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Report:

The investigation of the superconducting vortex lattice of the recently discovered tetragonal (space group I4/mmm) rare-earth boro-carbides, $RENi_2B_2C$ (RE = rare-earth), is a very active field of research. The interest has been triggered by the observation by small angle neutron scattering on $ErNi_2B_2C$ of a square vortex lattice when a large magnetic field is applied along the c axis [1]. Subsequently, a crossover to a conventional hexagonal vortex lattice at low field has been observed [2]. This crossover is not a peculiarity of $ErNi_2B_2C$ in the $RENi_2B_2C$ series since it has been observed for $LuNi_2B_2C$ and YNi_2B_2C [3-5]. For the three compounds, the vortex lattice is rotated by 45° with respect to the underlying crystal lattice.

Although the stabilization at high field of a square vortex lattice has been attributed either to nonlocal corrections to the London model [6] or to a square anisotropic term in the Ginzburg-Landau expansion [3], the magnetoelastic interactions can still be relevant for the properties of the vortex lattice. These arise due to the small difference in specific volumes of the normal material in vortex cores and the superconducting phase in the rest of the sample [7].

Surprisingly, as for the high T_c superconductors [8] an unusually large magnetostriction has been found for $ErNi_2B_2C$ by dilatometric measurements [9]. Recently, it has been argued that such measurements on superconductors are influenced by the shape of the sample [10]. Therefore we proposed to measure a compound of this family by high resolution X-ray diffraction which is independent of such geometric considerations. In a first step we chose a non magnetic member: $LuNi_2B_2C$ (superconducting temperature 16 K). The lattice parameters of the tetragonal structure are a = 3.46 Å and c = 10.63 Å.

The field produced by the cryomagnet lent by the Nuclear Scattering Group was applied along the c crystallographic axis and the Bragg reflection [220] was studied.

Since we needed high longitudinal resolution, ideal silicon monochromator and analyzer crystals were used. In addition we worked as close to the non dispersive mode as possible so that the scattering vectors (G) of monochromator, sample and analyzer match. In these ideal conditions the mosaic spread of the non ideal sample is totally decoupled from the longitudinal resolution. In practice we chose the Si [331] reflection (G =

5.01 Å^{-1}) for the monochromator and the analyser. They match nicely the $LuNi_2B_2C$ [220] (G = 5.14 Å^{-1}) reflection.
To compensate for a drift of the triple axis diffractometer which we noticed in a previous similar experiment (HS-552), we used an extra Si crystal which was fixed on the cryomagnet. Each measurement on the $LuNi_2B_2C$ sample was therefore followed by a measurement on this Si crystal. The actual value of the variation of G for $LuNi_2B_2C$ was obtained by a difference of the results of these two measurements. We assumed the Si magnetostriction to be negligible. The Si was moreover submitted only to the stray field of the cryomagnet which corresponds at the Si location to $\lesssim$ 20 % of the field applied to the sample.
In Fig. 1 we present the results obtained for the variation of the lattice parameter a measured with an X-ray energy of $\sim$ 200 keV. The thermo-magnetic history for the measurement is described in the figure caption. The variation of the lattice parameter amounts to $\sim 10^{-4}$ for a field of 2.5 T and surprisingly it is positive.
A similar experiment (HS-836) was performed by some of us on the same beamline on the high T_c superconductor $YBa_2Cu_3O_{6.95}$. It also yielded a positive magnetostriction. However, macroscopic (dilatometric) measurements were performed subsequently on the *same sample*. These measurements are difficult because of the large magnetic anisotropy resulting in a strong torque acting on the sample. They gave negative values for the magnetostriction in accord with the natural expectation that the lattice should contract as the density of flux lines increases.
Therefore we suspect our X-ray data to be wrong. The effect of the magnetic torque could be an explanation although it seems not to be relevant in the case of a microscopic measurement. However, during our experiments we noticed that the intensity of the Bragg reflection dramatically decreased as the field was increased and came back to its initial value as the field was reduced. It was unfortunately impossible to line up the sample to restore the full intensity of the Bragg peak as the field was increased. The goniometer is indeed not strong enough to allow for a tilt of a relatively large mass such as the cryomagnet. Therefore the crystal was not optimally aligned when a field was applied and this misalignment may be at the origin of a incorrect estimate for the interplanar spacing.

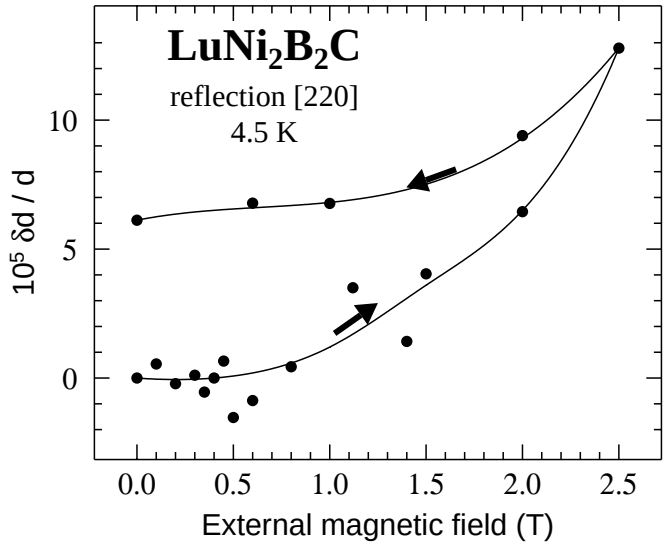

Figure 1: Relative variation of the interplanar spacing measured on the [220] Bragg reflection (corresponding therefore to the a lattice parameter) as a function of the field applied along the c axis of $LuNi_2B_2C$. The sample was cooled to 4.5 K in zero field. Then the field was increased from 0 up to 2.5 T (with several measurements, see the figure) and then decreased back to zero-field. The presented results are the average of several measurements.

References

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