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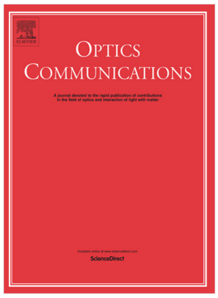

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Enhanced optical absorption in ultrathin silicon films using embedded silica-coated silver nanoparticles

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Abstract. Silver nanospheres with silica shells (Ag@SiO_2) embedded into the absorber layer are explored as a plasmonic optical absorption enhancement method for thin-film photovoltaic cells. We observe dramatically enhanced absorption of the solar spectrum into a semiconductor medium by embedding a single monolayer of Ag@SiO_2 nanoparticles in the central region of ultrathin mixed-phase amorphous/microcrystalline silicon (a/μc-Si) films. Optical absorption measurements indicate that integration of Ag@SiO_2 nanoparticles increased absorption in the 400–1100 nm portion of the solar spectrum by 26% and 88% for 290 nm and 100 nm thick a/μc-Si thin films, respectively, in comparison to control films without any nanoparticles. This enhancement is concentrated in the longer wavelength range where the photon energy to bandgap ratio is higher, potentially yielding even larger increases in net device efficiency. Taking into account the interference of light within thin films, we show that parasitic losses due to particle absorption are minimal, consisting <3% of the total absorption enhancement for 100 nm films. The dielectric shell serves two purposes: improved scattering cross-sections and charge recombination mitigation. The significant absorption enhancement coupled with low parasitic loss shown here lays a foundation for thin-film silicon photovoltaics based on directly integrated dielectric-shelled metal nanoparticles.

Keywords: plasmonics; photovoltaics; nanostructuring; thin films; near-field.

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1 Introduction

One of the key limiting factors in the performance of thin-film photovoltaics is poor absorption of red-to-near-infrared (red-NIR) light. This deficiency is particularly pronounced in devices that are not fabricated from direct bandgap semiconductors, such as nanocrystalline silicon. For thin film silicon solar cells, the most successful and widely adopted solution to this deficiency is nano/micro-scale texturing of the substrate and/or transparent electrode layers[1]. Though this approach is viable, it becomes less effective at longer wavelengths as posited by the well-established Yablonovich limit, and can induce defects in the nanocrystalline structure[2].

An alternative light trapping scheme in thin-film photovoltaics can be provided by plasmonic nanostructures[3,4,5]. On resonance, plasmonic nanoparticles act as nano-scale lenses, gathering