Interaction of spin-polarized electrons with surfaces: Single-electron Spectroscopy versus Two-electron Spectroscopy

Sergey Samarin* [1], **Oleg Artamonov**[†], **and Jim Williams ***

[*] School of Physics and Astrophysics, University of Western Australia, Perth 6009, Australia
[†] Department of Physics, St. Petersburg State University, St. Petersburg, Russia

Synopsis Spin-polarized Single- and Two-electron spectroscopies of various surfaces are compared and analyzed.
.

Spin-polarized two-electron spectroscopy, SP(e,2e) [1], and spin-polarized single-electron spectroscopy [2] have been applied to study nonmagnetic (W, Au, Ag) and magnetic (Fe, Ni, Co) surfaces as well as multi-layer structures. Examples of such studies are presented and analysed.

Two-electron spectroscopy with spin-polarized incident electrons provides information on spin-asymmetry of the Spectral Density Function (SDF) of the sample in the centre of the Brillouin zone [1]. A non-zero value of the SDF asymmetry indicates an imbalance of spin-up and spin-down states in the valence band of a ferromagnetic metal. If the asymmetries of the (e,2e) spectra, measured for non-reversed and reversed target magnetization, are denoted as A^{M1} and A^{M2}, then the spin-orbit (A_{SO}) and exchange (A_{ex}) contributions are given (to leading order) by: $A_{ex} = ½ (A^{M1} – A^{M2})$ and $A_{SO} = ½ (A^{M1} + A^{M2})$. In such a way the exchange and the spin-orbit interactions in a 3ML Co film on W(110) have been identified and located in energy– and momentum– space of the valence band [2].

In contrast to a Co film, a 5 ML Fe film does not show any spin-orbit component in the asymmetry spectrum although a substantial exchange component is observed in the binding energy spectrum and in the energy sharing distribution.

The emission of correlated electron pairs, excited by a spin-polarized incident electron beam from a thin Au layer on top of a Fe film, has been studied using SP(e,2e). The deposition of 1ML of Au on top of 5 ML of Fe decreases the spin-asymmetry of the SDF from 10% to 7% while still showing a ferromagnetic feature in the spectrum. At the same time in the asymmetry of the energy sharing distribution, a spin-orbit component of about 2% appeared together with an exchange component of about 7%, which indicates ferromagnetism in this structure. The ferromagnetic state of the Au/Fe structure is very stable and did not change during at least two months. Since (e,2e) spectroscopy is very surface sensitive this result may indicate a ferromagnetism of the ultrathin Au film on the Fe layer.

A thin Ni buffer layer (1 – 3 ML) between the 3 ML of Co and the W(110) substrate substantially improves the crystallinity of the Co film and enhances the spin asymmetry of the SDF (as measured by spin-polarized two-electron spectroscopy) and may indicate the increase of the magnetic order in Co film.

Three different modes of Spin-polarized single-electron spectroscopy, spin-dependent elastic scattering, spin-dependent electron energy loss spectroscopy (SPEELS), and spin-dependent secondary emission spectroscopy were applied with various kinematics to magnetic and nonmagnetic surfaces. It was shown that an intensity asymmetry in those spectra depends very much on the polar and azimuthal angles of the sample position [2].

References

[1] A. Morozov *et al.* 2002 *Phys. Rev.* B **65** 104425
[2] S. Samarin *et al.* 2016 *Phys. Rev. B* ***94*** *155440*

[1] E-mail: samar@physics.uwa.edu.au.edu