Novel photonic configurations in thin film photovoltaics to enhance light absorption

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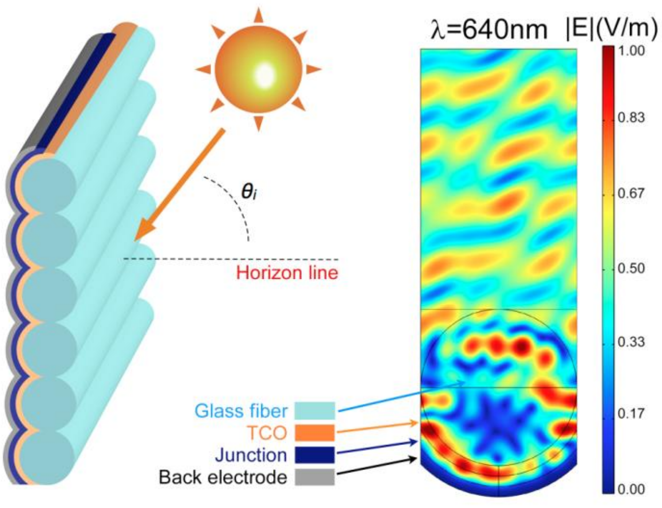
Thin film solar cells and, more in particular, organic solar cells present unique properties, such as flexibility, low fabrication cost, or an inherent visible semi-transparency of the active layer that make them an ideal technology for many different applications were the traditional Si based technology cannot be used. However, the use of extremely thin active layer prevents an efficient sunlight harvesting in such kind of devices.

In the current paper we present several approaches to enhance such light harvesting: 1) Using non-ordered one-dimensional photonic crystals to limit the loss in performance when the back metal electrode is thinned down to make the solar cell transparent. We will show 30% visible transparency cells with a 5.6% power conversion efficiency (PCE) equivalent to 72% the PCE of the opaque cell.[1] 2) In an alternative approach we enclosed the active material in between two metal electrodes forming an optical cavity designed to optimize photon trapping inside the cell. We will report experimental results demonstrating that it is possible to obtain 20% visible transparency cells with a PCE equivalent to 92% the PCE of the corresponding opaque cell. 3) We will also report on a cell where the substrate instead of being a planar transparent glass is formed by an array of transparent fibers (See Figure 1). In that configuration photons from the Sun are "longitudinally" coupled into the absorber material along the long axis of the active layer. In other words, photons to be absorbed by such material may travel a distance close to half the perimeter of the fiber, potentially increasing photon absorption probability to 1 at all wavelengths. This longitudinal light coupling or the efficiency of the cell becomes better as we increase the angle of incidence, reaching a maximum value at 55º. 4) Finally we will consider cases where plasmonic nano-particles are embedded in the device architecture to increase light scattering in the active layer.

Figure 1 *Left*: Schematic view of the of a fiber array cell architecture (very thin buffer layers are omitted for simplicity of the figure). *Right:* Field distribution when the light is incident at 55º.



[1] Betancur R., Romero-Gomez P., Martinez-Otero A., Elias X., Maymó M. & Martorell J. Transparent polymer solar cells employing a layered light-trapping architecture. *Nature Photon.* **7** 995-1000 (2013).