Hawaiʻi Natural Energy Institute Research Highlights

Advanced Materials

Encapsulation of Perovskite Solar Cells for Long Term Operations

OBJECTIVE AND SIGNIFICANCE: The objective of this program is to extend the lifetime of low-cost, high efficiency perovskite solar cells (PSCs) to meet the U.S. Department of Energy's 2030 cost target of $0.02/kWh.

BACKGROUND: Since the first report of PSCs in 2009, tremendous research efforts on absorber chemistry have boosted the power conversion efficiency of this material class from 3.9% to 25.7%. Although impressive, this attribute alone cannot guarantee the commercial success of PSCs, as any emerging technology must also meet the 20-25 year stability already achieved by other mature photovoltaic (PV) classes. To date, the durability of best performing PSCs is limited to few months at best, constituting an important roadblock in their deployment. In this project, HNEI partnered with the National Renewable Energy Laboratory (NREL) to accelerate the development of unique protection schemes to enhance PSCs' lifetime. Specifically, our team aims at eliminating two stress factors and technical barriers responsible for PSC degradation: 1) high temperatures during processing and 2) atmospheric effects during PV operations.

PROJECT STATUS/RESULTS: HNEI has developed a new composite integrating multi-functionalities such as *corrosion resistance*, *lightweight*, and *flexibility* as well as *tunable optoelectronics*. Unlike most conductive flexible polymers, where media are coated on top providing only *in-plane* conductivity, HNEI's transparent conductive composites (TCC) innovate by allowing simultaneous high optical transparency (%T>90% in the 370nm-2000nm region) and high *out-of-plane* electrical conductivity ($R<0.2\ \Omega.cm^2$). This unique characteristic is permitted by highly conductive 50-micron Ag-coated PMMA spheres protruding out of a transparent non-conductive polymer.

In this project, TCCs serve as gas-barrier located between the PSC and metal top contacts, providing a conformal hermetic seal repelling moisture and oxygen while preventing out-diffusion of volatile species. TCCs offer at least three main advantages over traditional "glass-glass" encapsulation. First, our composite fully cures at room temperature, which tackles the first barrier and eliminates all adverse thermal effects encountered in conventional sealant/adhesive technologies (which require curing above 100°C). Also, the protruding particles in TCC act as direct electrical access points to the underlaying structure. Therefore, the coating is not spatially restricted and can be applied directly on top of the PSC and can extend to the device edges, sealing directly the top and sides of the PV stack to the operating environment, which addresses the second barrier with no risk of lateral electrical shorting. Finally, there is no need for an extra encapsulating glass cover with TCCs, reducing module weight and cost.

Our team has demonstrated that TCCs can maintain virtually 100% of their optical and electrical properties for over 1,000 hours of outdoor exposure under Hawaiʻi's tropical semi-arid climate, while TCC-coated PSCs preserve over 90% of their initial efficiency after 1,000 hours of accelerated testing under 45% relative humidity at 50°C. Current efforts are focused on reducing TCC's water vapor and oxygen transmission rates to meet packaging standards. To date, this project has produced "**Transparent Conductive Composites—A New Class of Encapsulants for Durable Perovskite Photovoltaics**", presented at the MRS Spring 2023 meeting.

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