Preface

Photoelectron spectroscopy has its roots in the Nobel Prize-winning work of Albert Einstein and Kai Siegbahn. It is therefore both an honor and a humbling experience to produce a book that documents the excitement of the newest developments in this field.

According to Einstein's discovery of the law of the photoelectric effect, considered to be the dawn of the quantum age, the conservation of energy between the incoming photon and the outgoing photoelectron in the photoemission process allows the technique to uniquely measure the chemical and electronic structure of atoms, molecules, and solids. However, despite Seigbahn's original development of the technique for chemical analysis with high-energy X-rays, the use of low-energy photons with energies up to only about 1.5 keV by modern researchers, at both laboratory and synchrotron sources, results in extremely short photoelectron inelastic mean-free paths. As a result, this limited information depth has historically restricted experiments to the study of surfaces and shallow interfaces, or what is referred to in the literature as traditional surface science.

It is therefore no surprise that recent advances in both photon source and electron-spectrometer instrumentation have driven experiments into the extended 2–10 keV photon energy range resulting in what is now called *hard* X-ray photoelectron spectroscopy (HAXPES). Due to its relatively unlimited electron escape depths, HAXPES has emerged as a powerful tool that has general application to the study of the true bulk and buried interface properties of complex materials systems. Its areas of application are thus growing exponentially compared to more traditional measurements at lower photon energies.

In addition to the many advantages of being able to study "real" samples taken directly from air without the need for ion sputtering or other surface preparation, HAXPES has opened up other research areas that are included in this book such as:

- The study of highly correlated and spintronic electron systems with surface and interface compositions and structures that are different from their bulk.
- The combination of energy and angle measurements (X-ray standing wave, photoelectron diffraction, and angle-resolved valence photoemission) to produce elementally, chemically, and spatially specific electronic structure information.
- The study of realistic prototypical multilayer device structures under both *ambient* and *operando* conditions.
- The tuning of the photoelectron inelastic mean-free path and the X-ray penetration depth to study buried layers, interfaces, and nanoparticles with the specific nanometer and mesoscopic length scales relevant to modern industry, as, for example, today's semiconductor hetero-structures.

The brightness of third- and higher generation X-ray sources has also opened the possibilities of both high-resolution two-dimensional chemical imaging with depth resolution (photoelectron microscopy) in addition to time-resolved photoemission.

This volume provides the first complete, up-to-date summary of the state of the art in HAXPES. It is therefore a must-read for scientists interested in harnessing its powerful capabilities for their own research. Chapters written by experts include historical work, modern instrumentation, theoretical developments, and real-world applications that cover the fields of physics, chemistry, and materials science and engineering. In consideration of the rapid development of the technique, several chapters include highlights that illustrate future opportunities as well.

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