Local Surface Potential on Amorphous Silicon Thin Film Solar Cells
by Kelvin Force Microscope

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Abstract
Local surface potential on hydrogenated amorphous silicon (a-Si:H) solar cells have been evaluated by Kelvin force microscope (KFM). Surface potential distribution was observed in surface potential image for pin a-Si:H solar cells. The difference between average of surface potential on n-type μc-Si:H and that on pin a-Si:H solar cell increased with increasing built-in potential. The difference between local surface potential on large convex grains was smaller than that in the region between the large convex grains.

1. Introduction
In silicon thin film solar cells, microcrystalline materials such as hydrogenated microcrystalline silicon (μc-Si:H) are used as photo-absorption layer and doped layer materials. The μc-Si:H has hetero-structure composed of amorphous silicon (a-Si), crystalline Si grains, and grain boundaries. Typical Si thin film solar cells are prepared on glass substrates coated with textured transparent conductive oxide (TCO). Thus, the local properties in Si thin film solar cells would be different due to above effects. Therefore, we have investigated local properties of Si thin films and Si thin film solar cells by scanning probe microscope (SPM). Kelvin force microscope (KFM) is one of SPM techniques. The surface morphology and surface potential images can be obtained simultaneously. Previously, we reported that local surface potential is not uniform on μc-Si:H films [1]. We also reported the local surface potential distribution was observed on a-Si:H solar cells under light irradiation [2].

In this work, the local potential on a-Si:H solar cells was evaluated by KFM.

2. Experimental Methods
The samples evaluated in this work were a-Si:H solar cells which structure was Asahi U-type substrate / n-type μc-Si:H / i-type a-Si:H / p-type a-Si1-xCxB:H. Here, Asahi U-type substrates were glass coated with textured SnO2.

KFM measurements were performed in air at room temperature (around 25 °C) using SPM-9600 (Shimadzu). Pt coated Si cantilevers (Olympus, OMCL-AC240TM-R3) were used as a probe. In the KFM measurement, the probe scanned on the free surface of the n-layer.

3. Results and Discussion
Figure 1 shows (a) surface morphology and (b) surface potential images for pin a-Si:H solar cell without light irradiation. In the surface morphology images, large convex grains were observed as sown in Fig. 1(a). The large convex grains correspond to the textured surface of Asahi U-type substrates. In the surface potential images for the pin a-Si:H solar cell, the local surface potential on the large grains was smaller than that in the concave region between the large grains as shown in Fig. 1(b).

Figure 2 shows (a) surface morphology and surface potential images for n-type μc-Si:H films deposited on Asahi U-type substrates without light irradiation. The surface potential distribution obtained on the pin a-Si:H solar cells was similar to that obtained on n-type μc-Si:H films. The value of the surface potential on pin a-Si:H solar cells, however, was different from that on n-type μc-Si:H films. The difference between surface potential on n-type μc-Si:H and that on pin a-Si:H solar cell would correspond to built-in potential in a-Si:H solar cells. So, we measured surface potential images on n-type μc-Si:H films and pin a-Si:H solar cells deposited on Asahi U-type substrates by KFM. Then, the difference between average of surface potential on n-type μc-Si:H and that on pin a-Si:H solar cell was obtained. The difference between average of surface potential on n-type μc-Si:H and that on pin a-Si:H solar cell increased from 0.26V to 0.77V with increasing built-in potential from 0.61V to 1.30V. Based on this result, built-in potential was able to be evaluated from difference between
surface potential on n-type \( \mu \)-Si:H films and that on pin a-Si:H solar cells by KFM. The difference between surface potential on n-type \( \mu \)-Si:H films and that on pin a-Si:H solar cells by KFM, however, was smaller than the built-in potential. The KFM measurements were conducted in air. Therefore, this might be related to oxidization of free surface of the samples.

![Fig. 2](image1.png)  
Fig. 2 (a) Surface morphology and (b) surface potential images for n-type \( \mu \)-Si:H films without light irradiation.

![Fig. 3](image2.png)  
Fig. 3 (a) Surface morphology and (b) surface potential images for p-type a-Si\(_{1-x}\)C\(_x\):H films without light irradiation.

As written above, the surface potential distribution on pin a-Si:H solar cells was observed. Using above method, the local built-in potential was able to be evaluated in a-Si:H solar cells. Therefore, the difference between the surface potential on large convex grains for pin a-Si:H solar cells and that for n-type \( \mu \)-Si:H films deposited on Asahi U-type substrates was obtained. The difference between the surface potential in the region between the large convex grains for pin a-Si:H solar cells and that for n-type \( \mu \)-Si:H films deposited on Asahi U-type substrates was also obtained. The local built-in potential on large convex grains was smaller than that in the region between the large convex grains. This result would be explained by the difference between p-type a-Si\(_{1-x}\)C\(_x\):H and n-type \( \mu \)-Si:H films deposited on Asahi U-type substrates. Figure 3 shows (a) surface morphology and (b) surface potential images for p-type a-Si\(_{1-x}\)C\(_x\):H films deposited on Asahi U-type substrates without light irradiation. In Fig. 3, the local surface potential on the large convex grains was larger than that in the region between the large convex grains.

4. Summary

We demonstrated that built-in potential can be measured by KFM. In pin a-Si:H solar cells, the local built-in potential on the large convex grains was smaller than that in the region between the large convex grains. The difference between the local built-in potential on the large convex grains and that in the region between the large convex grains in a-Si:H solar cells with large built-in potential was smaller than that with small built-in potential. These results suggest that the properties would be affected by the local properties in pin a-Si:H solar cells.

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References