Thrust: Photon Management and Transparent Conductors

Grand Challenges and Key Problems

The thrust spans two major areas: light management and transparent electrodes for solar cells. The grand challenges are several folds: 1) Develop materials and structures to couple maximum sunlight into the solar cells and to control the above bandgap photon distribution for complete absorption with significantly reduced absorber materials. And use photon management to enhance the solar cells parameters including short circuit current and open circuit voltage. 2) Develop low-cost highly transparent (~95%) and low sheet resistance electrodes (<5 ohm/sq) for solar cells with n- and p-type contact capability. 3) Develop process to implement the above materials and structures in practical scalable solar cell manufacturing.

Existing Projects in our Thrust

Within the thrust, the light management component consists of Fan's project seeking to use optical design and detailed balance analysis to understand theoretically the fundamental limits and constraints on both the current and voltages behaviors of nanophotonic solar cells, whose project provides a guideline for design. Fan's project is complemented by Atwater's project that combines both theory and experiments to develop practical solar cell structures that incorporate advanced light management techniques. Within the light management component, we also have Wu's project that specifically examines development of methods for low-cost large-scale fabrication of light management structures.

The transparent conductor projects all address the grand challenge of higher performance at lower cost, emphasizing efficient carrier collection. Brongersma's project is examining the use of optimized 2D grid patterns which will reduce materials requirements for metal contacts. Banerjee's project investigates graphene contacts from both a fundamental (doping for highest conductivity) and practical (new large area growth techniques) perspective. The project of Walukiewicz and Ager is pushing directly on performance by expanding the transmission window of TCOs from the near-IR to the UV, essentially all of the useful region of the solar spectrum. They have also developed near-world record p-type transparent coatings and are working to integrate these into solar cell designs.

Potential Growth of BAPVC

Thus far, photon management is mainly aimed for enhancement of short circuit current. There are exciting opportunities: a) to explore photon management to reduce photon entropy loss to increase open circuit voltage. b) to integrate photon management together with electrical transport to fully engineer the structure to enhance solar cell efficiency as a whole. In addition, there are potential significant opportunities to integrate the materials innovations in the transparent conductor projects with the design and modeling efforts in the photon management projects. For example, transparent electrodes may be designed as an efficient structure for light management purposes. Alternatively, one may incorporate advanced optical design to reduce the loss in transparent electrode while maintaining its electrical properties. Lastly, it is also timely to study the integration of new photonic structures and transparent electrodes into practical scalable solar cell manufacturing.

Communication of the latest research performance metrics and new optical designs will be the key to realizing this opportunity within BAPVC.