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Low cost commercial high-efficiency selective emitter solar cells with non-busbar inkjet printing pattern

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ABSTRACT

The direct inkjet printing method involves the deposition of a wax droplet onto a wafer surface. Wax is used as a resistance layer during etch-back wet process, which coats on top of the dielectric surface with the same Ag electrode printing pattern. Drop on demand (DOD) inkjet printing selective emitter (SE) process has higher performance but more cost because of the additional raw materials, we need to balance the cost of wax exhaust and the efficiency rise. In this paper, we report a sort of new inkjet wax printing pattern, except at the busbar location which has the same printing pattern with the normality.

We tested the cell infrared ray response (IR), module power and module electroluminescence (EL), in contrast to the normal inkjet printing pattern cell we found there is no any abnormal phenomenon for the new inkjet printing pattern cell near bus-bar area. Furthermore, the conversion efficiency is comparable in the mass production environment.

1. Introduction

One way of reducing cost of crystalline silicon solar cell fabrication is increasing the conversion efficiency of the device. However, most high efficiency solar cell designs require more complex fabrication methods that also increase the fabrication cost [1,2]. Photolithography is an example of such an indispensable but costly process [3]. The most common use for photolithography in solar cell fabrication is for dielectric patterning, DOD inkjet printing together with the wet chemical etch back process is demonstrated to be a successful technology for mass production in SE solar cell fabrication [4,5]. However, higher efficiency designs are usually followed by an increase in fabrication complexity and manufacturing cost. Therefore, improvements in manufacturing technology which can produce higher efficiency solar cells without an increase in production cost are desirable.

The benefits of DOD inkjet printing together with etch back selective emitter process have been well known in solar cell fabrication [6]. During the inkjet printing process, in order to minimize the recombination at the heavily doping area and achieve a low specific contact resistance of the emitter electrode, the inkjet wax printing mask pattern is designed to cover the screen printing alignment tolerance and the Ag electrode contact layout. For the normal inkjet printing pattern the lateral and vertical tolerance between the wax mask and the Ag electrode is critical [7], so in order to minimize the wax exhaust, we need to choose a suitable tolerance.

A schematic of a typical inkjet printing and Ag screen printing design is shown in Fig. 1(a) and (b). It is a higher performance alternative to the homogenous emitter design typically used in screen-printed solar cells. In selective emitter design, after chemical etch back process two regions with different emitter doping profiles are formed on the surface of the Si wafer. The first region is the emitter, where the *p*–*n* junction is located. After chemical etching, doping concentration of this region is remarkably reduced to maximize the short-wavelength response of the device. The other region is the contact area, which provides the low resistance interface between the metal and the silicon.

2. Experiment

First we prepared multicrystalline wafers with the thickness of $200 \pm 20\,\mu m$ resistivity of 0.5–3 ohm/cm, area of $156\,mm \times 156\,mm$. and the Halm tester is uesd to test cell efficiency, Spire tester is used to test module power.

For the inkjet printing pattern we designed a sort of new inkjet pattern, which remains figures but no busbar design. The schematic of new design is shown in Fig. 2, Compared with Fig. 1 pattern there is no busbar but figures joined at busbar location, Fig. 2(b) is the same with Fig. 2(a) except figures un-joined underneath busbar location. The white line in Fig. 2 indicate the busbar location.

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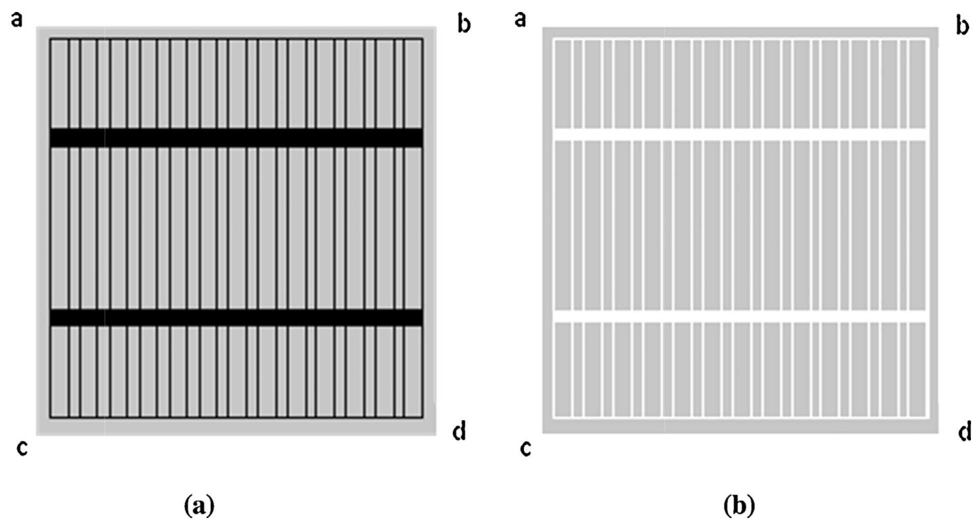

Fig. 1. (a) Normal inkjet printing pattern. (b) Pattern after Ag electrode printing.

For the comparison, we tested the cell efficiency, cell IR and module EL response, at the same time, we weighed the wax to calculate the wax cost saving. For the cell efficiency testing, we prepared two group wafers, each group is about 1000 pcs with even spliting to eliminate the wafer himself difference. For the wax cost saving calculating we firstly weighed 5 pcs wafers before inkjet printing, then weighed again after wax mask preparing.

For the IR test, we prepared two wafers, before inkjet printing process, both of them have the inline texture and diffusion process. During inkjet printing process, one taked inkjet printing pattern like Fig. 1(a), the another taked inkjet printing pattern like Fig. 2(a), after that followd by the PECVD, alignment screen printing and firing process, finally tested the cell efficiency and IR response.

For the module EL test, we chose 60 pcs cell of new inkjet printing pattern with the same conversion efficiency to encapsulate module, then tested the module EL, module power by Spire tester.

3. Results and discussion

The detail dates are shown in Table 1, from the cell testing results, we found that for different inkjet printing pattern the cell performance is equal, not only the Uoc, Isc and F.F. but also the Rs, Rsh and Irev2 (reverse voltage at −12 V).

After cell efficiency testing, immediately, we chose two pieces cell with different inkjet printing pattern to test the cell IR, the IR image is shown in Fig. 3(a) and (b).

From the images we cannot differentiate the difference between two cells with different inkjet printing pattern. Especially, from the IR images near the busbar area we can see both of their color is homogeneous, which represents the contact characteristic between the busbar and silicon keeping stable even the inkjet printing pattern without busbar.

The detail wax inkjet printing process weigh results of 5 pcs wafers weigh before and after inkjet printing is shown in Table 2 by calculating, in comparision with the normal inkjet printing pattern we can save about 12% wax for the non-busbar inkjet pattern directly.

Finally, we encapsulated a module with 60 pcs cell without busbar inkjet printing pattern. Module EL test image is showed in Fig. 4, module testing datas is shown in Table 3. from the test dates the package loss is calculated at 3.09% and 3.10% respectively, which is equal to the mass production baseline.

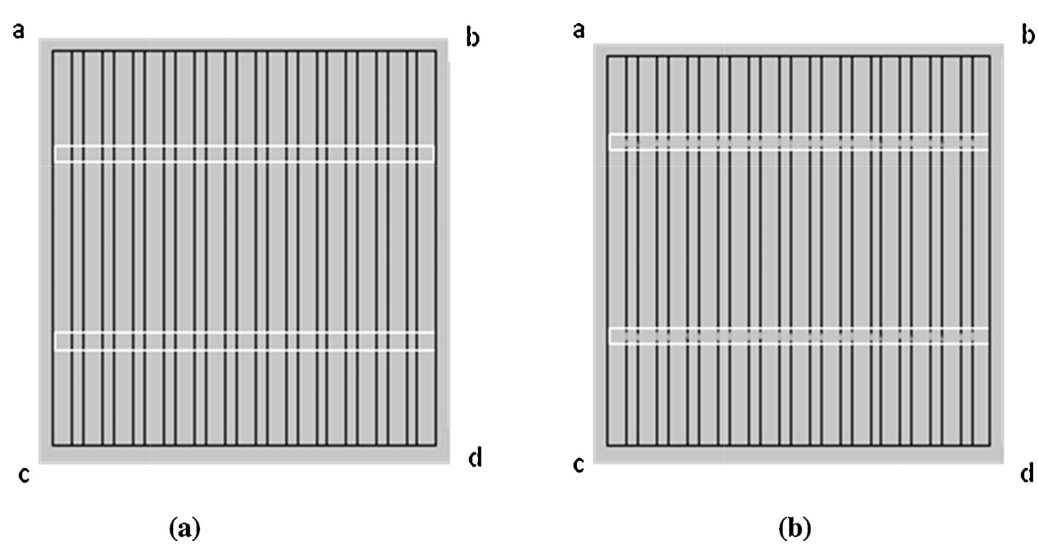

Fig. 2. Non-busbar inkjet printing pattern. (a) Figures joined underneath busbar location. (b) Figures un-joined underneath busbar location.