

A study on selective emitter formation through an oxide mask for silicon solar cells

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ABSTRACT: We present a study on an alternative process of selective emitter formation which uses diffusion through a thin oxide mask. Line openings in the oxide result in heavy n-type doping, suitable for front grid metallic contacts; the region under the thin oxide layer receives a light n-type doping. Two groups of cells were prepared, one using this selective emitter formation approach (group A), and the other prepared by heavy doping followed by emitter etch back (group B), in order to compare their performances. An improvement was observed in the blue response of the cells in group A, when compared to the cells of group B. On the other hand, diffusion length measurements using the red response resulted in higher values for group B than for group A, as a result of a better impurity gettering.

1. INTRODUCTION

Most high efficiency silicon solar cells use a passivated selective emitter. The reason for this is the following: good metal-emitter contacts, for low series resistance, require a highly doped n^+ region under the metal fingers. On the other hand, highly doped emitters lead to poor cell response in the blue region of the spectrum. Selective emitters are the logical consequence, having n^+ regions under the metallic fingers and lightly doped n regions in between. Good surface passivation of the lightly doped region, which can be achieved by a thin oxide layer, is essential for good blue response.

Such non-uniform emitters have been made by a two step diffusion process, or by a single doping step followed by etch back of the regions between the metallic contacts.

In this work, we present our first results on a study of an alternative process of

selective emitter formation which uses diffusion through a thin oxide mask. Line openings in the oxide result in heavy n-type doping, suitable for front grid metallic contacts; the region under the thin oxide layer receives a light n-type doping. This process of selective emitter structure formation may prove as satisfying as usual procedures [1][2] with respect to cell efficiency, and result in lower cost.

Two important issues addressed here are, on one hand, the possibility of achieving suitable doping levels for both emitter regions, and, on the other, whether the diffused-through oxide retains passivating characteristics.

2. EXPERIMENTAL DETAILS

Float zone p-type silicon wafers (3.64 $\Omega\cdot\text{cm}$) were used as test substrates and all

phosphorous diffusions were performed with solid doping sources at a temperature of 875 C.

In this approach of selective emitter formation using an oxide masked diffusion (OMD) the most relevant parameter is, of course, oxide thickness, since it will determine the ratio between the doping levels in the region of the fingers and in the layer below the oxide. Preliminary experiments were performed to establish optimum oxide thickness and diffusion time to achieve the desired sheet resistivities in both regions. Sheet resistivities, measured by the four point method on test wafers, were $75\Omega/\square$ in the lightly doped region under the oxide mask of the chosen thickness, whereas $22\Omega/\square$ were observed in the exposed region. The values we have chosen are similar to the ones reported by other authors on etched back emitter solar cells [3][2].

Two groups of cells were prepared, one using this selective emitter formation approach (group A), and the other prepared by heavy doping followed by emitter etch back (group B), in order to compare their performances. All cells are $300\mu\text{m}$ thick, and have no anti-reflection coatings. Cells in group A were prepared as follows:

- growth of a SiO_2 layer (4 nm)
- channel opening for finger heavy diffusion
- phosphorous diffusion, 2 hours at 875 C
- evaporation of Ti-Ag front contacts
- evaporation of Al back contact

and cells in group B:

- phosphorous diffusion, 2 hours at 875 C
- emitter etch back to $75\Omega/\square$ with a low fraction HF solution

- evaporation of Ti-Ag front contacts
- evaporation of Al back contact

In the later case we did not performed the oxidation step to passivate the front surface of the cell.

3. RESULTS

Both groups of cells were characterized by spectral response. In Fig.1 we present the results for a cell with selective emitter obtained with the OMD technique. After removal of the phosphorous doped oxide, the quantum efficiency (QE) shows a clear decrease in the short wavelength region. The higher QE in the former case is associated, we believe, with the presence of the oxide layer. Despite the phosphorous content, the oxide seems to retain its passivating properties, a result also observed by L. Ventura et al [5]. The decrease upon oxide removal is not associated with reflectivity changes since the oxide thickness is smaller than 40 nm.

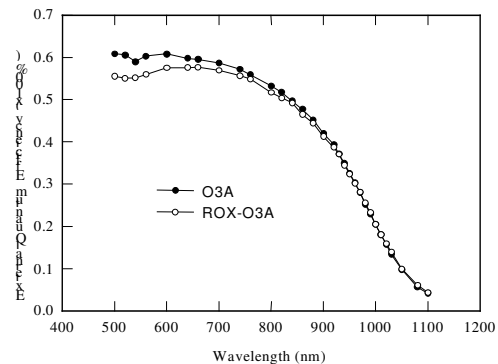


Fig.1- External quantum efficiency of a cell with a selective emitter obtained with diffusion through a thin oxide, before (O3A) and after (ROX-O3A) removal of the doped oxide.

Fig. 2 shows a comparison between a cell with an OMD selective emitter and a cell with a junction prepared by standard diffusion (not masked). In the blue region the OMD structure shows a better quantum efficiency due to the passivation effect of the doped oxide, still present on the surface of the cell. However, in the infrared region, the gettering effect, associated with the heavy doped n layer in the standard diffused junction, leads to a higher diffusion length in this cell.

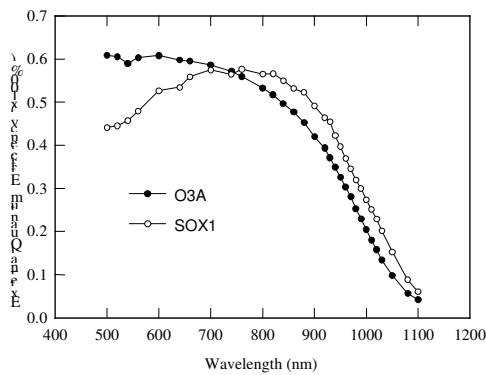


Fig. 2- Comparison of the external quantum efficiency for a cell with a selective emitter obtained with the OMD technique and a cell prepared by standard diffusion.

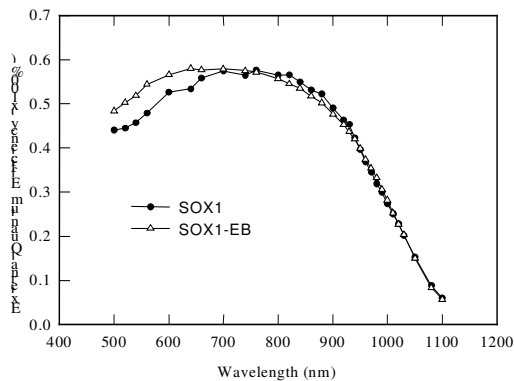


Fig.3- Effect, on the quantum efficiency, of etching back the n layer from 22 to 75 Ωcm .

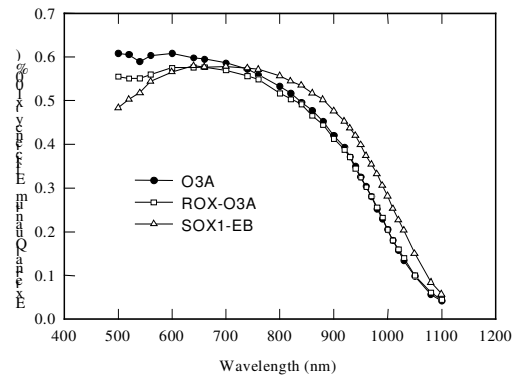


Fig. 4 - External quantum efficiency for a cell of group A (O3A) and for one of group B (SOX1-EB). Also shown the effect of removal of the doped oxide layer in the cell of group A (ROX-O3A)

We present, in Fig. 4, a comparison of the results obtained on a cell of group A (O3A), a cell of group B and on the cell O3A but with its oxide removed (ROX-O3A).

The interesting point is that cell ROX-O3A and cell SOX1-EB have the same n layer sheet resistivity, both have no surface passivation and nevertheless they show a quite distinct behaviour. Although further investigations are needed to clarify this point, it seems that the difference can be attributed to the difference in the phosphorous profile in the n layer. Actually, the impurity profile in the OMD selective emitter is expected to be different from an erfc distribution or an etched back profile, since the presence of the oxide mask affects the boundary conditions on the silicon interface, for phosphorous diffusion.

4. CONCLUSION

An alternative process of selective emitter formation using diffusion through a thin oxide mask has been outlined. The advantage of the process is that it enables junction formation and surface passivation in one step. These new structures show higher values of the quantum efficiency on the blue region of the spectrum than etched back devices with the same sheet resistivities, although the opposite happens in the long wavelength range.

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