MICROSTRUCTURAL CHARACTERIZATION FOR EMERGING PHOTOVOLTAIC MATERIALS

This special issue of the Journal of Materials Research contains articles that were accepted in response to an invitation for manuscripts.

Introduction

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Emerging solar cell technologies, in particular those based on organic molecules and polymers and inorganic-organic perovskites semiconductors, have begun to demonstrate their potential for inexpensive solar energy on a terawatt scale. The common characteristics of these technologies include: an ability to tailor the properties of the constituent materials (e.g., chemical composition, size, packing motifs); active layers that are thin (on the order of 100s of nanometers) and processed from inexpensive and highly scalable technologies using earth abundant raw materials; and complete solar cells that can be made pliable due to low production temperatures that allow fabrication on flexible plastic substrates. In each of these technologies, the microstructure of the photovoltaic active thin film plays a crucial role in performance of the solar cell, affecting everything from light absorption to charge carrier extraction. Increasing the power conversion efficiency and device lifetimes of these materials requires exercising nanoscale control over thin film microstructure and device interfaces across large areas. Each of these systems presents unique challenges to their full morphological and microstructural characterization, with issues ranging from poor scattering contrast between layers (organics) to overlapping diffraction features (perovskites). Advances in X-ray and neutron scattering methods have enabled many breakthroughs in understanding the relationship between thin film microstructure and device-level properties in these emerging energy materials, findings which have helped to improve photovoltaic performance over the last decade. Increased access to synchrotron and neutron sources, coupled with the development of new instrumentation and techniques that merge scattering and spectroscopic information, are providing exciting opportunities to probe the microstructural evolution of these materials from fabrication to fully operational devices subject to real-world environments.

This is the first Focus Issue of the *Journal of Materials Research* on Microstructural Characterization for Emerging Photovoltaic Materials. The issue includes a wide range of techniques that can be used to determine different microstructural information such as layer thickness, chemical nature, roughness and segregation, domain size, strain, the morphology of individual nanoparticles and the longer range structure amongst many others, and the application of these techniques to various material systems highlights the relevance of understanding and controlling the microstructure in these emerging solar cell materials. More and more publications in emerging photovoltaic materials include some extent of microstructure measurements for assessing materials and device performance, highlighting the timeliness of this Focus Issue. We hope readers will find this volume to be an insightful collection of research that captures the rapid advancement in the field of microstructural characterization of emerging photovoltaic materials.

Finally, we are very grateful to the authors and reviewers of the many high-quality manuscripts submitted to our *JMR* Focus Issue on Microstructural Characterization for Emerging Photovoltaic Materials and to Dr. Josue Martinez-Hardigree for his support.

ON THE COVER:

"The cover of this Focus Issue shows the spatial distribution of the charge collection efficiency in a perovskite solar cell with a methylammonium lead iodide absorber layer. The scanned area is 6 μm x 6 μm large, and the charge collection efficiency increases in vertical direction and from red to blue. It was measured by X-ray beam induced current (XBIC), using the highly focused X-ray beam from the nanoprobe beamline 26-ID-C at the Advanced Photon Source, and converted to charge collection efficiency using the methodology developed by Stuckelberger et al. at Arizona State University.

Scanning functional solar cells with nanoprobe X-ray beams enables a multitude of correlative X-ray microscopy applications. For example, the simultaneous operando measurement of charge collection efficiency by XBIC and of the elemental distribution by X-ray fluorescence enables their point-by-point correlation. This unveils the impact of stoichiometric variations on the electrical performance at the nanoscale and leads to directives for the synthesis of solar cells with higher conversion efficiencies."

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