Probing chemical and electronic properties of functional materials by hard X-ray photoelectron spectroscopy (HAXPES)

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Content

One focus of materials science is the development of new functional materials down to the nanometer range. They come in a wide variety of complex structures, chemistry and different dimensionalities. A key to understanding functional properties is to characterize their electronic and chemical structure. In this respect photoelectron spectroscopy (PES) is one of the most powerful techniques (for conductive samples). However, conventional PES is highly surface sensitive due to its small photoelectron escape depth which is not adequate to study complex materials or buried interfaces.

This deficiency is overcome by excitation with hard X-rays in the range ~2.5 -15 keV (HAXPES) [1] to produce energetic photoelectrons with significantly larger inelastic mean free paths. At many synchrotron radiation sources HAXPES meanwhile is an established technique [2]. Its high bulk sensitivity (escape depths of some 10 nm) is essential to non-destructively study true bulk properties of complex correlated materials, as-grown samples without any surface treatment, chemically sensitive materials covered by protective layers and to access buried functional interfaces in prototypical multilayer device structures. Most interesting is the study of electronic and chemical modifications at or near functional interfaces as a function of external parameters such as in-situ voltage biasing which is e.g. relevant for ferroelectric materials, memristive switches and photovoltaic devices.

The use of variable X-ray polarization facilitates to probe orbital character or magnetic properties of buried layers. Further, the excitation of X-ray standing waves facilitates to correlate electronic and atomic structure and to increase and control the depth sensitivity and selectivity to study electronic and chemical structure in buried layers and across interfaces in epitaxial heterostructures. HAXPES is applied e.g. to materials for energy storage, including batteries, electrolytes, and photovoltaics devices. Also, electrochemical processes at solid-liquid interfaces are studied, as well as catalytic processes even at high-pressure (>1 bar) conditions.

The capabilities of HAXPES for materials science applications will be highlighted by recent examples.

References