Plasma Ion Implantation: a Promising Method for Fabricating the Low Cost Interdigitated Back Contact Silicon Heterojunction Solar Cell

Huynh Thi Cam Tu[1], Koichi Koyama[1,3], Noboru Yamaguchi[2], Hideo Suzuki[2], Keisuke Ohdaira[1], Hideki Matsumura[1]

[1]Japan Advanced Institute of Science and Technology, Nomi, Ishikawa 923-1292, Japan
[2]ULVAC, Inc., Suyama, Susono, Shizuoka 410-1231, Japan
Email: tu-huynh@jaist.ac.jp

The world top records of efficiency of crystalline-silicon (c-Si) solar cells, 26.3% and 26.6%, are achieved by using the interdigitated back contacted silicon heterojunction (IBC-SHJ) structure [1,2]. However, the fabrication cost of the IBC-SHJ cell is still high because the formation of back electrodes usually requires many process steps. To simplify the fabrication of the back electrodes we have attempted to use the plasma ion implantation to convert some desired patterned areas of p-a-Si to n-a-Si [3, 4]. It was confirmed that, by applying the plasma ion implantation of phosphorous (P) atoms into p-a-Si with the appropriate annealing process, p-a-Si could be converted to n-a-Si while the passivation quality was kept sufficiently high. It was also confirmed that the SHJ cell could be fabricated by using the P plasma ion implantation [5]. Since the annealing after plasma ion implantation is one of the keys in this process, in the present study, we concentrated to reveal the annealing effects after plasma ion implantation on performance of solar cells.

Here, we fabricate the conventional SHJ cells with a structure of metal/ITO/p-a-Si/i-a-Si/n-c-Si/i-a-Si/n-a-Si/ITO/metal by deposition and by the counter-doping to convert the deposited p-a-Si to n-a-Si, using 5 kV-PH_3^+ plasma ion-implantation with a dose of 10^{16} cm^{-2}. The J-V characteristics of solar cells with deposited n-a-Si layer and those with n-a-Si converted from p-a-Si are shown in Fig.1. It is confirmed that

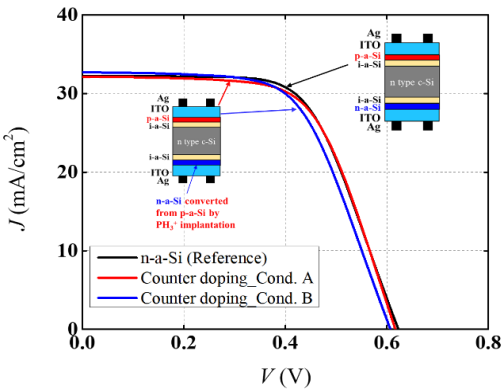

Figure 1: I-V characteristics of conventional and counter doping SHJ cell.

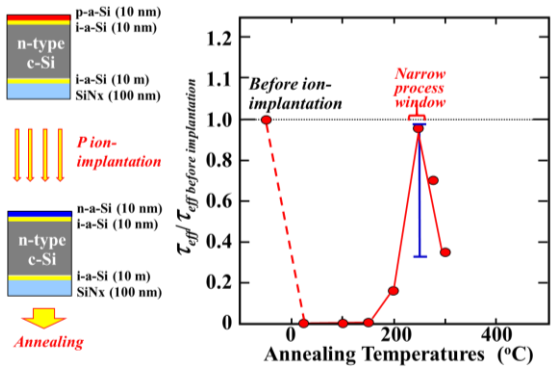

Figure 2: Normalized τ_{eff} of P-ion-implanted samples as a function of annealing temperatures

SHJ cells fabricated by plasma ion-implantation can be operated, although the results are preliminary at the moment. In the figure, the results of two annealing conditions are demonstrated; Cond. A: 240 °C for 100 min, and Cond. B: 200 °C for 650 min. This figure shows that the performance of ion-implanted solar cells is affected by annealing procedure. Figure 2 shows the recovering of carrier lifetimes of ion-implanted p-a-Si which is converted to n-a-Si, as a function of annealing temperatures. Since H atoms can terminate defects created by ion-implantation, the carrier lifetimes can be recovered by the annealing at temperatures only just above 200 °C. However, since p-a-Si is likely to degrade by annealing, the process window becomes quite narrow. The results demonstrate the necessity of proper selection of annealing procedure to obtain high performance solar cell and the importance to obtain proper p-a-Si which is strong for thermal treatment.

[1] K. Yoshikawa *et al.*, *Nature Energy* **2**, 17032 (2017).
[2] M. A. Green *et al.*, *Prog. Photovolt. Res. Appl.* **25**, 668 (2017).
[3] K. Koyama *et al.*, *Jpn. J. Appl. Phys.* **56**, 08MB21 (2017).
[4] 小山 晃一、第 77 回応物秋季講演会予稿集 (朱鷺メッセ)
[5] 小山 晃一、第 78 回応物学秋季講演会 講演予稿集

[3] Present Address: ULVAC Inc., Chigasaki, Kanagawa.