ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

Photon Amplifying Down-converter As The Contactless Top Cell For Tandem Devices

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Silicon based solar cells have been the majority in the photovoltaics (PV) industry for the last two decades. It is likely that they will keep dominating the market in the near future, due to the maturity of manufacturing process that has significantly reduced the cost. On the other hand, the efficiency of silicon based solar cells is limited by the thermalization loss. Although the UV and visible photons from the solar spectrum have considerably higher energy than that of the band gap (E_g) of silicon (1.1 eV), the excess energy is dissipated as heat in conventional silicon solar cell design and do not contribute to the power output.

The approach of tandem solar cell is aimed to utilise the excess photon energy above the E_g of silicon and hence improve the power conversion efficiency. Several material systems have been applied as the top cell on silicon devices and led to improvement in the efficiency. For example, perovskite / silicon two-terminal tandem device has achieved a power conversion efficiency of 28%.[1] However, although the performance of tandem devices is promising, they require electrical contact between the top and bottom cell and therefore introduce extra complexity into the manufacturing process of silicon devices. This will eventually impose extra cost to the production of the silicon cell apart from that of the top cell, hence limiting margin from the efficiency gain.

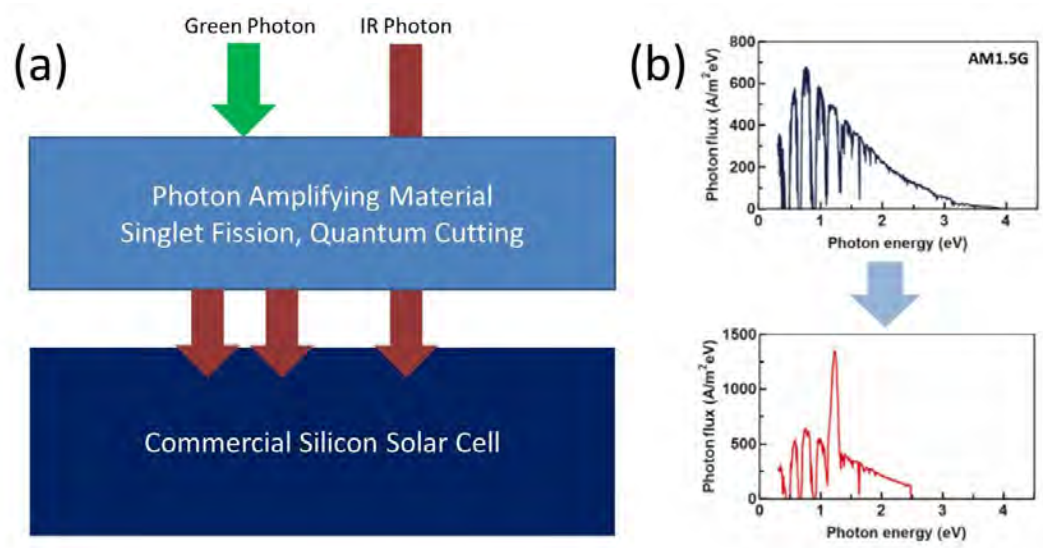

Figure 1. (a) A schematic of a photon amplifying down-converter on the top of a commercial silicon solar cell. It can absorb and convert the green/blue photons from the solar spectra into multiple IR photons. (b) The simulated change in the solar spectrum when absorbed by a down-converter as described.

Here, we introduce photon amplifying down-converter that can serve as an optical 'top cell' onto silicon.[2] In other words, it does not require electrical contact with the bottom silicon cell so it can be applied without significant change in the design of commercial devices. The down-converter is a material that can be incorporated into the solar cell module in ways of being coated on the cover glass or embedded into the encapsulation layer such as EVA or PVB. As shown in Figure 1a, the down-converter absorbs the high energy photons (green and shorter) while bypassing the red and IR photons directly to the silicon bottom cell. It converts the high energy photons into two IR photons that can be absorbed by the silicon, therefore doubles the total number of photons available for generating photocurrent. Before reaching to the silicon bottom cell, the broad band solar spectrum is therefore converted into that has a narrow band, while most of the visible to UV photon regions are converted into a sharp and intense IR feature that has energy just above the E_g of silicon, as shown in Figure 1b.

Several approaches are possible to achieve the function of the down-converter as described. In this talk, updates of the work on down-converter from our group will be presented. This will include our work on singlet fission in organic semiconductors and different ways of achieving quantum cutting in inorganic material systems.[3,4] One example is that we have demonstrated the feasibility of multiplying the number of photons in a hybrid system that consists of a singlet fission material and semiconductor quantum dots (QDs). As shown in Figure 2, the organic semiconductor (a tetracene derivative here) absorbs a blue/green photons and undergo an exciton multiplication process called singlet fission which generates two low-energy triplet excitons. The triplet excitons then transfer into the QD (lead sulphide here) via a bridging material that has similar properties to the singlet fission matrix. As QDs are very good light emitters, the triplet excitons are then converted back into IR photons, therefore overall the hybrid system converts one blue/green photon into two IR photons that can be absorbed by a silicon module. Another new mechanism of amplifying photons in inorganic semiconductors that was recently discovered will also be presented in this talk.

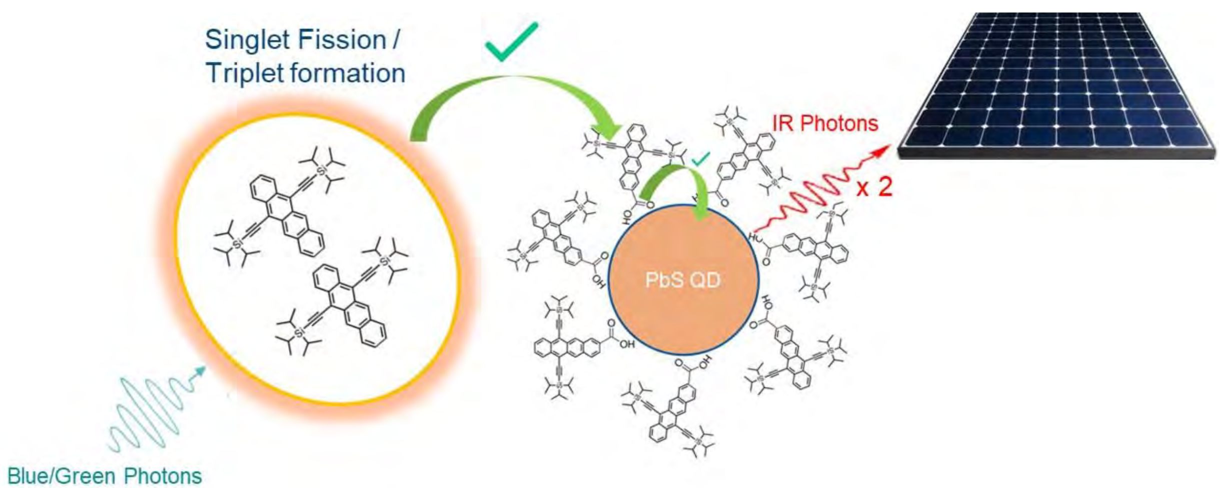

Figure 2. The schmatic of photon amplifying down-converter based on singlet fission material system.

References

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