Experiment title:		Experiment number:
ESRF	**Experiment title:** **Polarization mechanism of Ge in Fe_n/Ge_n multilayers.**	**Experiment number**: HE-2000
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Report:

Ferromagnetic metal /semiconductor multilayers have become a subject of intense studies stimulated by their potential applications in spin-based electronics. These studies revealed that in such systems the interplay between structure and electronic hybridization at the interfaces governs the observed unusual magnetic behavior. A key point is to understand how spin-polarized electrons or holes are injected from a magnetic material into a semiconductor. Numerous band structure calculations of ferromagnet/semiconductor Fe/Ge based magnetic multilayers predict a significant polarization of the Ge atoms at the interface with a total (spin + orbital) induced moment up to $0.1\mu_B$ [1].

In this work, we have studied the induced orbital magnetism on the 4p shell of Ge of Fe_n/Ge_m magnetic multilayers. In order to get information on Ge magnetism at the interface we have measured XMCD spectra at the Ge K-edge in a series of multilayers in which the thickness of Fe layers was kept constant t_{Fe} =2nm whereas the thickness of Ge layers was diffferent t_{Ge} =1nm, 1.5nm, 2nm and 5nm. For the sake of comparison, we have also studied thin films of $Fe_{1-x}Ge_x$ alloys with a concentration x=20%, 10 and 3%. All the samples have been grown by e-beam evaporation on a Si substrate under UHV conditions at the Institute of Physics of the Slovak Academy of Sciences (Slovak Republic) where - prior to the experiments at the ESRF - the samples have been structurally characterized by x-ray reflectometry and transmission electromicroscopy. Based on XRD measurements the interface roughness (or intermixing) is found to be less than 0.2nm which proves the high structural quality of the multilayers.

We have reproduced in Figure 1 the normalized isotropic Ge K-edge XANES spectra for all the Fe/Ge multilayers and thin films of GeFe alloys. As it becomes evident from the figure, the XANES spectral shape changes dramatically as a function of Ge thickness and/or concentration. In the case of a thick Ge spacer layer (considered as a thick Ge thin film), the XANES spectrum is dominated by a single peak with a shoulder at the high energy side. However, XANES spectra recorded on the alloy with low Ge concentration and on multilayers with small Ge layer thickness are dominated by another peak which appears at slightly higher energies. This result clearly indicates that there are drastic changes in the electronic structure of the 4p-states of Ge atoms when they are hybridized with 3d-4p states of Fe at the Fe/Ge interfaces. At a first glance one can argue that the observed behavior of the XANES spectra in the multilayers is due to a formation of FeGe alloy at the interface. The results of XMCD measurements indeed disprove this argument.

XMCD measurements of all samples have been performed at the Ge K-edge at temperature of 10K with a magnetic field of 2T applied parallel to the incoming X-ray beam. The XMCD spectra are shown on figure 2. One can observe that the spectral shape of the Ge K-edge XMCD in Fe_n/Ge_m multilayers is practically the same and is independent of the Ge thickness. However, the amplitude of the XMCD signals changes with Ge thickness and is the largest for thinner Ge spacer layers. This result shows that the Ge induced polarization decreases, as expected, from the interface to the Ge central layers. Moreover, it seems to indicate that the Ge induced magnetization decrease monotonically through the Ge layer and does not oscillate as it has been observed in the case of Fe/Ce or Fe/W multilayers.

In the case of $Fe_{1-x}Ge_x$ alloys, the spectral shape of the Ge K-edge XMCD changes strongly with the Ge concentration and is different from the one measured on multilayers. A very intense XMCD signal (up to 1% with respect to the edge jump) is observed for the most concentrated sample, x=20%. The XMCD spectrum is strongly dominated by a negative peak which indicates that the Ge 4p orbital moment is parallel to the total Fe magnetic moment. By lowering the Ge concentration, the XMCD signal becomes nearly symmetric which indicates that the orbital magnetic moment of the 4p-states is much smaller than for the sample with x=20% (the integral of the XMCD signal at the K-edge is proportional to the orbital magnetic moment). Finally, the shape of the XMCD spectra recorded on alloys and multyilayers is significantly different and this result indicates that the hybridization between Ge(4p)-Fe(4p-3d) states are strongly influenced by the structure.

The results presented in this report are still in the course of quantitative analysis and will be the subject of a future publication.

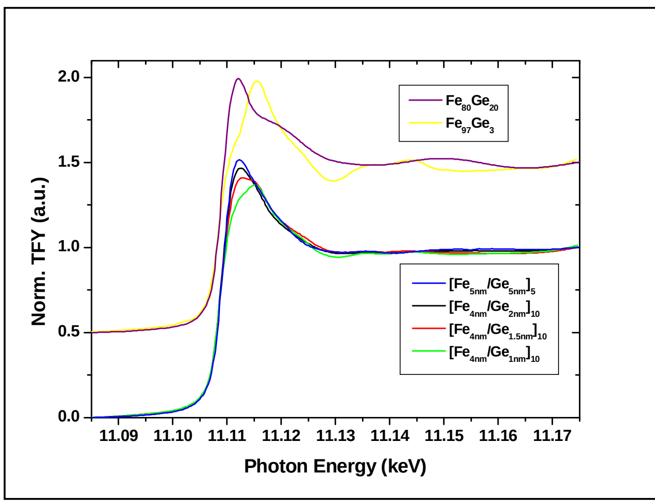

Fig.1: Isotropic normalized Ge K-edge XANES spectra for various Fe_n/Ge_m magnetic multilayers and $Fe_{1-x}Ge_x$ alloys. The XANES spectra for the alloys have been shifted by 0.5 for clarity of presentation.

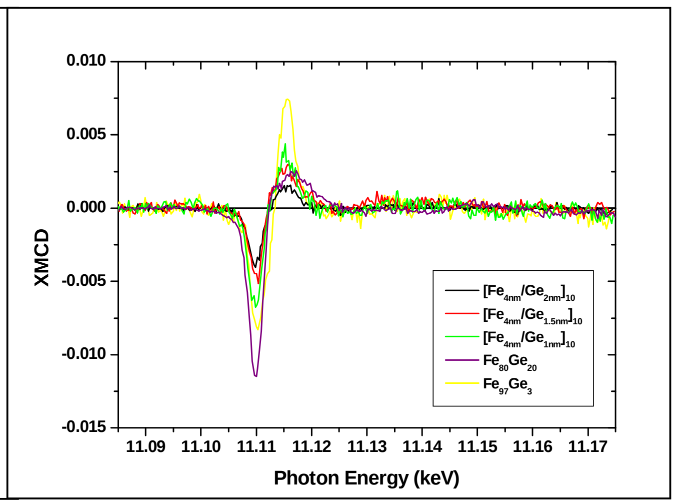

Fig.2: Ge K-edge XMCD spectra for various Fe_n/Ge_m magnetic multilayers and $Fe_{1-x}Ge_x$ alloys. The spectra have been recorded at 10K and under 2Tesla external magnetic field.

[1]. I. Cabria, A. Y. Perlov, and H. Ebert, Phys. Rev. B**63**, 104424 (2001).