Texture Size Control by Adding Glass Micro-Particles into an Alkaline Solution Used for Crystalline Silicon Solar Cells

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Recently, crystalline-silicon (c-Si) solar cells with the world top efficiencies over 26% are prepared by amorphous-silicon (a-Si)/c-Si hetero-junction back-contact (HBC) structures [1] Therefore, reducing production cost of the HBC solar cells becomes important. To reduce the cost, thinning of the c-Si substrates less than 100 µm is one of the key solutions. However, sunlight with long wavelength easily transmits through such thin c-Si, and thus, texturing of its back-side will be necessary to obtain enough reflectivity for long wavelength light. The back-side texture requires suitability for formation of patterned back-contact electrodes in the HBC solar cells and independency on mechanical strength in the thin c-Si substrates after texturing, thus, the development of a small size texture is essentially needed.

We discovered that by mixing low-cost glass micro-particles with a conventional solution, the texture size drastically reduces from 10 µm or more to sub-micron (0.3−2 µm) [2-4]. We named this unique texture-forming process as micro-particle assisted texturing (MPAT) process. The MPAT process is applicable for c-Si substrates with thickness down to 50 µm. Process time and c-Si loss are also reduced from 25 to 2 min and from 20 to 2 µm, respectively. Hereafter, "micro-particles" is used instead of "glass micro-particles" for simplicity. However, in these reports, only one kind of the micro-particles was used for the texturing. In this paper, we investigated the effect of several micro-particles in the texturing. We found a dependence of the texture size and the optical reflectivity on mixing ratio (or percentages by weight) (wt%) and diameters of the micro-particles.

We summarized the results for the dependence on wt% and the size of micro-particles in Fig. 1, in which the lowest reflectivity is plotted as a function of wt% of the micro-particles. For 0 wt%, in the conventional process, the reflectivity of c-Si after 10 min texturing is more than 22%. Using the same etching time, the reflectivity (R) is drastically reduced to less than 10% just by adding a small amount (about 1 wt%) of any micro-particles. In the present experiments, 98 µm one exhibits the best texture with reflectivity down to 7%, almost world top class low reflectivity. Both too small and too large micro-particles degrade the reflectivity.

Figure 2 shows a procedure for cleaning and passivation of the MPAT textured c-Si. After formation of the textures, immediately, cleaning by combination of several chemicals, and then passivated coating silicon-nitride (SiN_x)/amorphous-silicon (a-Si) stacked layers by catalytic chemical vapor deposition (Cat-CVD). An excellent passivation quality could be obtained with $\tau_{\mathrm{eff}} = 7.8$ ms, equivalent to a maximum surface recombination velocity $(\mathrm{SRV_{max}}) = 1.8$ cm/s. Therefore,

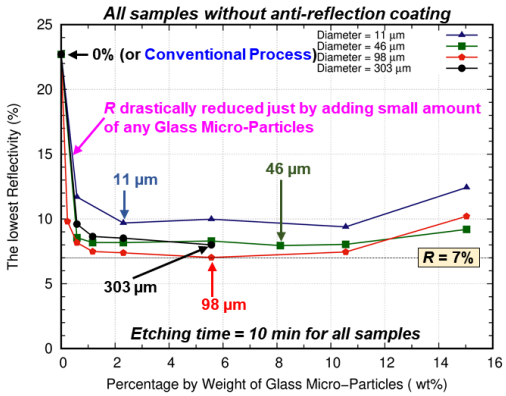

Fig. 1. The lowest reflectivity of the textured c-Si made by the MPAT process using various micro-particles diameters of 11 (blue triangle), 46 (green square), 98 (red pentagon), 303 µm (black circle) as function of percentages by weight.

the MPAT textured c-Si is promising for the fabrication of high-efficiency solar cells. The stacked layer also works as an anti-reflection coating (ARC) layer, showing the lowest R at 0.5%. Owing to the excellent passivation quality and effective ARC could be realized on the newly MPAT textured c-Si, we believe that this novel texturing procedure makes a progress for future high efficiency and low-cost HBC solar cells.

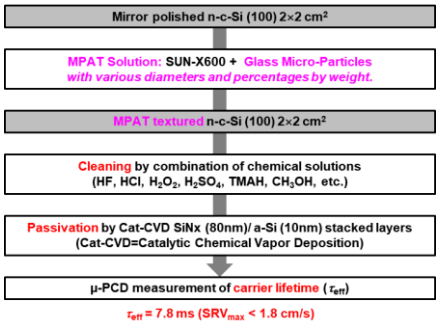

Fig. 2. A procedure for cleaning and passivation of the MPAT textured c-Si with electrical properties.

References

[1] K. Yoshikawa *et al.*, Nat. Energy **2**, 17032 (2017)
[2] C. T. Nguyen *et al.*, The 64th JSAP Spring Meeting, 2017.
[3] C. T. Nguyen *et al.*, 33rd European Photovoltaic Solar Energy Conf. Exhib., 2017.
[4] C. T. Nguyen *et al.*, MRS 2017 Fall Meeting & Exhibit, 2017

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