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Report:

We investigated changes of the magnetic properties of a single Fe monolayer on Au(001), induced by the interlayer exchange coupling to FeAu monoatomic superlattices. The method used was Grazing Incidence Nuclear Resonant Scattering of X-rays (GI-NRS). In combination with the ^{57}Fe probe layer concept the method gives local structural and magnetic information from a sample region pre-selected during the sample preparation. The studied system is shown on Figure 1. On an atomically smooth single crystal of MgO(001) an Au buffer layer was grown by Molecular Beam Epitaxy according to the receipt described in details in Ref. [1]. On the Au buffer, a ^{57}Fe monolayer of was deposited at room temperature. In the next step of the preparation a moveable shutter was used during the Au deposition to obtain a stepped Au spacer layer with the thickness ranging from 3 to 20 monolayers in the one monolayer steps. The step width was 1mm. Then, a monoatomic ($^{56}Fe_1Au_1)_3$ superlattice was prepared by alternating evaporation of ^{56}Fe and Au atomic layers. During the superlattice evaporation a part of the previously prepared system was shuttered allowing to study the uncoupled Fe monolayer properties. Finally, the whole sample was capped with a 2nm protective Au film. To cover the full range of the Au spacer thickness, two 10x10mm^2 substrates were used, with the control Fe monolayer on each. Before the synchrotron experiment, the samples were characterized using Magnetooptic Kerr Effect (MOKE) and the Conversion Electron Mössbauer Spectroscopy (CEMS). The GI-NRS measurements were performed at the ID22N beam line. The samples were mounted in the He cryostat and oriented with the step edges parallel to the direction of the x-ray propagation. The grazing incidence angle was optimized for the maximum of the delayed counts intensity. The count rate was substantially lower than expected for ID18, which has the optimum performance for ^{57}Fe monolayer experiments, so the collection of a reasonable spectrum took at least 6 hours as compared with 2.5 hour, which we planned in the proposal. In the temperature dependent GI-NRS investigations the time spectra were collected for the different sample positions corresponding to the selected thickness of the Au spacer and thus, the influence of the coupling in different regions of Fe monolayer was probed as a function of the Au_N spacer thickness, where N denotes a number of Au atomic layers in the spacer.

First, the temperature dependent GI-NRS measurements of the uncoupled Fe monolayer region were performed. The time-spectra measured at different temperatures are shown on the Figure 1b. The spectra accumulated above 200K are of paramagnetic character what is related to the Curie temperature of the system $T_c \approx 200K$, in perfect agreement with previous MOKE results. Below T_c quantum beats are visible indicating existence of the ferromagnetic order. The analysis of the 20 K spectrum gives unique data on the monolayer hyperfine parameters. Next, for the chosen temperatures 200K and 240K the measurements as a function of the Au_N spacer thickness were done. The time-spectra accumulated at 240 K (40 K above the monolayer Curie temperature) for the different N are shown in Figure 2. The top most spectrum represents the uncoupled Fe monolayer region. It is be clearly seen that quantum beats appear in the spectrum measured for the Fe monolayer region spaced from the top FeAu superlattice by the 4 ML Au spacer. Surprisingly, the direct proximity of the magnetic layer (N=2,3) does not lead to the hyperfine magnetic field enhancement, whereas the indirect coupling does, increasing T_c by at least 20%! At the Au thickness of 7ML the beats disappear again and then seem to change their character again at N=9 and N=11. The origin of these behavior is the interlayer exchange coupling, since the structure of the system is unaffected. The coupling decays with the spacer thickness in the oscillatory way, and similar behavior is reflected in the T_c vs. spacer thickness dependence. The detailed data evaluation is in progress.

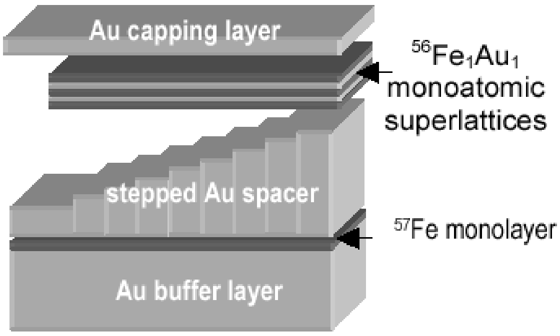

Fig.1a The layers configuration of the measured system is schematically shown.

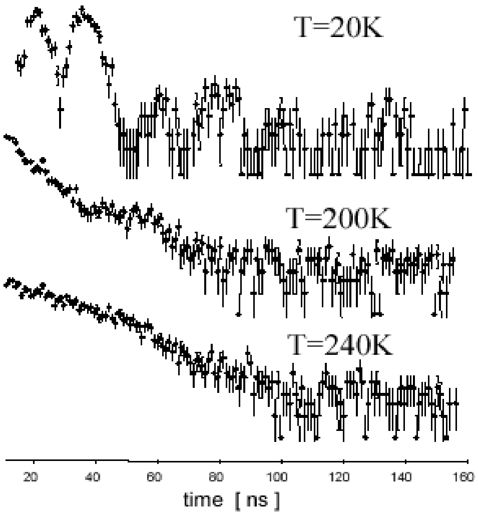

Fig.1b GI-NRS time-spectra collected for the uncoupled ^{57}Fe monolayer at 20K, 200K, 240K

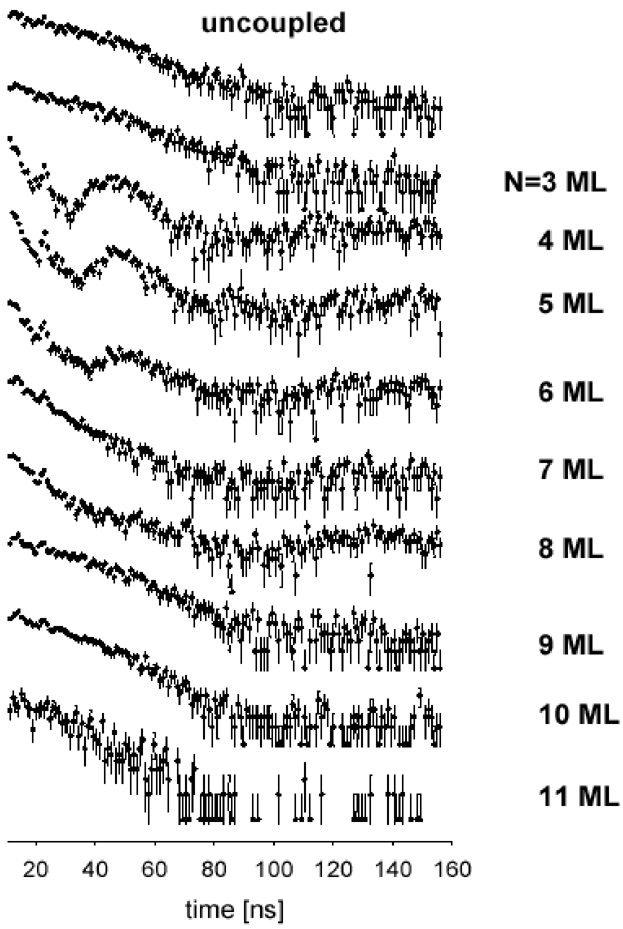

Fig.2 GI-NRS time-spectra collected for the system shown in Fig.1a taken at 240 K as the function of the Au spacer thickness N (in monolayers)

The preliminary results described above unambiguously prove that the magnetic properties of the Fe monolayer can be tuned by the interlayer exchange coupling to another magnetic system. The experiment suffered for low count rate (below 1Hz) and only half of the planned spectra were measured. We will apply for additional shifts allocated at ID18 to obtain the complete temperature dependence of the monolayer magnetism on the coupling to FeAu (perpendicularly magnetized) and to study the influence of the anisotropy type (in-plane/out-of-plane) as originally planned in the proposal.

References:

[1] N. Spiridis, J.Korecki , Appl. Surf. Science **141**, 313 (1999)