Magnetic induction in perovskite HTSC / FM multilayers

Introduction

The magnetic field profile at the interface of the ferromagnet La$_2/3$Ca$_{1/3}$MnO$_3$ (LCMO) and the superconductor YBa$_2$Cu$_3$O$_y$ (YBCO) in superlattices has been studied by specular ($q_x$-scan) and off-specular ($\omega$-scan) neutron reflectometry.

These investigations were motivated by Low-Energy $\mu$SR and bulk magnetization measurements which showed an unexpected magnetic behaviour below $T_c$:

- magnetization

The depth-resolution of these methods (if any) is not sufficient to allocate the increased magnetic flux to certain regions.

Summary

Evidence for a characteristic difference between the structural and magnetic depth profiles is obtained from the occurrence of a structurally forbidden Bragg peak in the FM state and the anomalous temperature dependence of the intensity of the first Bragg peak.

The comparison with simulated spectra allows us to identify two possible magnetization profiles:

1. A sizable magnetic moment develops within the SC layer that is antiparallel to the one in the FM layer.
2. A significant “dead” region in the FM layer that has no net magnetic moment.

Both are compatible with exchange bias. Scenario (1) is supported by an anomalous SC-induced enhancement of the off-specular reflection which testifies for a strong mutual interaction of SC and FM order parameters and may be the signature of a spatially inhomogeneous SC/FM interface state.

Suitable model potentials:

- change of 1$^{\text{st}}$ Bragg peak intensity below $T_m$
  $\Rightarrow$ increased contrast for $|<| >$ neutrons
  decreased contrast for $|>| >$ neutrons

- 2$^{\text{nd}}$ Bragg peak forbidden by symmetry of $V_{\text{nuclear}}$
  $\Rightarrow$ $B$ has an other $z$-dependence than $V_{\text{nuclear}}$
  (see simulations)

- $I_{\text{specular}} \times I_{\text{integrated}}$ for $T > T_c$
  $\Rightarrow$ no detectable magnetic roughness

- $I_{\text{specular}} < I_{\text{integrated}}$ for $T < T_c$
  $\Rightarrow$ increasing magnetic roughness

- exchange bias
  $\Rightarrow$ AFM layers must be present at the interface

SQUID measurement by F. Troubil, Uni. Konstanz — thanks!

Suitable model potentials:

- (YBCO(100 Å)/LCMO(100 Å))$_n$
  $T = 5$ K
  Cooled in $H = 100$ Oe exchange-bias field:
  $H_e = -60$ Oe