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Hard X-ray photoelectron spectroscopy (HAXPES) ($\leqslant$15 keV) at SpLine, the Spanish CRG beamline at the ESRF

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Abstract

In this contribution we present the actual status of the SpLine project devoted to the implementation of hard ($\leqslant$15 keV) X-ray photoelectron spectroscopy (HAXPES) in combination with surface X-ray diffraction (SXRD) at the Spanish CRG beamline (SpLine) at the European Synchrotron Radiation Facility (ESRF). The beamline is located at the bending magnet D25 at the ESRF and can be operated in the X-ray energy range 5–45 keV. The main project goals are the detection of very high kinetic energy photoelectrons up to 15 keV, in particular the simultaneous detection of the diffracted photons and photo-emitted electrons. Therefore, special effort has been devoted to develop a novel electron analyzer, capable of working at very high as well as low energies. The analyzer is a sector of a Cylindrical Mirror Analyzer (CSA300HV) with a five-elements retarding-lens system and a very compact size compared to standard hemispherical analyzers. Additionally, an ultra-high-vacuum system has been constructed which will simultaneously fulfill the requirements for HAXPES and SXRD. The vacuum chamber has two Be windows so that the in-coming and out-going X-ray beam will hit the sample and the X-ray detector, respectively. The complete system will be installed on a massive 2S + 3D diffractometer. Photoelectron spectroscopy and SXRD can be operated either simultaneously or independently from each other. Test experiments with a UV discharge lamp and a RHEED electron gun have been conducted demonstrating that the analyzer performs satisfactorily. The whole set-up is in the commissioning phase and full operation is expected in the course of 2005.

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1. Introduction

Nowadays, the great challenge in materials science is the incorporation of complex systems in the area of the nano-technologies [1]. A fundamental aspect is

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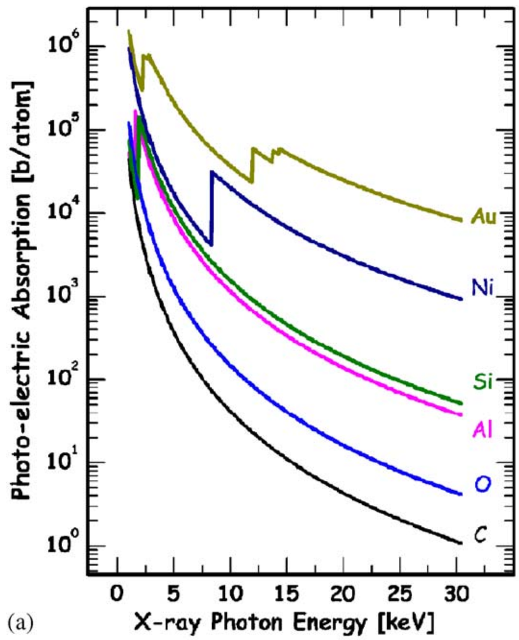
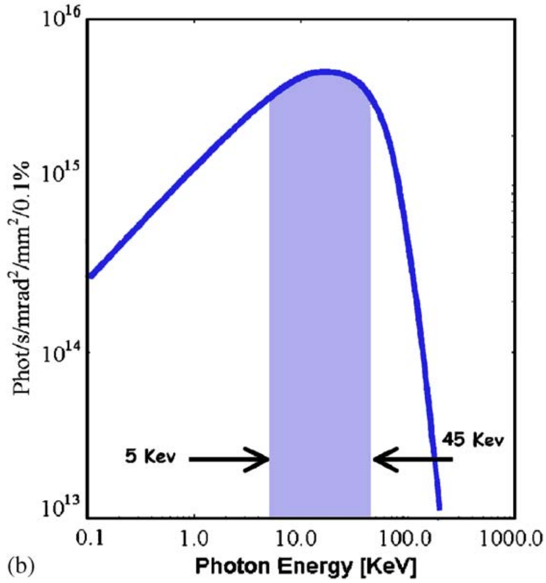
the production of materials with specific and controlled properties. Many of these materials are aggregates of different components, frequently multilayer thin films [1–3]. In these materials, the surfaces and interfaces define many of their properties and play a fundamental role in many technological processes such as in catalysis but also in the semiconductor industry. In two-dimensional systems, due to abrupt changes in the structure and the electronic coordination, a great variety of new and unexpected physical phenomena appear. Therefore, it is very important to develop an experimental setup capable to investigate different aspects under identical experimental conditions, in particular to differentiate between surface and bulk properties. It is important to stress that hard X-ray photoelectron spectroscopy (HAXPES) is sensitive to the chemical and physical properties of surfaces, buried interfaces, and the bulk. Its implementation at the Spanish CRG beamline (SpLine) at the European synchrotron radiation facility (ESRF) will make available to the European scientific community and in particular to the Spanish community, an exceptional tool capable to deliver in a direct way composition profiles over a depth of several 10s of nanometers.

Although, for many years, a continuous interest to develop this technique did exist, two factors have fundamentally hindered its implementation. Conventional X-ray sources (X-rays tubes) have the disadvantage that the greater the energy of the characteristic lines, the more characteristic lines coexist, which makes the interpretation of the results difficult. Moreover, the photon flux is relatively small, even more so when a monochromator is used, while simultaneously the effective photo-emission cross-section is reduced with increasing excitation energy. Fig. 1(a) shows, for some elements [4], the photo-absorption cross-section dependence with the excitation energy. Its diminution is particularly dramatic for low atomic number Z elements, with up to five orders of magnitude lower values for 15 keV than for 2 keV.



(a)



(b)

Fig. 1. (a) The photo-ionization cross-sections as a function of the photon energy are shown [4]. The figure shows a decrease of the cross-section by more than four orders of magnitude at 15 keV compared to that corresponding to the excitation energies typically used for XPS. The decrease is especially pronounced for low atomic number elements. (b) Radiation brilliance corresponding to SpLine branch B, where the experimental setup is allocated. Third generation synchrotron radiation sources provide, even from a bending magnet, more than ten orders of magnitude more brilliance than the most powerful conventional rotating anodes. In the beamline energy range (shadow region) the brilliance achieved is larger than 10^{15} Photons/s/mrad^2/mm^2/0.1%bw at 200 mA electron current.