# Hawaiʻi Natural Energy Institute Research Highlights

*Advanced Materials*

## *Printable Photovoltaics*

**OBJECTIVE AND SIGNIFICANCE**: The objective of this project is to develop high-throughput ink-based fabrication techniques for lightweight thin film photovoltaics (PV). This approach has the potential to reduce manufacturing costs and enable PV integration on non-conventional substrates such as polyamides or woven fabrics.

**BACKGROUND**: Crystalline silicon has been leading the PV market for over 20 years. These panels, found on rooftops and centralized production plants, are easily recognizable by their architecture, with interconnected wafer-like solar cells laminated under a flat sheet of glass. Although well-suited for stationary electrical production, the mechanical rigidity and weight of silicon PV modules become a burden for mobile applications, where portability is more critical than performance. To this end, R&D efforts have focused on methods to integrate ultra-light and flexible thin film solar materials onto lightweight/flexible substrates, including plastics (polyamides) and fabrics. Such devices can generate enough electricity to power small electronic devices for both civilian and military applications such as phones, electronic tablets, and sensors.

**PROJECT STATUS/RESULTS**: With support from the Office of Naval Research, the research team at HNEI's Thin Films Laboratory is developing a unique method to print thin film PV using liquid molecular inks, which contain the raw chemical elements necessary for the synthesis of the solar absorber. This low-cost printing process is intended to replace conventional vacuum-based deposition tools, which are costly to operate and maintain.

The research is currently focused on a multi-compound alloy ($CuInSe_2$, CISe) – a material which meets the mechanical and weight requirements for lightweight, flexible PV. HNEI's results demonstrate that high-quality CISe solar absorbers can be achieved with this printing technology, leading to solar cells with power conversion efficiency over 8%.

In addition, HNEI demonstrated that additives directly incorporated into the molecular ink, such as aluminum nitrate, can passivate native defects in CISe during fabrication, yielding to efficiency as high as 11% (Septina, 2021). Using state-of-the-art electron microscopy analysis available at UH, the HNEI team discovered that aluminum nitrate reacted with oxygen during CISe growth to form nano-sized amorphous alumina ($Al_2O_3$) grains. This new process was found to incorporate $Al_2O_3$ through the entire solar absorber's volume, passivating defects notably at grain boundaries and interfaces.

To date, this research has produced the following publication:


- 2021, W. Septina, et al, ***In situ* $Al_2O_3$ incorporation enhances the efficiency of $CuIn(S,Se)_2$ solar cells prepared from molecular-ink solutions**, Journal of Mater. Chem. A, Vol. 9, Issue 16, pp. 10419-10426.



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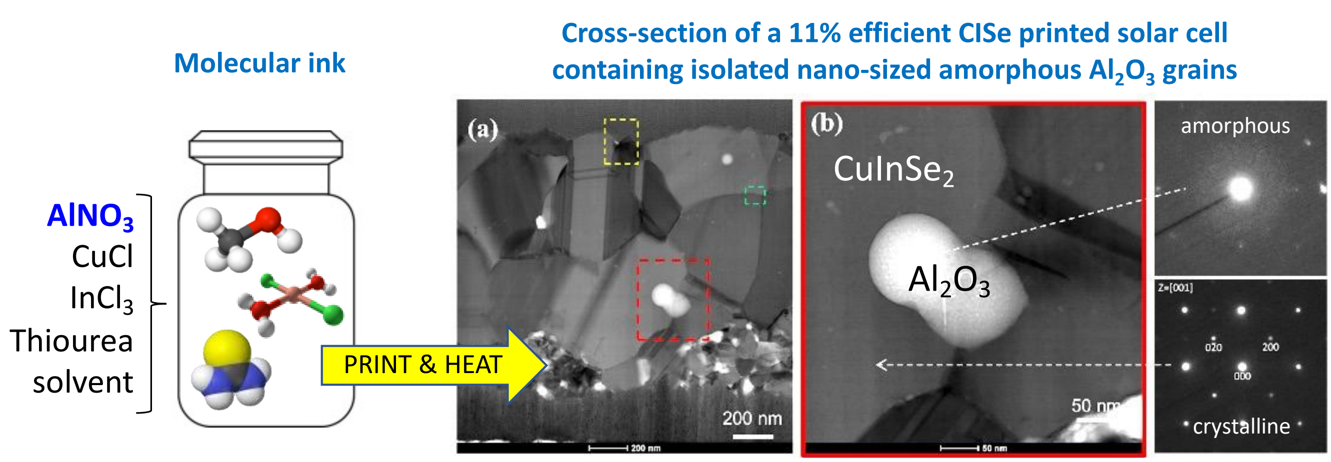



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