Microparticle-Assisted Texturing (MPAT) Process: Almost One Order Cost-Reduction, and Toward Mass Production of Low-Cost and High-Performance Crystalline-Silicon Solar Cells

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Recently, crystalline silicon (c-Si) heterojunction back-contact (HBC) solar cells with the energy conversion efficiency of >26%, reaching near the theoretical limit of ~30%, was achieved.[1] Reduction of the cell cost by using thin c-Si with thickness <100 µm becomes the key. We have developed a suitable texturing method for such thin c-Si, so-called Microparticle-Assisted Texturing (MPAT) process, in which glass microparticles were mixed with conventional alkaline-based texturing solutions to reduce texture-size, processing-duration, c-Si etched thickness loss, solution-consumption by almost one order of magnitude.[2] The MPAT process is applicable to c-Si with thickness down to ~50 µm, and also works well on both mirror-polished and as-cut c-Si wafers. Optical reflectivity is as low as ~7%, a near record value for random textures [3].

In this work, we aim to clarify whether the MPAT process is realistic in the mass-production of low-cost and high-performance c-Si solar cells. For such purpose, we developed the followings:

High-yield MPAT for multiple as-cut c-Si wafers

Typical full-size as-cut n-type c-Si wafers being used in actual solar cell fabrication were employed for texturing by the MPAT process. We developed a dedicated system (Fig. 1(a)) for multiple wafers with a pitch of 5 mm, which is like that in mass-production. As results, uniform textures from wafer-to-wafer were obtained (Fig. 1(b)) with the standard deviation of the optical reflectivity < 0.1%, and texturing yield almost 100% (Fig. 2 and 3). Therefore, this system is very cost-effective and industrially comparable.

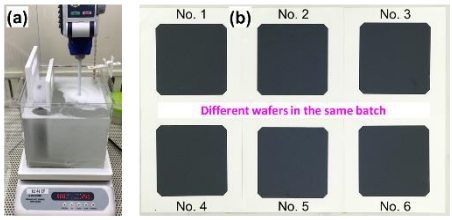

Fig. 1. (a) MPAT machine and (b) optical image of textured full-size c-Si wafers in the same batch by the MPAT process.

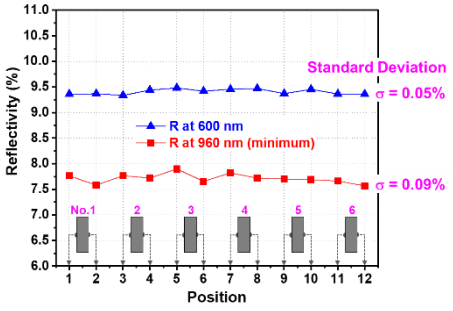

Fig. 2. Optical reflectivity of different wafers (numbered from 1 to 6) in the same batch, and for both sides.

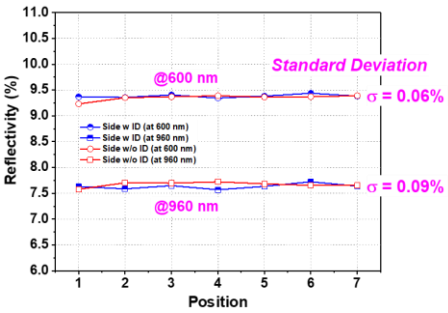

Fig. 3. Optical reflectivity of different positions along the diagonal (numbered from 1 to 7) of the same wafer.

Low-cost surface cleaning for multiple c-Si wafers

After the texturing, we developed a low-cost chemical surface cleaning for multiple wafers. The cleaning procedure is almost the simplest one since only a chemical solution was employed. Therefore, the cleaning is industrially comparable.

High-quality surface passivation

Just after cleaning, the c-Si surface was passivated by using a well-known catalytic chemical vapor deposition (Cat-CVD) silicon nitride (SiN_x)/amorphous (a-Si) stacked layers. As a result, an extremely high effective minority carrier lifetime (τ_{eff}) of 7.2 ms, corresponding to surface recombination velocity (SRV) of 0.38 cm/s was obtained, which is suitable for mass production of the high-performance solar cells. Note that, the developed surface cleaning is the key to the high-quality. [4,5]. In the cleaning, we control the wettability of the solutions on the textured c-Si surface by mixing with methanol to obtain high-quality surface passivation.[5]

Effective anti-reflection coating

The SiN_x/a-Si layers were used not only for surface passivation but also anti-reflection coating (ARC). Optical reflectivity after the ARC was < 0.5% at the wavelength of 600 nm, and < 2% in a wide range of 450–950 nm.

In summary, we confirmed that the MPAT process is suitable for mass-production of the low-cost and high-performance thin c-Si solar cells.

References

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