Spectral Engineering through Down Shifting by Silicon Nanocrystals to Improve Conventional Silicon Solar Cell Efficiency

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This work is focused on a third-generation PV concept known as down-shifting, which is the conversion of high-energy photons into low-energy photons suitable for achieving higher efficiencies in conventional silicon solar cells. Modeling has shown [1] that down-shifting the light incident on a single-junction silicon cell (SJSC) can improve the cell performance if the optical conversion efficiency is sufficiently high.

Silicon nanocrystals (Si-NCs), embedded in silicon oxide matrices, fabricated using electron cyclotron resonance plasma-enhanced chemical vapor deposition (ECR-PECVD), were studied as a down-shifting material for single-junction silicon cells.Photoluminescence (PL) peaks varied depending on the stoichiometry of the films, ranging from approximately 790 to 850 nm. Variable-angle spectroscopic ellipsometry was used to determine the optical constants of the Si-NC films. The extinction coefficients indicated strong absorption below 500 nm, ideal for a down-shifting material. Transmission Electron Microscopy (TEM) was used to determine the size, density, and distribution of Si-NCs. The quantum efficiency (both internal, IQE, and external, EQE) of Si-NC emission was measured using a calibrated integrating sphere system [2]. The results of these measurements as a function of the thin film parameters and their influence on the down-shifting efficiency will be discussed.

The authors gratefully acknowledge support from the Natural Science and Engineering Research Council of Canada (NSERC) Photovoltaic Innovation Network.

[1] A.M. Gabr et al., "Modeling Down-Conversion and Down-Shifting for Photovoltaic Applications" in IEEE Photovoltaic Specialists Conference, Austin, 2012.

[2] J. Sacks et al., "Quantum Efficiency Measurements of Down-Shifting Using Silicon Nanocrystals for Photovoltaic Applications" in IEEE Photovoltaic Specialists Conference, Austin, 2012.