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Efficiency enhancement of a-Si thin film solar cells by using different light trapping structures

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1.Introduction

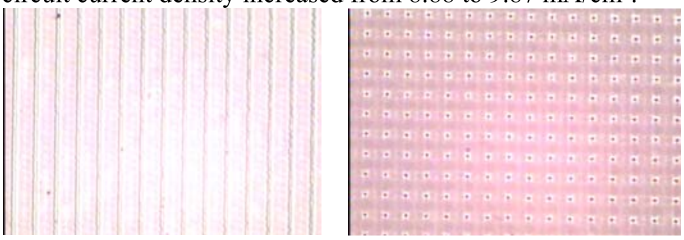
This is especially for silicon thin film solar cells, where the illuminated face electrode is produced with a roughened structure to reduce the thickness and costs of microcrystalline silicon thin film solar cells. In the 2004 year, A. V. Shahu, et al. suggested that the scattering of incident light by the electrode was enhanced after roughening treatment, such as the component efficiency of a double-face electrode with roughening treatment was found to increase[1]. At the same time, J. Krc, et al. conducted roughening treatment simulations and showed that the Haze ratio and long-wavelength quantum efficiency were enhanced, whereas the component's intrinsic layer thickness was reduced[2]. In the 2006 year, S. Fay, et al. used the LP-CVD process to produce textured ZnO transparent conductive films. By doping B_2H_6 with gas, the texture structure particles were smaller and evenly distributed[3]. In the 2008 year, Hitoshi Sai, et al. used different roughened structures to increase the long-wavelength external quantum efficiency (EQE)[4]. In the 2009 year, M. Python, et al. demonstrated that a V-shaped structure easily caused defects to occur with microcrystalline silicon thin film solar cells, and proposed a U-shaped roughened structure to improve the defects caused by the V-shaped structure[5]. At the same time, T. Söderström, et al. showed that the decay rate was reduced after applying roughening treatment to the interlayer[6]. Guozhen Yue, et al. used various ZnO thicknesses to enhance the long-wavelength quantum efficiency[7]. This study is mainly divided into two parts: The first part applied the transfer-print technique to an illuminated glass face to print different roughened structures to the reflective film. The second part used laser engraving to produce different roughened structures on the ITO electrode. The purpose was to enhance the current density and efficiency of components.

2. Experimental

A glass substrate (39 mm × 39 mm) was placed within an ultrasonic washer and vibrated in sequence with acetone, isopropyl alcohol (IPA), and deioned (DI) water each for 5 minutes. A nitrogen gun was then used to blow-dry the glass substrate and placed into an oven to bake for 5 minutes. Then, the cleaned substrate was put into a load lock chamber and vacuumed to 7×10^{-3} torr, it was conveyed to the VHF-PECVD main chamber and vacuumed to 6×10^{-6} torr at various substrate temperatures. The gases used in the experiment for the deposition of the i-layer a-Si:H were silane gas (SiH_4) and hydrogen gas (H_2). The chamber pressure and overall gas flow (SiH_4+H_2) were 1.5 torr and 400 sccm, respectively. The main variation of condition in the experiment was 5% proportion of silane concentrations [SC%=SiH_4/(SiH_4+H_2)x100%]. And the radio frequency (RF) power 50 W, substrate temperature is 250℃. The devices structure is glass/ITO/p-Si:H/buffer layer/i-Si:H /n-Si:H /Al. The p- and n-type doped layers. Process doping gases include Trimethylboron (TMB) and phosphine (PH_3). In order to achieving the optimum performance of p-i-n solar cells requires high doping and high conductivities of the electric-field and p- and n-type doped layers are under VHF excitation conditions and high hydrogen dilution. In order to reducing the recombination loss at p/i interface, we use the high hydrogen-diluted buffer layer deposited with SC=1% at p/i interface to improve device efficiency.

3. Results and Discussion

A laser engraver at 1064 nm wavelength was used to engrave the desired patterns. The scanning rate and laser power were adjusted to avoid penetrating the ITO thin film which would influence the component efficiency. The discussion was to analyze the ITO electrode surface after laser roughening treatment of a amorphous silicon thin film, and also analysis of the component's characteristics. Figure 1 is the OM photos of the ITO surface with different laser roughening treatments. Figure 2 shows the J-V curve for the silicon thin film solar cell with different laser roughening treatments. After the ITO surface was roughened, the optical path within the intrinsic layer was increased, which then enhanced the short circuit current density and efficiency of the component. After vertical laser scanning with the ITO surface (laser interval = 5μm), the component's short circuit current density increased from 8.88 to 9.48 mA/cm^2. When the ITO surface was treated by laser square scanning (laser interval = 5μm), the component's short circuit current density increased from 8.88 to 9.87 mA/cm^2.



(a) (b)

Fig.1 OM photos of the ITO surface with different laser roughening treatments (a) vertical (b) square

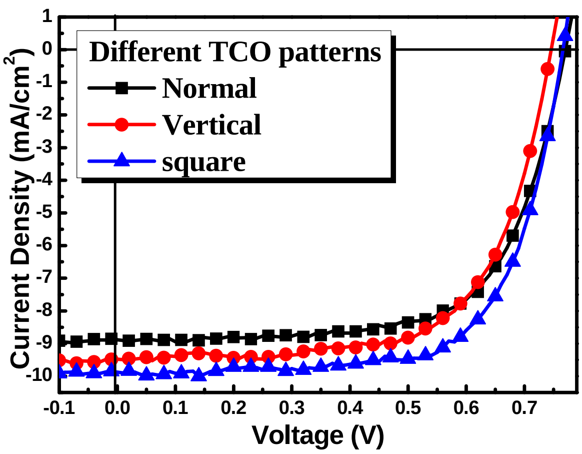
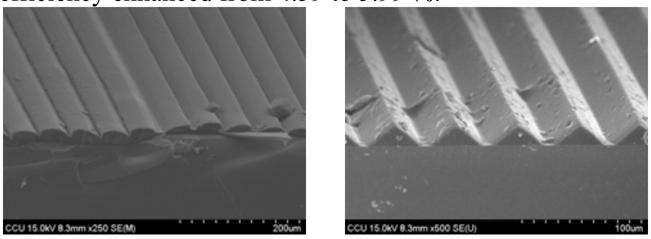


Fig.2 The J-V curve plots with different laser roughening treatments of ITO

The silicon thin film solar cells were first spin coated a UV glue layer onto the illuminated glass, and then was transfer-printed with an already-designed pattern on the

PDMS master film. A UV lamp was then used to cure the UV glue on the glass surface, and the PDMS master was finally removed. The PDMS master film included two main types of structure, respectively a 45° composite film and V-shaped film. The surface pattern after the transfer-printing is shown in Figure 3. As the transfer-printed reflective film of the glass surface increased the scattering of light, the optical path within the intrinsic layer increased, and then enhanced the component's short circuit current density and efficiency. When the reflective film structure was the 45° composite film, the short circuit current density of the component increased from 8.88 to 10.1 mA/cm^2, where the efficiency enhanced from 4.59 to 5.69%; when the reflective film structure was the V-shaped film, the short circuit current density increased from 8.88 to 10.37 mA/cm^2, where the efficiency enhanced from 4.59 to 5.99 %.



(a) (b)

Fig.3 UV-glue structures transfer-printed on the glass surface (a) 45° composite film (b) V-sharp

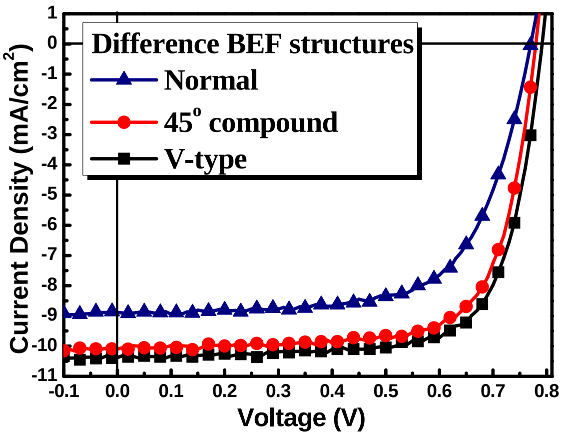


Fig.4 The J-V curve plots with different UV glue structures

Finally, we utilize V-shaped BEF and square-type of TCO structures on a-Si solar cells. Figure 5 shows the J-V curve for the silicon thin film solar cell with different light trapping structure. The optimum light trapping structure of solar cell by V-shaped BEF and square-type TCO was chose, the short circuit current density and power conversion efficiency of a a-Si solar cell can be increased from 8.88 to 12.35 mA/cm^2 and 4.59 to 6.29%, respectively.

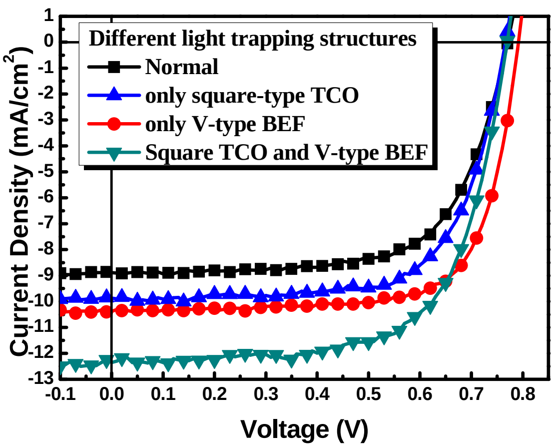


Fig.5 The J-V curve plots with different light trapping structure

4. Conclusions

In this study, we used the VHF-PECVD process to produce amorphous silicon thin film solar cells and applied the light trapping structure to the solar cell component. The results showed the light trapping structure increased the solar cell's component efficiency. When the illuminated glass face was transfer-printed with a reflective film and the ITO surface was treated with laser engraving, both measures showed to increase light scattering and enhance the component efficiency. When the surface of the ITO was treated with square scanning: V_{oc}=0.77 V, J_{sc}=9.87 mA/cm^2, FF=68.3 % and η=5.19 %. The BEF had the best characteristics with the V-shaped film structure: V_{oc}=0.79 V, J_{sc}=10.37 mA/cm^2, FF=73 % and η=5.99 %. When the surface of the ITO was treated with square scanning, the component had the best characteristics: V_{oc}=0.77 V, J_{sc}=9.87 mA/cm^2, FF=68.3 % and η=5.19 %. When combine V-shaped BEF with square-type of TCO structures, the short circuit current density and power conversion efficiency of a a-Si solar cell can be increased from 8.88 to 12.35 mA/cm^2 and 4.59 to 6.29%, respectively.

Acknowledgements

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