Depth-resolved magnetization reversal in antiferromagnetic [Fe/Cr]n multilayers under the applied field

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UGC-DAE Consortium for Scientific Research
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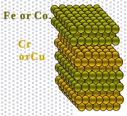
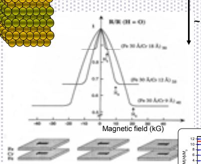
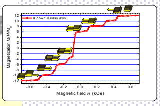
After the discovery of GMR in [F/AF] multilayers a lot of intriguing features have been observed experimatnally and predicted theoretically

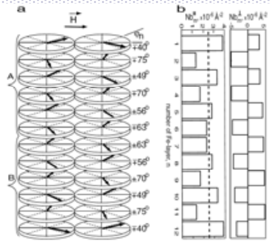


GMR of magnetic multilayers
M. N. Baibich, et al. PRL 61, 2472 (1988).



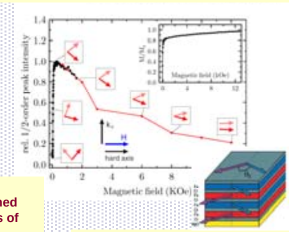


Ladder magnetization and layer-by-layer reversal
V. V. Ustinov, et al. PRB 54, 15958 (1996).



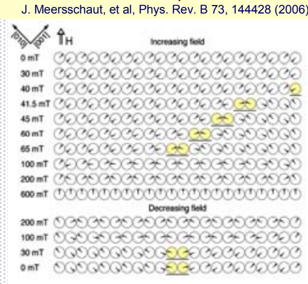
Configuration of the magnetization M in [Fe/Cr] ML H_{ext} applied in plane along one of the easy axes; dashed lines mark the hard axes. The only possible two types of domains are depicted. The results of the neutron reflectivity. (V. Lauter-Pasyuk et al., PRL 89, 167203 (2002))

Noncollinear coupling of iron layers through native iron oxide spacers revealed by the nuclear resonant refelctivity
T. Diederich, S. Couet, R. Röhlsberger, PRB 76, 054401 (2007)

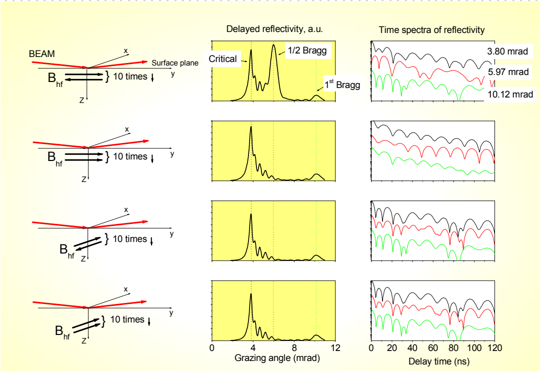


Spin-flop transition in layered antiferro
V.V. Ustinov, JMMM (2007)

Fe/Cr(100) superlattices in the external field, the Landau-Lifshitz equations of motion.
J. Meersschaut, et al, Phys. Rev. B 73, 144428 (2006).



Nuclear resonance reflectivity method



The nuclear resonance reflectivity (NRR) measurements include the angular dependency of the delayed signal + time spectra of reflectivity measured at different grazing angles and provide us with an exclusive depth-resolved information about the magnetization ordering in multilayers.

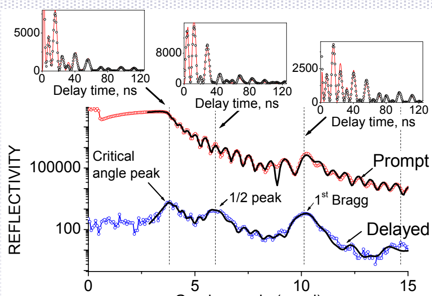
SAMPLE

[Si/SiO$_2$](substrate)/Cr(10nm)/[^{57}Fe(3nm)/Cr(1.2nm)]x10/Cr(2.8nm)

- has been grown using ion beam sputtering at room temperature in a UHV chamber with a base pressure of 1 x 10^{-7} mbar at Indore Centrum (India).

The measurements have been performed at the station BL09XU of SPring-8 at different values of the external field (0 – 1500 Oe).

Firstly without the external field

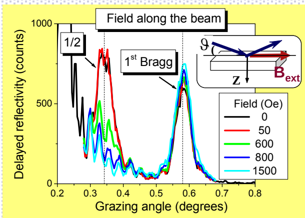


The fit of the delayed reflectivity curve should be done simultaneously with the fit of the time spectra of reflectivity. For the joint fit we use the parameters, obtained by the Mössbauer spectrum fit, measured beforehand in the Lab, and from the prompt reflectivity curve fit. The main purpose of the joint fit of the NRR data is the depth distribution of the three chosen $\mathbf{B}_{hf}$ and their effective orientation in plane. We expected that when the external field is absent, $\mathbf{B}_{hf}$ antiferromagnetically coupled between adjacent ^{57}Fe layers, has no any preferable azimuth direction in the surface plane. However, the fit of our data set has been more or less successful with the azimuth angles of 20º/-160º (or equivalently -20º/160º). For the explanation we consider the transverse partial coherence of the SR beam which restricts the fully coherent averaging of the scattering waves from different domains. With the value of the transverse coherence length for ESRF source of ~ 3 µm the estimations give the average magnetic domain size ~ 400 µm.

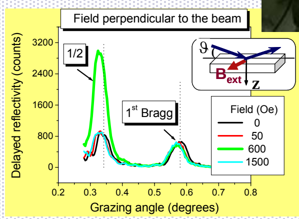
Our program package for data treatment is "REFTIM"
(http://www.esrf.eu/Instrumentation/software/data-analysis/OurSoftware/REFTIM)

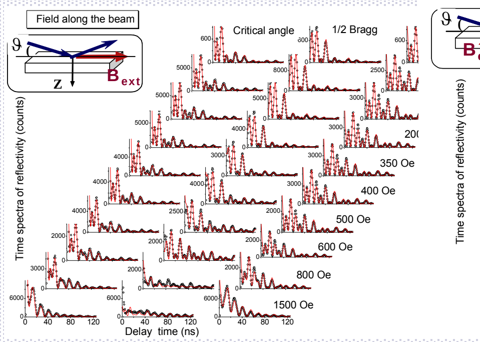
External field influence

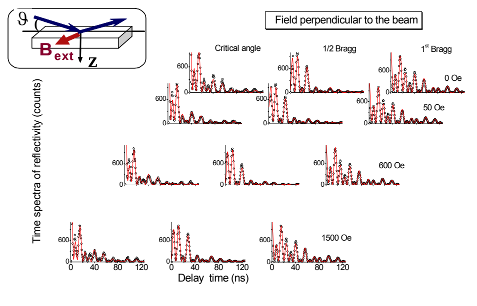
Longitudinal geometry



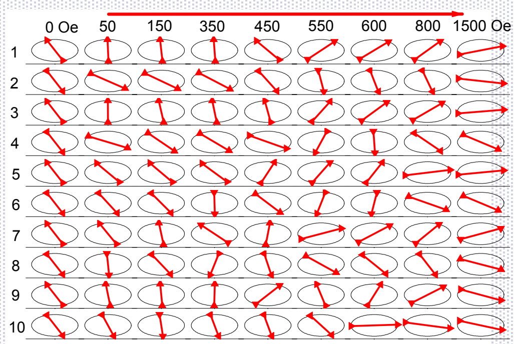
Transverse geometry







The obtained magnetization reorientations unfer the applied field



The obtained results gives a rather complicated picture of the layer-by-layer resolved reorientation of magnetization in ^{57}Fe layers under the applied field. The detailed analysis has shown that the collinear alignment in each magnetic sublattice and its cophasing rotation does not take place. We have seen that the reorientations even at the smallest applied field affected all layers but not just the top or bottom ones. The most specific magnetization state under the applied field is the twisted one, the bending details being the function of the applied field magnitude. The result should have some impact on the developing of the theory of the interlayer aniferromagnetic interaction. From our picture it is clear that in the theory we can not restrict ourselves by the interaction between just the adjacent magnetic layers, but should include the whole system simultaneously.

The results are published in http://arxiv.org/ftp/arxiv/papers/1507/1507.07074.pdf **and accepted to PRB**

ACKNOWLEDGMENTS. The Council for Scientific and Industrial Research, India. The work has been supported by RFBR grants No. 09-02-01293-a, 13-02-00760-a and 15-02-01502-a.