

High Efficiency Chemical State Surface Analysis Imaging with XPS

Sankar Raman¹, John F. Moulder¹ and John S. Hammond¹

¹ Physical Electronics USA, Chanhassen, Minnesota, USA

Surface analysis techniques are now commonly used for the characterization of surface modified materials such as biocompatible polymers and bio-implants, multilayer ultra-thin structures such as semiconductor dielectric gate structures and advanced data storage media as well as MEMS and NEMS structures. The most commonly used surface analysis techniques are Scanning Auger Microscopy (SAM), Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) and X-ray Photoelectron Spectroscopy (XPS). The average analysis depth of all three techniques is less than 5 nm while the spectroscopic spatial resolution of the three techniques is 8 nm, 80 nm and 8 μm respectively. Today the XPS technique is unique in its ability to provide quantitative chemical state information but the information from XPS imaging information has generally been limited to semi-quantitative elemental information. XPS instruments have been designed with “microscope” modes that can translate the spatial distributions of photoelectrons to kinetic energy resolved images (with elemental identification) with a few microns spatial resolution. The high spatial resolution in the “microscope” mode is achieved by limiting the solid angle of collection. This mode limits the count rate at a high spatial resolution from acquiring the desired high sensitivity chemical spectroscopic information. A newer approach to XPS imaging is the microprobe XPS mode with a monochromatic scanning x-ray microprobe XPS. This approach uses a raster scanned, microfocused, x-ray source to define a microprobe spatial resolution of < 8 μm while allowing the energy analyzer to operate with a high solid angle for higher collection efficiency. Recently a 128 channel detector mode has been added to this scanning XPS system to allow the acquisition of an energy dispersed “snapshot” spectrum with chemical state information at each pixel. We will present two applications of this new scanning microprobe technology for high efficiency quantitative surface chemical state imaging.

The surface chemistry of bond pads for semiconductor devices plays a vital role in the bond strength and device reliability. Figure 1a shows a 10 μm diameter scanning x-ray induced secondary electron image (SXI) of the bond pad structure. Figure 1b shows a rapid 12 minute Si 2p image of the bond pad with 128 channel spectra acquired at each pixel. Figure 1c shows the three basis spectra from three regions of the bond pad that are used for LLS fitting to define the chemical state images of silicon oxynitride (Figure 1d), silicon oxide (Figure 1e) and a mixture of tungsten silicide and silicon oxide (Figure 1f). Further data will be discussed in the presentation illustrating chemical state quantification.

Development of fuel cell technologies has included the use of polymeric materials as proton exchange membranes (PEM) coated on either side of the polymer thin film with Pt electrodes. The lifetime of these fuel cell structures is influenced by the chemical modifications as a function of depth of the polymer films. Based on the 170 μm thickness of the PEM, XPS chemical state imaging of cross-sections of the film can provide useful information on the chemical state degradation as a function of the use of the fuel cell. Figure 2a shows the optical micrograph of a cross-section of a used PEM structure. Figure 2b shows a 9 μm diameter scanning x-ray induced secondary electron image of the same area as the optical micrograph. Figure 2c shows the results of 8 minute C 1s chemical state imaging of the cross section showing overlay images of the PEM polymer chemistry (blue) and the chemical modified carbon material in the regions of the two electrodes (red). Further data will be discussed in the presentation of

the chemical state modifications from the cross-sections of the polymer material.

The presentation therefore illustrates the high efficiency of chemical state XPS imaging with a scanning x-ray microprobe.

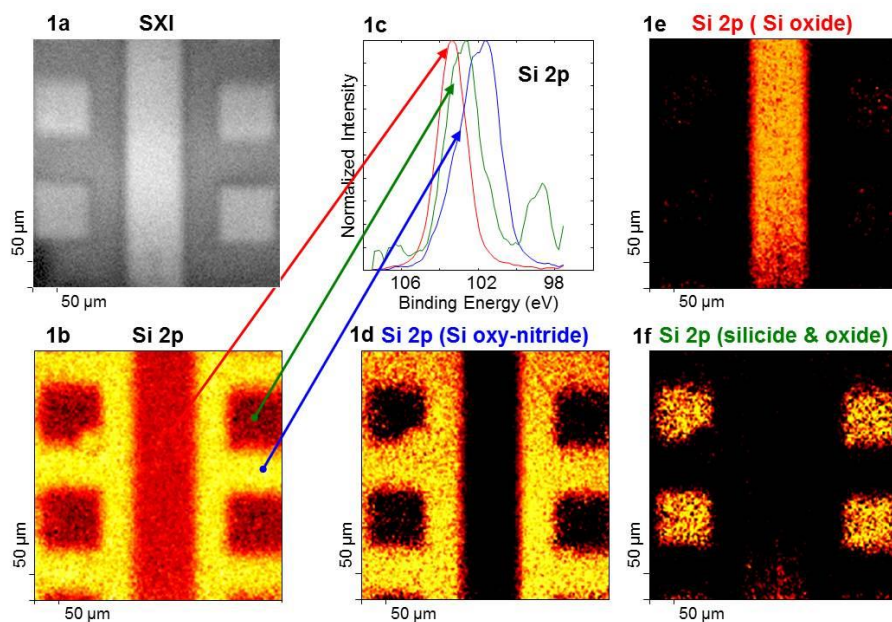


Figure 1: a) SXI of bond pad, b) Si 2p peak area map, c) reference spectra extracted from the Si map data, chemical state images of d) silicon oxynitride, e) silicon oxide and f) a mixture of tungsten silicide and silicon oxide

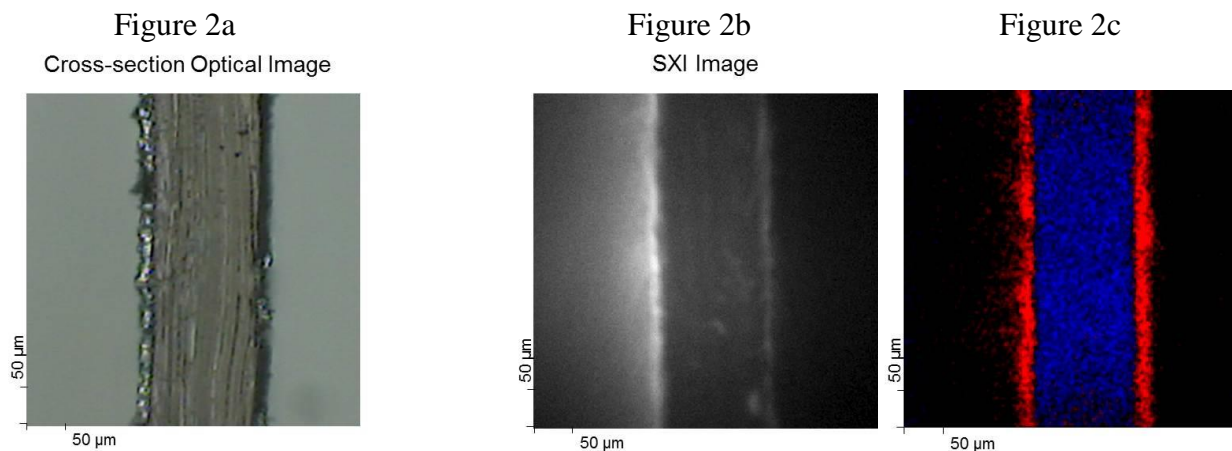


Figure 2a shows the optical micrograph of a used PEM structure. Figure 2b shows a 10 μm diameter scanning x-ray induced secondary electron image (SXI) of a similar area as the optical micrograph. Figure 2c shows the results of 8 minute C 1s chemical state imaging of the cross section showing overlay images of the PEM polymer chemistry (blue) and the chemically modified carbon material in the regions of the two electrodes (red).