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A New Interdigitated Nanopillar HIT Solar Cell with 26.09% Efficiency Achieved by Using Silicon-Carbide-based Window Layer

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Abstract

In this paper, we study a new Interdigitated Nanopillar HIT Solar Cells using Silicon-Carbide-based window layer (INSC-HIT) by Silvaco TCAD simulation with measurement calibration. According to the simulation results, the Interdigitated Nanopillar performance can enhance the light absorption and the antireflection. Using Silicon-Carbide-based window layer is able to enhance the short-circuit current density by reducing the parasitic absorption loss and reflection loss. The maximum short-circuit current density of 42.12mA/cm^2 is achieved. Also, the conversion efficiency of INSC-HIT is 26.09% which is higher than that of the conventional planar HIT solar cell (24.7 %).

1. Introduction

Amorphous/crystalline silicon (a-Si/c-Si) heterojunction with intrinsic thin layer (HIT) solar cell technology has been demonstrated to be promising candidate for high efficiency of solar cells. An inserted intrinsic a-Si thin layer can improve interface quality and its transport properties. Also, by inserting an intrinsic a-Si thin layer between n-type c-Si and the back surface field (BSF) can lower the rear surface recombination velocity. Therefore, the conversion efficiency can reach 24.7% at a low temperature fabrication of below 200℃ by improving interfaces quality [1]. Meanwhile, Silicon nanopillar (SiNP) based solar cells have also attracted great attention recently. The unique properties in the fields such as antireflection, light trapping, carrier's radial separation mechanisms, and reduced transmission losses could be improved [2]. Therefore, nanostructure solar cells have been shown to have higher conversion efficiency than planar solar cells. In addition, SiC have been shown as promising candidates for more transparent window layers than a-Si have. Moreover, it can reduce parasitic absorption losses in the ITO and a-Si layer without degrading the electrical performance of device [3].

In this contribution, the New Interdigitated Nanopillar HIT Solar Cells using Silicon-Carbide-based window layer was proposed as shown in Fig. 1. We demonstrated that the characteristics of it are significantly improved.

2. Device Fabrication

For the new solar cell presented here, n-type float-zone c-Si wafers with a resistivity of 2 to 5 Ω · cm are used. The wet etching results in nanopillar with feature size ranging from 1.4 to 2.0 µm. On the back side of the c-Si wafers, an n-type a-Si layer and metal are deposited with intrinsic a-Si passivation layer and back ITO. On the front side, intrinsic a-Si and p-type a-SiC layers are deposited, followed by an ITO layer and metal grid. Intrinsic a-Si is used in solar cells with front side and back side materials in order to sustain the good surface passivation quality, thereby enabling to examine the influence of p-type a-SiC only. For a-Si deposition, radio frequency (Rf) plasma-enhanced chemical vapor deposition (PECVD) is used, whereas ITO is deposited by Rf sputtering. The metal back contact is deposited by thermal and electron-beam evaporation. The device parameters are listed in the Fig. 1.

3. Results and Discussion

Fig. 2 (a)-(d) shows the best trade-off with different *H*, *D*, *P* and *T*. With SiNP arrays, light scattering between the SiNPs is greatly enhanced. Also, the absorb region prolongs the optical path length and hence results in stronger light trapping. Thus, the INSC-HIT proposed can significantly cut the required c-Si wafer thickness in heterojunction solar cells thereby reducing the cost.

Fig. 3 (a) and (b) shows the SiNP has a higher electric field and photogenerated carrier distribution profile. We find electric field region is large enough to accelerate carrier transport. Therefore, the photogernerated carriers reach the contact without significant recombination. And, most of the carriers are concentrated inside the pillar, confirming strong light absorption by the SiNP array.

Fig. 4 shows the absorption and reflection as a function of wavelength for the device with p-type a-SiC window layer and p-type a-Si window layer respectively. We can clearly see that the p-type a-SiC layer has a lower reflection than the a-Si layer has. Because of the p-type a-SiC can reduce parasitic absorption losses and it is more transparent in the wavelength range of 300 to 700 nm. That is why the p-type a-SiC is a better window layer in the front of the silicon heterojunction solar cell.

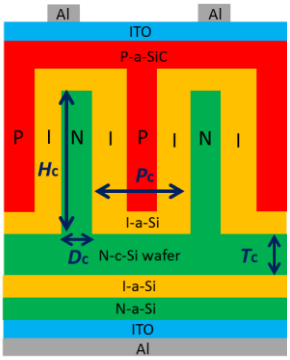
Fig. 5 shows the external quantum efficiency versus the light wavelength for the conventional HIT solar cell and our INSC-HIT solar cell. Using SiC material with a wide-gap (~2.2 eV), the EQE in shorter wavelength can be improved. But the EQE in middle wavelength appears slightly worse.

4. Conclusions

In summary, we have demonstrated that our INSC-HIT solar cell can enhance the light absorption and the antireflection. Moreover, we have shown that by replacing the p-type a-Si with p-type a-SiC the device reflectance and parasitic absorption are reduced, leading to a higher short circuit current density. The maximum short-circuit current density of 42.12 mA/cm^2 is achieved. Also, the conversion efficiency of INSC-HIT is 26.09% which is higher than that of the conventional planar solar cell (24.7 %).

References

[1] M. Taguchi, *et al.*, *IEEE J. Photovoltaics*, **4** (2014) 96.
[2] S. M. Wong, *et al.*, *IEDM* **10** (2010) 704.
[3] D. Zhang , *et al.*, *IEEE J. Photovoltaics*, **4** (2014) 1326.



Parameters	INSC-HIT
SiNP height (*Hc*)	1600 nm
SiNP diameter (*Dc*)	130 nm
SiNP period (*Pc*)	410 nm
N-c-Si wafer(*Tc*)	80 μm
P-a-SiC	200 nm
I-a-Si	10 nm
ITO	80 nm
Al contact	80 nm

Fig. 1 Cross-section of the new INSC-HIT Solar cell and the parameters used in this work.

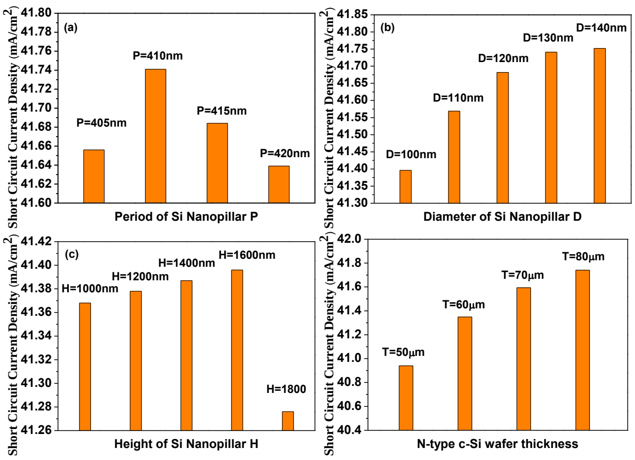
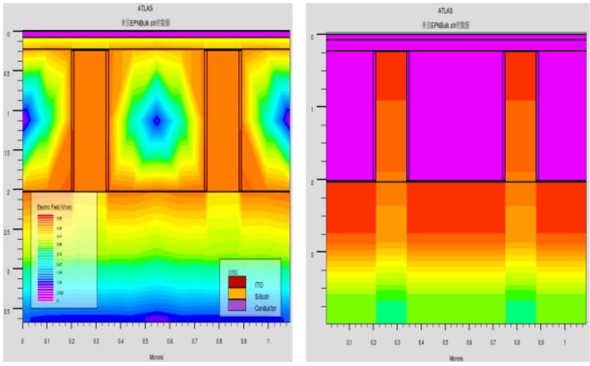


Fig. 2 Short Circuit Current Density of the new SiNP arrays with (a) diameter variations, (b) height variations, (c) periodicity variations, and (d) N-c-Si wafer thickness variations.

Table I. Performance comparison of the conventional HIT solar cell and our novel INSC-HIT solar cell.

simulation	Conventional HIT [1]	INSC-HIT
Short-circuit current (mA/cm^2)	39.5	42.12
Open-circuit voltage	0.75	0.7397
Fill factor	0.832	0.837
Conversion Efficiency	24.7	26.09



(a) (b)

Fig. 3 Simulated (a) electric field and (b) photogernerated carrier profile of the new SiNP array solar cell.

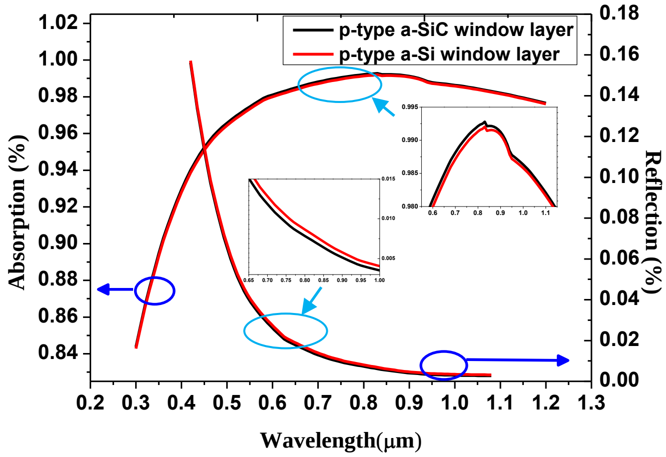


Fig. 4 Absorption and Reflection as a function of wavelength for the device with p-type a-SiC window layer (black) and p-type a-Si window layer (red) respectively.

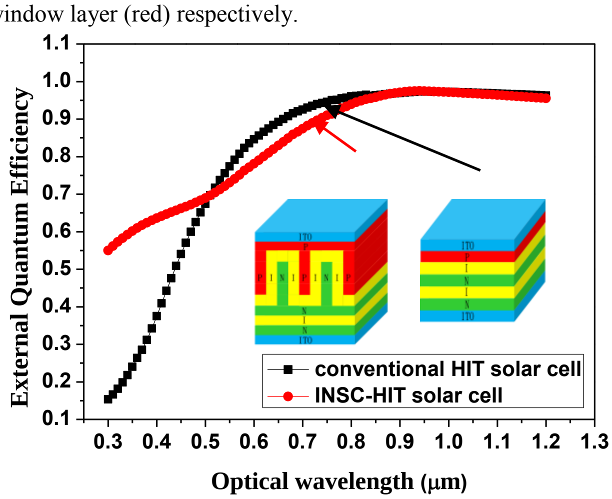


Fig. 5 External Quantum Efficiency versus the light wavelength for the conventional HIT and our new INSC-HIT solar cell. The measurements are carried out under AM1.5G illumination.

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