THICKNESS AND COMPOSITION ANALYSIS OF THIN-FILM SOLAR CELLS VIA MICRO-XRF

Andrew Lee, Matthew Chipman, Dr. Bruce Scruggs, PhD

1 Edax Inc., 91 McKee Drive, Mahwah NJ 07430 USA

Thin-film solar cells (TFSC) have developed into a highly efficient source of energy in solar cell technology, with cell efficiencies approaching twenty percent. Optimizing the performance and manufacturing process of TFSC’s has become vital, and assessing the uniformity of each thin-film is an important part of optimizing that efficiency. This presentation will explore the capabilities of micro-X-ray fluorescence (micro-XRF) in evaluating the thickness and composition of TFSC’s, along with key micro-XRF system designs that are advantageous to this application.

TFSC’s are categorized based on the photovoltaic (PV) material used, such as Copper, Indium, Gallium, Selenium (CIGS), or Cadmium-Telluride (CdTe). These PV materials have a metal contact layer underneath, and are deposited on a substrate. Key factors include the uniformity of the composition and thickness of the PV material; performance is known to degrade with variations. Thus, a non-destructive technique which can attain thickness and composition distributions of PV films is advantageous for improving efficiency of the manufacturing process.

Micro-XRF is an elemental technique, with a deeper beam penetration depth relative to an electron probe, allowing detection of layers not possible with electron-based analyses. An X-ray tube is used to generate Bremsstrahlung radiation, which is then either internally reflected through a glass capillary, or mechanically collimated. This allows a small X-ray diameter while retaining high count-rates. Diameters range from ~20µm up to 2mm. Based on the intensities of the fluoresced element lines, micro-XRF is capable of calculating the thickness and composition of thin-films in TFSC’s. In addition, the sample navigates underneath the X-ray beam via an “X-Y-Z” stage, which can generate a two dimensional raster to observe uniformity of the thin-film over a larger area. With the recent introduction of larger area XRF silicon drift detectors, higher count-rates can be processed, allowing more data to be processed in less time. Micro-XRF provides a unique form of elemental analysis which comparable techniques for this application, such as hand-held and bulk XRF, cannot.

In this example, micro-XRF was used to study the quality of the sputter coating process by observing the uniformity of CIGS and Molybdenum (Mo) thin-films on a solar cell sample. It consisted of a float glass substrate, with a Mo layer (typically < 0.5 µm), followed by the CIGS layer on top (typically < 2 µm). A 40 x 40 mm portion of the panel was analyzed by setting up an automated raster of 35 x 35 points. With the use of only one thin-film CIGS/Mo/Glass calibration standard, the thickness values for the CIGS and Mo layer were calculated and plotted for a visual representation. The CIGS layer, Figure 1, shows substantial variation, particularly towards the edge of the sample, where the thickness (in microns) significantly tapers down. Figure 2 shows that although the thicknesses of the entire CIGS layer may vary, the Selenium atomic percent within the layer remains relatively homogeneous. As seen in this example, the capabilities of micro-XRF lend unique advantages for distributional analyses of TFSC thickness and composition, which are important factors in finding ways to improve their efficiency.

Fig. 1. X/Y plot of calculated CIGS thickness (microns)  
Fig. 2. X/Y plot of Selenium atomic % in the CIGS layer