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Three Challenges of Photovoltaics: Passive Tracking, Light Traps and The Thermodynamics of Radiation

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Abstract:
Solar energy is still far away from reaching its full potential. Our research dealt with three challenges that we perceive as critical to the progress of solar cells: Active tracking, Light trapping, and the thermodynamics of the photovoltaic effect.

Passive tracking uses material that is reactive to the sun and can enable motor-less tracking. Several passive tracking concepts were suggested before, but all had significant losses that made them impractical. We have developed a passive tracking method using an assembly of a dense collection of reflecting microspheres capped with liquid between two glass slides that can switch between opacity to transparency based on the illumination intensity termed a reactive reflector. In the talk, we will analyze the bubble-driven force that induces the medium's transparency and shows the proposed approach's ability to track the sun.

Light trapping refers to an optical scheme that enhances the absorption of a given solar material. The most common approach is internal ray randomization that facilitates total internal reflection within the cell material. Despite efforts to surpass this approach with advanced photonic and plasmonic concepts, this approach still dominates the market due to its scalability and cost-effectiveness. We have proposed external light trapping as a scalable approach that can surpass internal light trapping while being cost-effective. Moreover, external trapping decouples the electronics from the optics aspects of solar power generation. This decoupling offers higher efficiency for existing materials such as Silicon and perhaps overcasting the shortcomings of prospect materials such as perovskites. Moreover, this ability opens the possibility of past materials to become useful once more.

Lastly, we will highlight the shortcoming of thermodynamics to deal with the photovoltaic effect dominated by detailed balance law. We will show that a photovoltaic system cannot mutually obey the detailed-balance and thermodynamics' first law. However, the two are solvable if some emissivity is assumed to exist below the material's bandgap. We invoke the second law of thermodynamics to find how much of this emissivity should be present in a given situation. As a result, the thought-after thermodynamic formulation of the photovoltaic effect emerges. Such unification is of particular importance to solar energy concepts designated to operate at elevated temperatures such as thermophotovoltaics, thermophotonics, and concentrated solar cells for space missions.

Date & Location:

Tuesday, October 22, 2020, 11:00
Zoom meeting