The potential sunlight harvesting efficiency of single walled carbon nanotube solar cells

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Recently, laboratory-scale solar cells have been demonstrated which show clear evidence of the successful exploitation of semiconducting single walled carbon nanotubes (SWNTs) as primary absorbers of sunlight energy. The unique properties of SWNTs may allow for high efficiency solar cell devices however little progress has been made to quantify this. Also, all SWNT species have their own peculiar absorption features covering different regions of the spectrum. So, which nanotube species are most appropriate for solar cell applications? How much of the power in the terrestrial solar spectrum could this material harvest? Shockley and Queisser used detailed balance calculations to derive a fundamental limit to the power conversion efficiency of a single junction solar cell. However these calculations are based on several assumptions, at least one of which does not apply in the case of SWNTs. One assumption is that all photons with energy greater than the semiconductor bandgap are absorbed. This requires a smooth continuum of states above and below the gap, as is the case with bulk semiconductors such as silicon but, due to the one dimensional confinement of electron and phonon states in a SWNT, it's density of states contains discrete van Hove features, which render the assumption invalid. Also, it is assumed that the absorption of one photon produces only one exciton. Whilst this is true for most semiconductors, there is evidence to suggest that SWNTs may exhibit multiple exciton generation from single photons.

An in-depth analysis of the potential of SWNTs to harvest sunlight will be presented, using the best currently available data to simulate the absorption properties of different semiconducting SWNT species and thus calculating a species-dependent potential sunlight harvesting efficiency. Then, the same model is used to simulate relevant multijunction scenarios including a high efficiency device absorbing in the visible and a similar device with an absorption profile tailored to harvest primarily in the infrared, whilst minimising absorption in the visible.