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Prospects of X-ray Photoemission Electron Microscopy at the first beamline of Polish synchrotron SOLARIS

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The first Polish synchrotron radiation facility "Solaris" is currently being built in Krakow [1]. The first experimental beamline at "Solaris" will use bending magnet radiation and two exchangeable end-stations: a spectroscopic X-ray photoemission electron microscope (SPE-XPEEM) and a soft X-ray absorption spectroscopy (XAS) chamber. In this contribution we present the beamline specification and exemplary results obtained with our end-station microscope, which (in the status nascendi of "Solaris") has been operated at the NanoXAS beamline in Swiss Light Source (SLS). The end-stations should be available for broad users community at "Solaris" in 2015/2016.

The SPE-XPEEM instrument, equipped with the energy analyzer, can also work in the Low Energy Electron Microscopy (LEEM) mode, which expands its application field also to structural surface studies. A preparation chamber is attached to the microscope, which enables in situ MBE growth and characterization of metal and oxide surfaces, films and nanostructures. Most of the X-PEEM [2] capabilities including imaging with chemical and magnetic [3] sensitivity given by XAS, X-ray photoemission spectroscopy and magnetic dichroism (XMCD and XMLD) could be tested and verified. The full-field spectro-microscopy and micro-spectroscopy including broad range of elements and their chemical as well as magnetic states will be demonstrated for in situ and ex situ prepared surface nanostructures.

The best spatial resolution of approximately 15 nm is demonstrated in Fig.1 where secondary electrons XPEEM image of self-organised Fe stripes prepared on a W(110) single crystal is shown.

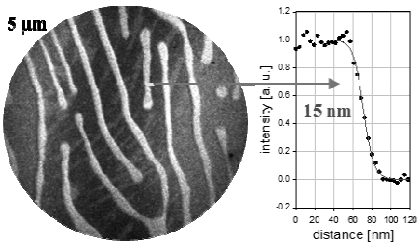

Figure 1. XPEEM images of Fe stripes on a W(110) single crystal at the Fe L3 edge. The intensity profile across an Fe stripe demonstrates the spatial resolution of 15 nm.

The XPEEM micro-spectroscopic capabilities can be best exploited for multicomponent or structured samples, such as multilayers and wedge-shaped samples used for thickness dependent studies. An example of such a sample is an epitaxial Fe/Au/Co structure grown on W(110). The base 200 Å Fe(110) layer is followed by a (111)-oriented 7 Å Au film. Using a shutter in front of the tungsten crystal, a part of the sample was covered with 20 Å of cobalt. In this manner, at the border between the Fe/Au bilayer and the exchange coupled Fe/Au/Co trilayer, a Co microwedge was formed with a thickness ranging from 0 to 10 ML, as determined by the quartz microbalance. In Fig. 2a, an image of the Co microwedge area is presented, which was obtained as a difference between two images: the first one taken at the L3 edge of Co and the second one at the pre-edge energy (i.e., 10 eV below). The intensity changes across the image, from the dark area, without cobalt, to the bright area, where the Co thickness saturates at 10 ML, can be quantitatively examined by analysing the local XAS spectra. The XAS spectra for the Fe/Au and Fe/Au/Co areas are presented in Fig. 2b as A and B, respectively.

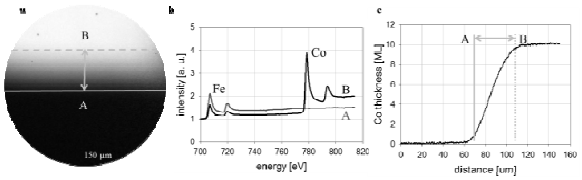

Figure 2. (a) Differential image of Co distribution in a microwedge and the surrounding area of the sandwiched Fe/Au/Co sample described in the text. The FOV was 150 µm. (b) XAS spectra taken at positions A and B. (c) The L3 Co intensity profile across the Co microwedge. The vertical lines refer to the corresponding lines in (a). The Co thickness scale is derived within the linear thickness – intensity relation.

The intensity profile (Fig. 2c) demonstrates that the thickness of the Co layer can be precisely determined at a given position on the sample.

Another exemplary result is shown in Fig.3, where both chemical an magnetic sensitivity is exploited to image the magnetic domain structure in Fe/Au/Co trilayers grown in situ on W(110).

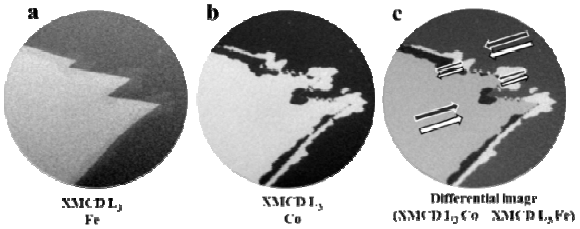

Figure 3. Magnetic domains structures in Fe/Au/Co trilayers grown on W(110) as seen by XMCD-PEEM. Arrows indicate relative magnetization alignment of Fe and Co layers.

Magnetic domain structures were imaged for both magnetic sublayers by tuning the L3 absorption edges of Fe (Fig. 3a) and Co (Fig. 3b). Inside the domains, the magnetisation direction of Fe is reflected in the Co layer – the Fe and Co layers are ferromagnetically coupled. At the domain borders, a secondary domain structure is observed with antiparallel Co and Fe magnetisation alignment, as shown schematically by arrows in the Fig. 3c. This secondary structure can be better visualised based on the image obtained as a difference between the Fe and Co XMCD images (Fig. 3c).

The set of images presented in Fig. 4 shows the evolution of the magnetic structure during the thickness-induced in-plane spin reorientation transition (SRT) in Fe/W(110) [3]. All the XPEEM images presented in

Fig. 4 are the single frames from a movie recorded during the growth of the Fe film at the Fe L_3 edge for the circularly polarised photons.

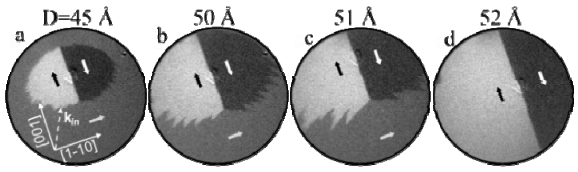

Figure 4. In-plane thickness-induced SRT in Fe/W(110) observed using XPEEM with circularly polarised X-rays at the Fe L3 edge. The FOV was 150 μm.

For all images (frames) in Fig. 4 the exposure time was only 0.2 s. It demonstrates the usefulness of the XPEEM technique for studying slowly varying physical processes in real time.

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