

X-RAY PHOTOELECTRON EMISSION SPECTROMETRY SYSTEM

TECHNICAL FIELD OF THE INVENTION

The present invention relates to the field of x-ray photoelectron emission spectrometry, and more particularly to an apparatus and method of x-ray photoelectron emission spectrometry using an x-ray beam directed to the surface of a sample at a small incidence angle.

BACKGROUND OF THE INVENTION

X-ray photoelectron emission spectrometry, also known as x-ray photoemission spectrometry (XPS), is a well-established technique for the analysis of the chemical states of elements found near the surface of a material. In particular, the shift in the binding energy of electrons of various atoms according to their chemical state forms the basis of electron spectroscopy for chemical analysis (ESCA). In ESCA methods employing x-ray photoemission spectrometry, an x-ray source of known photon energy is used to excite photoelectrons in a sample, and the energy distribution of the excited electrons is determined by an electron spectrometer. The difference in energy, after correction for the work function of the spectrometer, is the binding energy of those electrons.

As ESCA methods employing x-ray photoemission spectrometry have been applied to surface and interface layers of increasing chemical and structural complexity, several factors have become evident. The shape of the lines in the photoemission energy spectrum must often be analyzed since the chemical states of a specific element or elements may be too similar in binding energy for their photoemission lines to be completely resolved.

It is also frequently desirable to determine the concentrations of a specific element in different chemical states at different depths in the sample. In this respect, the photoemission yield is inherently attenuated with depth below the surface. It would be desirable, therefore, to enhance the photoelectron emission from elements which may be buried beneath the surface, particularly in a material consisting of thin film layers.

There are several known approaches for carrying out ESCA methods employing x-ray photoemission for obtaining depth-dependence. Previous ESCA methods employing x-ray photoemission have made use of the principles of grazing angle incidence of the exciting x-rays or grazing angle takeoff of the emitted photoelectrons. With decreasing angles of incidence, the penetration depth of x-rays into a surface is likewise decreased, since slight increases in depth require traversing ever longer attenuating paths to reach a specified depth. Within a specific grazing angle of incidence known as the critical angle, ϕ_c , x-rays are known to be abruptly reflected from a surface, a process known as total external reflection. This reflection is accompanied by an even stronger decay of the x-ray field with depth into the sample. If the angular acceptance of photoelectrons emitted by the material is similarly limited to increasingly grazing exit angles, the depth of the emitting atoms is limited by the increasing attenuation which their photoelectrons will necessarily incur on their path out. By comparing the changes in the x-ray photoemission signal of a specific element as the angle of incidence of the x-rays or the takeoff angle of the photoelectrons

is varied, some idea of the depth distribution of the emitting atom species may be obtained.

Some known ESCA methods employing grazing angle x-ray photoemission spectrometry measurements utilize the rotation of a sample with respect to a fixed x-ray source and a fixed electron spectrometer. The rotation of the sample brings about a change in grazing incidence angle and also brings about a change of alignment of the sample with respect to the electron spectrometer, an effect which can result in a distortion of the photoemission lineshape in the energy spectrum of the electrons. Furthermore, all cases of photoemission in which the sampling depth is determined by the mean free path of escaping electrons necessarily results in a photoemission line which is distorted by inelastic energy losses. These distortions can be especially important in the case where the photoemission lines of several chemical species overlap.

Another prior art ESCA method to obtain depth dependence employing x-ray photoemission spectrometry uses a fixed, collimated x-ray beam that is directed to a fixed sample at a specified angle. The photoemission electrons accepted by the electron spectrometer are limited to those leaving the sample at a specific angle, which may be varied. When the electron spectrometer is positioned to accept electrons which escape the sample with a large angle relative to the surface, they may originate from a certain range of depths without being significantly attenuated. When the electron spectrometer is positioned to accept only electrons which escape at a very small angle relative to the surface, the range of depths from which they originate is much smaller, since the escape path involves traversing a greater length of material at a given depth. In this example, the escape angle of the electrons may be determined by actual motion of the electron spectrometer relative to the sample or by the motion of an admitting slit between the sample and an electron spectrometer which accepts electrons over a range of angles.

However, distortions in electron spectrometry occur with this method due to changes of electron transport characteristics in the sample and in the electron energy analyzer at different electron escape angles.

Aside from its use in x-ray photoemission spectrometry, the variable grazing incidence angle technique has also been utilized in prior art which sought to obtain elemental analysis with depth dependence by collecting the x-ray fluorescence radiation of atoms which were excited by a collimated x-ray beam. In that case however, the energy resolution of fluorescent radiation is insufficient to obtain the chemical state of the atoms, and attention to the relative alignment of the detector and the sample is not of significance.

It is only in the case of x-ray photoemission spectrometry, where the relative analysis may involve chemical species which differ from each other by energies of the order of less than 2 electron volts (eV), that attention to the lineshape and the distortions which may occur to it are of some consequence.

All of the prior art ESCA methods employing x-ray photoemission spectrometry described above employ apparatus elements in which the position of the sample surface that is exposed to the x-ray beam is varied with respect to the electron analyzer during the course of the analysis. And this variation in the position of the sample surface that is exposed to the x-ray beam and the electron analyzer is a cause of distortion in the emitted electron spectrum.