

Plasmonic layers of colloidal Ag nanoparticles for enhancement of light trapping in silicon solar cells

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During the last decade, extensive studies have been undertaken concerning a possibility to use Au and Ag nanoparticles (NPs) supporting localized surface plasmons (LSP) for achieving enhanced light absorption in silicon solar cells [1]. In particular, theoretical studies made significant progress in optimizing the design of Si solar cells containing plasmonic NPs and in understanding the mechanisms of increasing their efficiency, whereas experimental investigations of plasmonic effects in Si-based photovoltaics are much less developed. Primarily this is due to the lack of simple and reliable methods of incorporation of plasmonic NPs layers into silicon solar cell structures.

Until now the mostly often used method of metal NPs incorporation into Si solar cell structures is the thermal-evaporation induced formation of metal thin films with subsequent annealing to form NPs [2]. Although the method provides good physical contact between metal NPs and a substrate, it possesses such considerable disadvantages as an inability to vary the NPs shape and difficulties of varying the NP size and obtaining big NPs with narrow size distribution: the latter is very important since only big-size NPs demonstrate high-efficiency light scattering whereas light absorption prevails in case of small-size NPs.

The present work is devoted to the development and investigation of the other method of metal NPs incorporation into Si solar cell structure, namely the deposition of colloidal metal NPs from liquid suspension with subsequent solvent evaporation. Although this method has been formally used in the middle of 2000s by one group to deposit big-size Au NPs on top of several types of solar cells [3, 4], the very low level of surface covering by NPs (about 1%) as well as the absence of any optical data

(reflectance spectra) in these publications suggest that hardly the metal NPs plasmonic properties were responsible for the observed improvements of Si solar cells efficiencies. In view of the above our first task was to achieve high levels (at least 10%) of solar cell surface covering by metal NPs and confirmation of this level of covering by optical (reflectance spectra) and direct SEM measurements.

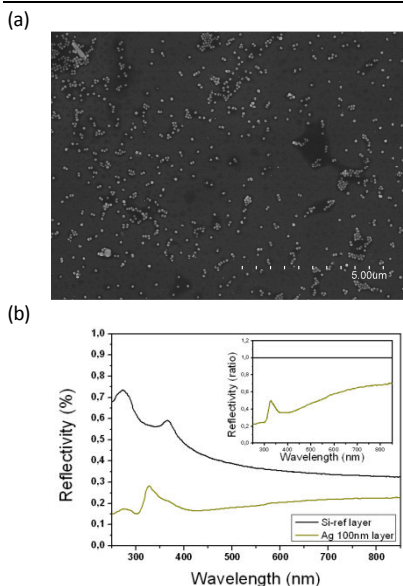


Figure 1: (a) SEM image of Ag NPs layer deposited on silicon. The covering factor is about 6%. (b) Reflectance spectra of the Si substrate before (upper curve; the reference spectrum) and after (lower curve; the working spectrum) 100-nm Ag NPs deposition. The inset shows a ratio of the working spectrum to the reference one and demonstrates antireflection properties of the silver NPs layer.

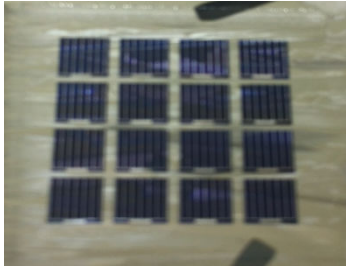


Figure 2: Layout of a set of 16 aSi/cSi solar cells on one common glass substrate.

We used 100-nm diameter colloidal Ag NPs (NanoComposix, USA) to prepare the plasmonic layers. We used two types of Ag NPs bearing different organic ligands on their surface, either citrate anions or polyvinylpyrrolidone. Two methods of deposition were used: (i) the deposition on bare substrates, and (ii) the deposition on preliminary functionalized substrates. To the best of our knowledge, this is the first time when the functionalization method, which results in covalent attachment of Ag NPs to substrate surfaces through a chemical linker (3-mercaptopropyltriethoxysilane in our case) is used for metal NPs deposition onto solar cells. Having in mind the necessity of Ag NPs incorporation into different solar cell structures, we carried out deposition of colloidal Ag NPs on Si, ZnO, and SiNx surfaces and investigated SEM images and

optical reflectance spectra of the corresponding substrates. A regime of multiple deposition as well as a post-deposition heating of substrates were applied to achieve high values of the covering factor. Fig. 1 shows SEM image and reflectance spectra of Si substrate before and after covering by a layer of 100-nm Ag NPs. As one can see, a considerable decrease of reflectance is observed over all spectral region investigated (250-850 nm).

As the next step, we carried out the deposition of colloidal Ag NPs on ZnO surface of heterojunction aSi/cSi solar cells (the layout of a set of such cells is shown in Fig. 2). The effect of Ag NPs deposition on the solar cell optical properties as well as external quantum efficiency will be presented in our poster.

References

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