MAR10-2009-005419

Abstract for an Invited Paper
for the MAR10 Meeting of
the American Physical Society

Plasmonics for Photovoltaics[1]

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Photovoltaics is transcending its former status as an elegant yet expensive boutique energy technology, and is developing the potential to significantly impact energy supply. Reaching this ultimate goal requires a reduction in the cost per Watt of generated electricity, which motivates both increased conversion efficiency and reduction in material utilization. Both are facilitated by enhancing the optical absorption in solar cell active layers. I will describe a plasmonic photovoltaic design approach in which metallic nanostructures can couple sunlight into guided modes of thin absorber films, enhancing photoabsorption and photocurrent. Recent progress has enabled quantitative understanding of enhanced absorption in plasmonic absorber structures. Full-field electromagnetic simulations are used to calculate spatially and spectrally-resolved photocurrents in plasmonic photovoltaic devices, which can be compared quantitatively with measured solar cell spectral response. Semi-analytic multiple scattering models also yield insights about scattering into guided and free space modes, and losses from parasitic metallic absorption. Experimentally we have observed short-circuit current and efficiency enhancements under AM1.5G solar irradiation for thin GaAs plasmonic solar cells. We will also discuss recent results for enhancement of absorption and photocurrent in thin film amorphous Si solar cells, which feature nanoscale plasmonic structures fabricated by nanoimprint lithography that outperform previously-designed light trapping structures for amorphous silicon cells. Finally, I will describe optical design of light scattering structures that are capable of exceeding previously anticipated absorption limits. Attention to fundamental light-matter interaction physics enables design of solar cells whose absorption surpasses 'classical' light trapping limits for planar textured sheet absorbers, enabling new thin solar cell designs.

[1]Support by the US Department of Energy is gratefully acknowledged.