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APPLICATION NOTE

K-Alpha:

Mapping of the Work Function of a Damaged Solar Cell

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The Thermo Scientific™ K-Alpha™ X-ray Photoelectron Spectrometer (XPS) System has been used to measure and map the work function of a damaged solar cell structure. Part of the structure had become delaminated, and three clearly defined areas were visible, each having a different work function. Features on the work function maps can be correlated with the chemical composition of the surface.

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Introduction

In many areas of materials technology, it is important to control both the chemical composition and the electrical properties of the material. One example of this need is in the manufacturing of solar cells.

In this case, the solar cell is based on a thin film of CIGS (Cu (In, Ga) Se_2). The full structure of the device includes an upper electrode containing indium tin oxide (ITO) zinc oxide and cadmium sulphide. The whole structure is separated from a steel substrate using layers of molybdenum and chromium.

The solid lines in Figure 1 show the profile obtained from the CIGS device. The dashed lines in this Figure show the profile from a damaged area of the device. This profile is consistent with the damage being due to delamination of the device.

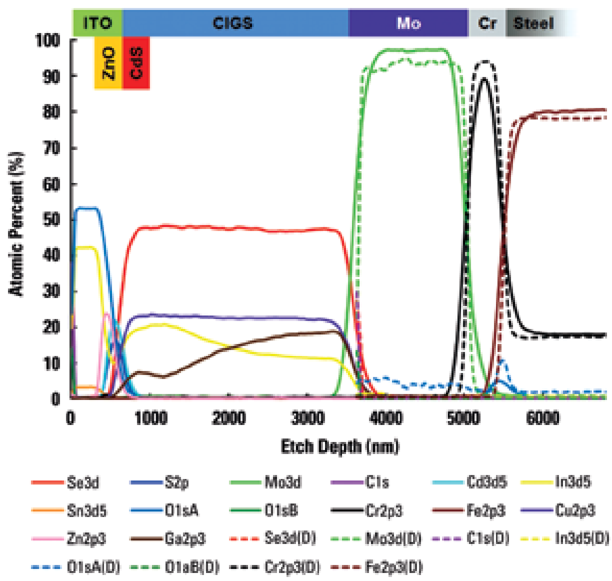

Figure 1: Depth profile through CIGS device

Thermo Scientific K-Alpha XPS

Experimental

Work functions can be measured on a photoelectron spectrometer as follows. A spectrum is acquired from the whole spectral range so that cut-off energy can be measured at both low and high binding energy. It is usually necessary to bias the sample to avoid effects due to the work function of the instrument. Figure 2 shows the two extreme ends of a survey spectrum acquired from gold using a monochromated source of X-rays (Al Kα, photon energy 1486.6 eV). The whole spectrum is shifted so the Fermi level is aligned with 0 eV binding energy. The high binding energy cut-off is then measured and subtracted from the known photon energy, as shown in Figure 2 and the work function is given by the difference between the cut-off energy and the photon energy. In this case, a value of 5.1 eV was calculated, in good agreement with the photoelectric work function of clean gold.

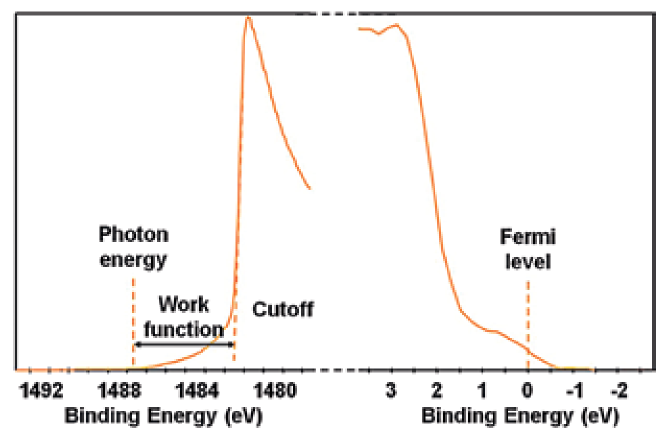

Figure 2: Part of the survey spectrum from gold acquired using monochromatic Al Kα radiation

The method relies upon the spectrometer being accurately calibrated and the photon energy being accurately known. On the K-Alpha instrument, there are internal standard samples (copper, silver and gold) which are used by the instrument to calibrate the XPS binding energy scale auto-matically. The photon energy can be checked by measuring the position of an X-ray induced Auger peak on the binding energy scale and adding it to the known kinetic energy for that peak in the Auger spectrum. This is done automatically in the K-Alpha during the calibration process using the copper sample which is built into the instrument.

Results

Figure 3 shows the live optical view of the damaged solar cell at the analysis position of the K-Alpha.

XPS analysis at the three posi-Figure 3 showed that the area labelled 'ITO' is essentially undamaged indium tin oxide. The area labelled 'Ag' is largely silver which is used as an electrical contact to the device. The third area consists of molybdenum with some remnants of the CIGS material. This is consistent with the damage being due to delamination of the device.

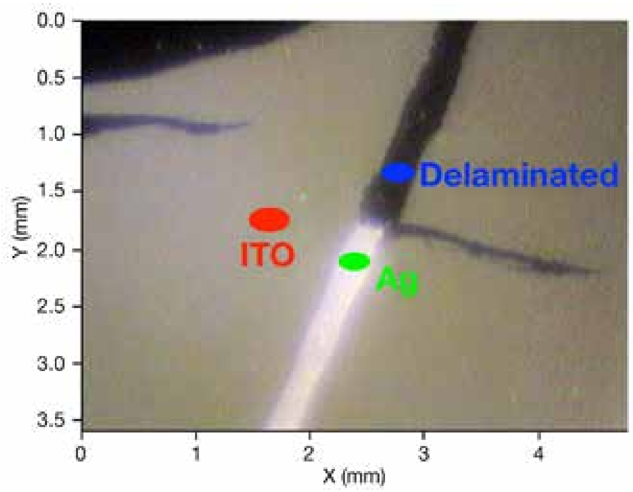

Figure 3: Optical view of damaged solar cell tions indicated in device at the analysis position of K-Alpha

It is then possible to map an area which includes the three materials and construct a work function map. This type of map is shown in Figure 5 which was collected using an X-ray spot size of 50 µm. The three regions of the sample are clearly visible in the work function map. The maps were constructed using the advanced PCA (Principal Component Analysis) algorithms which are integral to the Thermo Scientific Avantage software supplied with K-Alpha.

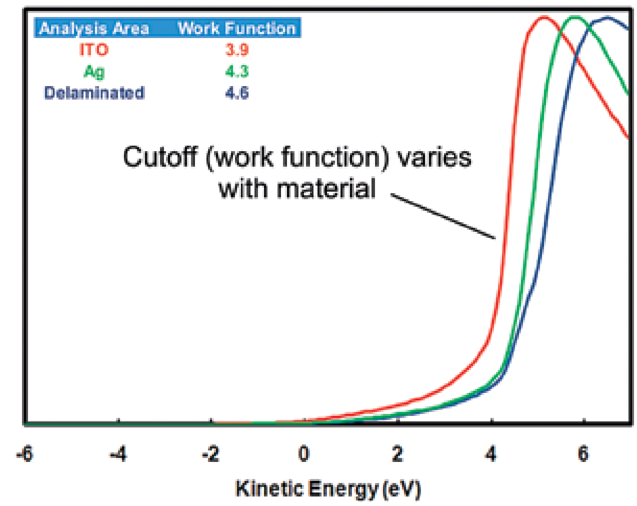

Figure 4: The cut-off region of the XPS spectrum from each of the three areas of the sample

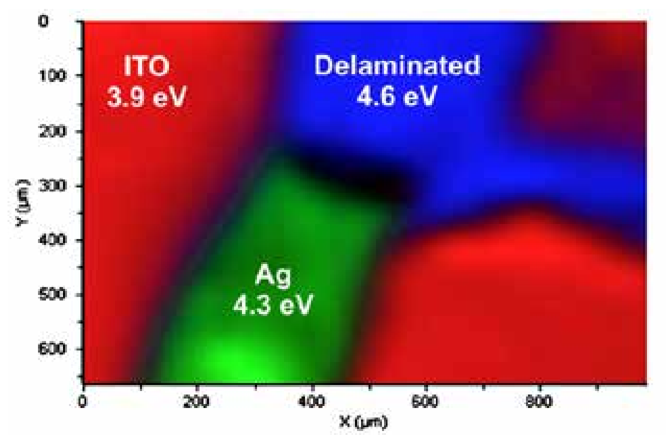

Figure 5: A work function map of the sample using a 50 µm X-ray spot from the K-Alpha work function values are shown on the image

Summary

Work function can be measured rapidly and accurately using the K-Alpha. In addition, it is possible to map the work function over the surface of a sample when PCA is applied to the spectra.

Keywords
K-Alpha, Mapping, PCA, Surface Analysis, Work Function, XPS

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