An NREL scientist installs small solar panels at NREL's Outdoor Test Facility for the Perovskite Photovoltaic Accelerator for Commercializing Technologies (PACT). *Photo by Werner Slocum, NREL 67121*

Metal Halide Perovskite Photovoltaics Research

Metal halide perovskite (MHP) photovoltaics (PV) are a potentially transformational next-generation energy technology. These materials have remarkable and tunable physical properties that enable a range of process approaches to produce high-efficiency devices. NREL efforts address both basic material and device-level considerations to advance the state of the art in MHP PV and accelerate its path to market.

Activities and Capabilities

- **Materials and Device Development**—Given the tunable nature of perovskite materials across composition, electronic gap, and other properties, NREL has developed considerable capabilities to examine and characterize basic material considerations for critical PV-relevant properties. The NREL team employs perovskites' tunability to develop both single-junction and multijunction materials and devices. NREL has materials synthesis capabilities for MHP absorber layers, as well as for contact materials integral to device performance, stability, technological life cycle, and sustainability/circularity.
- **Determining Reliability/Durability**—Longer-lasting PV systems are critical to reducing the cost of solar electricity and mitigating the environmental and health impacts of PV. Accordingly, reliability is a major area of work for MHP PV cells at NREL. To better understand, identify, and ultimately mitigate failure mechanisms, the NREL team subjects MHP PV cells to different thermal and environmental stresses to study their performance dynamics and conducts detailed materials characterization before and after operational stressing. Meanwhile, NREL's PV reliability group ensures that lab-based insights are relevant to module-level devices in the field. At the Outdoor Test Facility (OTF), researchers test the long-term performance of advanced PV technologies like MHP under both standard and accelerated outdoor conditions.
- **Materials Processing and Manufacturing**—The unique properties of MHP permit high-efficiency PV cells to be constructed by vapor phase, solution phase, or hybrid processes. Careful consideration is needed to successfully couple the material components with a processing technique to integrate those components into high-performance

devices. NREL has a range of approaches for translating developed understandings of materials and devices into the materials integration process, with the goal of overcoming challenges to manufacturability.

- **Sustainability and Circularity**—NREL's MHP PV effort aims to have large, terawatt-scale impacts. Solar cells at this scale could represent a significant source of electronic waste, necessitating a good understanding of MHP PV's operational stability, life cycle, and related considerations. The NREL team strives to minimize environmental impacts during manufacturing and end of life for MHPs, alongside research into their refurbishment and recycling.

- **Engagement and Activities**—NREL's MHP team is engaged with the broader academic community, partnering with numerous university research teams in the United States and abroad. U.S.-based industry is also directly engaged across NREL's MHP research and through the U.S. Manufacturing of Advanced Perovskites (US-MAP) Consortium (*https://www.usa-perovskites.org*). These collaborations ensure that NREL's work remains at the forefront of global MHP PV research.

Metal Halide Perovskite Team Reference Work

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https://www.nrel.gov/pv/perovskite-solar-cells.html

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