Bifacial Tandem Photovoltaics for Ultra-High Energy Yield

Background

As silicon photovoltaic (PV) technology approaches its efficiency limit, a transition to high-energy-yield alternatives is seen as critical for further reduction of levelized cost of energy (LCOE). Example replacement technologies include bifacial modules that take available insolation on their rear side, and tandem modules—in which two solar cells of different bandgaps are stacked to make more efficient use of the full sunlight spectrum—that may achieve >33% module efficiency by surpassing the single-junction efficiency limit. In a two-terminal tandem configuration, the sub-cells are connected in series and their currents must be matched at their maximum power point to avoid power loss. Therefore, the sub-cells have optimum bandgap combinations as guided by the well-known detailed-balance model. For example, under AM1.5G spectrum, the maximum tandem efficiency is achieved by pairing 1.63-eV top cell with 0.93-eV bottom cell; and using silicon (with a bandgap of 1.12 eV) as a bottom cell, the optimum top cell bandgap is around 1.7 eV. Note that these calculations assume the PV module is only illuminated on one side. No existing mature PV materials have the desired 1.7 eV bandgap, which poses significant challenges in commercializing tandem technology. For example, cadmium telluride (CdTe) technology, which accounts for 20% of the US PV market, has a bandgap of 1.4–1.5 eV; gallium arsenide (GaAs) technology, which holds the efficiency record for single-junction PV devices, has a bandgap of 1.42 eV. Although perovskite technology delivers promising efficiency at 1.7 eV bandgap, it is not stable at such wide bandgaps, whereas 1.55–1.65 eV perovskites are considerably more stable.

Invention Description

Researchers at Arizona State University have developed a two-terminal bifacial tandem device that combines the bifacial and tandem technologies for higher efficiency and energy yield, and thus lower LCOE. In a two-terminal bifacial tandem configuration, due to the additional insolation on the rear side (bottom cell) of the module, the conditions for current-matching between the top and bottom cells are altered and the optimal top-cell bandgap shifts to lower values. This enables mature PV technologies, with lower bandgap, to be used in tandems. For example, using silicon as a bottom cell, calculations show that to reach an optimal top-cell bandgap between 1.40 eV and 1.55 eV—corresponding to a range of common photovoltaic absorber materials, such as methylammonium-lead-iodide perovskite, CdTe, and GaAs—an albedo between 25% and 60% will suffice. As a result, for a wide range of top-cell bandgaps and albedos, bifacial tandems produce
more power than both monofacial tandems and single-junction bifacial crystalline silicon cells.

This invention also relaxes the bottom-cell bandgap constraint in tandem devices. In other words, it enables better tandem performance when having an underperforming bottom cell. For example, in state-of-the-art perovskite/perovskite tandem devices, the bottom perovskite cell is the current-limiting cell because its 1.25-eV bandgap is too high to absorb low-energy photons (thus a low current). And, lower-bandgap perovskite materials tend to be unstable. However, with this invention, generating more current in the bottom cell from albedo can solve the current mismatch issue to achieve higher energy yield in outdoor applications.

Potential Applications

- High-energy-yield photovoltaic modules

Benefits and Advantages

- Combines bifacial and tandem technologies for ultra-high energy yield
- Bifacial design relaxes both top-cell and bottom-cell bandgap constraints in a two-terminal tandem
- Design can accommodate bonding layer for electrical connection of top and bottom cells

Research Homepage of Professor Zachary Holman