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Invited

Super-High Efficiency Solar Cells: Present and Future

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Research approaches to obtain one-sun solar cell efficiencies 30%, and even up to 35% at air mass 1 are now well understood. Such high efficiency cells are becoming available in the laboratories. These cells will be used in terrestrial power generation, space power generation and consumer electronics. For even higher efficiencies, concepts other than spectral splitting are needed. Various novel concepts, that will allow new types of super-high efficiency solar cells in the future, will be discussed. The uppermost limit of solar cell efficiencies is based on thermodynamics and should be around 90%.

High-efficiency solar cells have many practical applications. Owing to the area-related balance of photovoltaic system costs, there are significant advantages for high-efficiency solar cells versus low-efficiency cells. The balance of system costs include land costs, array structure costs and others. These costs cannot be reduced easily. Therefore, it is very important to develop high efficiency, or even super-high efficiency solar cells.

To design super high-efficiency cells has been a very challenging endeavor. On one hand, one has the thermodynamical limit, which effectively sets the uppermost efficiency that any solar cell structure can attain. The uppermost limit is about 90%. This is obtained from thermodynamical calculation (1).

Alternatively, one can obtain a practical limit of solar cell efficiencies by the now-conventional concepts of spectral splitting. Cells of efficiencies above 30% and up to close to 35% can be obtained using multi-bandgap cells (2). Various examples of experimental results will be given.

For even higher efficiencies, spectral compression, broad band detection, and other novel concepts must be used. The basic ideas involve the optimization of three fundamental parameters of solar cell performance - photocurrent, photovoltage and fill factor, under sunlight illumination. The photocurrent may be maximized by multipair or multi-photon excitation, whereas the photovoltage and fill factor must be maximized by having the semiconductor material and charge separation region as high quality as possible. A possible technique is to have a charge-generation (and sunlight absorbing layer) localized in a small volume, separated from but very close to the charge-separation region. Additional design considerations must be focussed on maintaining high photovoltage and fill factor. An analysis of possible mechanisms behind the reported 35% efficient novel silicon solar cell will be given (3).

References:

1) Henry, C.H., J. Appl. Phys. 51, 4499 (1980)

2) Fan, J.C.C., Solar Cells 12, 51 (1984)

3) Li J, et. al., Appl. Phys. Lett. 60, 2240 (1992).