BAPVC Annual Project Report

Project Title: Thin-Film Vapor-Liquid-Solid Growth of Optoelectronic Quality InP on Metal substrates

PI: Ali Javey
E-mail: ajavey@berkeley.edu

Summary:

The work focuses on understanding and characterization of the thin-film vapor-liquid-solid (TF-VLS) growth technique as a low-cost process technology for III-V thin film solar cells on metal/glass substrates. In the last review period, we have focused on understanding and controlling the nucleation events of TF-VLS InP. Furthermore, optoelectronic characterization of the grown InP has been performed in depth to shed light on the potential PV efficiencies that may be feasible to obtain using this growth technique. Collaboration with Purdue has been initiated to further understand the material performance limits of TF-VLS InP. Finally, in collaboration with NREL, a preliminary cost model is developed.

Key Accomplishments:

Recently, a method for growth of ultra-large grain (>100 μm) semiconductor thin-films on non-epitaxial substrates was developed by our group via the thin-film vapor-liquid-solid growth mode as shown in Figure 1a. The resulting poly-crystalline films exhibit similar optoelectronic quality (Fig. 1b,c) as their single-crystal counterparts. Deterministic control of nucleation sites was developed via substrate engineering, enabling user-tuned inter-nuclei spacing of up to ~1 mm (Fig 2). Besides examining the theory associated with the nucleation process, this work presents an important advance towards controlled growth of high quality semiconductor thin films with unprecedented grain sizes on non-epitaxial substrates.

In addition to the excellent optoelectronic quality and novel routes towards microstructure engineering presented by the TF-VLS method, a cost analysis of p-body InP cells fabricated utilizing a TF-VLS process was carried out in collaboration with NREL (Fig 3). The results show that for efficiencies that are within reach of these thin films, the manufacturing costs can be ~$0.5/Watt.

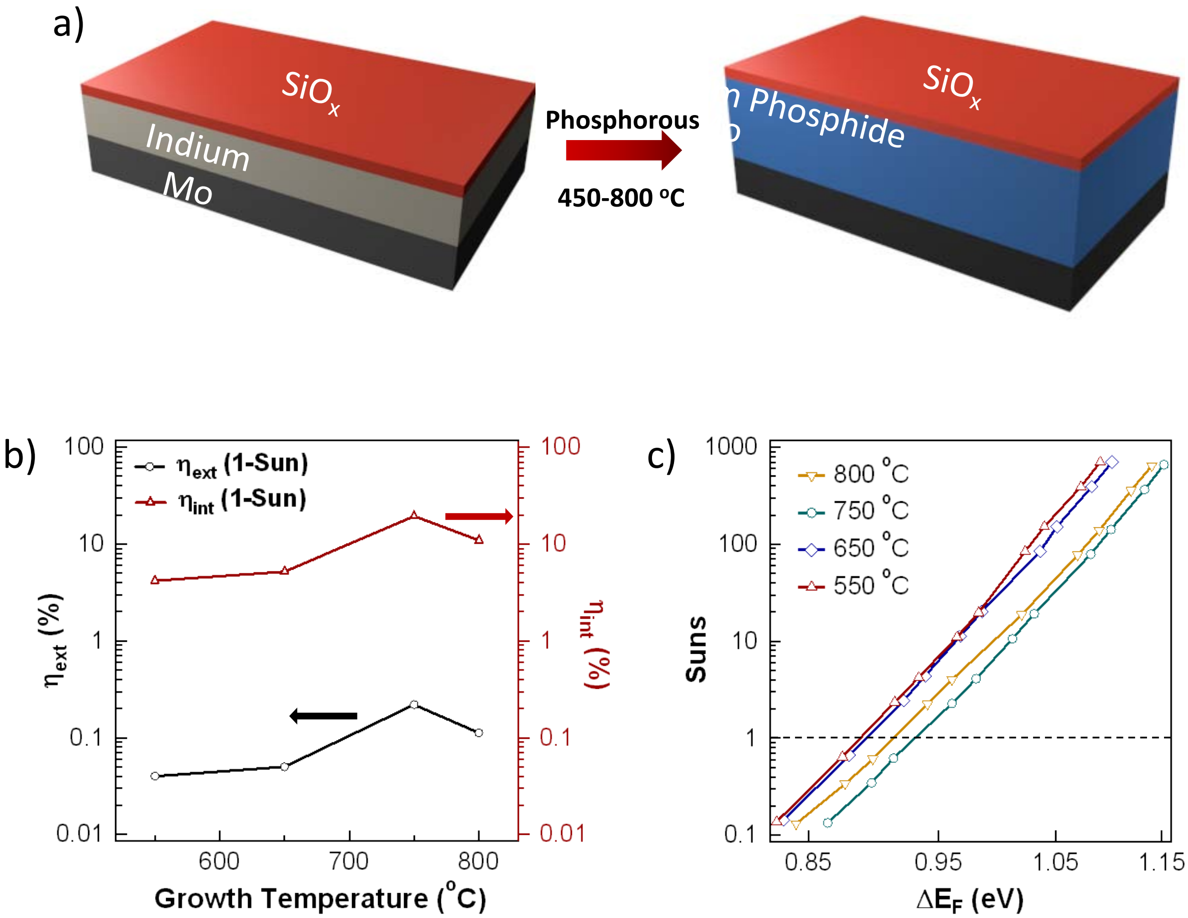

Figure 1: Growth method and optoelectronic characterization. **a**, Schematic view of the thin-film VLS growth technique for planar InP films.**b**, Measured external luminescence efficiency and extracted internal luminescence efficiency as a function of growth temperature. **c**, Optically measured "I-V" curves obtained from external luminescence efficiency measurements. Here, Suns represents the intensity of the absorbed laser light (1-sun = 100 mW/cm^2), and corresponds to the photogenerated current level. The quasi-Fermi level splitting (ΔE_F) represents the resulting V_{OC} that would occur to balance the photogenerated current.

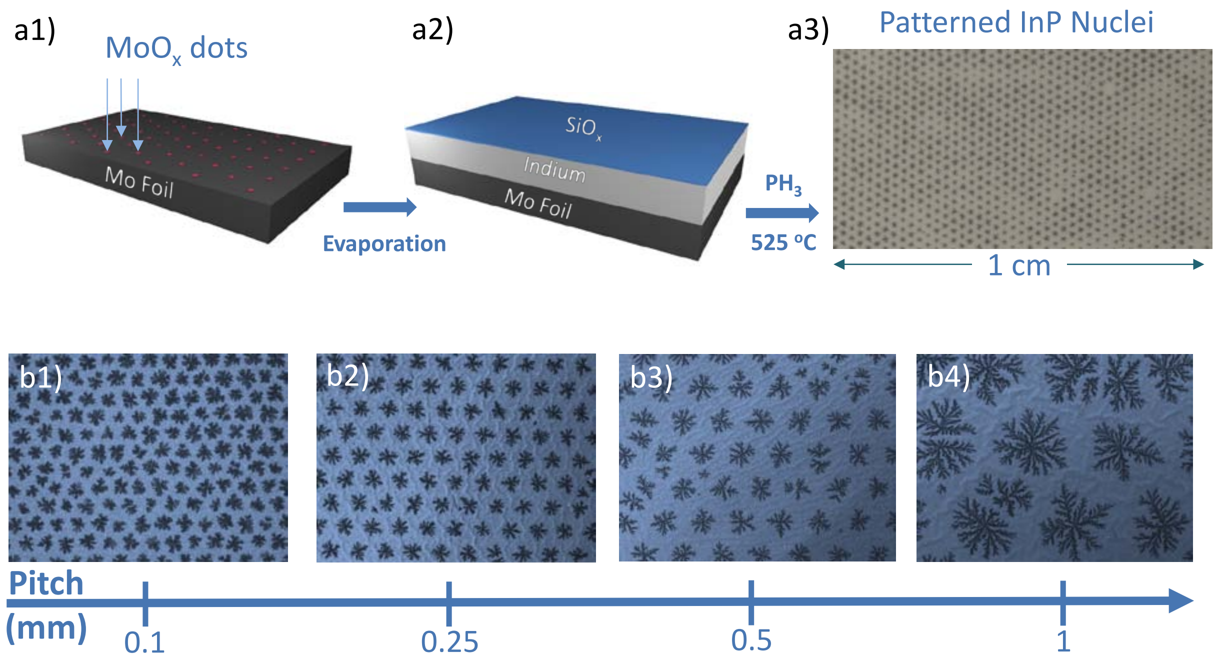

Figure 2: Patterned nucleation in the TF-VLS growth mode. a1) Schematic of a Mo foil with a hexagonal MoO_x dots as the nucleation sites. Center-to-center pitch, *s*, between the MoO_x pattern is varied between 0.1 mm to 1 mm. (a2) In/SiO_x stacks are subsequently evaporated on the patterned Mo/MoO_x substrate. (a3) An optical image of ~1 cm × 0.5 cm substrate with 0.25 mm MoOx pitch after partial InP growth, clearly demonstrating large area control over nuclei position. b1-4) Optical images of partially grown InP on patterned Mo/MoOx substrates with MoO_x pitch of 0.1 mm (b1), 0.25 mm (b2), 0.5 mm (b3), and 1 mm (b4).

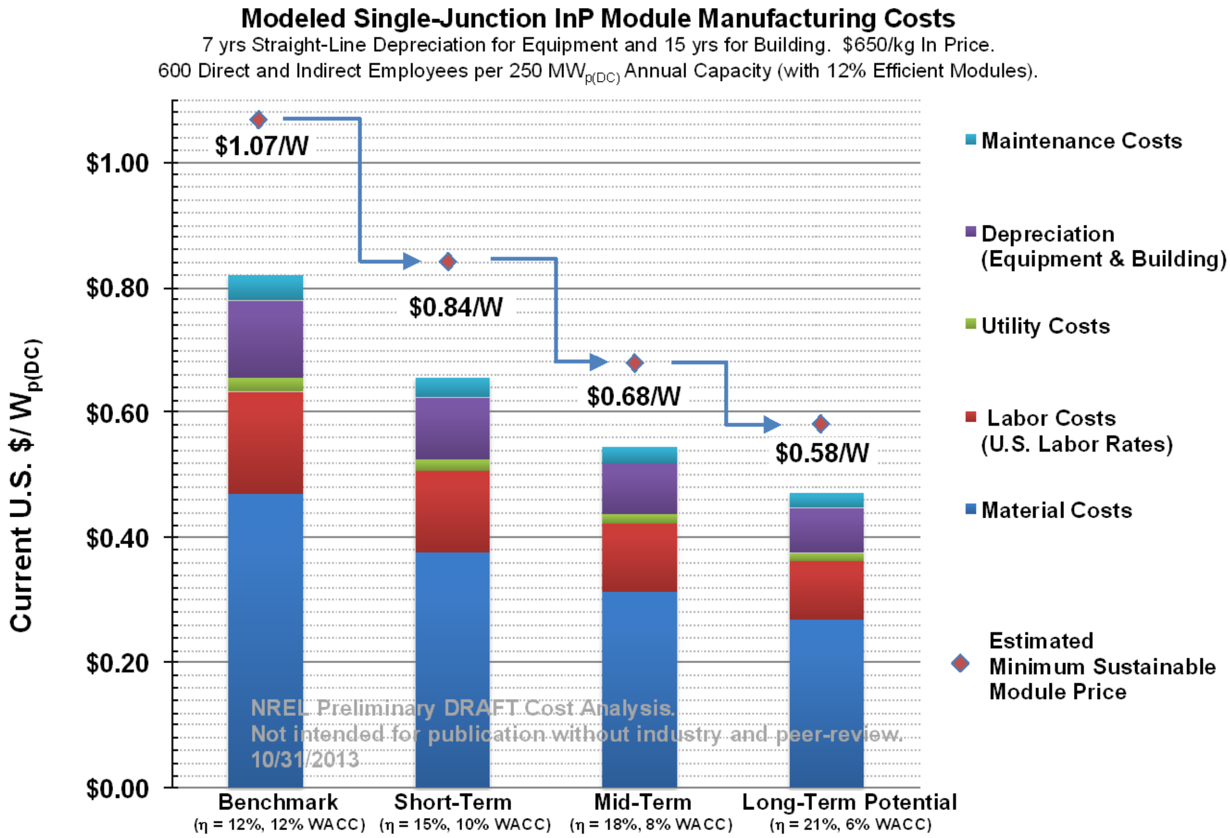

Figure 3: Cost Modeling of TF-VLS InP PV Modules for different efficiency points.

Future Work:

In the future, devices will be made utilizing these devices on both n- and p-body InP substrates.