ESRF	**Experiment title:** Interlayer coupling across semi-metallic iron monosilicide	**Experiment number:** HE 1809
Beamline: ID22N	**Date of experiment:** from: 8 December 2004 to: 13 December 2004	**Date of report:** 1 February 2006
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Report:

Aim of the experiment

For the experiment, a Fe(40 Å)/$Fe_{0.57}Si_{0.43}$(34 Å)/Fe(20 Å) trilayer grown on an Au-buffered MgO substrate was prepared. This sample was of particular interest, because magnetization measurements revealed a strong biquadratic interlayer coupling of the two outer iron layers, with a strong temperature dependent coupling strength and an unconventional exponential thickness dependence [1]. At low temperatures, no interlayer coupling was found in the trilayer. Above a critical temperature of 180 K, a strong biquadratic coupling turned up which disappeared again near room temperature. Due to the remarkable resemblance with the interlayer coupling in Fe/Cr multilayers [2], we anticipated that the coupling behavior could be explained in the frame of the loose spin model [3]. According to this model, fluctuating magnetic moments in the spacer mediate the biquadrate interlayer coupling. To investigate whether fluctuating moments are indeed present in the FeSi spacer, we selectively enriched the iron in the FeSi spacer layer, and measured the magnetic properties of the FeSi layer with Nuclear Resonant Scattering (NRS) of Synchrotron Radiation.

Measurements

The experiment was performed at the beamline ID22N. In order to obtain a complete overview of the evolution of the magnetic properties in the FeSi spacer, measurements were performed at 11 different temperatures, starting from 20 K up to room temperature. At four temperatures (20 K, 150 K, 200 K and RT), additional timespectra were measured at different external magnetic fields (2.0 T up to 5.7 T). Figure 1 shows a selection of the measured spectra as a function of increasing temperature, taken in zero external field.

Results

The measured NRS time spectra are strongly temperature dependent. Whereas the low-temperature spectra revealed a pronounced quantum beat pattern, the beats gradually disappeared with increasing temperature, ending up in a pure exponential decay at room temperature. To probe the microscopic magnetic properties of the spacer layer of an interlayer coupled multilayer system is already considered a difficult task. But, here, we can even relate the temperature dependence of the microscopic properties to the temperature dependence of the interlayer coupling.

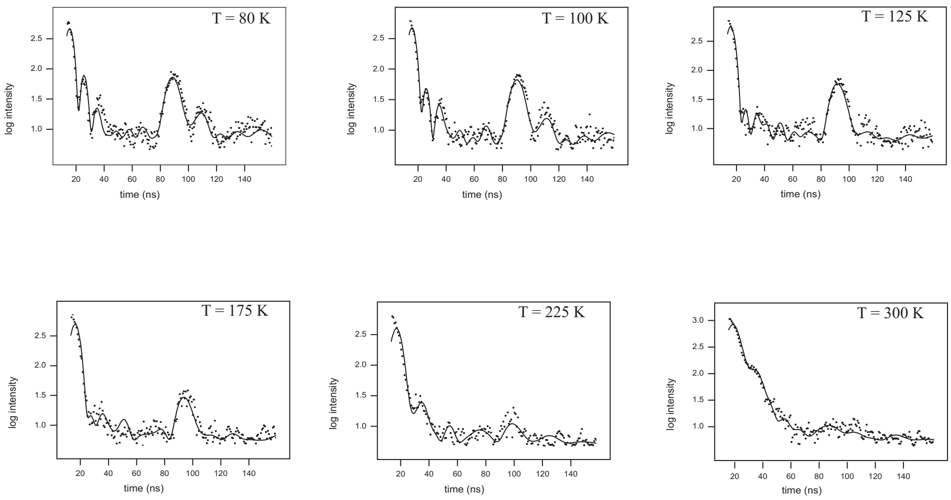

Figure 1 : Selection of the measured time spectra as a function of increasing temperature, taken in zero external field. The solid lines through de data represent the fits obtained by the fitting routine CONUSS [4].

Recent analysis of the measured timespectra with the fitting program CONUSS [4], seems to confirm the hypothesis of fluctuating moments in the FeSi spacer. The low temperature spectra could be analyzed with a FeSi spacer made up of three sites, each with a different static hyperfine field. At higher temperatures, the damping of the timespectra could be reproduced by allowing the three hyperfine fields to fluctuate between two opposite directions, modeled through the stochastic theory of of Blume-Tjon [5]. The higher the temperature, the higher the observed fluctuation frequencies of the hyperfine fields. At room temperature, fluctuation frequencies in the MHz regime were obtained. With these quantitative results, we are able to explain the biquadratic interlayer coupling in $Fe/Fe_{0.57}Si_{0.43}/Fe$ trilayers in the frame of the loose-spin model. A publication is in preparation, and is prospected to be submitted for publication in 2006.

References

[1] B. Croonenborghs, *Magnetostatic coupling mediated by metastable FeSi*, Ph.D. thesis, Katholieke Universiteit Leuven, 2004.

[2] J. Meersschaut et al., Phys. Rev. Lett. 87 (2001) 107201.

[3] J.C. Slonczewski, J. Appl. Phys. 73 (1993) 5957.

[4] W. Sturhahn, Hyp. Interact. 125 (2000) 149.

[5] M. Blume and J. A. Tjon, Phys. Rev. 165 (1968) 446.