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 1. 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.

Table 1. Comparison of two procedures, with and without using an additive.

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<tr>
<td>(a)</td>
<td>283</td>
<td>235-245</td>
<td>40-50</td>
<td>10-30</td>
<td>50</td>
</tr>
<tr>
<td>(b)</td>
<td>276</td>
<td>276-182</td>
<td>1-7</td>
<td>&lt; (0.3-2)</td>
<td>6</td>
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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]