Improving the efficiency of the solar Photovoltaic cells using different technologies

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Abstract

Solar photovoltaic (PV) is a technology which converts sunlight in to electricity that mainly used in solar panels. Solar energy is one of the promising and growing renewable energy source which can replace fossil fuels by 2050. Though it's a promising energy source the cost per kwh is one of the main drawbacks concerned currently. Increasing efficiency of the solar PV would be the better solution for the reduction of the cost of solar energy. In this review article a new type of technology have been discussed which can be used to increase the efficiency of the solar photovoltaic cells. A new type of light trapping structure containing ring-shaped metallic nanocavity arrays is proposed for the absorption enhancement in ultrathin solar cells with few photonic waveguide modes.[1]

Introduction

The following article is a mini review on increasing efficiency of the solar photovoltaic cells (PV) by recently developed technologies. The PV effect was discovered in 1954.[2] The first-generation solar cells are made from silicon and usually it's a flat plate. Later the thin film solar cells were developed and they are commonly made from amorphous silicon or nonsilicon materials such as cadmium telluride. The thin film solar PVs are made of thin films of a few micrometers thick containing semiconductor materials. The latest solar cells are made of variety of materials including solar dyes, solar inks and conductive plastics.[2]

PV systems are carbon free clean renewable energy source. But one of the main drawbacks of this PV system is the higher price. But recently the price of these systems has dropped to a certain level with the improving technology and it is resulted in the price of the unit of energy produced as well.[1]

Reviews

In this review article, mainly the general review of a new technology which can be used to improve the efficiency of the photo voltaic cells is discussed and summarized based on the recently published journal. The technology suggests the enhancement in absorption of ultrathin solar PV cells patterned by metallic nanocavity arrays.

Large Absorption Enhancement in Ultrathin Solar Cells Patterned by Metallic Nanocavity Arrays[1]

A new type of light trapping nanocavity array is proposed to enhance the absorption in the ultrathin solar cells with few photonic waveguide modes. The absorption enhancement mechanism was studied using FDTD simulations. The ultrathin solar cells which consists of three layers Ag bottom layer, 100 nm thick C-Si and 50 nm thick Si_3N_4. The nanocavity array is coated on the Ag bottom layer. The array consists of square nanocavities with length *L*, depth *h* and lattice constant *P* which are arranged in square lattice as shown in figure (1a). These nanocavities are separated by ridges with width S = P-L.[3]

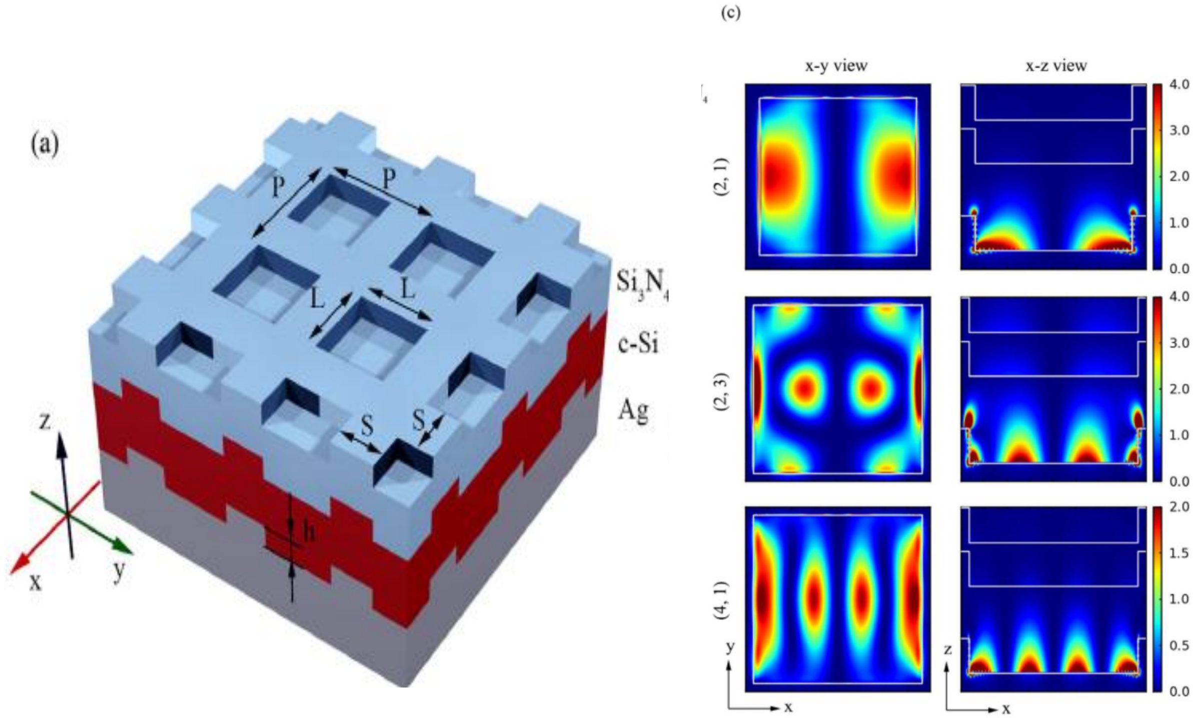

Figure 1: (a) Schematic of the stimulated structure. The ring shaped nanocavities on the Ag bottom layer are arranged in a square lattice. (c) Patterns for Ez^2 component of the electric field in the x-y and x-z plane.

In the first analysis, enhancement in absorption was analyzed using series of nanocavity arrays with fixed ridge width (*S* = 40 nm) and varying cavity side lengths (*L*) ranging from 100 to 460 nm. A dramatic absorption enhancement was observed in the longer wavelength range of 700nm -1100nm. This enhancement was explained by a mode profile as described in the figure (1b). According to the mode profile explained the SPP standing waves in these cavity modes are optimally bound within the ultrathin c-Si layer of the solar cells and the electric fields are greatly enhanced in the c-Si layer region. These activated cavities dramatically enhance the absorption.

Light trapping ability was optimized using nanocavity arrays using various ridge widths (S = 20, 40, 60, and 80 nm) and with varying cavity side lengths (L) ranging from 40nm to 520nm. Noticeable enhancement in the absorption was observed in the spectral range of 700nm - 1100nm. This is due to the excitation of plasmonic cavity modes in these nanocavity arrays figure (2). The absorption enhancement was red shifted with the increasing length L which is due to the cavity mode resonance condition explained by the following equation (1).[5]

$$L + 2\delta(\lambda_{SPP}) = \sqrt{m^2 + n^2}\,\frac{\lambda_{SPP}}{2}, \tag{1}$$

Where, λ_{SPP} is the SPP wavelength and $\delta(\lambda_{\mathrm{SPP}})$ the penetration depth of SPPs into the Ag reflectors. The absorption enhancement for the cavity mode increases with S which is due to the increase in efficiency of the cavity modes. This can be explained as S increases the resonance on the ridges increases resulting in the redshift on the resonant modes of the cavities. So, it can be concluded that the activation of the cavity modes mainly depends on the resonant scattering of the ridges between the nanocavities.

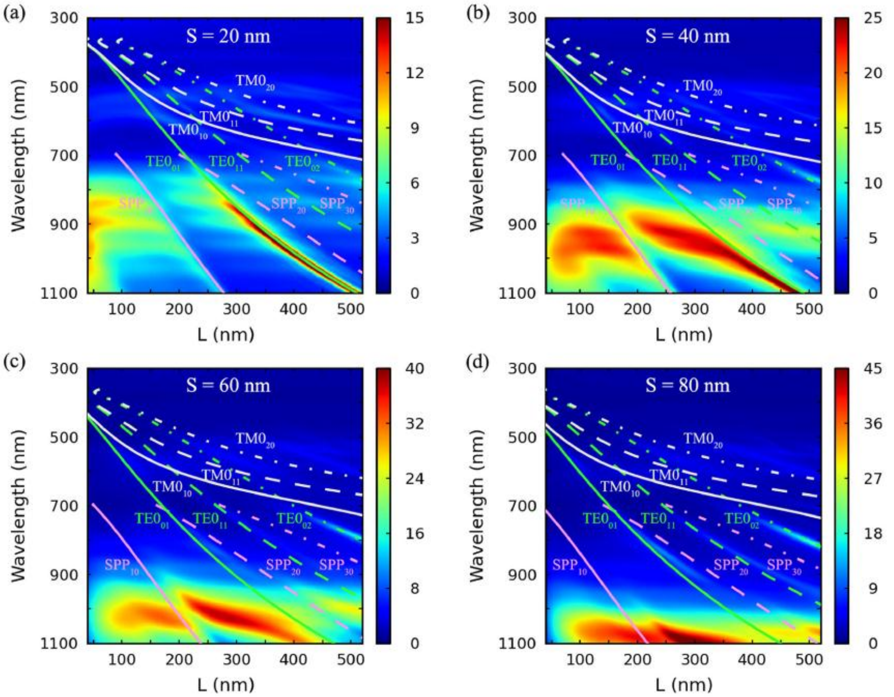

Figure 2: (a-d) absorption enhancement for nanocavity arrays as a function of wavelength and cavity side length L for different ridge width S's relative to the corresponding bare structure.

Also, when S increases the effective scattering cross section also increases. As a reference, different waveguide modes which could be possible exist in the nanocavity arrays are numerically calculated and overlaid on the maps per the following phase matching conditions.

$$\beta_{\mathrm{mode}}^{2} = \left(\frac{2\pi}{\lambda}\sin\theta + i\frac{2\pi}{S+L}\right)^{2} + \left(j\frac{2\pi}{S+L}\right)^{2}, \qquad (2)$$

where *i*, *j* = 0, ± 1, ± 2… , denoting different phase matching conditions, *λ* the incident wavelength, *ϑ* the incident angle and *β*mode is the propagation constant of a specific waveguide mode, for which the corresponding value in the bare structure is used for simplicity.

Then, the angular dependence of the absorption enhancement of the nanocavity arrays was studied using an optimal nanocavity array with S = 40nm and L = 240 nm was studied. From

these studies the angle dependent properties of J_{sc} are noticed. when the incident angle increases, coupling between the incident light and the nanocavity modes will become stronger resulting in a nearly angle insensitive absorption enhancement property
of the nanocavity arrays under unpolarized incident light figure (3).

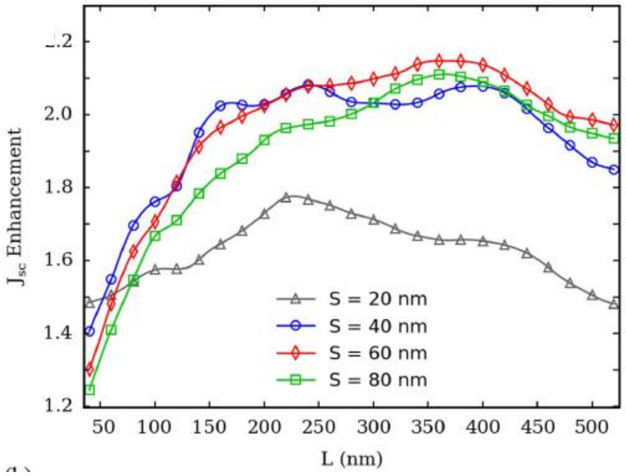

Figure 3: *Jsc* enhancement as a function of cavity side length *L* for nanocavity arrays with various ridge width *S*'s, relative to the corresponding bare structure.

Finally, the absorption enhancement of different nanocavity arrays was quantified across the solar spectrum by calculating the maximum short circuit current density with the assumption of each absorbed photon produces one electron-hole pair. From the calculations, it was found that the nanocavity arrays with S = 40, 60, and 80 nm have similar Jsc enhancement and all of them increases the absorption of the nanocavities. From all of these above calculations the optimized designs is obtained at S = 60 nm and L = 360 nm with the corresponding Jsc enhancement factor of 2.15.

Conclusion

Therefore, this nanocavity array is a suitable design in the solar cells for the light trapping which can result in the enhancement in absorption by dozens of time.

References…

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