Polarized Neutron Reflectivity Study of an $YBa_2Cu_3O_7/PrBa_2Cu_3O_7/YBa_2Cu_3O_7$ Tri-Layer

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We report the results of the magnetic field distribution measurements inside a 330Å/500Å/1150Å tri-layer of $YBa_2Cu_3O_7/PrBa_2Cu_3O_7/YBa_2Cu_3O_7$ (YBCO/PBCO/YBCO). A preliminary analysis points to a possible coupling of two superconducting YBCO layers via the antiferromagnetic PBCO layer.

Clarifying the physics of high-temperature superconductors (HTS) is one of the most important challenges in condensed-matter physics. There is an experimental evidence for several unconventional effects in HTS. One of the most remarkable is the recently observed giant proximity effect (see e.g. [1] and references therein). A supercurrent in Josephson junctions was found to run through relatively thick non-SC barriers. This contradicts with the conventional theories where one would expect exponential suppression of supercurrents with barrier thickness because of the short coherence length of HTS's. However, till now, the giant proximity effects have been studied by means of the *local* techniques only. So it is still not clear either the giant proximity or the pinholes and/or microshorts are responsible for the observed effects.

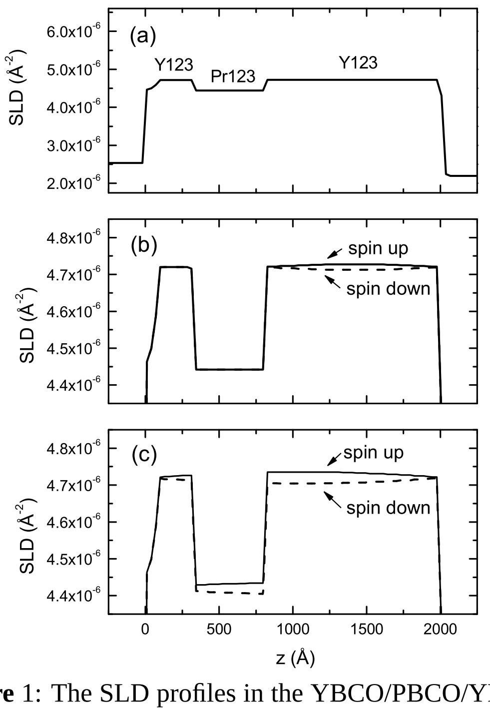

Figure 1: The SLD profiles in the YBCO/PBCO/YBCO tri-layer sample in the normal state (a) and in the superconducting state (b) and (c). The solid and dashed lines in (b) and (c) denotes the SLD profiles for spin-up and spin-down neutrons, respectively.

Here we report the first preliminary studies of the giant proximity effect by means of the *bulk* technique as the polarized neutron reflectivity technique. The tri-layer sample was consist of $YBa_2Cu_3O_7/PrBa_2Cu_3O_7/YBa_2Cu_3O_7$ layers with the relative thicknesses 330Å/500Å/1150Å. The neutron scattering lengths density (SLD) profiles are shown in Fig. 1. In the normal state the SLD profile is determined by the neutron scattered on the nuclears and it is expected to be the same for spin-up and spin-down polarized neutrons [Fig. 1(a)]. In the superconducting state the magnetic field is expelled from the superconducting volume of the sample. Thus, in addition to the nuclear, the magnetic scattering is occur that cause the difference in SLD profiles for spin-up and spin-down neutrons. Two simple models have been tested. In the first [see Fig. 1(b)], it was assumed that the magnetic field is screened only within the two superconducting YBCO layers while in the antiferromagnetic PBCO one it is equal to the external field. In the second model the whole structure was assumed to be superconducting [see Fig. 1(c)]. To cancel

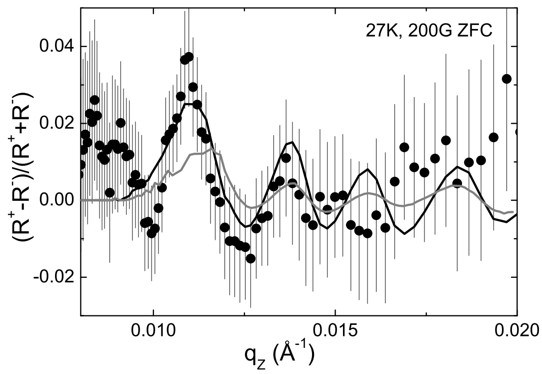

Figure 2: $(R^+ - R^-)/(R^+ + R^-)$ vs. q_z ($T = 27$ K, $H = 200$ G zero-field cooled). The grey and black lines are calculated for the models presented in Figs. 1(b) and (c), respectively.

the nuclear contribution in the reflectivity spectra $R(q_z)$, the ratio $(R^+ - R^-)/(R^+ + R^-)$ has been plotted in Fig. 2. Here q_z denotes the neutron wave vector, and the indexes $+$ and $-$ stay for spin-up and spin-down, respectively. The comparison of the experimental data with the curves calculated for the models presented in Figs. 1(b) and (c) leads to the conclusion that most probably the superconducting YBCO layers are coupled through the antiferromagnetic PBCO layer. This statement is also confirmed by our low-energy μSR measurements performed on the same sample. It was observed that the magnetic field measured inside of both YBCO layers is screened better than if it is estimated for separate YBCO layers in the Meissner state [2].

[1] I. Bozovic *et al.*, Phys. Rev. Lett. **93**, 157002 (2004).

[2] D.G. Eshchenko *et al.*, PSI Sc. Report 2003 III, 97.

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