LOW COST APPROACHES TO SOLAR CELL PROCESSING

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Abstract

This paper discusses several cost effective approaches in which a solar cell, in particular bifacial cell, can be fabricated. Cost savings can be achieved by reducing the number of high temperature steps to only one, groove formation, the use of double sided illumination and low cost spray-on films for anti-reflection coatings as well as diffusion and metallization masks. Thus efficiency of moderate values can be converted to higher ones at the same cost.

1. Introduction

The bifacial cell aims at using any substrate resistivity and wafer thickness for its fabrication. The structure, because of the isolated contacts on both front and rear is less expensive to fabricate, especially in the metallization stage. Also, the exclusion of the vacuum evaporator used for rear metal contacts for the single sided cells is very cost effective in capital equipment cost. The fact that the cells can be illuminated from both sides for increased output performance gives the structure an edge of the single sided ones. This gives the cells wider applications than the single sided ones and the moderately efficient cells on one sided illumination can be made to give higher on double sided illumination [1].

The processing sequence of a high efficiency solar cell involves at least three high temperature steps for emitter diffusion/wet oxidation, boron diffusion/oxidation and heavy phosphorus diffusion. These many high temperature steps can be reduced to two [2-3] with the use of spin-on dopants without sacrificing much of the cells electrical performance.

The use of spray titanium dioxide (TiO_2) is equally useful in reducing the many high temperature processing to one. The spray-on TiO_2 film has shown some promising characteristics as mask for impurity diffusion, and metallization as well as an anti-reflection coating [4]. The titanium dioxide in conjunction with the rapid thermal annealer can reduce the thermal budget of silicon solar cells since the diffusion involves only a short period of time (in a matter of seconds).

2. Rapid Thermal Annealer

The rapid thermal annealer (RTA) is very useful in reducing the processing time and hence cost in thermal budget, labor, gases etc. The diffusion of grooves with the use of thermal annealer as well as the conventional tube furnace have been compared [5]. This work showed no difference in grooves diffused with the conventional furnace and the RTA grooves.

3. Bifacial solar cell processing

The processing sequence involves; saw damage removal or surface texturing, cleaning, emitter diffusion, oxidation, rear grooves scribing and cleaning, boron diffusion, rear grooves masking oxide growth, front grooves scribing and cleaning, heavy phosphorus front grooves diffusion, metallization and testing.

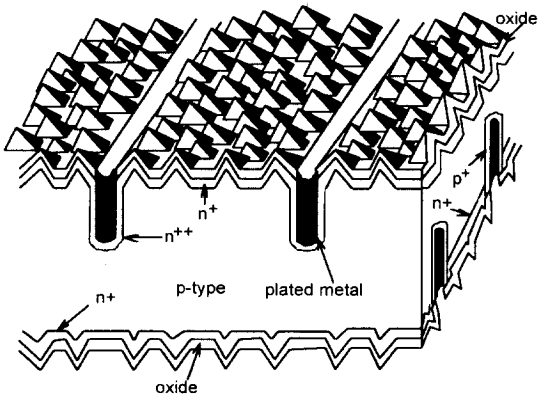

Figure 1: Schematic diagram of a bifacial solar cell

The fabrication of a bifacial cell requires the scribing (or defining two set of metal fingers for the case of photolithography process) of two sets of grooves on front and rear of cells (see figure 1). Laser (Nd:YAG) has been used widely for groove formation because of the exceptional control over the groove aspect ratio. The us of alternative means of groove formation with low initial capital and on going cost which gives the same groove geometry would be desirable. The use of the drafting plotter which is capable of scribing in the x and y directions for a complete grid pattern scribing would be very useful. This type of scribing method should support batch grooving of wafers to reduce the scribing time and cost of production.

4. Adaptation of Plotter for mechanical grooving

The adaptation involves mainly the improvisation of the stock for the diamond point scriber used for the groove formation, characterization of different tips to ascertain the suitability of each tip, understanding of certain attributes of the plotter to enable a proper control of the machine by software. This type of scriber has been found to support batch grooving of cells thereby reducing the human intervention and time of scribing [6]. The bifacial cells grooved with the adapted plotter was found to give identical electrical performance [typically V_{oc} of 660 mV, and J_{sc} of 33 mA/cm^2 on planer substrates] as its laser scribed counterparts.

5. Incorporation of TiO_2 into buried contact processing

The TiO_2 thin film is widely used as anti-reflection coating but not as a diffusion mask for impurity and a plating mask. A fourth use concerns surface passivation because when titanium dioxide is annealed in an oxygen ambient, a thin film of silicon dioxide is grown beneath the TiO_2. This thin oxide would therefore form a passivating layer for the silicon surface. The preliminary work on this application showed that, there is no deterioration of the minority carrier life time before and after annealing of the thin film of TiO_2 in oxygen ambient. The advantage is that the refractive index of the film increases after the annealing. This is advantageous, especially , for encapsulated cells. By using the thin film of TiO_2 formed by this low cost process the bifacial processing could be made more flexible and cost effective.

6. Double sided illumination of double sided solar cells

Until now the DSBC cells have been tested like single sided cells and the bifacial nature is not utilized. However, two dimensional modeling has shown that, 0.2 sun illumination on the rear surface with 1 sun front is good enough to bias the rear to the required high voltage so as to remove the injection level dependence of the effective rear surface recombination velocity [7,8]. Under this stated condition, the fill factor does not show any deterioration. The double illumination situation is very practical as in the case of albedo collection in the fields. Thus double illumination can enhance the electrical output parameters of the cells in module.

7. Conclusion

The cost of solar cells must be reduced in order to attract its widespread use. Apart from the material costs, the processing cost can influence the final cost of a solar cell. The processing costs can be reduced if the many high temperature steps are reduced to only one, by using RTA for diffusion instead of the conventional furnaces, the use of spin-on diffusion which can be deposited outside the furnace and capitalizing on the usefulness of the isolated rear contact scheme of the bifacial cells to increase output through rear illumination in conjunction with the front. This will mean fabricating higher efficiency cells at lower cost.

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