Development of n-type silicon bifacial solar cell

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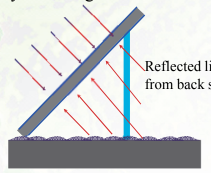
研究の目的

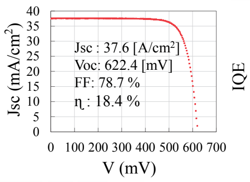
Bifacial solar cell generates the electricity from both sides.

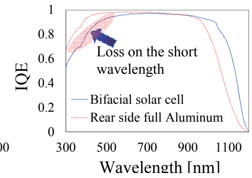
Front side efficiency ＋ Rear side efficiency → Bifacial solar cell efficiency

It is expecting high out put efficiency by modeling the bifacial solar cell.



The initial bifacial solar cell fabricated on n-type Cz-Si and IQE was compared with rear side full aluminum.





I-V characterization of initial solar cell

Cell parameters	Jsc [A/cm²]	Voc [mV]	FF [%]	η [%]	Area [cm²]
Full Al-BSF	37.8	638	79.9	19.3	239

IQE shows a loss on the short wave length, there are two possible explanations on this loss. First one is front side emitter the other is front side passivation.

Purpose of this research:

(1) Improve the front side emitter characterization by modulating the p^+ emitter sheet resistance and its diffusion depth.

(2) Investigate the excellent passivation.

実験

Ⅰ. N-type bifacial solar cell process

Wafer: 156 × 156 mm² n-type 180 μm thickness Cz-Si wafers, with a resistivity around 1.7 Ω · cm.

(Front) p-type emitter: Boron thermal diffusion.

(Rear) n-type emitter: Phosphorus thermal diffusion.

- Saw damage removal and wafer cleaning
- Both sides alkaline texturization
- BBr_3-diffusion and in-situ oxidation
- Rear side etching
- $POCl_3$ emitter diffusion
- HF cleaning
- SiO_2/SiN_x stack on both sides
- Screen printing on both sides
- co-firing/edge isolation

Ⅱ. Boron diffusion

Four different sheet resistances have been investigated. p^+ emitter sheet resistance was modulated by controlling the drive-in temperature.

Drive in process				oxidation	
Temperature	Time duration	O_2 flux	N_2 flux	O_2 flux	N_2 flux

Deposition process:
After entering the furnace gas mixture heats up and BBr_3 and oxygen are reacting according to the following chemical process:

$$4BBr_3 + 3O_2 \rightarrow 2B_2O_3 + 6Br_2$$

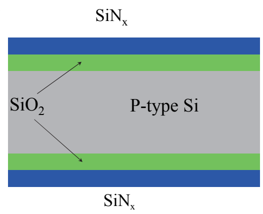
$$2B_2O_3 + 3Si \rightarrow 4B + 3SiO_2$$

Drive-in process:

$$Si + B \rightarrow SiB_x \text{ (boron rich layer)}$$

Ⅲ. Evaluation of passivation layer

To investigate the perfect passivation, SiO_2/SiN_x on the front side of the n-type Cz-Si was observed.

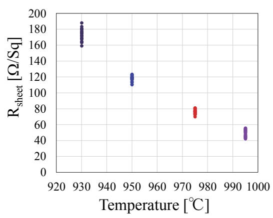


Ⅳ. Solar cells

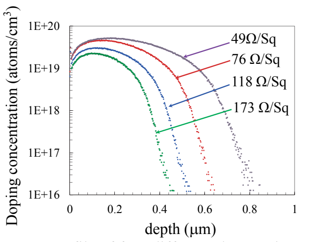
We have investigated the bifacial solar cell with four different sheet resistances with SiO_2/SiN_x passivation layer. Rear side emitter sheet resistance and passivation layer are the same for all cells.

結果 and 考察

P⁺ sheet resistance



Temperature dependence of sheet resistance of boron diffusion.

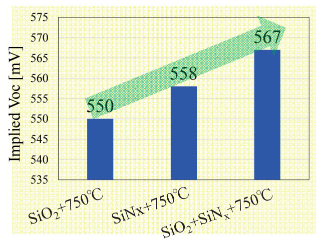


SIMS profile of four different sheet resistance.

Increasing of drive-in temperature by 20-25℃, reduces the sheet resistance by 15 Ω/Sq, but no significant difference of boron concentration on the surface.

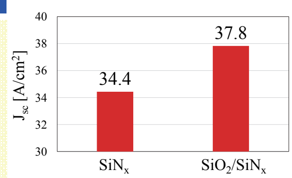
R_{sheet}	173 Ω/Sq	118 Ω/Sq	76 Ω/Sq	49 Ω/Sq
Emitter concentration on surface [atoms/cm³]	1.2×10^{19}	1.7×10^{19}	2×10^{19}	2×10^{19}

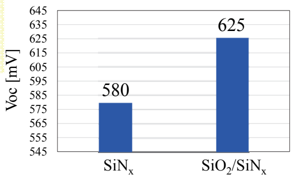
(1) Passivation quality of SiO_2, SiN_x and SiO_2/SiN_x as the front side passivation layer of n-type bifacial solar cell.



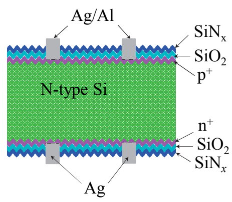
Implied V_{oc} is improved by SiO_2/SiN_x. Bifacial solar cell was investigated by SiO_2/SiN_x passivation layer. (right figures)

(2) Front side passivation affect on the n-type bifacial solar cell.



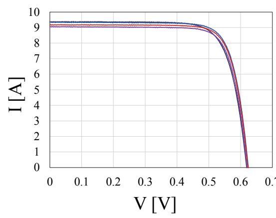


Solar cell

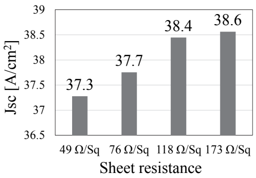


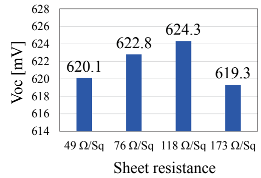
Schematic bifacial solar cell structure

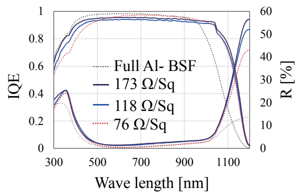
Bifacial solar cells are fabricated on n-type 156 × 156 mm² single crystalline Si with four different sheet resistance. Rear side emitter is the same for all cells.

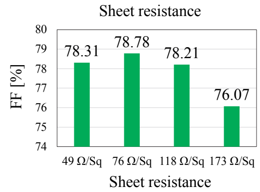


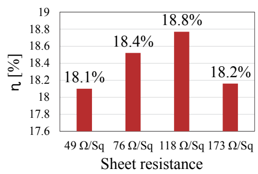
Profiles \ Parameters	Jsc [A/cm²]	Voc [mV]	FF [%]	η [%]
173 Ω/Sq	38.561	619.3	76.07	18.16
118 Ω/Sq	38.447	624.3	78.21	18.77
76 Ω/Sq	37.754	622.8	78.78	18.52
49Ω/Sq	37.278	620.1	78.31	18.1

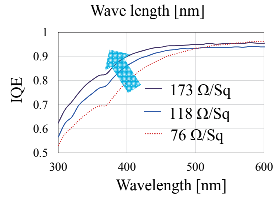












By modulating the front side sheet resistance with a SiO_2/SiN_x passivation layer a conversion efficiency of 18.8 % was achieved. Results of bifacial solar cells show that, J_{sc} increases with the increasing of sheet resistance due to the shallow diffusion length. The highest V_{oc} and highest efficiency were observed with the sheet resistance of 118 Ω/Sq. The IQE shows a slight increase in the short wavelength with the increasing of sheet resistance. The loss in the short wavelength for all sheet resistance most probably comes from the poor passivation of both the front and rear sides. In total it can be said that high efficiency bifacial solar cell can be obtained by modulating the boron diffusion. Perfect passivation for both front and rear sides need to be investigated to increase the cell efficiency.

結論

In this study, we fabricated a bifacial solar cell on n-type Cz-Si wafers with different sheet resistance. By modulating the p^+ emitter sheet resistance, an efficiency of 0.4% enhancement was observed. The SiO_2/SiN_x passivation on the front side of n-type bifacial solar cell results in low implied V_{oc}. There is still a loss was observed on the short wavelength by spectral characterization even after modulating the p^+ emitter sheet resistance. It maybe relates to the passivation quality. A more detailed analysis of the front as well as the rear side passivation needs to be investigated.