Laser doping for selective emitter solar cells
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Abstract - Selective emitter solar cells were fabricated with a reduced number of technological steps. Laser doping is often discussed in relation to silicon photovoltaic cell efficiency enhancement. In this paper, we present results of the development of a selective emitter structure for multicrystalline silicon solar cells suitable for industrial mass production. A pulsed laser is used to obtain highly doped regions that will receive the screen printed silver grid. Therefore, we designed using solidworks software a single type of pattern for square cells (multicrystalline silicon). We resolved the problem of grid mismatch between the laser pattern and metallic grid. Observation of laser treatment surface shows the perfect continuity of the lines and good flatness of the edge of finger and bus bar.

Keywords: Selective Emitter - Solar Cells - Laser Treatment - Solidworks.

1. INTRODUCTION

In the field of solar energy especially for solar cells, cost and efficiency of the cell is a critical point. Currently in the photovoltaic industry based multicrystalline silicon, we always try to implement solutions to improve performance.

One way to overcome the electrical performance limitations of screen-printed solar cells is through the use of a selective emitter. The emitter structure presents two different zones, one lightly doped between grid fingers and one heavily doped directly beneath the metal contacts of the cell.

The laser -assisted doping [1-3] provides a way to boost local regions of the silicon beneath the contacts of the solar cells to produce structures with selective emitters Metal/n ++.

The There are other techniques to achieve selective emitters, including:
- Etch-back: it is a method that involves an over-doping of the emitter by POCl3, which can reach 20-30 Ω/□ after a metal mask by screen printing or lithography is applied, then the non-metallic parts are attacked back to square-up resistance 100 Ω/□ [4].
- Screen-printed phosphorous doped paste: the principle is to add the dopant with the metallization paste, then make a post annealing to allow diffusion of the dopant in the material side [5].
- Dissemination masking: the principle of conventional photovoltaic with emitter; the antireflective-passivating layer (SiO2/SiN3) is then treated by laser to make apertures following the pattern of the metal grid; a second diffusion step follows to create selective emitter only in those regions [6].

2. EXPERIMENTAL

In this work, we used the so-called ‘laser-assisted doping’ method for achieving selective emitter on multicrystalline silicon (mc-Si).

This technique allows localized phosphorus doping on silicon regions by reducing the metal–emitter contact-resistance and thus improves the efficiency of the solar cell.

The figure shows process flow for the laser doping cell with POCl3 diffusion. In this work we present an experimental approach for the realization of selective emitter by laser on mc-Si wafers.

The phosphorous rich dead layer formed naturally after diffusion process is used as phosphorous source to perform the n++ region. Homogenous and lightly doped emitters were formed on p-type mc-Si wafers by thermal diffusion of POCl3 using a Lydop furnace. The sheet resistance of the emitter is 60 Ω/□.

The first step consists in the saw damage removing and the texturing of raw wafers.

In the second step, a conventional POCl3 furnace diffusion is performed: during this step, a PSG layer with a thickness of approximately 100 nm grows.

The third step (residual PSG etching) the PSG layer is immediately removed by a HF dip.

The fourth step consists in the deposition of an anti-reflection layer (ARC) of silicon nitride (SiN) by Plasma-Enhanced Chemical Vapor Deposition (PECVD).

The fifth step is the actual laser doping step, during which the n++ areas of the selective emitter are patterned according to the front side metallization grid. The laser beam is circular with a radius of 40 μm and has a Gaussian energy density. Notice that this fifth step is the only additional step compared to standard cell processing.

The following steps are then the same as those used for standard cell processing. The sixth is the screen-printing of front and back contacts as well as their cofiring in a belt furnace. The seventh and last step includes laser edge isolation.
Emitter resistance of these cells was a round 65 $\Omega/\square$, which is typical for industrial standard cells.

Fig. 1: Process flow for laser tailored selective emitter solar cells

Therefore, using Solidworks (SW) software we designed a pattern for square mc-Si cells (grid 1). With this pattern we reproduced the scheme of silver grid to be deposited on the emitter surface. With the optical microscope we were able to define the characteristics of the metal grid, namely the number of busbar and finger, their width and the spacing between them (grid 2).

Once the pattern made by the SW software, the file is converted to DXF format to allow playback on the laser software interface. The n++ pattern is then performed on the emitter surface and finally overlayed with metallic grid (silver screen-printing).

At the end, an optical control is performed to evaluate the correlation between the two grids. The steps of grid design to its realization by laser are shown in figure 2.

Fig. 2: Flowchart of the steps of grid design to its realization by laser

3. RESULTS AND DISCUSSIONS

3.1 Specifications of the grid treated by laser

The figure 3 shows the new specifications of the grid square plate (Gridline specifications for square wafers of 10 cm $\times$ 10 cm).
- Dimension of the gridline: 9.6 cm $\times$ 9.6 cm
- Finger number: 43
- 02 bus bars of 2 mm width each
- Distance between the 02 bus bars: 5 cm
- 43 fingers of 100 $\mu$m width each.
3.2 Result of superposition

Comparing mc-Si wafer with SiNₓ layer and laser treated according to the diagram of a metallic grid is shown in figure 4.

![Figure 3: Photography of a-silver screen-printed grid, b- laser pattern on SiNₓ coated n+ emitter](image3)

Note that the pattern of laser-treated grid represents more than offset metallic, this discrepancy is explained by the fact that laser enlarges the dimensions of the grid. The results obtained are shown in figure 5 and figure 6.

![Figure 4: Photograph from the superposition of grid metallic and grid treated by laser](image4)

![Figure 5: Photograph of the overlap between the fingers alignment fingers](image5)

The analysis from the superposition of the grid laser treated on the metal grid leads to the following results:

- The gap between the two grids starts from 23rd finger.
- The spacing between grid fingers in the laser-treated is higher than that in the metal grid.
The spacing between the bus-bars in the grid laser treated is higher than that in the metal grid as shown in figure 6.

![Figure 6](image)

Fig. 6: Photograph of the overlap between the bus-bars

### 3.3 Grid designed by Solidworks

Laser engraving on n+ (60 to 65 Ω/□) mc-Si wafers coated with silicon nitride (SiNₓ) uses the parameter: Power = 6 W, Speed = 250 mm/sec, Frequency = 20 kHz. The dimension of grid designed by solidworks is shown in figure 7.

The new Diagram of the grid has corrected parameter:
- Bus-bar: 2.6 mm / E: 1.2; 21.8 mm / E3: 47 mm, L: 96 mm.
- Must: L: 0.3 mm / E: 1.97 mm, L: 96 mm.

The fingers bear on a whole line, interrupted by two busbar of 2.6 mm with a spacing of 47 mm.

![Figure 7](image)

Fig 7: Dimension of grid designed by Solidworks

### 3.4 Optical Measurement

The figure 8 shows the dimensions of a new grid on a laser processed mc-Si wafer with silicon nitride layer. This figure contains four images taken by optical microscope. Laser treatment is very clear on the wafer surface.

A surface image indicating the laser treatment for the formation of a selective emitter presented in figure 8 show the perfect continuity of the lines and good flatness of the edge of finger and bus-bar. We confirmed that the surface appearance had changed in the laser treated area. These different appearances are related to the mechanism of laser process as explained below.

![Figure 8](image)

Fig. 8: Optical microscope images of:
- a- Edge isolation width, b- Finger width
- c- bus bar width, d- Distance between two fingers
Laser causes the melting of silicon and simultaneously diffuses dopant atoms by heat induction to the solid-phase doping precursor. Then, dopant atoms are incorporated into the molten silicon region by the liquid-phase diffusion during the melt recrystallization of silicon [7].

Therefore, the surface appearance was changed by laser treated, which induced the melting of silicon. Thus, the selective emitter was formed only in laser treated area.

3.5 Superposition of the new grid laser treated with metallic grid

The superposition of a new grid (laser treated) with metallic grid is shown in figure 9 and figure 10.

Fig. 9: Photograph of alignment fingers

Fig. 9 shows all the fingers of the new grid are juxtaposed with those of the metallic grid. We can conclude the perfect alignment of the grid fingers.

Fig. 10: Photography of alignment bus-bars

Fig. 10 also shows all the bus-bars of the new grid are juxtaposed with those of the metallic grid. So we can obtain a grid with the same dimensions of the screen-printed grid.

4. CONCLUSION

In this paper we presented an innovative process for selective emitter patterning featuring a single additional step compared to standard workflow. We used a high frequency laser to selectively dope the areas under the front contacts on mc-Si wafers with a thin layer of silicon nitride (SiNₓ).

Laser doping is a promising method for creating selective emitters. Its main advantage is the localized nature of the laser beam, which allows melting of the surface area without heating the bulk. However, laser-induced defects, contaminations and discontinuities in the laser-doped junctions degrade the solar cell performance. In conclusion, the multicrystalline silicon solar cells fabrication by laser doping is studied.

The selective emitter wanted in our project for optimal parameter, a power 6 W and a scanning speed of 20 mm/sec. The formation of the selective emitter by the laser method is very simple and very fast without additional processes. Therefore, we designed using solidworks software to a single type of patterns for square mc-Si cells.
REFERENCES


