N-type bifacial solar cell with selective emitter structures formed by wet chemical etching

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Purpose of research

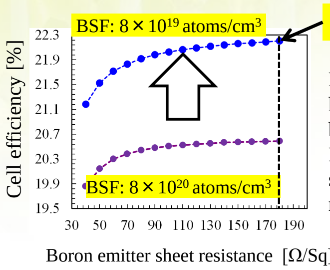

Figure 1: PC1D simulation of bifacial solar cell[1].

Figure 1 shows that above 22% efficiency has been estimated of bifacial solar cell by PC1D simulator [1].

Purpose of the research: Developing the selectively doped structures of p^+/p^{++} and n^+/n^{++} bifacial solar cell.

Experimental

Figure 2 shows the selectively doped n-type bifacial solar cell structure. Selective doped emitters were fabricated by a screen-printed resist masking technology with the combination of chemical wet etching technology. Electrodes were screen printed with 40 μm finger width and 1.4 mm busbar width on the selectively doped 240 μm width fingers and 1.48 mm busbars.

I-V measurements were performed at 25℃ on a reflective metal plated chuck. Chemical mixture of HF and HNO_3 were used for formation of selectively doped area.

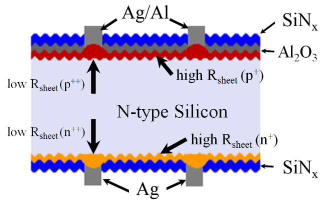

Figure 2: Selective emitter bifacial cell structure.

Results

A) Boron selective emitter bifacial solar cell

Table Ⅰ. Illuminated *I-V* characteristic results of n-type bifacial solar cells featuring homogeneous and selective emitter structures.

Emitter structure	J_{sc} (mA/cm^2)	V_{oc} (mV)	FF [%]	η [%]
Home p^+ / home BSF	38.4	636.5	77.5	18.93
Selective p^+ (49/160 Ω/□) / home BSF	38.3	640.9	77.3	18.96

B) Phosphorus selective BSF bifacial solar cell

Table Ⅱ. Illuminated *I-V* characteristic results of n-type bifacial solar cells featuring selective n^+ BSF and homogeneous p^+ emitter structure.

Emitter structure	J_{sc} (mA/cm^2)	V_{oc} (mV)	FF [%]	η [%]
Selective n^+ BSF(30/60 Ω/□) / home p^+	38.8	643.5	80.1	19.9
Selective n^+ BSF(30/160 Ω/□) / home p^+	38.9	650.3	79.7	20.2

As shown in Table 1, the cells with boron selective emitter shows an average V_{oc} of 640.9 mV, which is about 4.4 mV higher that of the homogeneous emitter cells. In the case of phosphorus selective BSF cells, it shows an average V_{oc} of 643.5 mV for selective n^+ BSF(30/60 Ω/□) and it is 650.3 mV for selective n^+ BSF(30/160 Ω/□). A cell efficiency of 20.2% is obtained for selective n^+ BSF (30/160 Ω/□). Phosphorus selective BSF bifacial solar cell shows higher V_{oc} and higher FF, however the J_{sc} does not change for both cases. Due to the higher sheet resistance in the etched-back field area, the selective emitter cells showed higher series resistances (R_s), and thus, lower FFs than those of the homogeneous emitter cells. Because of this the selective boron emitter solar cell does not show its full potential.

Discussion

Recombination loss analysis

To investigate the recombination losses on the finished cell, V_{oc} loss analysis was performed.

The increase in V_{oc} is mainly ascribed to the decrease in Auger recombination in the etched-back field area. It is evident from the calculation that most of the recombination is attributed to the screen printed contact area and the rear side BSF of the cell. According to this estimation, the cell V_{oc} can be further improved by optimizing the rear-side n^+ layer and metallization fraction of both the front and rear sides of the cell. These results of increment of V_{oc} and cell efficiency match with our previous results of PC1D calculation[1]. However, the J_{sc} of the selective emitter cell almost does not change compared to that of the homogeneous solar cells. This is because the cell does not show its full potential.

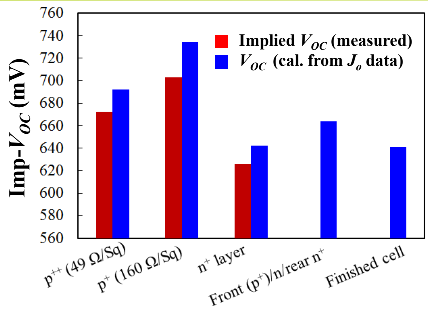

Figure 3: Corresponding implied V_{oc} of various structures as measured using the implied V_{oc} method and as calculated from the J_0 data.

Conclusion

In this study, we developed a boron selective and phosphorus selective BSF bifacial solar cells. In order to increase the fill factor and decrease the recombination at the contact area, a deep boron emitter and phosphorus profiles were employed. The p^+/p^{++} and n^+/n^{++} structures were fabricated by the chemical wet etching process. A higher V_{oc} of 650.3 mV was achieved by developing the phosphorus selective BSF bifacial cell. A higher cell efficiency was expected by reducing the surface recombination below the contacts of highly doped p^{++} and n^{++} regions by minimizing the electrode area and investigating a proper passivation layer for BSF side of the cell.

Reference and Acknowledgement

[Reference]

[1] Shalamujiang Simayi, Toshimitsu Mochizuki, Yasuhiro Kida, Katsuhiko Shirasawa, and Hidetaka Takato, Jpn. J. Appl. Phys. **56** 102303 (2017).

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