Interlayer coupling in EuS-based superlattices

P. Sankowski and P. Kacman

Institute of Physics PA S and ERATO Semiconductor Spintronics Project,
Al. Lotników 32/46, Warsaw, Poland

Ferromagnetic EuS-based multilayers, with narrow-gap semiconductor (PbS) as well as an insulating (YbSe) diamagnetic spacers were studied. It was proven experimentally, by neutron reflectivity, that consecutive EuS layers are antiferromagnetically coupled in both, EuS/PbS and EuS/YbSe superlattices (SL) [1]. In order to determine the strength of the antiferromagnetic interlayer coupling (IC), the intensity of the first magnetic SL Bragg peak vs. applied external magnetic field was measured. Moreover, the in-plane anisotropy and the domain structure were studied by polarized neutron reflectivity, [2]. Despite the fourfold symmetry of the growth plane, a preferred orientation of domain magnetization directions along one of the two possible in-plane axes was found, i.e., [210] and [110] for EuS/PbS and EuS/YbSe, respectively.

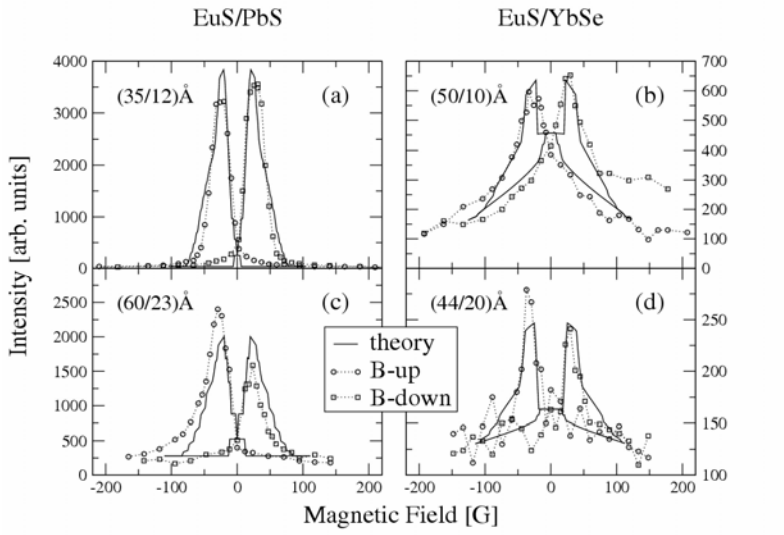

Fig. 1. The dependence of the intensity of the antiferromagnetic neutron reflectivity peak *vs.* magnetic field for EuS/PbS and EuS/YbSe SLs. The numbers in parenthesis give magnetic/nonmagnetic layer thickness. Dotted lines represent the experimental results, solid lines — the simulations.

The dependence of the intensity of the antiferromagnetic neutron reflectivity peak *vs.* magnetic field is presented in Fig. 1. This dependence was then simulated using a Stoner-Wohlfarth model. The total magnetic energy of the SL, which consists of IC, cubic anisotropy, and Zeeman terms, was minimized as a function of the magnetization directions. The values of the IC strength J and the anisotropy K constants were obtained by least-square fitting of the calculated peak intensities vs. magnetic field to the experimental data. To reproduce the observed spectra it was necessary to take into account also the magnetic/nonmagnetic interfacial roughness, by assuming a Gaussian spread of J. For both EuS/PbS and EuS/YbSe SL, the best fit was obtained for the directions of the in-plane easy axes, which agree with

those determined by polarized neutron reflectivity. Addition of a uniaxial anisotropy term (along the directions determined by the polarized neutron experiments) to the Stoner-Wohlfarth Hamiltonian further improved the fitting for the EuS/YbSe structures.

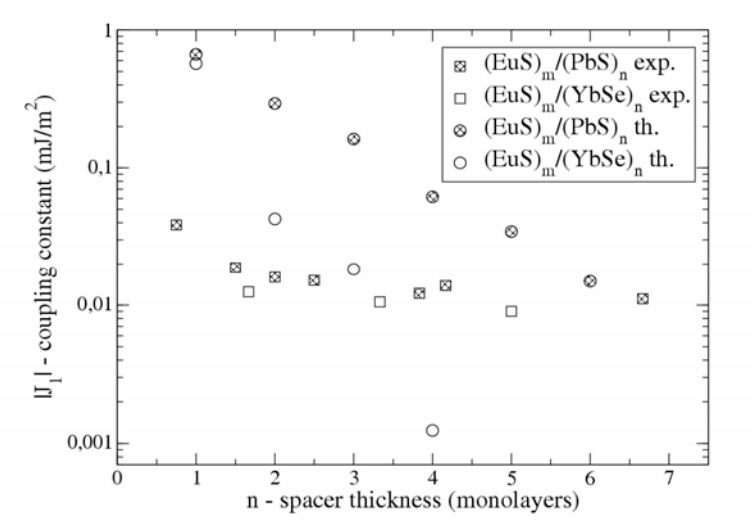

Fig. 2. Interlayer coupling constant J_1 as a function of spacer thickness for $(EuS)_m/(PbS)_n$ and $(EuS)_m/(YbSe)_n$ SLs. Squares represent values obtained form neutron experiments and circles the model predictions.

In the tight-binding theoretical model [3], the IC phenomena in both, EuS/PbS and EuS/YbSe semiconductor SL were explained in terms of the electronic band structure effects. The model predicts AFM IC between EuS layers in both studied systems, as seen in the experiment, and also a smaller strength and a shorter range of IC when the EuS layers are separated by YbSe instead of PbS. In [3] it was also shown that the deformation of the lattice due to the strains present in the SL does not change the IC considerably. Here we have improved the calculation by taking into account the neglected before spin-orbit interaction in PbS. The comparison of the theoretical predictions about the strength and range of IC with the fitted J values is presented in Fig.2. The J values obtained from the fitting to the neutron scattering spectra are lower and decrease slower with the thickness of the spacer layer than predicted by the model.

Work supported by the FENIKS EC Project: G5RD-CT-2001-00535 and the Polish State Committee for Scientific Research grant PBZ-KBN-044/P03/2001.

[1] H. Kępa, C.F..Majkrzak, A.Yu. Sipatov, T.M. Giebultowicz, Physica B **335**, 44 (2003).
[2] H. Kępa, P. Sankowski, P. Kacman, A. Yu. Sipatov, C. F. Majkrzak, T. M. Giebultowicz, J. Mag. Mag. Mat. Proceedings of ICM, Rome 2003.
[3] P. Sankowski, P. Kacman, Acta Phys. Polon. A,.**103**, 621 (2003).

Name of the presenting author: Piotr Sankowski
e-mail address: sank@mimuw.edu.pl
url's: http://www.mimuw.edu.pl