-called vortex core pinning defect creation.[1] Less explored is the interplay between vortices and magnetic media, which could offer pinning forces superior to those from core pinning. To unequivocally discern the effect of the magnetic medium, it is of great advantage to study systems where the magnetic ordering transition takes place inside the superconducting phase, allowing comparisons with and without the magnetically ordered phase. Borocarbides are ideal for this due to the relatively high superconducting transition temperature T_c and tunability of T_c and magnetic ordering temperature (T_N).[2]

Experimental

Large single crystals of $ErNi_2B_2C$ [2] were selected and polished mechanically down to 40-60μm thick, ~250μm wide and ~1.5mm long. Transport measurements were performed in three systems with different cooling methods, among them a variable temperature insert in the15T DC magnet at NHML-LANL. All systems were equipped with rotators, and a **J**⊥**H** configuration was used.

Results and Discussion

In **Figure 1a** we show a transport measurement of the critical current density J_c vs temperature at $\mu_0 H$ = 0.5 T for **H**||c. At low temperature, J_c decreases rapidly as *T* increases, with a peak in J_c(T) at T_N, which corresponds to a two-fold increase. The maximum at T_N occurs over a large range of *H.* The height of the J_c peak decreases with increasing *H*, the opposite field dependence than that of the peak observed near H_{c2}, indicating a different origin of the two maxima. This leads us to speculate that the peak at T_N has a magnetic origin, as magnetic pinning tends to be attenuated as the magnetic field modulation of the vortices becomes smaller. In **Figure 1b** Angular measurements show that this peak is observed only around the c axis and T=T_N= 6 K. At lower T=4.2K another c-axis peak appears that has different shape and temperature dependence, attributed to magnetic twin boundaries (see inset).[3]

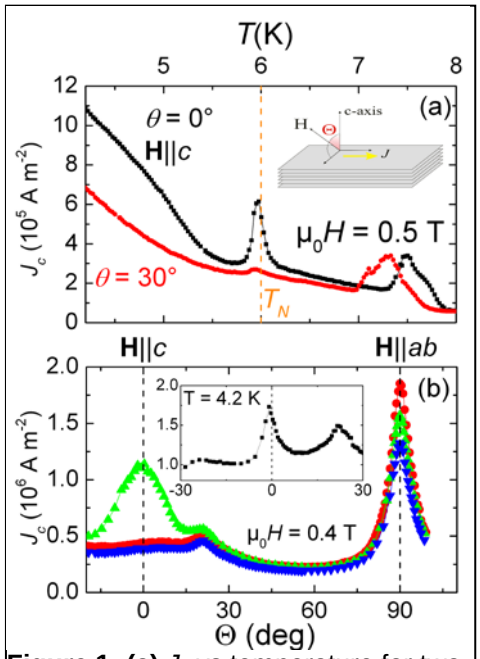

Figure 1: (a) J_c vs temperature for two magnetic field orientation Θ.**(b)** J_c vs Θ for different temperatures.

Conclusions

We observed in transport measurements an enhanced value of J_c in $ErNi_2B_2C$ single crystals at the Néel temperature for magnetic fields applied parallel to the *c* axis. This study opens a new avenue to investigate the interaction between superconductivity and different magnetic phases, such as those known in Er, Ho and Tm borocarbides. In addition, new developments can be expected for other superconductors with coexistence of magnetic phases, such as underdoped copper- and iron-based superconductors.

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