2-D MODELLING of N-TYPE IBC SOLAR CELLS USING SILVACO ATLAS SIMULATION

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***Abstract* - Processing of industrially feasible Interdigitated Back Contact (IBC) solar cells involves significant research and challenges. Simulation models of IBC cells, not only helps in understanding the cell behaviour inline with the experimental results but also help further in predicting the cell performance, adding to the cost effectiveness in the cell processing. The paper initially analyses about the cell behavioural with varying the cell pitch size and then provides with a predictive analysis on the cell behaviour in relation with varying bulk resistivity.**

***Keywords*— Interdigitated back contact solar cells; n-type;**

I. INTRODUCTION

Present day scenario witnesses significant research into developing low cost industrially feasible technology for IBC solar cells, which is a challenging task by itself. Due to the 2D nature of the carrier flow in these cells, complex simulation tools are required to obtain/perform a complete analysis.

II. MODELLING IBC SOLAR CELLS

The work presented in this paper is a step towards understanding the IBC cells with simulation performed using Silvaco ATLAS. The paper focuses on the behavioural trends in the cell parameters viz. internal quantum efficiency (IQE), short-circuit current density (Jsc), open-circuit voltage (Voc), fill factor (FF) and efficiency (η), with variations in IBC pitch size.

A. *Experimental Cell Process*

An IBC cell structure is mainly characterized by its –

Pitch: Distance between consecutive n^+ BSF /p^+ regions.
Emitter Ratio: Ratio of p^+ emitter width to pitch size.
Base: Width of the n^+ BSF region
Metal Width: Contact opening width.

The IBC cells are fabricated on 160 µm thick *n*-type 10 ohm-cm FZ silicon wafer, with front surface textured and passivated with shallow n^+ front surface field (FSF) and covered with 70nm SiNx antireflection layer. The phosphorous back surface field (BSF) is defined by $POCl_3$ diffusion with SiNx coating. Laser opening the mask layer and BBr_3 diffusion defines the emitter pattern [1].

The processed cells are designed with pitch configurations of 1000, 1400, 2200 and 3500 µm, with constant base of 530 µm, thus resulting in an emitter ratio of 0.47, 0.62, 0.70, 0.75 and 0.84 respectively. The p^+ and n^+ cells contacts, with an approximate metal width of 150 µm, are formed by screen printing followed by contact firing. The present industrial technology poses limitations on the dimensions provided by screen printing, laser patterning and laser ablation when compared to photolithography techniques.

B. *Simulation Model Unit-Cell*

The unit IBC cell for simulation is designed corresponding to the above experimental process, with the loaded measured doping profiles and substrate parameters as shown in Fig.1.

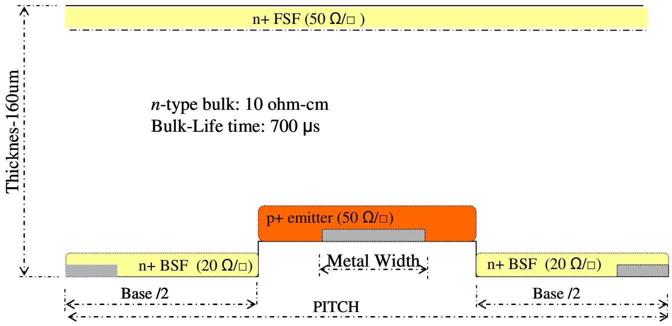

Fig. 1 IBC unit cell used in the simulation

III. RESULTS AND DISCUSSION

A. *IQE Results*

The IQE results of simulation and experiment, for pitch 1400 and 2200 µm is shown in Fig.2.

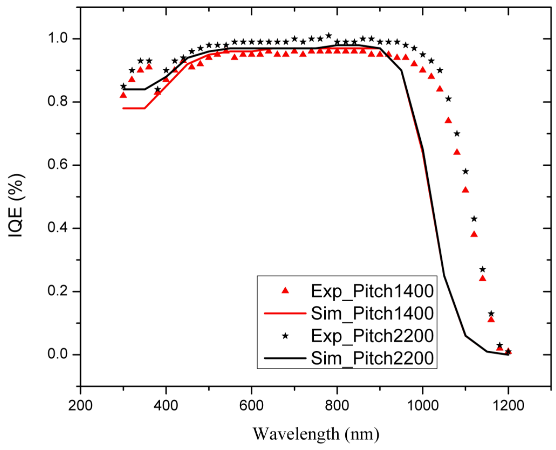

Fig. 2: Experimental versus simulated IQE of the cells with different pitch

Similar results are also observed for the other cell pitches. The mismatch between the experimental and simulation results at higher wavelength is due to the effects of texturization of the front surface. Texturization enhances the light-ray travel path and thus increases absorption and photogeneration at higher wavelengths in silicon. The present simulation model does not take into account this effect and therefore underestimates the Jsc value however; the model could be used to have an insight into the behavioural trend in Jsc, Voc, FF & η.

B. Cell Parameters with Variations in Emitter Ratio & Bulk-resistivity

Fig.3-4 captures about the observed trends in Jsc, Voc, FF & η, with varying bulk resistivity of the substrate, for the given emitter ratio.

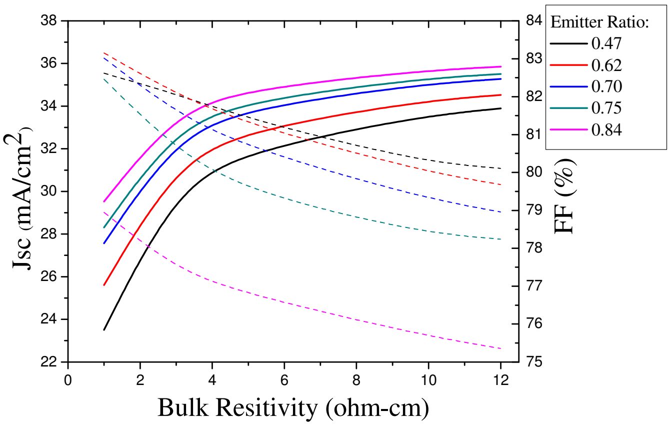

Fig. 3 Simulated Jsc and FF behaviour

Considering a fixed substrate bulk resistivity, with an increase in emitter ratio, Jsc increases. This is due to the better minority collection probability over a wider emitter region. At the same instant, FF decreases which is due to the increase in the travel path for the majority carriers generated over the emitter region. This lateral travel distance over the emitter is much greater than the cell thickness offering resistance to the carrier flow and thus affecting the FF.

With varying the bulk resistivity due to the presence of fewer dopant impurities enhances the minority carrier collection thus an increase in Jsc. The higher substrate resistivity however decreases FF due to the offered resistance to the flow of majority carriers.

On the other hand, Voc, with an increase in emitter ratio results in an increased region of better passivated emitter in comparison to the fixed base width. This results in an enhancement in Voc, due to the surface passivation effects. Considering the effects on Voc for a wider range of bulk resistivity, it shows a constant behaviour. As Voc has a strong dependence on the doping profiles and as during the simulation run, the same doping profile was used and therefore the constant behaviour in Voc is observed.

Considering the above effects seen in Jsc and FF, the effect on the efficiency variation is clearly a compromise between these parameters. A trade-off parameter exists to have an optimum pitch considering the given cell design.

With the presented IBC design with constant base width, the best performance of the cell is obtained for an emitter ratio between 0.70-0.75 corresponding to 1800 and 2200 µm cell pitches.

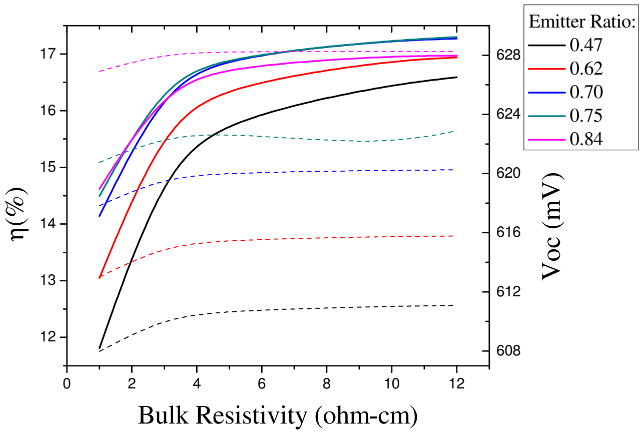

Fig. 4 Simulated η and Voc behaviour

IV. CONCLUSIONS

The simulation provides an initiative to help understand the IBC cell characteristics in relation to its dependence on the pitch. Further simulations considering variations in other design parameters viz. doping profiles, base width, metal openings and metal penetration, recombination velocity etc. would help obtain a detailed analysis of IBC cell characteristics.

As an *n*-type ingot shows wide variations in the bulk resistivity, due to the phosphorous segregation phenomenon, carrying out the simulation analysis varying the bulk resistivity, provides with a predictive analysis about a single optimum cell design considering the wide range variations in resistivity offered by *n*-type ingots.

ACKNOWLEDGMENT

The work has been supported by the EU within the LIMA project under contract no.FP7-248909 and acknowledges the European Commission and the LIMA consortium.

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