EMITTER DOPING INFLUENCE ON ELECTRICAL PERFORMANCE OF C-Si CELLS UNDER CONCENTRATED LIGHT

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Abstract

In the present work we have investigated the influence of the emitter doping on the cell performance of c-Si devices at one sun and under concentrated light. We have realized different devices using FZ p-type Boron doped wafers and varying the sheet resistance of the emitters aiming at analyzing the effects of junction depth and concentration on the surface of doped elements affecting the recombination process. We made a comparative study of the electrical behaviour of different devices (current-voltage and quantum efficiency characterization) at one sun and under concentrated light. The best result achieved is $\eta > 19\%$ at 100 suns.

1. Introduction

The PV Concentrator Technology (C-Technology) is considered an attractive and promising application to make PV technology competitive in medium and long term. In fact by using optical concentrators to focus direct sunlight it is possible to increase the intensity of sunlight striking the cell and then to decrease solar cell area and consequently the cell cost by the concentration factor. In such a way the influence of the cost of the solar cell on the whole PV system can be reduced. In the medium concentration application (<200 X) the share of the cost of the solar cells with respect to the whole photovoltaic system should be negligible (<8-10%) [1, 2].

A strategy to satisfy this request imposes the development of simple and cost effective technological processes able to realize high efficiency solar cells.

The solar cells for concentration differ from flat panel solar cells in their ability to work at high irradiances, and consequently at very high current density. Therefore the main differential characteristic is the contacting structure intended to reduce the ohmic losses. For an example, heavier doped substrates and deeper emitters are usually required. These constraints, however, often give undesirable drawbacks, first of all a diminished value for the recombination lifetime in the base region.

Our purpose is to find a process, easy to transfer to industrial application, able to produce solar cell efficiency of 20% under concentration regime, up to 100 suns. During the last years we developed a simple process involving only two photolithograph steps, easy to transfer to industrial application.

In the present work we studied influence of the emitter doping on the performance of high efficiency crystalline silicon solar cells under elevated irradiation level.

2. Experimental section
2.1. Cell processing

The structure of our cell is schematized in Figure 1:

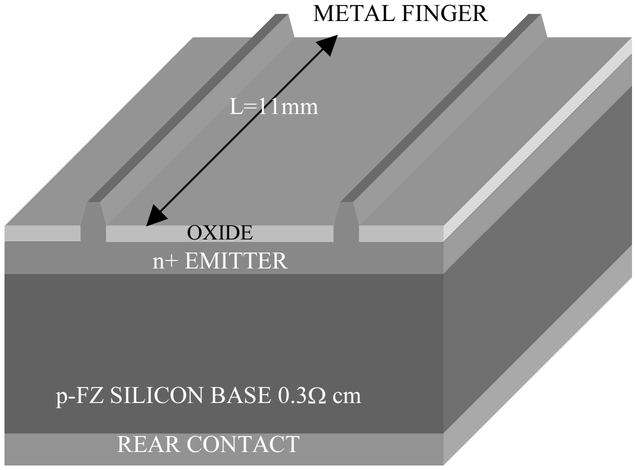


Figure 1: Schematic representation of the unit element of c-Si solar cell.

In our process we have chosen to use monocrystalline <100> oriented silicon Floating Zone 250 μm thick wafers having high p-type doping density as well as 0.3 Ωcm resistivity. The main steps of the fabrication of our cell (realized in a 200 m^2 100 class clean room controlled environment) can be schematised as follows:

Wafer cleaning / Phosphorous diffusion and drive-in / Thermal oxidation /Al back contact / Ti-Pd-Ag front contact / MESA etching / Double Layer Antireflection coating.

The emitter realization has been monitored measuring the minority carrier lifetime after the realization of each high temperature step, using the transient photoconductive decay revealed by a WCT 100 lifetime tester [3, 4]. The very high current level of this kind of devices (Jsc up to 7 A/cm^2) imposes simple and specific processes able to increase fingers/busbar thickness on the contacting structure intended to reduce the ohmic losses. The height of the metallization, obtained using lift off technique, is around 9 μm.

2.2. Metal grid design

Minimizing the series resistance of solar cells is especially important in concentrator systems. One way to reduce the resistance is to increase the grid coverage, but at the expense of blocking light from the cell. An optimum grid-line pattern minimizes the combined effect of the four loss mechanisms directly associated with the grid. They are: (1) emitter-layer resistance; (2) grid-metal resistance; (3) shading loss due to grid reflection; (4) contact resistance between the metal and the semiconductor. Other loss mechanisms in the cell typically have little or no dependence on the pattern selected for the front-surface grid, and thus, usually, are not included into the analysis [3, 4].

Generally, during the design of the metal grid of a solar cell the width of the metal fingers is fixed by technological constraints. The optimisation of the metal grid is practically restricted to finding the separation between the fingers that results in the best compromise among shading and resistive losses.

The metal finger width limit of our photolithographic process is around 18 μm. The shape of the obtained fingers is trapezoidal. We used a conventional frontal grid with 2 bus-bars outside illuminating area and a series of fingers connecting them (Figure 2); the active area of the cell is fixed to 1.21 cm^2:

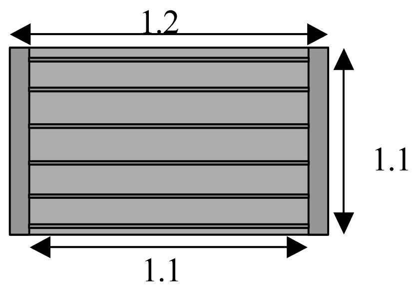


Figure 2: Metal grid geometry.

A semi-empirical computer model [5, 6] is used to determine the grid geometry and spacing for optimum design. The achieved values of Voc and Isc at 1 sun (based on earlier results using similar silicon and optimum processing) take part in the simulation together with the sheet resistance, the surface doping, the silicon resistivity and thickness, the grid metal line resistivity, thickness and width and so the spacing of the grid lines is optimized (Table I).

Table I: Metal grid parameters used for our cells.

Finger width (μm)	Finger spacing (μm)	Finger height (μm)	Number of fingers	Shadowing losses (%)
18	245	9	44	7.35

3. Results and discussion

We made a comparative study of the electrical behavior of different devices (current-voltage and quantum efficiency characterization) at one sun and under concentrated light, to investigate the influence of different fabrication conditions on the electrical performances of the devices, for each technological step of the process. The investigation includes the analysis of the SIMS and SRP profiles of the emitter doping (Figure 3) and measurements of the minority carrier lifetime after the realization of each high temperature step.

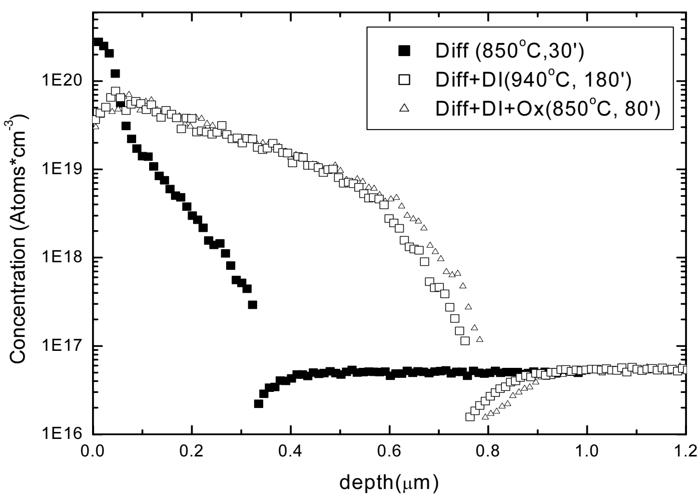


Figure 3: SRP profile of the emitter layer after diffusion and diffusion + drive-in processes.

The feasibility of the devices is proved by the fabrication of a number of cells with similar performances. The cells have been assembled to make all the measurements easily and to provide an extended contact that can reduce considerably the series resistance during the characterization.

We focused our attention on two different types of emitter: one with a thickness of 0.35 μm and the other with a thickness of 0.80 μm.

These solar cells have been characterized by external quantum efficiency (Figure 4) and current voltage measurements performed in dark and light range from 1 up to 100 suns.

The best cell realized in our laboratory using a specific grid for concentration application, achieved the efficiency of 18.54% at 1 sun illumination condition (Voc=634 mV; Jsc=35.45 mA/cm^2; FF=82.40%) (Figure 5).

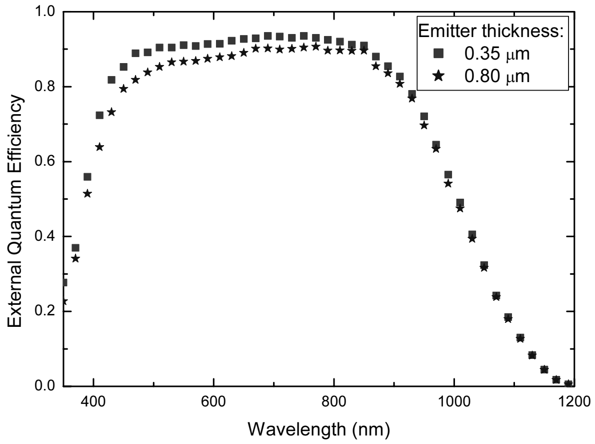


Figure 4: External Quantum Efficiency of devices with different emitter thickness.

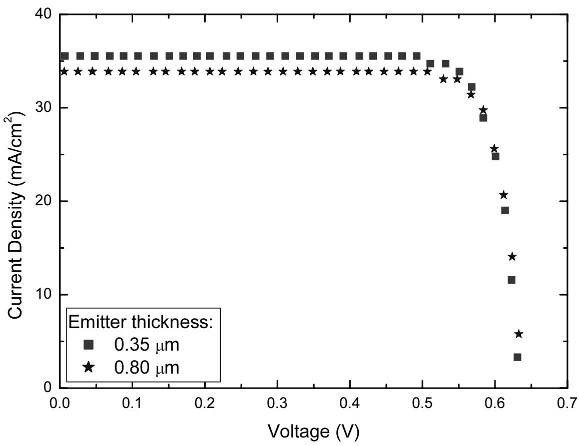
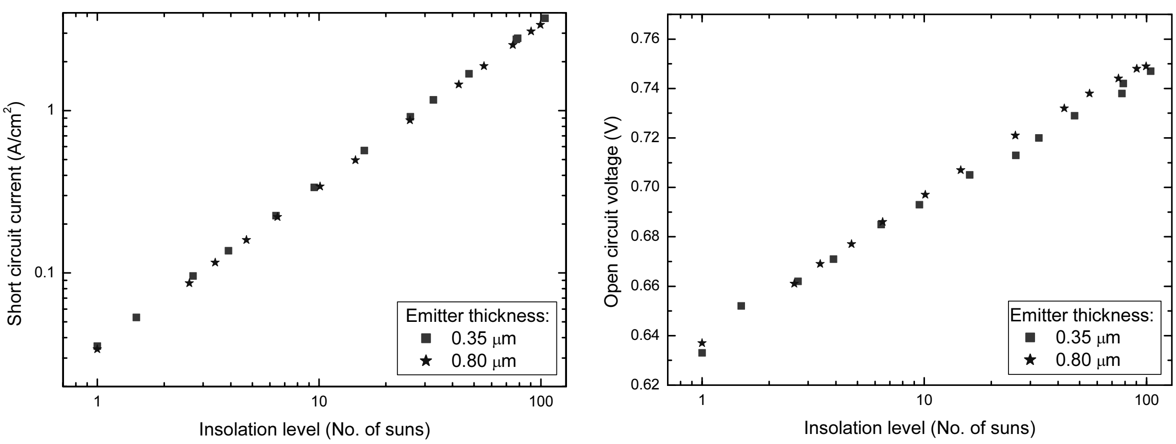


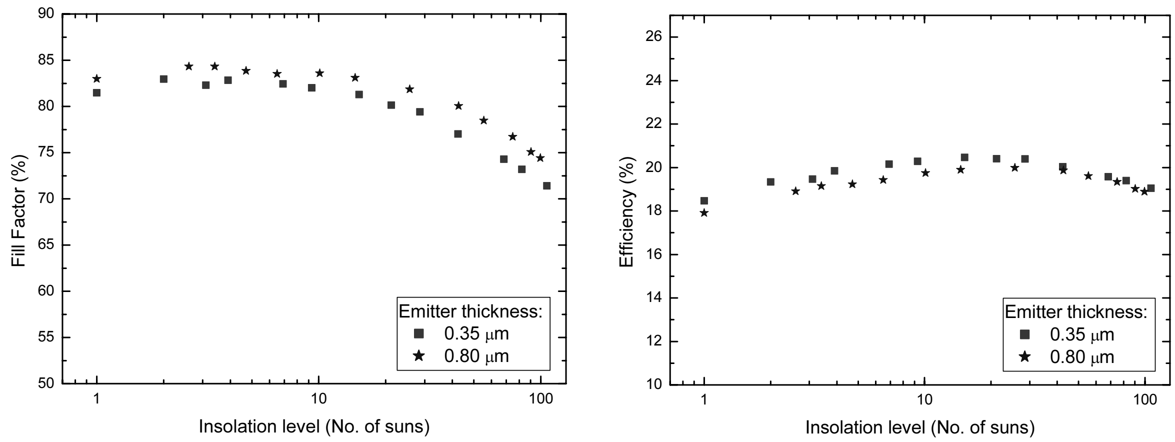
Figure 5: I-V curves at 1 sun for devices with different emitter thickness.

The cells have been characterized under concentrating light using a flashed simulator (Pasan Sun Simulator III) with a pulsed xenon lamp (AM 1.5 spectral distribution and 1000 W/m^2 irradiance). Light has been concentrated using a Fresnel lens.

The best results are reported in Figure 6. All the measurements were carried out at 25°C.



(a) (b)



(c) (d)

Figure 6: Comparison of measured parameters for cells with different emitter thickness up to a concentration of 100 suns: (a) Short circuit current; (b) Open circuit voltage; (c) Fill Factor; (d) Efficiency.

As expected, while the cell with thin emitter shows better performance at 1 sun illumination conditions and under low concentration (<30 suns), the cell with thicker emitter shows better results under concentrated light (>30 sun) (Figure 6). The best result obtained is η>19% at 100 suns.

4. Conclusions

In this work we made a comparative study of the electrical behaviour of different devices (current-voltage and quantum efficiency characterization) at one sun and under concentrated light, to investigate the influence of the emitter doping on the electrical performances of the devices.

In the optimisation of the frontal grid for a solar cell for concentrating system, it is important to consider not only the technological limit of the finger width but also the shape of the finger obtainable because it can influence the volume of the deposited metal. Although at one sun it could be a good choice to optimise the grid assuming the finger section rectangular, at higher irradiation levels the error in the resistance of the metal can be considerable also for grids having little differences in the finger width/distance.

References

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