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Energy Dispersive Spectrometry Analysis of a CIGS Solar Cell

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Key Words

- CIGS
- COMPASS
- EDS
- Phase Analysis
- Spectral Imaging
- Solar Cell

Abstract

The Thermo Scientific NORAN System 7 energy dispersive spectrometry (EDS) system was used to investigate the elemental structure of a thin-film CIGS solar cell. The sample was investigated in both the planar and cross-sectional views.

Introduction

CIGS solar cells are based on copper indium gallium diselenide [Cu(In,Ga)Se_2] thin films. These solar cells have demonstrated excellent efficiencies and are potential replacements for silicon based solar cells, which are more expensive to produce and are substantially thicker.

CIGS solar cells are formed by layering thin films on a substrate (historically glass, but currently polymers) as shown on Figure 1. The molybdenum layer and the zinc oxide layer form the electrical contacts. The CIGS film acts as the sunlight absorber layer, with a thin CdS layer forming the p-n junction. The most common manufacturing methods evaporate or sputter copper, indium, and gallium simultaneously or sequentially onto the substrate. Vaporized selenium is reacted with the film to establish the final film composition.

The major challenge in producing these thin layer solar cells is to control film composition. Reproducibility of required layer structure in commercial volumes has proven to be problematic and this is critical as the electrical properties of the cell depend on the exact composition of the layers. EDS analyses can be used to determine the spatial distribution of the elements through the device.

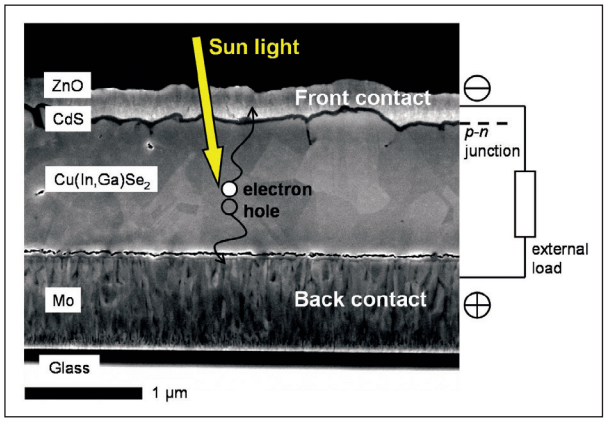
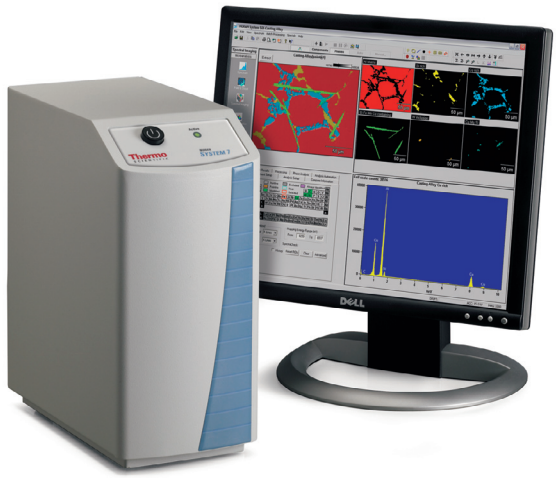


Figure 1: Scanning electron micrograph of a Cu(In,Ga)Se_2 solar cell (cross-section) and its mode of operation[1]



Thermo Scientific NORAN System 7

Experimental

A commercially available CIGS solar cell was disassembled to extract a portion of a single cell. It was analyzed in both the planar and cross-sectional views. The cross-section view was prepared in an epoxy mount and polished.

Examination took place using a Tungsten-filament SEM. Planar-view analyses were performed initially at 20 kV to determine the elemental constituents. Subsequent analyses of the cross section were performed at 5 kV to reduce the interaction volume. When it was discovered that a substantial portion of the substrate was polymer, care was taken to keep the induced charge to low levels. Even at these levels, a small amount of charging was present and drift compensation was required for mapping.

NORAN System 7 was used to collect X-rays from a NanoTrace SiLi detector. Both Point and Shoot spectral mode and Spectral Imaging mapping mode were used to characterize elemental constituents of the sample.

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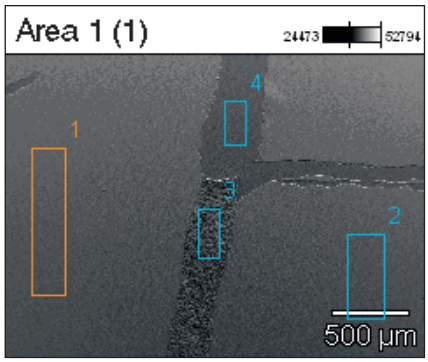

Figure 2a: Planar view of delaminated CIGS material

Results

Planar View

During disassembly, some of the CIGS material delaminated from the substrate (Figure 2a). This provided a unique opportunity to measure (1) the top layers of the sample, (2) the underlying metallic substrate, and (3) the metallic surface electrical contact material. Figure 2b is a Point and Shoot spectral analysis of these regions.

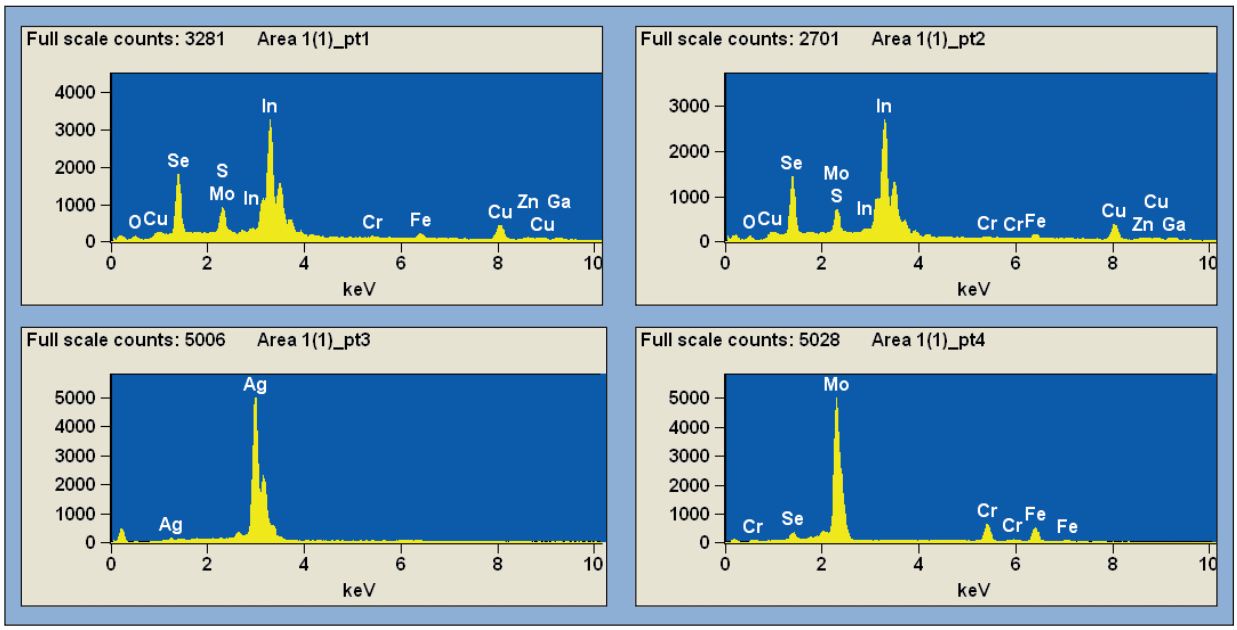

Figure 2b: EDS spectral analyses of the top surface of CIGS material

Table 1: Quantitative Elemental Composition Analysis of the Top Surface of CIGS Material

	O-K	S-K	Cr-K	Fe-K	Cu-K	Zn-K	Ga-K	Se-K	Mo-L	Ag-L	Cd-L	In-L
Area 1(1)_pt1	17.38	4.59	0.82	2.41	12.39	2.51	2.90	22.93	2.31		7.42	24.32
Area 1(1)_pt2	17.60	4.53	0.69	2.49	12.31	2.88	3.01	21.63	2.09		7.77	24.99
Area 1(1)_pt3										100.00		
Area 1(1)_pt4			17.66	18.42				2.92	61.00			

Locations 1 and 2 on the film are the same material consisting of a majority of In and Se with a small amount of Cu and a small amount of Ga. Only small amounts of Zn, O, Cd and S are measured due to the thin nature of these layers.

Location 3 on the metallic contact layer seems to be Ag paint.

Location 4 where the film is removed shows the base Mo substrate that the layers are grown on.

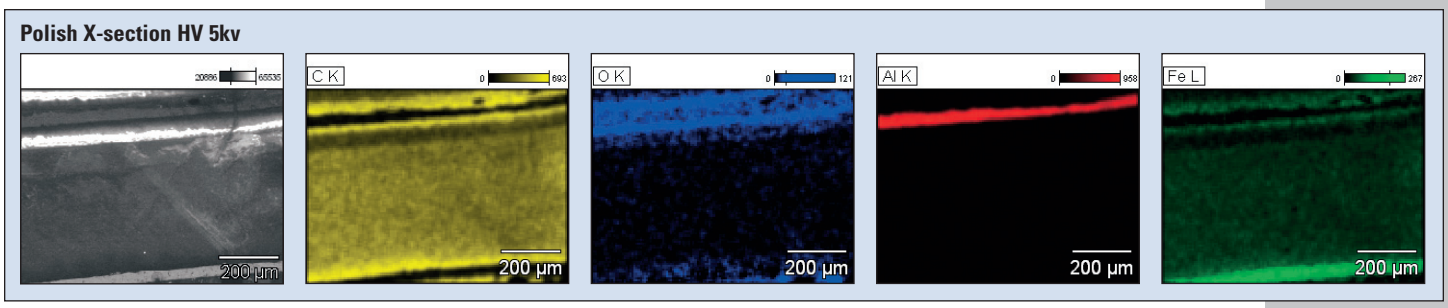

Figure 3: Electron image and net count elemental maps of CIGS cross-section at low magnification

Cross-sectional View

Low Magnification

A Spectral Imaging mapping analysis was performed at low magnification on the cross-section sample to understand all of the layers that constitute the material. The thickness of all of the layers was approximately 1/3 mm. Interestingly, a majority of the layers consisted of C, indicating a large polymer content in the layers. In addition to the polymer layers, Aluminum and Iron layers were also observed, Figure 3.

High Magnification

Further investigation concentrated on the outmost surface of the Iron layer at higher magnification. Elemental maps indicated layers of Cu, Ga, Se, Mo and In. Quantitative maps, Figure 4, removed the background X-ray intensity of the maps and formed maps with a much higher contrast than observed in the gross count maps. Thermo Scientific COMPASS software phase analysis was able to locate the individual layers in the structure at the micro scale, Figure 5. COMPASS maps reveal a Mo layer against the Fe substrate, followed by 2 Cu-Ga-Se layers. The first Cu-Ga-Se layer had very low X-ray counts and the second layer was higher in In content. The low X-ray count layer seemed to be recessed in physical appearance indicating preferential polishing of this particular layer of the sample may have occurred. Because of the thin nature and common environment, this preferential polishing indicates a different hardness and could derive from a different composition than the following layer. The thickness of the Mo layer was just under 1 µm while the Cu-Ga-Se layers were just under 3 µm and 1.5 µm respectively. No CdS or ZnO phases were observed, probably due to their thin nature and the larger X-ray generation volume.

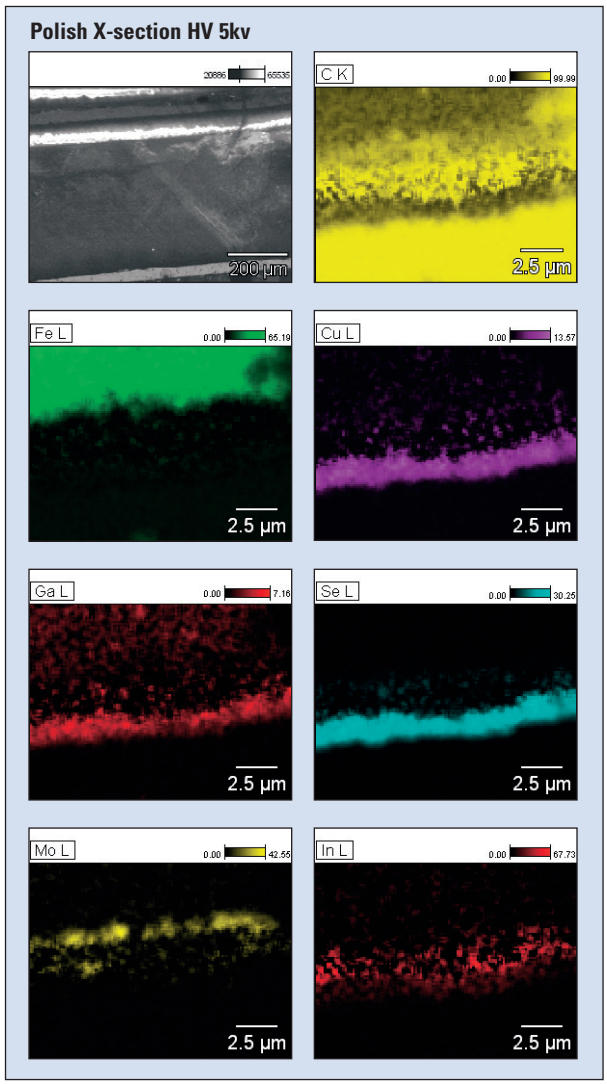

Figure 4: Quantitative element maps of CIGS cross-section at high magnification

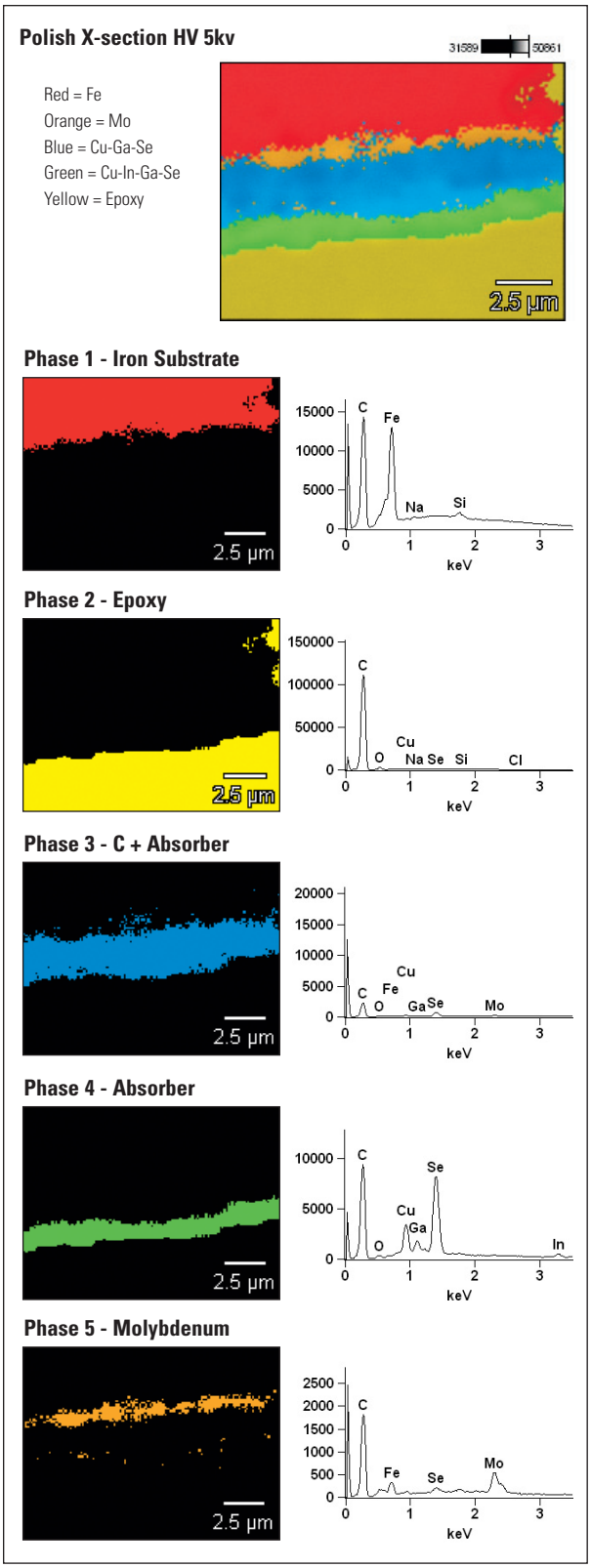

Figure 5: Compass phase maps of CIGS cross-section at high magnification

Summary

Energy Dispersive X-ray spectroscopy provides compositional information about the structure of CIGS solar cells. If a majority of the sample is polymer, low beam energy and beam current, and drift compensation are required to obtain meaningful results. The spatial resolution of the results depends upon the incident electron beam energy and the beam diameter. Ultra-thin layers may not be observed in bulk samples.

Conclusion

The NORAN System 7 enables the analysis of complex samples such as a CIGS solar cell under low accelerating voltages and beam currents in the scanning electron microscope.

Reference

1. D. Abou-Ras et al. Elemental distribution profiles across $Cu(In,Ga)Se_2$ solar-cell absorbers acquired by various techniques. Proceedings of EMC 2008, volume 1, p. 741.

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