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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 multicristalline silicon solar cells suitable for industrial mass production. Under the selective emitter project or regions located below the metal grid is carried out by screen printing dope. Therefore, we designed using solidworks software to a single type of patterns for square cells (multi crystalline silicon).**

***Keywords*— Selective Emitter, Solar Cells, Laser Treatment, Solidworks**

I. 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.

Currently in the PV industry based on multi-crystalline silicon, it is still trying to implement solutions for better performance. Among these techniques, technology-assisted laser doping [1, 2] 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 + +.

There are other techniques to achieve selective emitters, include:

- Etch-back: it is a method that involves an over-doping of the emitter by POCl3, which can reach / 50 Ω □ after a metal mask by screen printing or lithography is applied, then the non-metallic parts are attacked back to square-up resistance 100Ω / □ [3].

- 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 [4].

- Dissemination masking: the principle of conventional photovoltaic device transmitter more reflective layer over the passivation layer (SiO2/SiNx) ', then through a laser is made overtures following the pattern of the metal gate, a second diffusion step follows create selective emitter only in these regions [5].

II. Experimental

In this work, we used the so-called "laser-assisted doping" method for achieving selective emitter on multi crystalline silicon. This technique allows localized on doped silicon regions phosphorus to reduce the sheet resistance of the metal-to-transmitter and thus improve the efficiency of the solar cell, Fig. 1 shows process flow for the laser doping cell with a POCl3 diffusion.

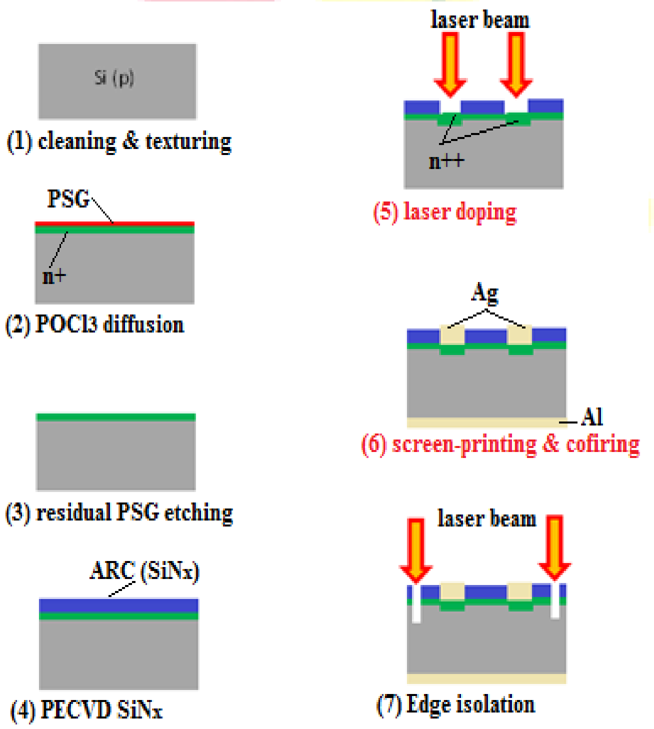

Fig. 1 Process flow for laser tailored selective emitter solar cells. Step 1: The wafer surface is textured with random pyramids. Step 2: POCl3 furnace diffusion creates a shallow doped emitter together with a phosphosilicate glass (PSG). Step 3: Hydrofluoric acid removes the PSG layer .Step 4: SiNx anti-reflection coating (ARC) is deposited. Step 5: laser doping. Step 6: Screen printing and firing of the front and back contacts Step 7:edge isolation.

In this paper we present an experimental approach for the realization of selective emitter laser on silicon wafers multi-crystalline from a thin layer of phosphosilicate Glass (PSG) formed naturally after diffusion process trichloride phosphoryl. Homogenous and lightly doped emitters were formed on p-type Multi-crystalline silicon wafers (mc-Si), by thermal diffusion of POCl3 using a Lydop furnace from SEMCO Engineering. The sheet resistance of the emitter is 60 Ω/□.

The first step consists in the saw damage removing and the texturing of raw wafers using a KOH solution. 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 (SiNx) 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: in the fifth step, the residual PSG layer is etched using a HF solution.

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 around 65 Ω / □, which is typical for industrial standard cells.

Therefore, we designed using solidworks software to a single type of patterns for square cells (multi crystalline silicon). With the optical microscope was able to define the characteristics of the metal grid, namely the number of busbar and finger width of the busbar and the spacing between them, the finger width and the spacing between them.

Once the pattern made by the SW software, the file is converted to DXF format to allow playback on the software interface of the laser, once played on the software file, the following laser treatment on platelets covered with a layer of PSG, once the line pattern produced by laser is completed, the plate is overlaid with metallic plate treated to see the correlation between the two grids.

III. Results and Discussion

A. Specifications of the Grid Treated by Laser

There after the laser on several plates and through the characterizations performed (measurement of the square by four points resistance, and take pictures by optical microscope) treatment have optimized parameters namely laser power, speed and setting the repetition frequency and spot size.

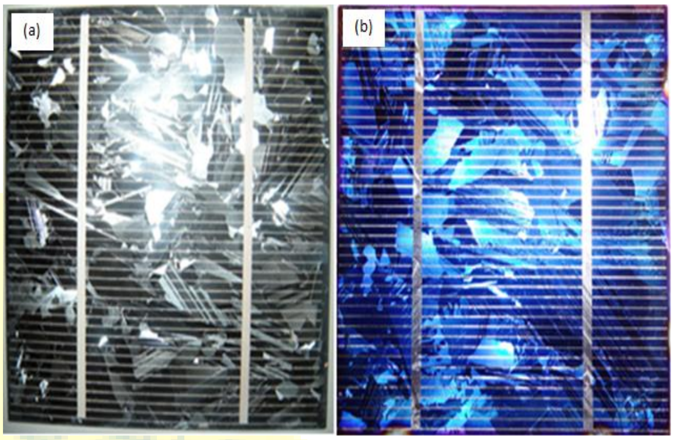

Fig. 2 Photograph of: a) Grid Metallic, b) Grid treated by laser

Fig. 2 shows the new specifications of the grid square plate (Gridline specifications for square wafers of 10 cm x 10 cm).

- Dimension of the gridline: 9.6 cm x 9.6 cm
- Finger number: 43
- 02 Bus bars of 2 mm width each
- Distance between the 2 bus bars: 5 cm
- 43 fingers of 100 µm width each.

B. Result of Superposition

Comparing mc-Si wafer with nitride laser treated according to the diagram of a metallic grid is shown in Fig. 3.

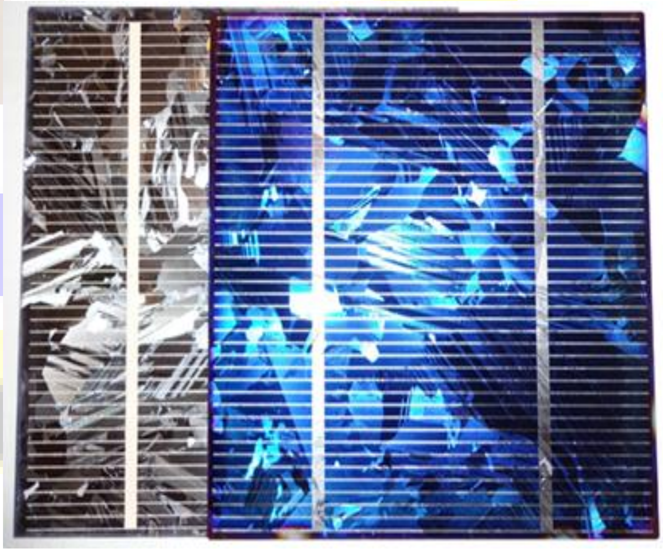

Fig. 3 Photograph from the superposition of Grid Metallic and Grid treated by laser.

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 Fig. 4 and Fig. 5.

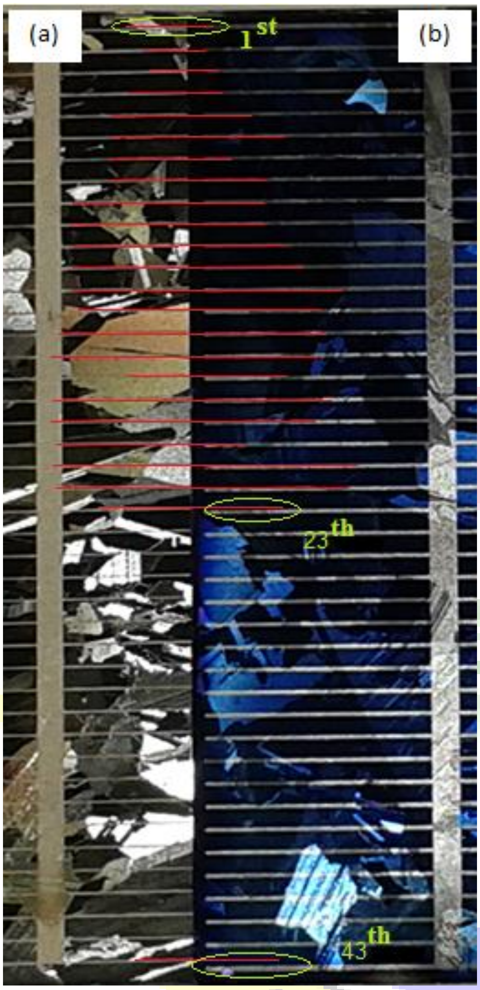

Fig. 4 Photograph of the overlap between the fingers.

The analysis from the superposition of the old grid laser treated on the metal grid leading 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 and this is shown in Fig. 5.

Fig. 5 Photograph of the overlap between the bus-bars.

C. *Grid Designed by Solidworks*

Under the selective emitter project or regions located below the metal grid is carried out by screen printing dope. Therefore, we designed using solidworks software to a single type of patterns for square cells (multicrystalline silicon), Fig. 6 shows dimension of grid designed by solidworks.

- I sent the file to the grid designed by solidworks.
- The file format that the software laser can read is the DXF.

Laser engraving on multicrystalline silicon wafers of silicon nitride (SiNx) broadcast from 60 to 65 Ω / □ and laser parameter: P = 6 W, V = 250 mm/sec, F= 20 KHz.

New Diagram of the grid:

- Busbar: 2.6 mm / E1, 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.

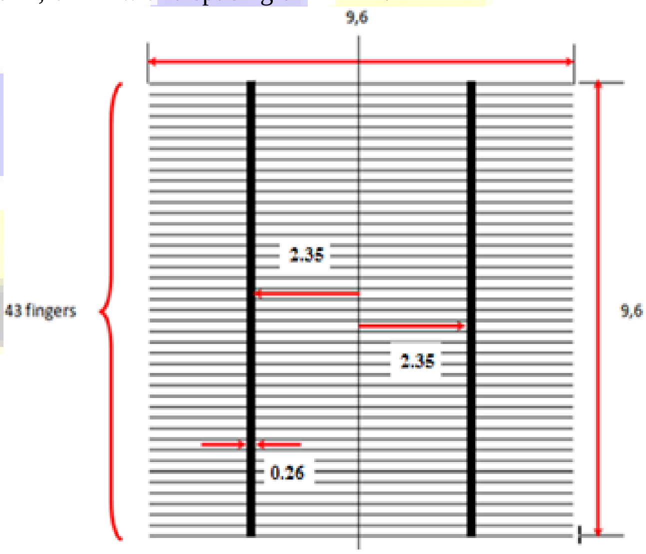

Fig. 6 Dimension of grid designed by solidworks

D. Optical Microscope

Fig. 7 shows the dimensions of a new grid on a laser processed wafer with multi-crystalline silicon nitride. This figure contains four images taken by optical microscope a, b, c and d. Laser treatment is very clear on the plates used.

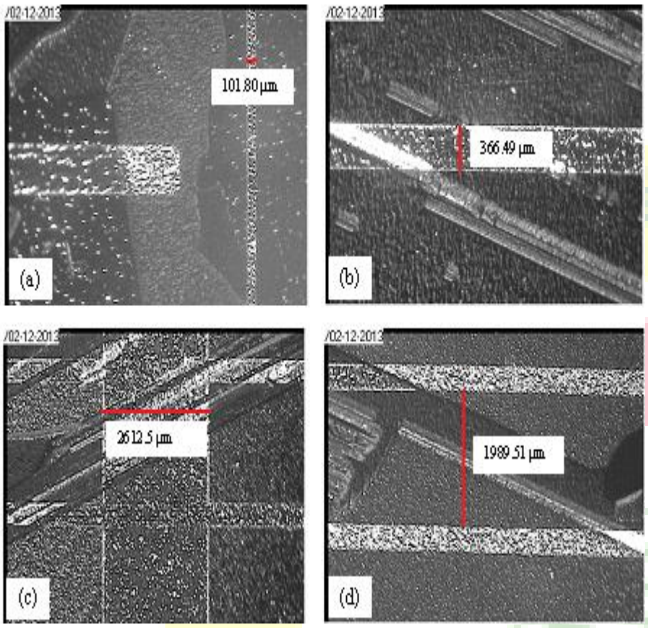

Fig. 7 Optical microscope images of: a) width edge isolation, b) width finger, c) width bus bar, d) Distance between two fingers.

A surface image indicating the laser treated for the formation of a selective emitter is shown in Figure 7. We confirmed that the surface appearance had changed in the laser treated. These different appearances related to the mechanism of laser are explained as follows. Laser treated causes the melting of silicon and simultaneously creates 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 [6].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.

E. Superposition of the New Grid Laser Treated With Metallic Grid

The superposition of a new grid laser treated with metallic grid, which is shown in Figure15 and 16.

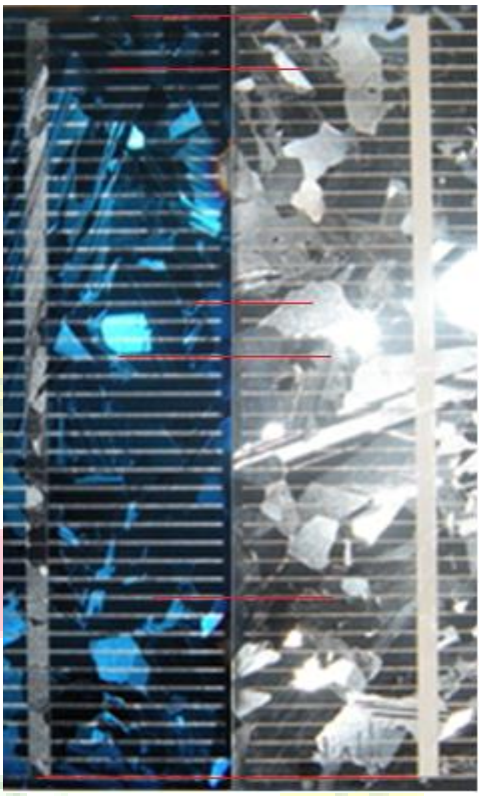

Fig. 8 Photograph of Alignment fingers.

Fig. 8 shows all the fingers of the new grid are juxtaposed with those of the metallic grid.

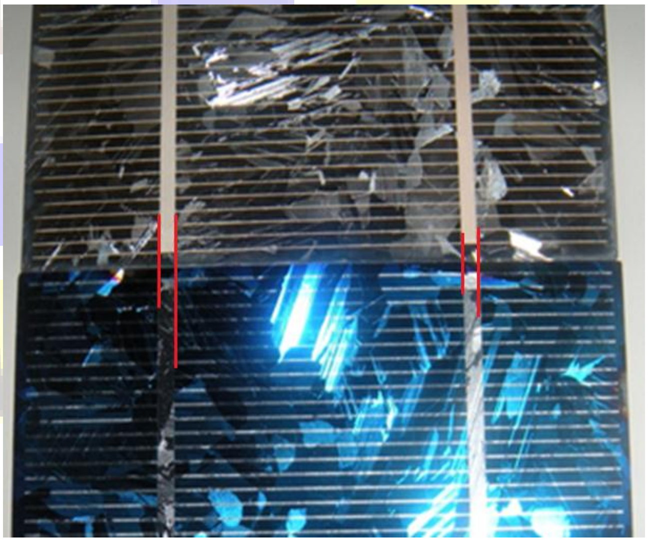

Fig. 9 Photograph of Alignment bus-bars

Fig. 9 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 metallized gate.

IV. CONCLUSIONS

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 silicon wafers multi-crystalline from 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. Under the selective emitter project or regions located below the metal grid is carried out by screen printing dope. Therefore, we designed using solidworks software to a single type of patterns for square cells (multi crystalline silicon).

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