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Monocrystalline Si Solar Cells with Selective Emitter Structure Formed by Ion Shower Doping Technique

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1. Introduction

The selective emitter structure can provide high conversion efficiency solar cells, which has low contact resistance and less Auger recombination. The structure can be formed by laser doping and ion implantation techniques [1, 2]. However, these techniques have disadvantages such as high production cost, low through-put, large implantation damages, and so on. For the future silicon solar cell, it is important to reduce the production cost with keeping high conversion efficiency. It is desired to realize selective emitter structure cell using novel technique. In this study, we propose ion shower doping technique as a new process to form selective emitter part, and possibly low doping emitter as well with low production cost and high through-put. The production cost of this technique is expected to be lower than that of laser doping or ion implantation.

2. Ion shower doping system

As the favorable characteristics of the ion shower doping, the beam size is approximately 800 mm x 100 mm, which is much larger than that of conventional ion implantation [3]. Therefore, high through-put more than 1000 wafers/hour can be obtained. In addition, it is possible to use a hard mask for selective doping. We assume that both high and low doped regions can be formed for selective emitter structure solar cells by this technique. However, in order to apply ion shower doping technique for the solar cell process, it is necessary to clarify the basic properties such as doping uniformity after thermal activation and the effect of possible impurities and damages interfused by the ion shower doping on the cell efficiency.

3. Experiment

We fabricated two kinds of solar cell devices, one was conventional solar cells and the other was selective emitter structure solar cells. We evaluated the conversion efficiency with detailed analysis of the electrical properties. For the solar cell fabrication, we used 200 μm thick, 125 x 125 cm^2, p-type Cz silicon wafers with texture structure. Figure 1 shows the solar cell fabrication process flow. The wafers were cleaned by SC-1 and HF. Then, the n-type emitter layers with phosphorus (P) doping were formed by $POCl_3$ diffusion. The wafers were then annealed at 860 ^{0}C for 20 min. For the fabrication of selective emitter structure solar cells, we used high-pure carbon hard mask on the wafers with low dose emitter layer. For the high does selective emitter parts, the doping does and energies were 3.0E+15 ions/cm^2 and 10-30 keV. The wafers were then annealed at 860 ^{0}C for 30 min for the dopant activation. The SiNx were deposited by plasma enhanced chemical vapor deposition on the front side. Finally, Ag fingers and Al were screen printed and fired for the front and back contacts, respectively. The electrical properties and conversion efficiency with their distributions were measured by solar simulator (Bunkoukeiki Co.) and MP-15 (Lasertec), respectively.

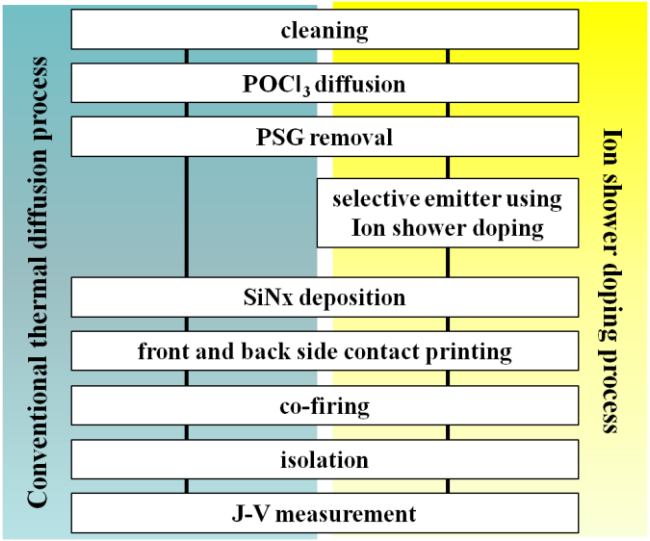

Fig. 1 Solar cell fabrication process flow.

4. Results and discussions

Figure 2 shows the J-V characteristics and conversion efficiency distributions of selective emitter structure and conventional structure cells, respectively. For the distributions of conversion efficiency, there was no difference with the excellent uniformity between the selective emitter structure cell and conventional structure cell. In addition, it is clear that the efficiency of selective emitter cell was higher than the conventional structure cell. This was achieved because the selective emitter structure solar cells had low contact resistance and less Auger recombination. However, the thermal annealing for activation of selective emitter parts were applied after fabrication of low does emitter layer. Thus, the lifetime of selective emitter structure cell might be deteriorated

comparing to the conventional structure cell due to the crystalline damages caused by the longer annealing times. So, we believe that the conversion efficiency should be further improved after process optimization.

Voc, Isc, and FF of selective emitter structure cell were all higher than those of conventional structure cell. The series resistance was lower than that of conventional structure cell because of high density of P in the selective emitter parts.

Figure 3 shows the distribution of current density corresponding to the wavelengths of 405 nm and 920 nm evaluating n-layer and substrate, respectively. There was no difference with the excellent uniformity for the distributions of current density at each wavelength. Therefore, we conclude the ion shower doping technique did not show any possible disadvantages such as metal impurity incorporation and spatial variation in the doping dose.

From these results, ion shower doping technique is useful for fabrication of selective emitter parts with high through-put. The selective emitter structure solar cell includes both thin emitter layer with low doping density and the selective emitter parts with high doping. We believe the ion shower doping technique can achieve both. This technique may also be applied for the back surface field fabrication. We believe further improvement should be achieved by the process optimization suitable for the ions shower doping such as P profile for the low doping dose layer and contact electrode fabrication.

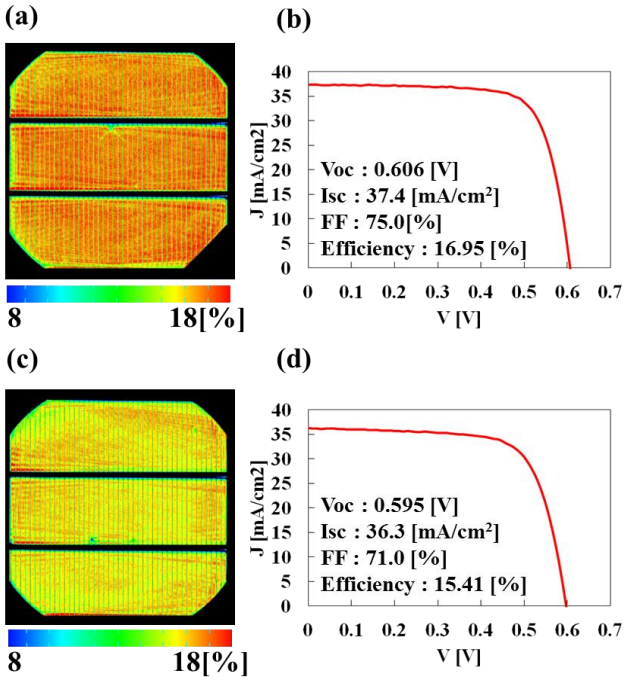

Fig.2 Distribution of conversion efficiency and J-V characteristics (a), (b) selective emitter structure cell and (c), (d) conventional structure cell

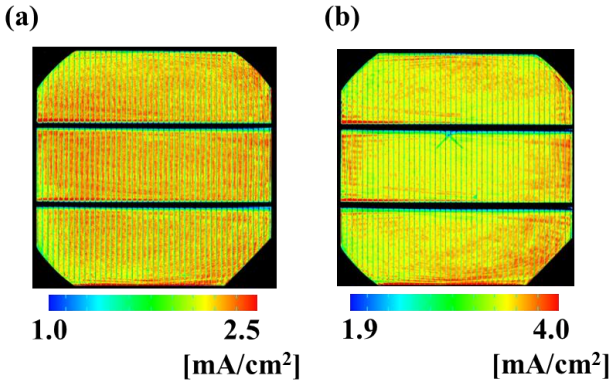

Fig.3 Distribution of current density at each wavelength (a) 405 nm and (b) 920 nm

5. Conclusions

We fabricated solar cell devices using ion shower doping technique to form selective emitter parts. The conversion efficiency, Voc, Isc and FF were shown higher than conventional structure cell. We believe further improvement can be achieved after the optimization of process conditions. The ion shower doping technique has great potential to fabricate the selective emitter structure solar cells with high through-put and low production cost.

Acknowledgement

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References

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