Plasmonic Nano-antennas for Absorption Enhancement in Thin-Film Silicon Solar Cells

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Abstract:

In this contribution, we theoretically demonstrate significant light absorption enhancement by adding plasmonic nano-antennas on top of thin-film amorphous silicon solar cells. This enhancement is attributed to resonance light scattering of core-shell (silica-silver) nanostructures.

The interaction of light waves with nanostructures induced light emission and absorption enhancement is a key question in the development of optical devices such as light-emitting diodes and solar cells (SCs). Efficient thin-film SCs based on microcrystalline silicon (μc-Si) or amorphous silicon (a-Si) with an achievement of a broadband absorption require that the absorbing layer's thickness should be at least a few micrometers. Unfortunately, this is unfeasible due to high and defect-related carrier recombination. Therefore, enhancing light absorption in thin-film Si SCs has become crucial. In the past few years, many techniques have been proposed to enhance light absorption. One of the most widely used techniques is the light-trapping or light-incoupling technique caused by scattering surface textures. In addition, the excitation of surface plasmon polaritons on metallic nanostructures caused strong near-field amplitude of the incident light waves, and a resonantly enhanced scattering cross section have widely been used as well.
In this work, we propose the use of plasmonic core-shell nanostructures made by silica (SiO_2) core coated with silver (Ag) shell placed on top of thin-film Si SCs to enhance light absorption. The entire device structure is sketched in Fig. 1. Through optical simulations based on the finite element method with the commercial software package COMSOL multiphysics we found that a significant absorption enhancement up to 20.8% is feasible. The antenna consists of a 20 nm radius SiO_2 core and a 20 nm thick Ag shell. The broadband absorption enhancement can be observed in Fig. 2. The same figure also shows the normalized absorption cross-section of the antenna. It is seen that at wavelengths around the resonance scattering wavelength of 441 nm the enhancement is achieved. This is caused by the interaction of incident light waves with the SiO_2-Ag core-shell antenna.

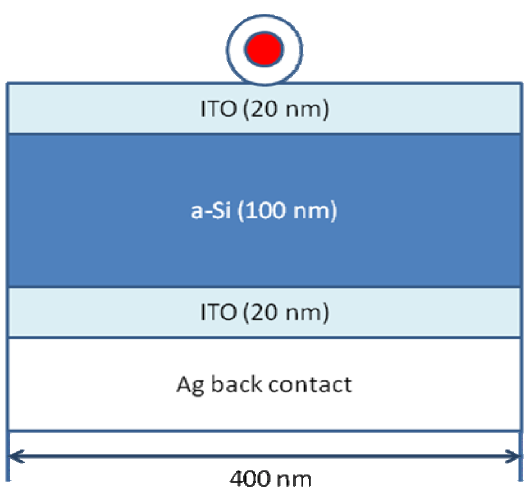

Fig. 1. A cross-section of the investigated SC. (ITO stands for indium tin oxide).

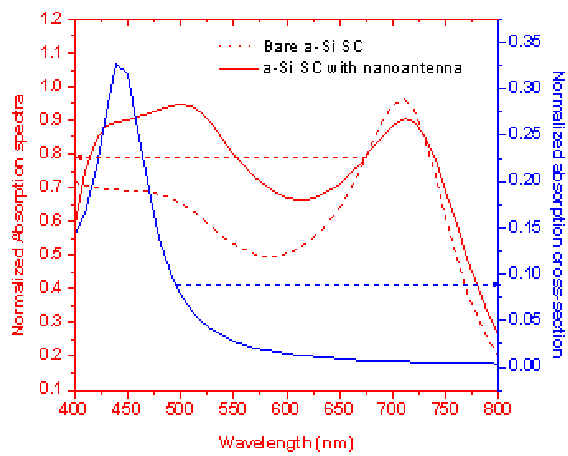

Fig. 2. Normalized absorption spectra of the investigated SC (red lines) and absorption cross-section of the proposed single core-shell antenna (blue line).