Influence of interface mixed layer on non-collinear exchange coupling in V/Fe multilayers

A. Ranecka,[1] M. Pugaczowa-Michalska,[1] and L. Smardz[1]

[1] *Institute of Molecular Physics, Polish Academy of Sciences, Smoluchowskiego 17, 60-179 Poznań, Poland*

The interlayer exchange coupling (IEC) through non-magnetic spacers plays an important role in the potential application of magnetic systems. However, the type and strength of the IEC dependence on the thickness of non-magnetic spacer have not been completely explained. The objective of this work is to determine the mechanisms leading to non-collinear exchange coupling in V/Fe multilayers (MLs). The samples were deposited onto naturally oxidised Si(100) substrates at room temperature (RT) by UHV magnetron sputtering.The mixed layer thicknesses near the Fe-V interfaces of the studied multilayers were determined in-situ using X-ray photoelectron spectroscopy (XPS). Ex-situ studies using standard X-ray diffraction confirmed the strong (110) texture of the multilayers. The results of systematic in-situ XPS studies of the integral intensity of the Fe-2p peak as a function of the nominal thickness of the Fe sublayer deposited on vanadium allowed us to estimate the thickness of the pure iron layer that forms the mixed layer at about 0.4 nm. Assuming the same thickness of the vanadium layer that forms the mixed layer, the total thickness of the mixed layer in the Fe-V interface region was about 0.8 nm. Magnetic characterization of the V/Fe MLs with constant thicknesses of the Fe sublayers equal to 0.6 nm (about three (110) atomic layers) confirmed the oscillatory nature of the IEC with a period of 0.6-0.8 nm of the vanadium layer. At a temperature of 300 K, four energy minima are visible confirming local maxima of the antiferromagnetic coupling for V thickness of about 1.2-1.4, 1.8-2, 2.6-2.8, and 3.2-3.4 nm. The experimentally determined thickness dependence of the coupling energy was sufficiently consistent with results obtained from the ab-initio calculations for (110) Fe-V-Fe trilayers with ideal interfaces without mixed layers. It should be emphasized that in the case of the experimentally studied V/Fe MLs, there is practically no layer of pure iron, but only an alloy with variable concentration in the direction perpendicular to the substrate.The antiferromagnetic coupling of the V/Fe MLs was also confirmed in magnetoresistance studies. So far, in the analysis of the interlayer exchange coupling based on the fit of the Stoner-Wohlfarth model to the experimental hysteresis loops have been limited to two terms: bilinear and biquadratic. In the case of the 1.6 nm - V/0.6 nm - Fe ML the measured hysteresis loops could not be satisfactorily fitted to the model considering only these two terms. Therefore, the hysteresis loop analysis additionally takes into account the contribution from the cubic constant of the IEC. Furthermore, using the IEC modification by hydrogen absorption in the V spacer, possible mechanisms responsible for biquadratic and cubic coupling are given. The modification of the coupling using hydrogen absorption is fully reversible. After desorption of hydrogen in air at RT, the sample returned to the original state.