低濃度ボロン領域除去による、n-PERT 表面の改善
Front Side Improvement for n-PERT Solar Cell by Removing the Boron-depleted Region

シャラムジャン　スマイ*(1)、木田 康博(1)、白澤 勝彦(1)、鈴木　竜暢(2)、高遠 秀尚(1)
(1)産業技術総合研究所福島再生可能エネルギー研究所
(2)日本化成㈱
Shalamujiang Simayi*(1), Yasuhiro Kida(1), Katsuhiko Shirasawa(1), Tatsunobu Suzuki(2), Hidetaka Takato(1)
(1)Fukushima Renewable Energy Institute, National Institute of Advanced Industrial Science and Technology
(2) Nippon Kasei Chemical Co., Ltd.

E-mail: sharamujan-simayi@aist.go.jp

Bifacial n-type solar cells having the structure shown in Figure 1 feature a boron emitter on the front and phosphorus emitter on the rear as a back surface field (BSF). Boron emitter is one of the main factor which effects to the efficiency of this type of bifacial solar cells. Tube-furnace diffusion with the liquid BBr_3 is an option for forming the front boron emitter. The process for forming the boron emitter results in an unexpected boron rich layer on the top of the boron-doped region [1]. The boron-rich layer, which has a negative effect on the performance of n-type silicon solar cells, is resistant to chemical etching, but can be removed by oxidation. In situ oxidation after the diffusion or low-temperature oxidation after deglazing are two methods that are the commonly used methods to convert the boron-rich layer into boron surface glass. However, such oxidation steps cause depletion of boron near the surface of the wafer, because boron is more soluble in oxygen than in silicon [2, 3]. This boron-depleted region can enhance surface recombination of the minority charge carriers in the boron emitter, due to band bending within the depletion region. Consequently, elimination of the depletion region would appear to be a necessary step in optimizing the performance of the solar cells. Therefore, in this study our main goal was improve the efficiency of n-PERT solar cell by tuning the front-side emitter by removing the depleted region.

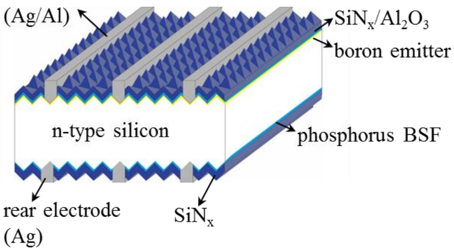

Figure 1: cross section of n-PERT solar cell

As shown in figure 2, the improved boron profile was obtained by etching the surface by 0.15 μm to remove the boron depleted region. In this experiment, the boron depleted region was removed by a chemical solution consisting of HF and HNO_3 which was developed by Nippon Kasei Chemical Company Limited. The sheet resistance was increased from 49 Ω/□ to 60 Ω/□ by removing the depleted region. The J_{0e} values were measured on a symmetrical $p^+/n/p^+$ sample for these non-etched and etched emitters. J_{0e} value improved from 121 fA/cm^2 to 103 fA/cm^2 by removing the depleted region.

The measured one-sun *I–V* parameters for both the boron emitter depleted region non-etched and etched solar cells are summarized in Table I. A slight increase was observed in J_{sc} in the case of sample in which the boron-depleted region was removed. This increase in J_{sc} is due to the increase in the boron concentration on the surface produced by removing the boron-depleted region. The other main differences observed were in the values of V_{oc} and the fill factor (FF). A 3.5 mV increment in the V_{oc} was observed in the solar cells in which the boron-depleted region had been removed. The reduction in the J_{0e} was responsible for the increase in the V_{oc}. The FF was 1.8% lower in the case of cells in which the boron-depleted region was not etched. The dark *I–V* curves, series resistance, and contact resistivity are important parameters in understanding the differences in the FF. More detailed investigations about the differences of FF will be discussed in the conference.

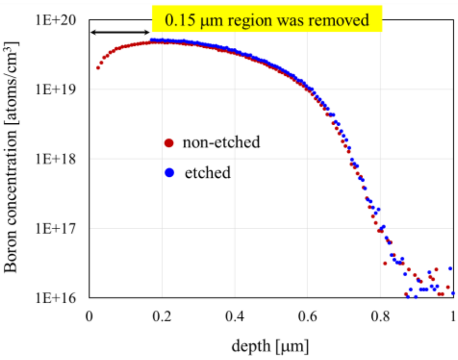

Figure 2: SIMS profiles of surfaces with non-etched and etched boron-depleted regions.

Cell type	J_{SC} [mA]	V_{OC} [mV]	FF [%]	η [%]
Depleted region non-etched	38.1	636.5	77.9	18.9
Depleted region etched	38.5	640.0	79.7	19.6

Table 1: *I–V* results for cells with un-etched and etched boron-depleted regions.

References

[1] Kyungsun Ryu, Ajay Upadhyaya, Hyun-Jin Song, Chel-Jong Choi, Ajeet Rohatgi, and Young-Woo Ok, APPLIED PHYSICS LETTERS, Vol. 101, 073902 (2012).
[2] Shalamujiang Simayi, Yasuhiro Kida, Katsuhiko Shirasawa, and Hidetaka Takato, In: Proceedings of the 31th European Photovoltaic Solar Energy Conference; September 14–18th, 2015, Hamburg, Germany; pp. 947–949; DOI: 10.4229/EUPVSEC20152015-2CV.4.14.
[3] E. Lohmüller, S. Werner, J. Schön, M. Thanasa, S. Mack, W. Wolf, F. Clement, and D. Biro, In: Proceedings of the 28th European Photovoltaic Solar Energy Conference; 2013, Villepinte, France; pp. 1043–1047; DOI: 10.4229/28thEUPVSEC2013-2BV.1.5.