GATAN

Experiment Brief

MonoCL4 Cathodoluminescence Detector

Title

Revealing the spatial distribution of phases in perovskite solar cells for the development of high efficiency and stable devices

Gatan instrument used

The MonoCL4™ detector is the leading spectroscopic cathodoluminescence (CL) system for scanning electron microscopes (SEMs) and focused ion beam (FIB) SEMs that offers unrivaled sensitivity with the fastest imaging speeds to analyze beam-sensitive materials.

Background

Since the first report of efficient solar cells being fabricated in 2009, perovskite materials have attracted widespread attention for photovoltaic applications due to the simple and cheap manufacturing methods available. However, widespread commercialization of perovskite-based devices is being held back by their instability under operational conditions. Current research includes a focus on the development of more stable compositions. The key to this, are experimental techniques able to map phase segregation with a spatial resolution suitable for analyzing individual grains as small as 30 nm; CL has recently been demonstrated as such a technique[1]. Although, to prevent degradation of the sample under exposure to high-energy electrons, extremely low probe currents are required, necessitating the use of the highest sensitivity CL detection system.

Materials and Methods

Perovskite solar cells incorporating rubidium (Rb) demonstrating enhanced thermal- and photo-stability were investigated. Spectrally resolved CL imaging was used to reveal the interplay of rubidium iodide (RbI) with excess lead iodide (PbI_2) in the phase formation of mixed-cation, mixed-halide perovskites. The distribution of PbI_2, perovskite, and Rb-rich phases were revealed by wavelength filtered imaging; damage to the sample was minimized through the use of extremely low electron beam currents of just 13 pA. Improved device performance was ascribed to Rb-doping suppressing the yellow non-perovskite phase and re-distribute the PbI_2 phases.

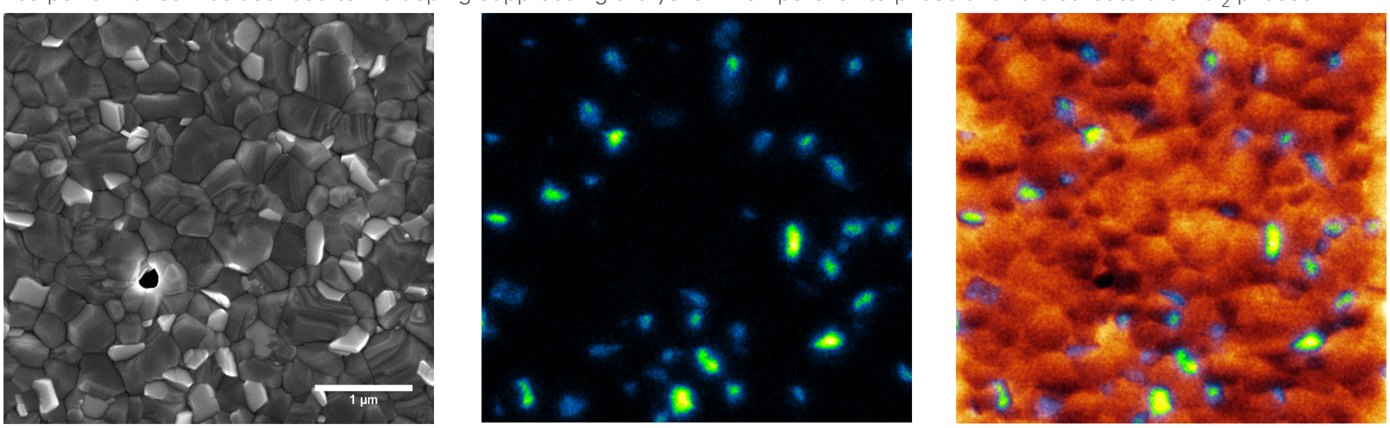

Figure 1. (Left) SEM image of perovskite film with 20% excess Pb_{I2} and 5% RbI doping. The distributions of the PbI_2 phase (center) and perovskite phases (orange-to-red colors in the right-hand image) are revealed through spectrally resolved CL imaging by use of dichroic filters inserted into the panchromatic light path; PbI_2 grains as small as 30 nm are revealed.

Summary

The distribution of PbI_2, perovskite, and Rb-rich phases were revealed by wavelength filtered imaging using electron beam currents of just 13 pA. Despite these weak excitation conditions, the supreme sensitivity of the MonoCL4 detector empowered by its' unique design concept enabled high-quality phase distribution maps to be captured with excellent signal-to-noise ratio while minimizing degradation of the sample under investigation. Improved device performance and stability could be ascribed to Rb-doping suppressing the yellow non-perovskite phase and re-distribution of the PbI_2 phase.

Credit(s)

[1] The Duong et al., Nano Energy 30, December 2016, Pages 330–340

Gatan, Inc. 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.

Dr. Mark Lockrey is a Microanalysis Research Officer for the Australian Capital Territory Research node of the Australian National Fabrication Facility. He is based at Australian National University, Canberra where the facilities include state of the art growth, processing, and fabrication of photonic and electronic devices. Mark's research interests are focused on electron-beam processing of materials and CL analysis of nanomaterials and characterization of III-V semiconductors.

EB-MonoCL4-CL-CA-FL1-MAY17