Laboratorium für Neutronenstreuung, ETH Zürich & PSI

MPI für Festkörperforschung, Stuttgart

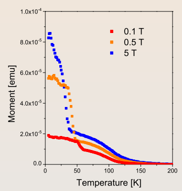
J. Stahn, C. Niedermayer, T. Gutberlet, J. Chakhalian, C. Bernhard, H-U. Habermeier

Magnetic Induction Distribution in $La_{2/3}Ca_{1/3}MnO_3$ / $YBa_2Cu_3O_7$ Multilayers

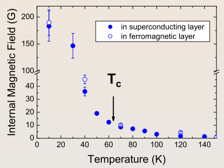
Intro

These investigations were motivated by Low-Energy μSR and bulk magnetization measurements on ferromagnet (FM) / high-T_c superconductor (HTSC) multilayers, which showed an unexpected magnetic behaviour below T_c:

magnetisation

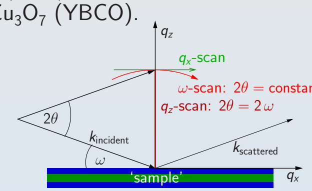


Low-Energy μSR



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

Thus specular (q_z-scan) and off-specular (q_x-scan) polarised neutron reflectometry has been applied to study the interface of the FM $La_{2/3}Ca_{1/3}MnO_2$ (LCMO) and the HTSC $YBa_2Cu_3O_7$ (YBCO).

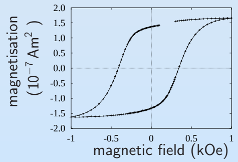


q_z is normal to the sample surface, in-plane structure is averaged over several μm.

q_x probes lateral inhomogeniouties (interface roughness and domains).

Magnetometry

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



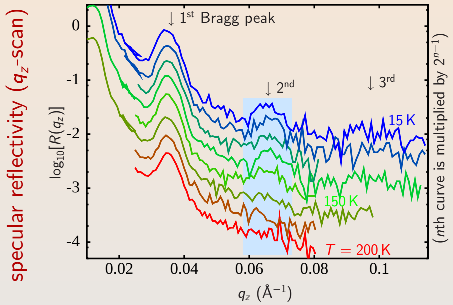
$T = 5$ K
$H = 100$ Oe
$H_e = -60$ Oe

(c) exchange bias
⇒ AFM layers present at the interfaces

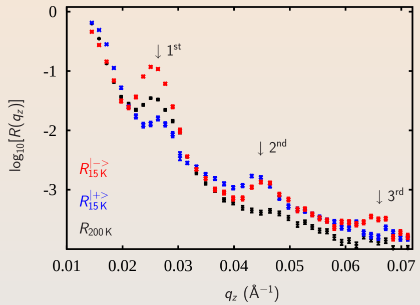
Neutron Reflectometry

Morpheus@SINQ	instrument	ADAM@ILL
[YBCO(100 Å)/LCMO(100 Å)]$_7$	sample	[YBCO(150 Å)/LCMO(140 Å)]$_6$

cooled and measured in $H = 100$ Oe

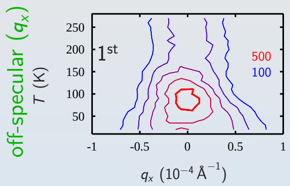


(a) change of 1st Bragg peak below T_m
⇒ increased contrast for $|-\rangle$ neutrons
decreased contrast for $|+\rangle$ neutrons

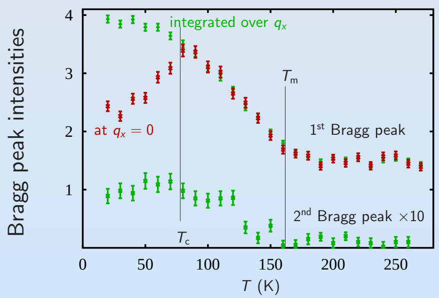


(b) symmetry-forbidden 2nd Bragg peak
⇒ B has an other z-dependence than $V^{nuclear}$

Decay of the 1st Bragg peak intensity below T_c
⇒ off-specular, non-polarised measurements:



$I(q_z, T)$ map for the 1st Bragg peak



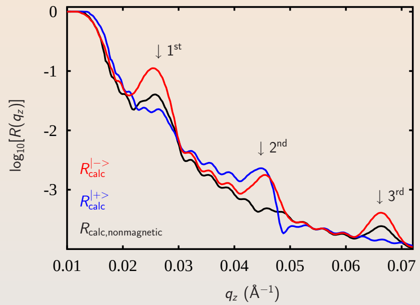
(d) $I_{specular} \propto I_{integrated}$ for $T > T_c$
⇒ no detecatble magnetic roughness

(e) $I_{specular} < I_{integrated}$ for $T < T_c$
⇒ increasing magnetic roughness

Simulation

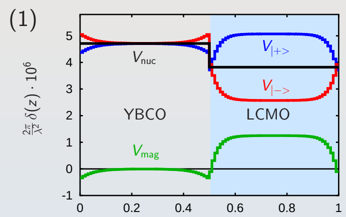
Calculated with the computer code EDXR of P. Mikulík.

model potential (1)

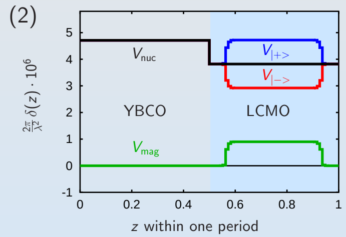


suitable model potentials:

(1)



(2)



Summary

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

The comparison with simulated spectra allows us to identify two possible magnetization profiles, both being compatible with exchange bias (c).

(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.

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. (d, e)

References

This work was performed on Morpheus at SINQ, PSI, Switzerland and on ADAM, ILL, France with the help of M. Wolff.

contact: jochen.stahn@psi.ch

see also: cond-mat/0408311 v1