Supplementary Information

New strategy to promote conversion efficiency using high-index nanostructures in thin-film solar cells

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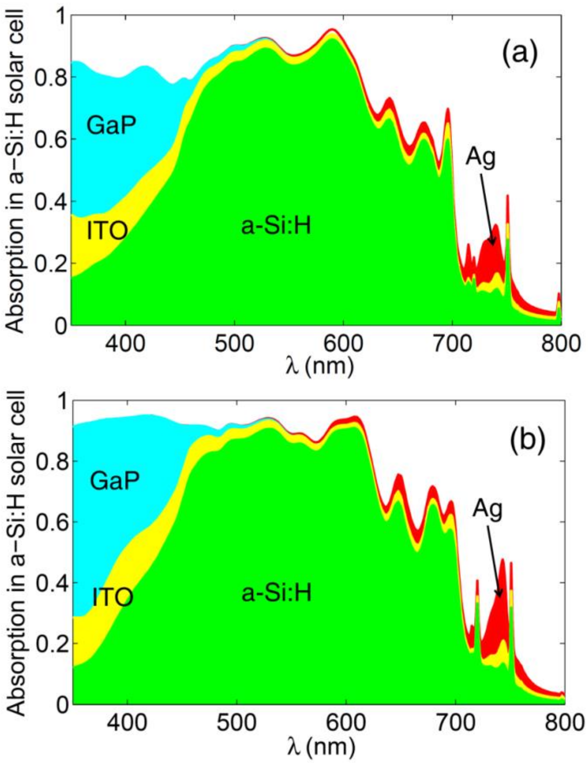
Supplementary Figures



Supplementary Figure S1. Normalized light absorption in each layers of the a-Si:H thin-film solar cell. The spectral absorption for the solar cell with the flat scatterer (a) and the stepped scatterer (b). The calculation is carried out under the normal incidence.

Supplementary Note 1

Optical and electrical simulation details

Based on the FEM software package, Maxwell's equations can be easily solved for executing the optical simulation. All simulations are under a normal incidence except for special instructions. Because the designed scatterer is assumed to have a high symmetry, the transverse electric (TE) and the transverse magnetic (TM) polarized incident light are equivalent under the normal illumination. In this situation, the TE polarized incident light is used for all simulations. Under an oblique incidence, both TE and TM polarized incident light are calculated, and only averaged results are shown. The complex optical constants for Ag, AZO, ITO, a-Si:H and GaP are taken from the previous experimental works[46-49]. The optical absorption within each layers in the solar cell can be obtained by the optical simulation. Mostly, the distribution of electric field intensity ($E(\vec{r},\lambda)$) at each single wavelength is the bridge to connect the optical and electrical simulations. In the electrical simulation, the wavelength dependent generation rate of carriers can be expressed as[19]:

$$G(\vec{r},\lambda)=\frac{\varepsilon''\left|E(\vec{r},\lambda)\right|^2}{2\hbar},$$

where ε'' is the imaginary part of permittivity of a-Si:H. Also, this generation profile should be weighted AM1.5G spectrum[50] to simulate one sun illumination. The details for using the FEM to realize the electrical simulation can be found in a previous report[36]. The only difference here is that more accurate generation profile is used in this work. The electronic material parameters of a-Si:H are taken from the previous studies[51,35]. And 5 Ωcm^2 series resistance and 5 $k\Omega cm^2$ shunt resistance are applied to the solar cell[28].

Supplementary Note 2

Parasitic absorption in solar cell

In the designed solar cell, the light absorption occurs in all layers including scatterers, ITO, AZO, Ag and the active layer. But only the absorption in the active layer can be converted into the photocurrent. The light absorption in other layer can be considered as the parasitic absorption that wastes the light energy trapped by the solar cell. Figure S1 shows the light absorption in all layers of the solar cell with the flat scatterer and the stepped scatterer. Because GaP has a high transmittance in the long wavelength region (>500nm) and a high absorption ability in the short wavelength region (<500nm), a large parasitic absorption is formed in dielectric scatterer when λ<500nm. Besides, the parasitic absorption in ITO and Ag are also the optical loss channels in the solar cell. In this work, the parasitic absorption in GaP scatterers wastes a lot of light energy in the short wavelength region. Choosing another material that has high index and less light absorption may overcome this undesirable optical loss, and could improve further the conversion efficiency of the a-Si:H thin-film solar cell.

Supplementary References

46. Palik, E & Ghosh, G. *Handbook of Optical Constants of Solids*. New York, NY, USA: Academic, 1997.
47. Ferry, V. E. *Light Trapping in Plasmonic Solar Cells*. California Institute of Technology Pasadena, California 2011
48. Paetzold, U. W. *Light Trapping with Plasmonic Back Contacts in Thin-Film Silicon Solar Cells*. Dissertation-RWTH Aachen University, 2013.
49. Aspnes, D.E. & Studna, A. A. Dielectric functions and optical parameters of Si, Ge, GaP, GaAs, GaSb, InP, InAs, and InSb from 1.5 to 6.0 eV. *Phys. Rev. B* **27**, 985-1009 (1983).
50. Solar irradiance. http://rredc.nrel.gov/solar/spectra/ am1.5/ASTMG173/ASTMG173.html
51. Swartz, G. A. Computer model of amorphous silicon solar cell. *J. Appl. Phys.* **53**, 712–719 (1982).