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High Temperature Solar Cells

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Solar cells capable of converting light to electricity efficiently at temperatures of 400C would allow hybrid solar plants to utilize both direct (PV) and indirect (thermal) conversion in a single facility. Such high temperature solar cells would surround and be in thermal contact with the heat receiving elements of Concentrating Solar Power (CSP) plants and boost their overall light to electricity conversion efficiency to about 40%. The resulting dramatic reduction in plant capital cost together with the capacity to store thermal energy cheaply would at last make electricity derived from the sun market competitive with electricity from fossil fuels thus providing a powerful economic driver for reversing climate change.

Silicon solar cells cannot be used for this purpose because they suffer a decrease in open circuit voltage so large as totally to destroy their capacity for the conversion of light to electricity at 350C. Classical solar cell theory suggests that increasing the semiconductor band-gap from 1ev characteristic of silicon to 3ev characteristic of wide band-gap semiconductors (WBGS) reduces the loss of open circuit voltage by about a factor of three, sufficient for WBGS cells to function satisfactorily in CSP applications. Unfortunately, materials with band-gaps of 3ev absorb such a small fraction of the solar spectrum that their use also is negated.

This presentation describes an approach to solar cell architecture that circumvents the problem described above by surrounding 3ev WBGS materials in nanowire (NW) form with highly light absorbing graphene shells.

A single layer of graphene of course absorbs only a small fraction of the incident light. However, the large surface area provided by the NW's in concert with their nanophotonic properties ensure efficient light absorption. This cell architecture was also chosen because it takes advantage of several unique aspects of the quantum electrodynamic properties of graphene such as contact doping and electron "puddle" formation. Solar cell structures based on these considerations exhibit favorable voltage and current characteristics at 400 C.

Graphene is well known to absorb light independent of wavelength across the entire solar spectrum. Indeed graphene's absorption coefficient directly yields the value of the fine structure constant thus making graphene the strongest light absorber known today. Furthermore, graphene acts as its own hole conductor thus functioning as a superb electrode.

The materials of construction of these cells are plentiful, not resource limited and environmentally benign. Results of measurements on prototype cells will be presented. This work was done under the auspices of Dimerond Technologies in collaboration with Prof. Sanjay Behura of the University of Illinois at Chicago under an MRC contract.

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