Study of biquadratic coupling in Fe/Cr trilayers.

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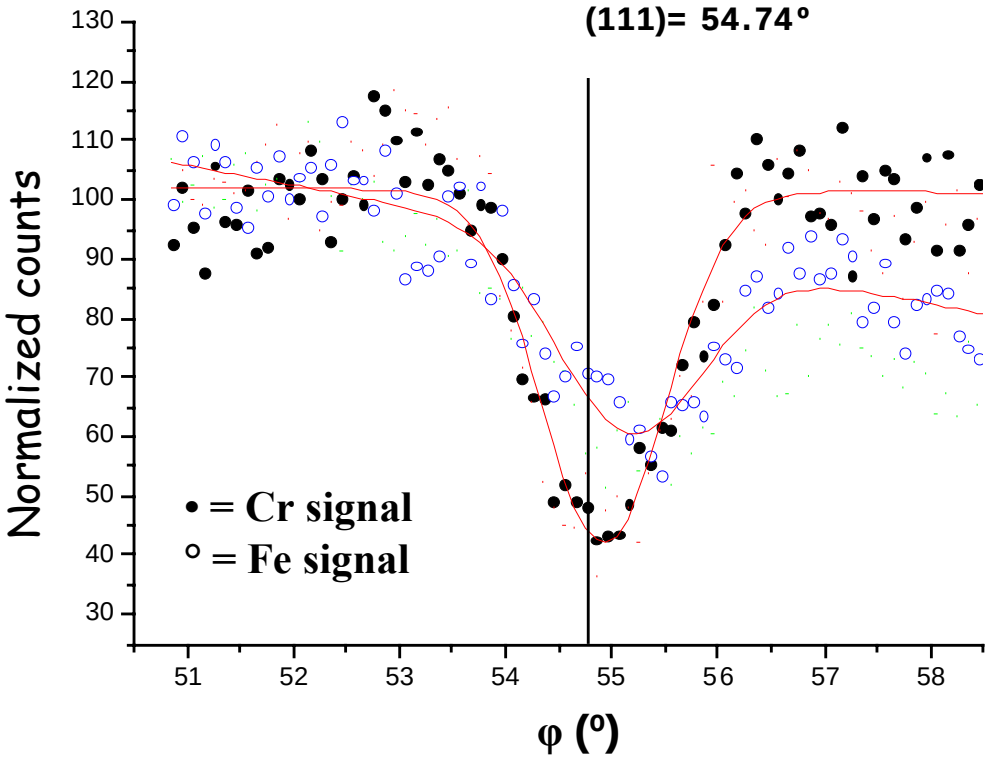
Previous investigations on Fe/Cr trilayers grown at T>423K showed that the difference in the coupling strength is dependent on the growth temperature of the system [1]. Fe(3nm)/Cr(6nm)/Fe(3nm) trilayers were grown at different temperatures (295K, 400K and 575K). Magnetization curves were measured by vibrating sample magnetometry and with MOKE. Strain was measured with Rutherford backscattering spectroscopy in channeling geometry along the (111)-axis for the Fe and Cr layers separately. X-ray reflectivity measurements determine the total thickness and roughness present in the Fe/Cr trilayer.

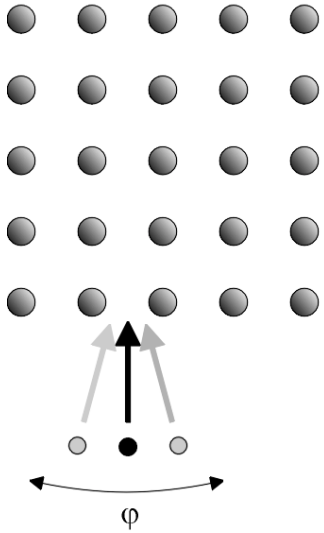
Rutherford backscattering Spectroscopy

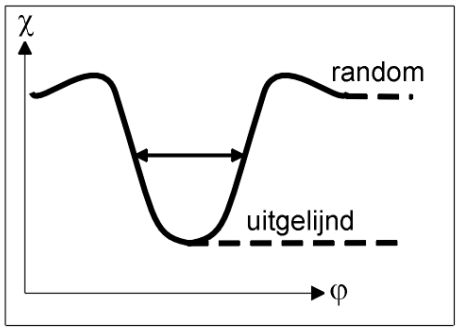
CHANNELING

Trilayer grown at 575K (B0633)

Cr channeling direction : X = 54.90°
Fe channeling direction : X = 55.17°



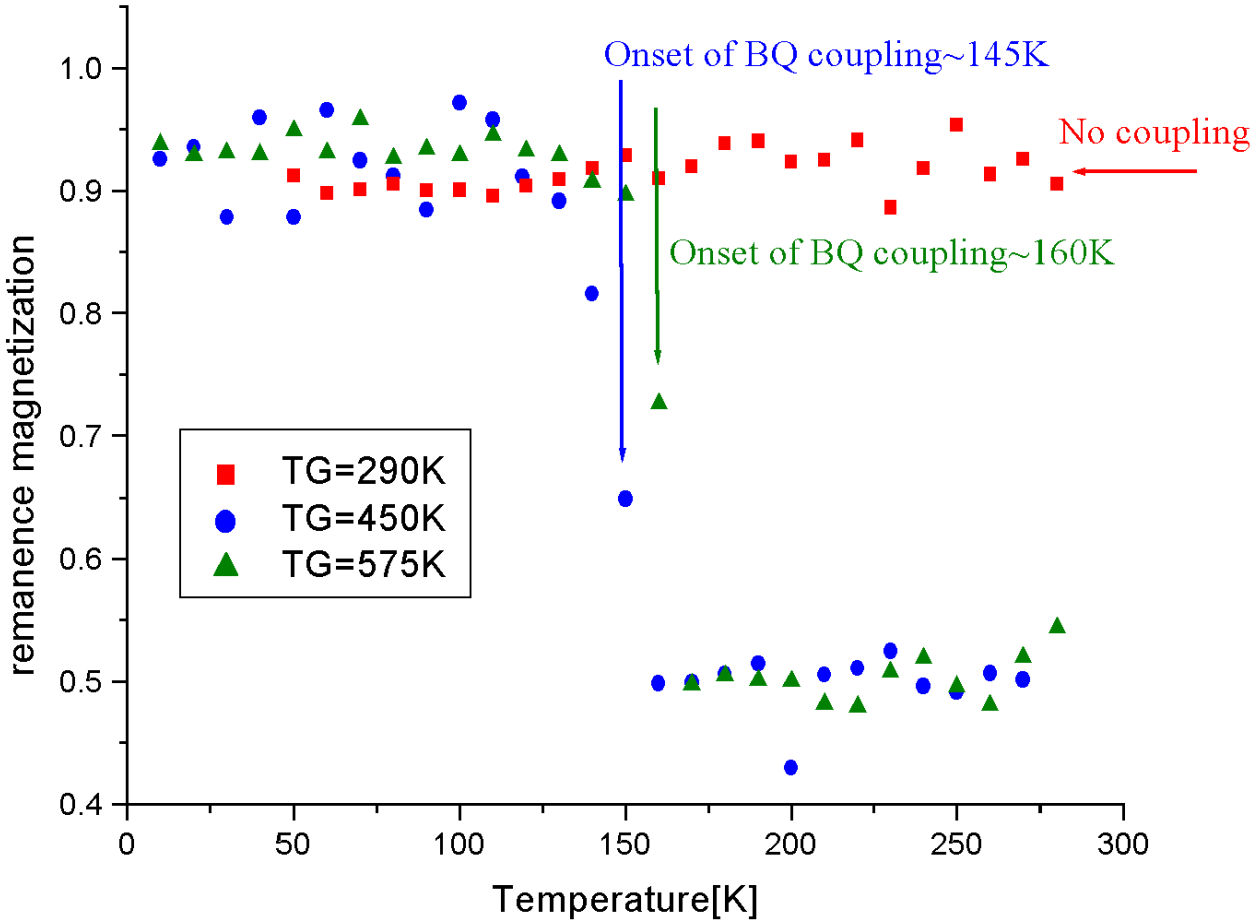




Cr layer : $\frac{a_{//}}{a_{\perp}} = 1.01$

Fe layer : $\frac{a_{//}}{a_{\perp}} = 1.02$

Remanent Magnetization.



For the samples TG = 450K and TG = 575K, the onset of BQ coupling is clear. T_N is expected to be ~150K according to the work of Fullerton [2].

Trilayers grown at different temperatures.

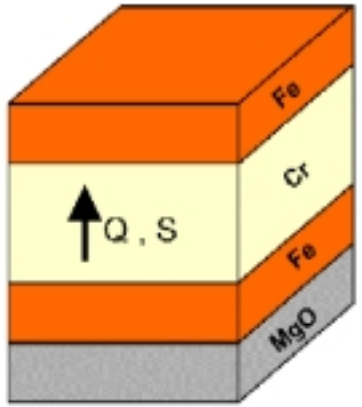
epitaxially grown Fe/Cr/Fe trilayers
on MgO(001).

Fe thickness 3 nm

Cr thickness 6 nm

Au capping layer 3 nm.

Growing temperature:
TG = 290K (B0514)
TG = 450K (B0710)
TG = 575K (B0633)



sample characterization :

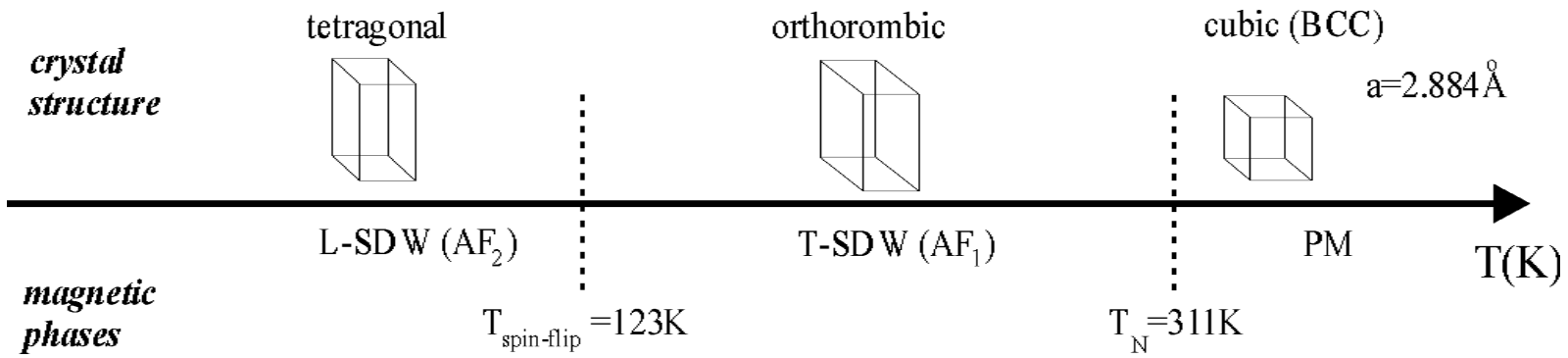
✓ The epitaxial growth was characterized by RHEED.

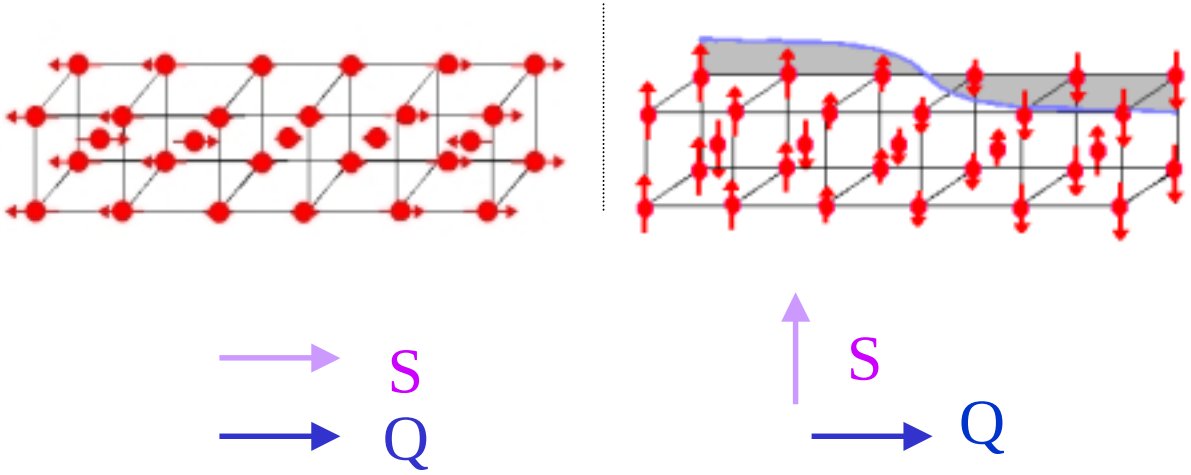
✓The thickness of the layers and the quality of the interfaces were studied by XRR.

✓ Strain in the Fe and Cr layers was measured with RBS.

✓ The position dependence of the coupling was studied with MOKE.

Cr magnetism in bulk

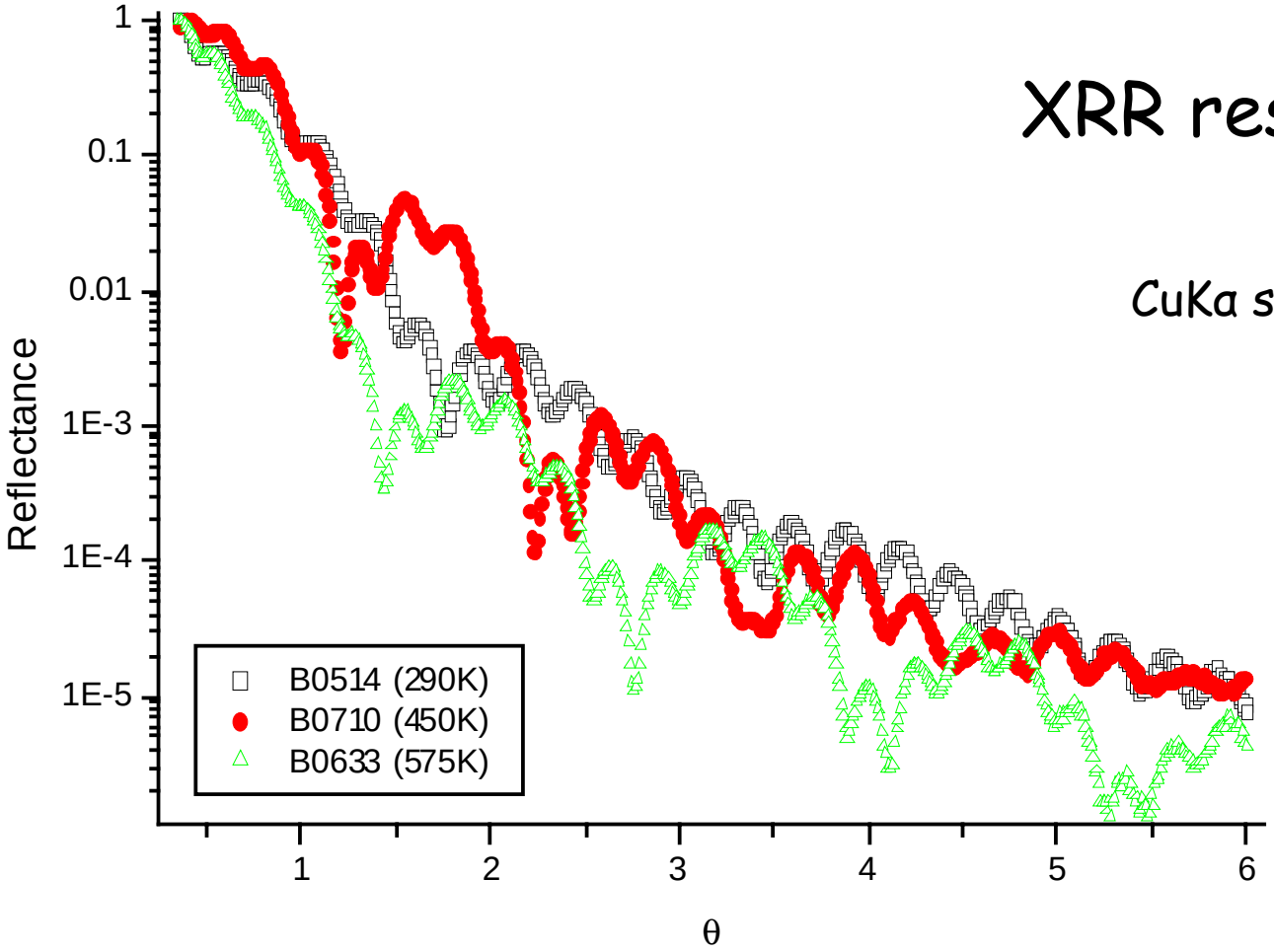




Bulk Cr is antiferromagnetic. The moments form a periodical variation (spin density wave, SDW) with a wavelength of ~ 20 lattice constants below Nèel temperature, T_N=311K.

XRR results

CuKa source (λ=1.54Å).



	σ Vac/Au (Å)	σ Au/Fe (Å)	σ Fe/MgO (Å)	Th(Au) (Å)	Th(Fe/Cr) (Å)
B0514	0.0	2.5	0.8	27	125
B0710	0.0	1.9	2.0	31	123
B0633	0.9	0.8	0.8	33	128

$\sigma^2 = \sigma_{rough}^2 + \sigma_{diff}^2$

Conclusions

✓ VSM measurements show the onset of biquadratic coupling for the trilayers grown at 450K and 575K at ~150K, while the trilayer grown at 290K does not show any transition in the measured range.

✓ XRR measurements show a clear dependence on the growth temperature of the trilayer. A decreasing roughness at the Fe/Au interface is observed for increasing growth temperature.

✓ Strain was measured with RBS by channeling along the <111>-axis of the Fe/Cr. A compression of 0.01% and 0.02% along the growth direction has been observed in the Cr and Fe layers respectively for the trilayer grown at 575K (B0633).

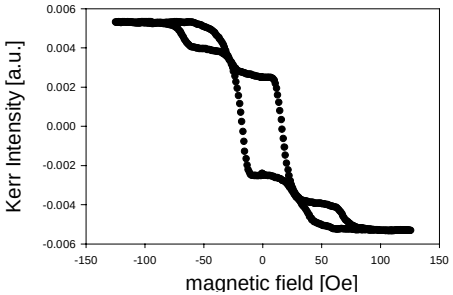
✓ MOKE was used to study the difference in coupling on different places on the sample. The results show an inhomogenity for the samples grown at 290K and 575K.

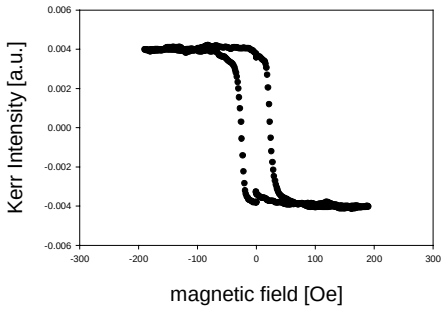
✓ CEMS and XRD were performed and results are still under evaluation.

[1] J.Dekoster et al., J. Magn. Magn. Mater. 198-199, 303 (1999)
[2] Fullerton et al. Phys. Rev. Let. 75, 2 (1995)

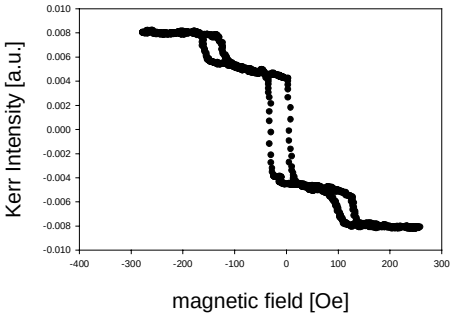
MOKE results

B0514
(290K)

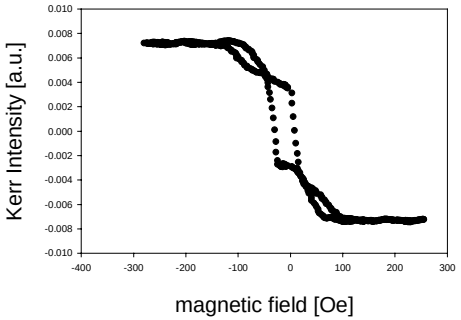




B0710
(450K)



B0633
(575K)



MOKE shows a different coupling at different places on the sample grown at 290K (B0514). The trilayers grown at 450K and 575K show a small change in biquadratic coupling.