

Screen-printing point contacted solar cells with boron back surface field

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ABSTRACT: Applying the point contacted structure on the P+ surface of the mono-crystalline silicon solar cell for the metallization effectively decreases the surface area of the semiconductor directly contacted with the metal. The boron solubility in silicon is one order higher than the aluminium does, and the boron doped surface can still be available for adding other passivation layers. We have used this structure in industrialized screen-printing solar cell manufacture line in order to highly improve the performance of the solar cells. In this paper we will report the brief production techniques sequence and the different methods to approach to this structure. Brief analysis and explanation of this solar cell's design and characteristics will be performed in the end.

Keywords: point contacted, screen-printing

1. INTRODUCTION

With the decreasing of the thickness of the mono-crystalline wafer below 200 μ m, the rear surface determines the efficiency of the solar cells¹. On the other hand, the bowing of the conventional full aluminium rear surface layer is the critical problem we have to deal with².

In this paper, we are trying to use two methods in industrial production line to solve the problems. The first is using boron back surface field instead of the traditional Al BSF, as the boron solubility in silicon is one order higher than the aluminium does, and the boron solubility in silicon can still be available for adding other passivating layers; the second is using screen-printing point contacted structure to make the contact

on the P+ surface. In the following description the PC-BBSF solar cells will be the short of the solar cells with the structure of the point contacted boron back surface field.

2. EXPERIMENTS AND PROCESSING

2.1 Processing of the PC-BBSF solar cells

The processing sequence of the PC-BBSF solar cells that is carried out by us is shown in figure 1. We are using the p-type CZ mono-crystalline silicon wafer (3-6 Ω -cm) with a thickness of 200 μ m. The saw damage removal and the texture by an alkaline etch is the first step, followed by a back to back gas phase boron diffusion with BBr₃, forming the boron back surface field. The boron diffusion temperature is around

1020°C for 20 minutes, and the wafers are only placed on the side against the flow and the face sides are placed the accompanied wafers. After the diffusion the wafers create the even brown colour BSG, it can be removed by electrolysis. Then we have to use the one-side acid erosion to clean the non-boron-diffusion surface to avoid the intersect diffusion that will destroy the following emitter diffusion. Using the spin-on SiO₂ latex protecting the boron surface, then start the emitter diffusion with POCl₃. Contrasting the conventional N⁺ surface deposition, the silicon nitride layers (a-SiN_x:H) on the front side and the back side are deposited supplying an antireflective coating and passivation for the PC-BBSF solar cells. However the ratios of the SiH₄ and NH₃ forming the SiN are different, and the SiH₄ is higher on the P⁺ surface for the better passivation. The metallization is applied by screen printing, pointed AgAl paste on the P⁺ back side is printed and dried. Then the aluminium rear contacts and the silver front were printed and fired in a single co-firing step.

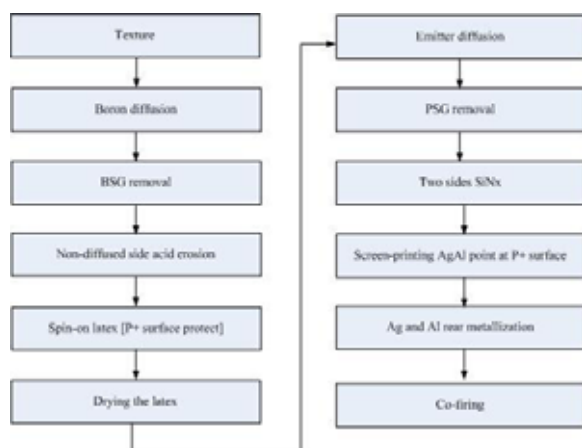


Figure 1: Processing sequence of the PC-BBSF solar cells

2.2 The structure of the PC-BBSF solar cells

With the solar cells' processing sequence description, the illustration of the structure is shown in figure 2.

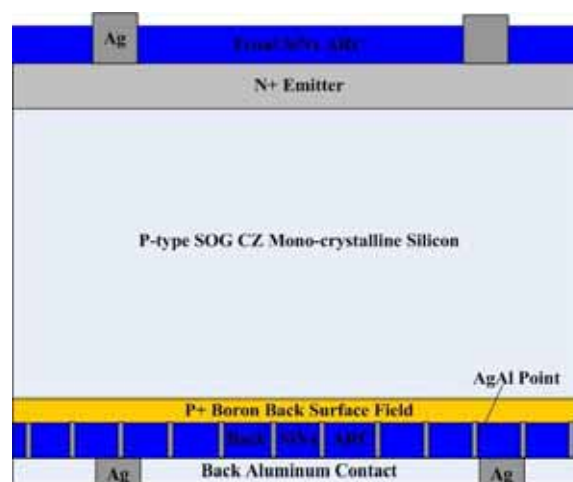


Figure 2: Structure of the PC-BBSF solar cells

3. RESULTS AND DISCUSSION

3.1 Lifetime analysis

The high processing temperature in the boron diffusion is the fatal factor for the low resistivity SOG silicon. The comparison of the minority carrier lifetime of the two resistivity mono-crystal silicon (1Ωcm and 6Ωcm) is presented in figure 3. For the high resistivity wafer the after-boron diffusion minority carrier lifetime is around 57μs, while the low resistivity wafer is only 4.4μs. The oxygen percentage difference between the wafers is the main reason to explain it. The boron-oxygen complex created during the driven process of the boron diffusion around 1020°C contaminated the wafer³.

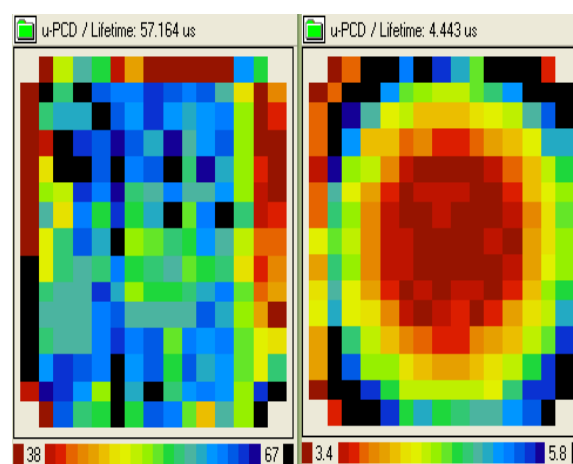


Figure 3: Comparison of the minority carrier lifetime mapping of the two resistivity mono-crystal silicon ($1\Omega\text{cm}$ and $6\Omega\text{cm}$)

3.2 One side acid erosion and diffusion protection

After the boron diffusion, the non-boron-diffusion layer was also doped by boron, which will destroy the following phosphorus diffusion. The main reason is that considering the diffusion temperature of boron and phosphorus, combining the diffusion coefficient D at this temperature the boron diffused depth is much deeper than the phosphorus, and it cannot be compensated by the following emitter diffusion.

The suitable protection layer is quite hard to find, the spin-on SiO_2 latex can interdict the phosphorus diffusion but not boron. We are using the one-side acid erosion after the removal the BSG. The removal thickness is around $3\text{-}5\mu\text{m}$. The one-side acid erosion is the key procedure for the whole process. The implied V_{oc} for skip this procedure is less than 450mV , while with the procedure it will easily be above 600mV .

3.3 Metallization

Choosing the right SiN_x layer on the P^+ surface is important. It will not only have the good passivation ability, but also easy for AgAl to fire through during the co-firing step. The ratio of the SiH_4 to NH_3 need to be chosen carefully, otherwise the series resistance will have a huge increase. The refractive index $n=2.5$ for the Si-riched SiN layer at back surface, which is much higher than the refractive index of the front surface². The photo of the back surface of the PC-BBSF solar cells after firing will be shown in figure 4.

The diameter of the hole for printing the AgAl is around $150\mu\text{m}$ and the distance between the two holes is 1mm . The comparison photo of the back surface field of pointed contact solar cells with the conventional full Al BSF solar cell is

presented on figure 4.



Figure 4: Comparison photo of the back surface field of pointed contact solar cells (left) with the conventional full Al BSF solar cell (right)

3.4 IV test results

The IV test results are listed on table 1.

Table I: The IV test of the PC-BBSF solar cells

V_{oc} [mV]	I_{sc} [mA/cm ²]	R_s [Ω]	R_{sh} [Ω]	FF [%]	η [%]
624	33.2	0.0096	34.3	74.3	15.4

From the IV test result we have proved that the pointed contacted structure has already worked. However the series resistance is still higher than the conventional full Al BSF solar cells, it can be improved when we optimize the pointed contact structure, the SiN_x layer and the AgAl paste. The lower FF is mainly because for the low shunt resistance and the contact, which will also be improved in our following research.

4. CONCLUSION

In this paper, we are presenting a new mono-crystalline CZ silicon solar cell structure with the point contacted at the boron back surface field for industrial production line. The high temperature during the boron diffusion procedure is a critical problem for which can not be used for low resistivity wafers. The screen printing AgAl point structure has been proved can be a substitute method for full

aluminium BSF, which will thoroughly solved the bowing problem of the full aluminium BSF solar cells. However considering the IV test results, it still need to be improved in order to decrease the series resistance and get better contact.

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