Jochen Stahn, Christof Niedermayer
Laboratorium für Neutronenstreuung, ETH Zürich & PSI
Hanns-Ulrich Habermeier, Jacques Chakhalian, Bernhard Keimer
MPI für Festkörperforschung, Stuttgart
Christian Bernhard, Justin Hoppler
Departement de Physique, Université de Fribourg

Interface magnetisation in a high-T_c superconductor / ferromagnet multilayer

#A2

interfaces and layered systems — new physics and spintronics?

general idea: the close contact of materials with different (alternative) properties might lead to new phenomena

e.g. – interface of $SrTiO_3/LaTiO_3$ (insulators) is metallic

a multilayer reduces the dimension and forces the interaction coupling phenomena might show up

e.g. – RKKY-interaction
– collosal magnetoresistance
– changed characteristic temperatures

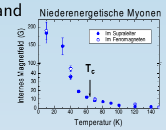
present case: multilayers of a FM with a HTSC (both metals) seem to show an metal/insulator transition in ellipsometry for small periods — but stay superconducting / magnetic

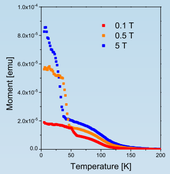
so: what happens with the magnetisation and the superconduction order parameter?

earlier findings:

enhanced magnetism below T_c

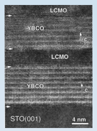
coexistence of FM and SC in RuSrCuGdO





→ competitive order parameters

artificial multilayers to investigate
– interaction of FM and SC at the interfaces and
– coupling through the layer



samples:

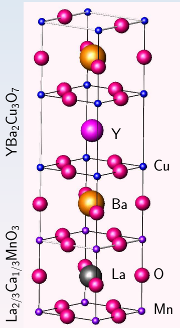
materials: HTSC YBCO $YBa_2Cu_3O_7$
YPBCO $Y_{0.6}Pr_{0.4}Ba_2Cu_3O_7$
FM LCMO $La_{2/3}Ca_{1/3}MnO_3$
substr. STO $SrTiO_3$

size: $10 \times 10\,\mathrm{mm}^2$

produced: by *P*ulsed *L*aser *D*eposition

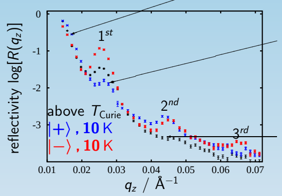
period: 200 Å to 500 Å
5 to 16 periods

ratios: 1 : 1 and 1 : 2
to cause extinction



polarised reflectometry

$\mathbf{H} = 100$ Oe, field cooled
$T = 10, 300$ K



splitting of the edge of total reflection
⇒ changed potential of the surface

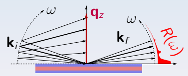
intensity variation of the 1^{st} Bragg-peak
⇒ changed potential in the FM layers
$B_{\|}$ can be determined

appearance of a 2^{nd} order Bragg-peak
⇒ $B_{\|}(z)$ and $V_{nuc}(z)$ have different symmetry

no half-order Bragg-peak
⇒ parallel alignment of **B** in the FM layers

PNR measurements performed on Morpheus and AMOR at SINQ and on ADAM at ILL

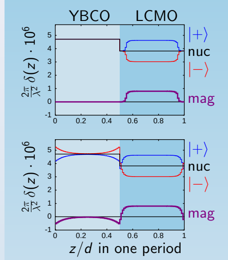
measurement scheme



closed cycle refrigerator (8 K) & Helmholtz coils (1000 Oe)

B inside the superconductor and doping dependence

the specular reflectivity can be simulated by assuming eigther

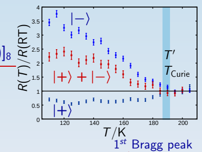


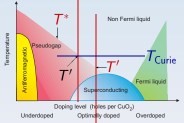
– an AFM-region within LCMO
charge-injection from YBCO leads to a doping of LCMO and thus to an AFM ground state

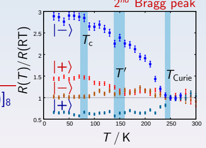
or

– an antiphase magnetic proximity effect
AF coupling of Mn and Cu moments through oxygen, or Cooper pairs penetrate into LCMO and are *polarised*
⇒ antiparallel magnetisation in YBCO

J. Stahn *et al.*: PRB **71**, 140509 (2005)

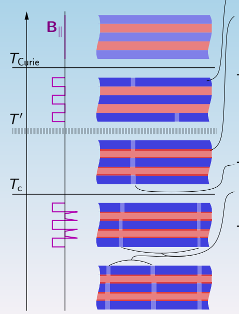






appearance of the 2^nd Bragg peak varies with the doping level (comparable to T^*)

conclusion



- all LCMO layers are magnetised parallel
- interface effect of $\mathbf{B}(z)$ of the order of 10 Å is measured at $T_c < T' \approx 140$ K $< T_{Curie}$

– *magnetic dead layer* or *antiphase proximity effect*

- simultaneous appearance of Bragg-sheets

– vertical correlation of magnetic domains

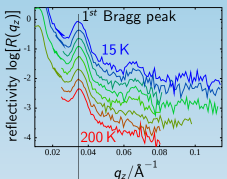
- increase of off-specular scattering below T_c

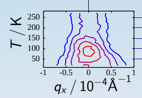
– shrinking of magnetic domains / characteristic lengthscale

- correlation of domain size with $T < T_c$ and XMCD measurements support the *antiphase proximity effect*

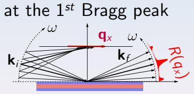
T_c and lateral changes

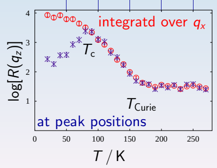
specular reflecyivity at various T





off-specular reflecyivity at the 1^{st} Bragg peak





normalised peak- and integrated intensity of the 1^{st} Bragg peak

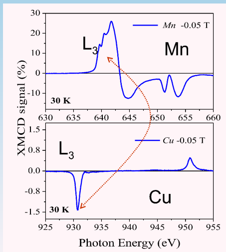
magnetic domains (lateral correlation length) shrink below T_c from 10 μm to 5 μm when cooling

x-ray magnetic circular dichroism:

– magnetic moment on Cu detected

– it is antiparallel to the moment on Mn

antiphase proximity effect is strongly supported



measurements performed at APS, Chicago.
graph taken from a talk by J. Chakhalian given at the Summer School on Interfaces of Oxides, Stuttgart, July 2005
Nature Physics **2**, 244 (2006)

contact: jochen.stahn@psi.ch