

# Experiment Brief

## Monarc Pro CL system and EDAX Octane Elite Super detector

### Title

Quantitative analysis of trace elements in solar cells by energy dispersive and cathodoluminescence spectroscopies

### Gatan Instrument Used

The Monarc<sup>®</sup> Pro cathodoluminescence (CL) system and EDAX Octane Elite energy dispersive x-ray spectroscopy (EDS) detector enable precise analysis of composition and crystal structure with simultaneous spectral mapping.

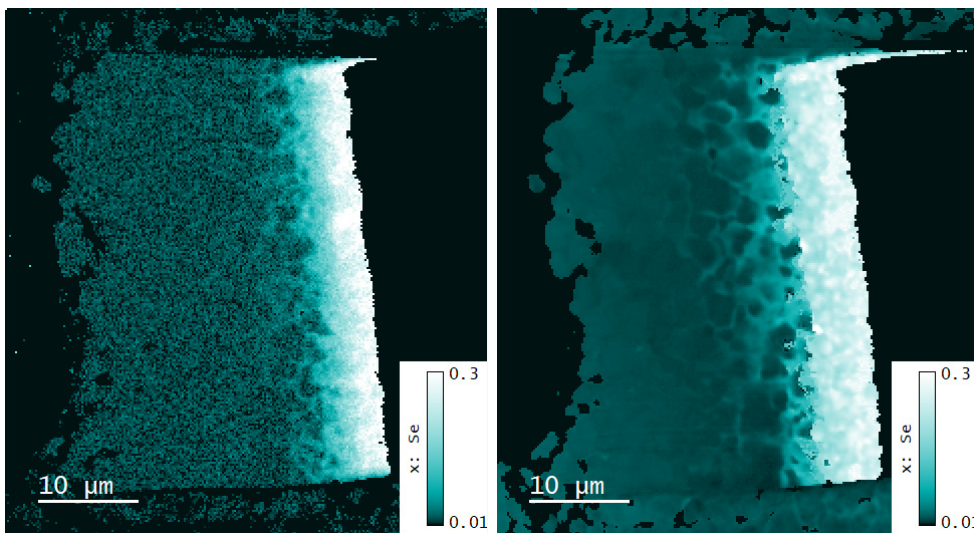
### Background

The adoption of thin-film solar cells is a critical component of the government's energy reduction plans. However, there remains a large opportunity to improve the efficiency of these devices by developing a greater understanding and control of the composition and crystal structure of (e.g.,) CdTe/CdSeTe devices. However, there are no single techniques that provide a comprehensive understanding of these materials, thus requiring multi-modal analysis using EDS and luminescence techniques such as CL. We present a novel method for simultaneous capture and analysis of EDS and CL spectroscopic data to reveal the distribution of Se down to trace levels.

### Materials and Methods

A multilayer CdTe/CdSe<sub>x</sub>Te<sub>1-x</sub> (2500/500 nm thick) solar cell was analyzed using an EDAX Octane Elite Super EDS detector and Monarc Pro CL system installed on a scanning electron microscope (SEM). Simultaneously acquired spectrum images (or hyperspectral maps) were captured using DigitalMicrograph<sup>®</sup> software over a 30 x 40 μm cross section prepared by focused ion beam milling angled at 7°. An efficient workflow was enabled using the Monarc system's EDS-compatible collection mirror. Analysis was performed in DigitalMicrograph software which now uses the advanced analytical engine of EDAX APEX EDS software.

From the EDS map, Se can be seen to diffuse into the CdTe layer with non-uniform lateral distribution. However, the Se concentration falls below the minimum detection limit within ~2 μm of the junction. By comparison to the CL map, which reveals the grain structure, Se diffusion was enhanced along grain boundaries. Furthermore, there is good correlation between the Se distribution as determined by EDS and CL (determined using the electronic band gap of CdSe<sub>x</sub>Te<sub>1-x</sub>) with CL revealing vertical Se diffusion 15 μm from the junction and down to concentrations <0.5 at. %.



**Figure 1.** The proportion of Se/Te as determined by EDS (left) and CL (right), milled surface starting from the left (top surface) to right (substrate). The composition, as determined by CL, was based on the peak position by NLLS analysis and used  $E_g(x) = (1-x)E_{g_{CdTe}} + xE_{g_{CdSe}} - bx(1-x)$  to relate the emission wavelength (band gap) to CdSeTe alloy composition assuming a bowing coefficient of  $b = 0.725$  eV [1].

### Credit(s)

We would like to thank Prof. M Walls, Professor of Photovoltaics for Power Systems in the Centre for Renewable Energy Systems Technology (CREST) at Loughborough University, for providing the sample.

Gatan is the world's leading manufacturer of instrumentation and software used to enhance and extend electron microscopes—from specimen preparation and manipulation to imaging and analysis.

### Summary

CL and EDS signals were captured simultaneously, allowing for perfect pixel registration between the techniques. Elemental quantification was completed by EDS, while grain boundaries and trace elemental maps were identified using CL. This simultaneous capture presents a distinct advantage over the utilization of either technique in isolation. EDS and CL data complement one another to give a more complete sample analysis, including elemental quantification below or near the detection limit of either technique alone.

### References

- [1] J Yang, et al., Chinese Physics B: Rapid Communication 28 086106 (2019).