Quick Formation of Sub-Micron Scale and Low Reflectivity Textured Structures for Crystalline-Silicon Solar Cells

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Textured crystalline silicon (c-Si) structures have been used for reducing the reflection of sun-light at front surface of solar cells. However, when the thickness of c-Si wafers is thinner than 100 μm for lowering solar cell cost, the reflection at the back-side becomes important to confine sun-light inside c-Si substrates. For higher efficiency solar cells, back-side is used for electrodes as shown in back-contact hetero-junction (BHC) cells, for instance. Thus, textured structures at the back-side should be smaller than a few μm scale for fitting to patterning process to make n-type and p-type electrodes.

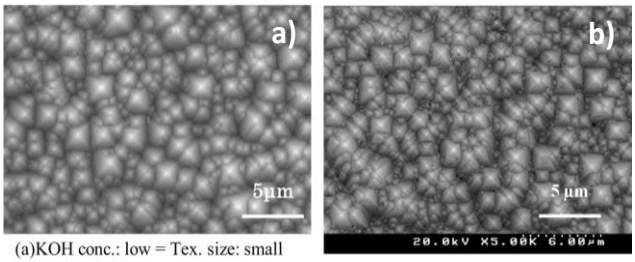
Among various technologies for making textures, industrially acceptable one appears limited to the method forming pyramid structures by using alkaline etchant. Thus, we developed a new method to form sub-micron scale and low reflectivity textured structures by using alkaline-based chemicals with some kinds of additives.

The textured structure was formed by two procedures on 283 mm-thick mirror-polished c-Si wafers. In process (a), the samples were etched by a commercial alkaline etchant SUNX-600 (by Wako Pure Chemical Industries, Ltd.) heated up to 80-90°C, in 50 min, and in (b) an additive was added into the same solution with similar temperature. We summarized the difference between two processes in **Table I**. Clearly the additive is very effective to reduce pyramid size (from 10-30 μm to <(0.3－2μm)), c-Si loss (from 40-50 μm to 1-7 μm) and texturing time (from 50 min to 6 min), leading to much reduction of texturing cost.

Two surface images of textured samples observed by scanning electron microscope (SEM) are demonstrated in **Fig.1**, and a) shows the image in Ref. [1] and b) shows the image of ours of process b). It is known that various size of pyramid from 0.3 μm to 2 μm is uniformly scattered in our sample with additives.

We also measured the reflectance of the textured structures as shown in **Fig. 2.** After adding additive, the reflectance of the textured structure reduces about 1.8-2.4% in the range of 400 to 1050 nm wavelength. At about 1000 nm, the textures of processes a) and b) have minimum reflectance, 9.9% and 8.0%, respectively, without anti-reflection coating.

We also compared our textured structures with that of Ref. [1] as shown in Fig. 2 by dot-points. In Ref. [1], they produced textured structures with various sizes, such as "large" (~1 μm) by green dot-points, "medium" (~2 μm) by red dot-points, and "small" (3-5 μm) by blue dot-points. Obviously, our textured c-Si has lower reflectance than that of all their data.



(a)KOH conc.: low = Tex. size: small ~1μm, Ra: 0.65μm

Fig.1 SEM images of textured surface. b) shows ours.

Table I. Comparison of two procedures, with and without using an additive.

Process	(a)	(b)
Initial c-Si thickness [μm]	283 μm	
Textured c-Si thickness [μm]	235-245	276-182
c-Si loss by etching [μm]	40-50	1-7
Texture / pyramid size [μm]	10-30	< (0.3-2)
Texturing time [min]	50	6

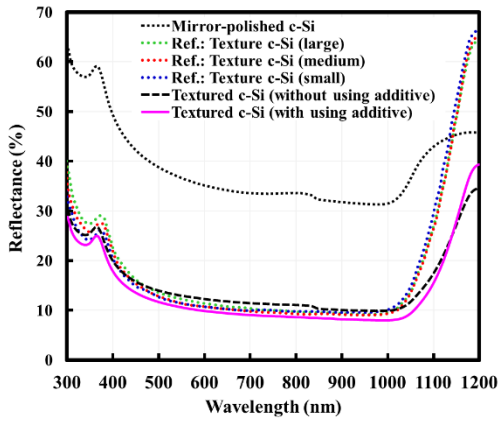


Fig. 2. (Color Online) Reflectance of mirror-polished (black square-points) and textured c-Si wafers. Dot-points show reflectance of textured c-Si wafers of Ref. [1] with difference texture sizes, such as large (green dot-points), medium (red dot-points), and small (blue dot-points). Black dash-line shows reflectance of textured c-Si wafers formed by a commercial etchant SUNX-600, without using an additive, and pink solid-line in case of using an additive.

In summary, we have successfully developed a novel texturing procedure which can realize very low reflectance, very small c-Si loss, and short consumption time. This may be applicable to low cost and very thin c-Si solar cells.

[References]

[1] K. Nakamura, M. Aoki, I. Sumita, H. Sato, Y. Kumagai, Y. Kawata, and Y. Ohshita, in *2013 IEEE 39th Photovolt. Spec. Conf.* (IEEE, 2013), pp. 2239–2242

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