

Polarised Neutron Reflectometry Studies of $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}/\text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3$ Multilayers

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Multilayers of the high- T_c superconductor $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ and the CMR ferromagnet $\text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3$ show an unexpected deviation of the magnetization topology with respect to the nuclear one. Polarized neutron reflectometry measurements were used to deduce the vertical field distribution as a function of the temperature. This change in topology occurs between the superconducting and the ferromagnetic transition temperature.

In previous experiments multilayers of the high- T_c superconductor (SC) $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ (YBCO) and the colossal magnetoresistance ferromagnet (FM) $\text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3$ (LCMO) have been investigated to deduce the vertical profile of the in-plane magnetic induction. Clear evidence was found, that the magnetic induction does not show the same topology as the nuclear structure [1, 2].

The investigations were repeated with more appropriate samples (increased number of bilayers, larger layer thicknesses) and a more elaborate measuring scheme. The results presented here were taken on a $[\text{YBCO}(200 \text{ \AA})/\text{LCMO}(200 \text{ \AA})]_8/\text{SrTiO}_3$ sample.

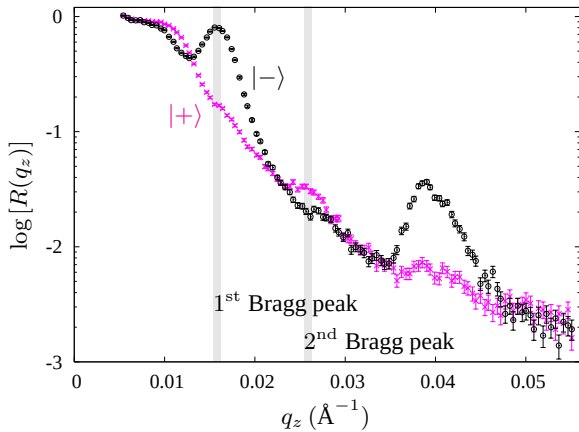


Figure 1: Reflectivity for $|-\rangle$ (black balls) and $|+\rangle$ (grey crosses) neutrons at $T = 15 \text{ K}$. The sample was field-cooled and measured at $H = 100 \text{ Oe}$.

Fig. 1 shows polarized specular reflectivity measurements at a temperature well below the superconducting transition temperature T_c . The structurally forbidden 2nd Bragg peak appears due to the different topology of the magnetic induction compared to the nuclear profile [1, 2]. The magnetic induction is no longer constrained to the LCMO layer. To investigate the temperature dependence of this effect, polarized measurements of the maximum intensity of the 1st and the 2nd Bragg peak were performed (see Fig. 2).

The intensity increase of the $|-\rangle$ and the decrease of the $|+\rangle$ neutrons of the 1st Bragg peak are caused by the increasing magnetic induction in the LCMO-layers below $T_{\text{Curie}} \approx 240 \text{ K}$. We assume that the initial weak increase of the peak intensity at T_{Curie} (equal for both neutron spin states) of the 2nd Bragg peak is driven by a magnetic roughness. Below a temperature T' , well above T_c , the intensities for the two spin states split. This splitting reaches its maximum when approaching T_c .

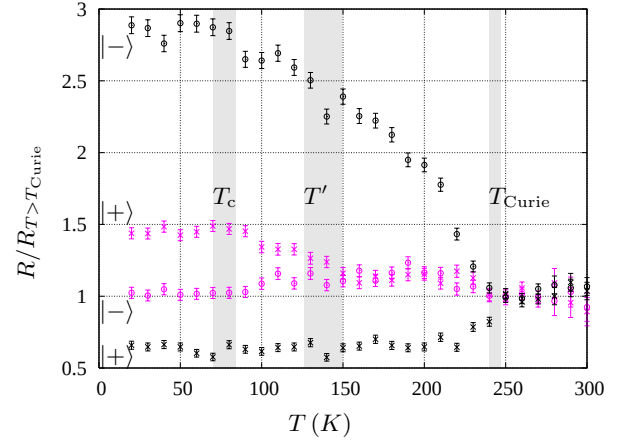


Figure 2: Reflectivities at the positions of the 1st ($q_z = 0.007 \text{ \AA}^{-1}$, black) and 2nd ($q_z = 0.017 \text{ \AA}^{-1}$, grey) Bragg peaks for neutrons in the spin states $|+\rangle$ (crosses) and $|-\rangle$ (balls) as a function of temperature. The sample was field cooled and measured at $H = 100 \text{ Oe}$. See also Fig. 1. The reflectivities are normalised at $T > T_{\text{Curie}}$. The grey bars give the temperature ranges for the transition temperatures T_c and T_{Curie} , and for the onset T' of the splitting of the 2nd Bragg peak intensities.

The comparison with simulated reflectivity curves allows the identification of two possible magnetisation profiles: a sizable magnetic moment within the SC layer antiparallel to the one in the FM layer, as proposed by F.S. Bergeret [3], or a "dead" region in the FM layer with zero net magnetic moment.

Since the splitting of the two spin states occurs at a temperature well below T_{Curie} , the profile with a magnetic dead layer is highly unlikely. We therefore propose an antiphase magnetic proximity effect as described in [1]. A possible explanation for the occurrence of this effect above T_c may be found in terms of strong SC fluctuations in that temperature range which are well known to be prominent in underdoped high- T_c superconductors.

[1] J. Stahn *et al.*, *cond-mat/0408311* (2004).

[2] J. Stahn *et al.*, *PSI Scientific Report 2003 III*, 66.

[3] F.S. Bergeret *et al.*, *Europhys. Lett.*, **66**, 111 (2004).

Work fully performed at SINQ

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