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MERCURY: MODELLING OF IBC CELLS WITH FRONT FLOATING EMITTER

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ABSTRACT

We propose IBC cells with a Front Floating Emitter (FFE) as promising alternative to IBC cells with a more conventional Front Surface Field (FSF), opening routes to using more conventional industrial processing for manufacturing of efficient IBC cells. In order to properly understand and design these cells 2-D device simulation is key. We combined device simulation with Design Of Experiments techniques, in order to effectively sample the large parameter space involved.

1. INTRODUCTION

Recently, we have introduced [1] the Mercury cell: an IBC cell with a front floating emitter (FFE) and wide BSF areas, as sketched in Fig 1.

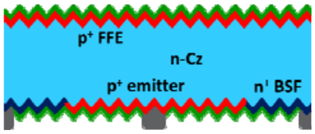

Fig 1: schematic cross-section of an IBC Mercury cell

This cell is considered to be the next generation of ECN's n-Pasha and n-MWT technology. It features a similar number of process steps, resulting in a potentially cost-effective and competing technology. The Mercury cell is more flexible in design than a regular IBC cell with a front surface field, because the electrical shading is suppressed by the pumping effect of the front floating emitter, as explained in our recent publications. Therefore wider BSF areas can be allowed, and patterning methods with larger feature sizes can be applied without sacrificing the efficiency level. This opens the way to PVD metallized IBC cells without an isolation layer between BSF metallization and emitter diffusion. The cell's back-contact nature allows excellent module integration with ECN's back-contact foil technology.

2. 2-D EFFECTS IN MERCURY CELLS

One of the key questions we faced is how to design and analyse such a cell. The characteristics of a classic front junction cell can be understood quite well with a 1-D model, such as PC-1D. In the Mercury FFE cell however 2-D effects come in to play and have big effects on the cell performance, and modelling becomes essential. With this simulations we had several ends in mind.

- Make design decisions. How should we select the BSF and emitter width to ensure optimum performance. How does bulk resistivity come into play.
- Check the impact of the dopant type of the front side (FSF or FFE) on cell performance. Hence the FFE and FSF were described with the same j_0 and R_{sheet}: in practical solar cells FFE and FSF diffusion will have different values.

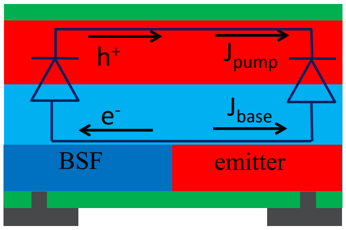

Fig 2: h+ current in FFE and e- current in base

Two currents in particular influence cell performance (Fig 1): the lateral majority h+ current through the FFE, experiencing the sheet resistance of the FFE (typically 60Ω/□), the lateral majority e-current through the base, experiencing the wafer sheet resistance, typically 350 Ω/□ for a 5 Ωcm, 150 um thick wafer. A high voltage drop in the base biases the base-FFE junction above towards short circuit, promoting the pumping effect, however it comes at the price of a FF loss due to Ohmic dissipation. The voltage drop due to h+ flow in the FFE has the opposite effect of decreasing the pumping effect. Effects in the FFE are smaller than in the base because of the lower sheet resistivity.

When the pumping current across the base-FFE junction above the emitter is small (per unit length of the junction), a wide emitter helps to create sufficient pumping capacity.

3. APPROACH

For the unit cell analysis we considered 4 design parameters: bulk resistivity, bulk minority carrier lifetime, BSF width and emitter width. In order to sample this parameter space effectively we combined device simulation with Quokka [2] or Silvaco Atlas [4] with DOE (Design Of Experiments). We used a Latin hypercube sampling method [3] to sample the parameter space. Sufficient samples were taken to allow fitting a 3-rd degree polynomial surface to the typically 4 dimensional set of data points. The residuals were inspected to assert that we obtain good fits. Once a satisfactory fit is obtained, the surface can be evaluated at for instance any bulk resistivity.

4. RESULTS

In Fig 3 we show simulated efficiency results of IBC structures with conventional FSF and Mercury FFE structures. The simulations have been done with quokka as a function of the unit cell geometry: along the horizontal axis is the emitter width, along the vertical axis the BSF width.

We see huge differences in performance for FFE and FSF cells. For FSF cells the electrical shading quickly becomes important as the BSF width gets wider. This results in a strong current decrease as the BSF gets wider.

In the FFE cell, for each BSF width there is a clear optimum emitter width. If the emitter is too narrow it has insufficient pumping capacity, if it is too wide lateral voltage drops in the base become too large and the FF will suffer. We see from the current contour plots that indeed the pumping effect is stronger for high Rbulk. For the efficiency the effect is less pronounced because the enhanced pumping comes at a FF loss.

For the FFE cell there is a range of geometries where the efficiency is well preserved for wider BSF widths due to the pumping effect. By sacrificing a bit of efficiency, larger features on the rear side can be allowed, opening routes to efficient IBC cells with simplified processing.

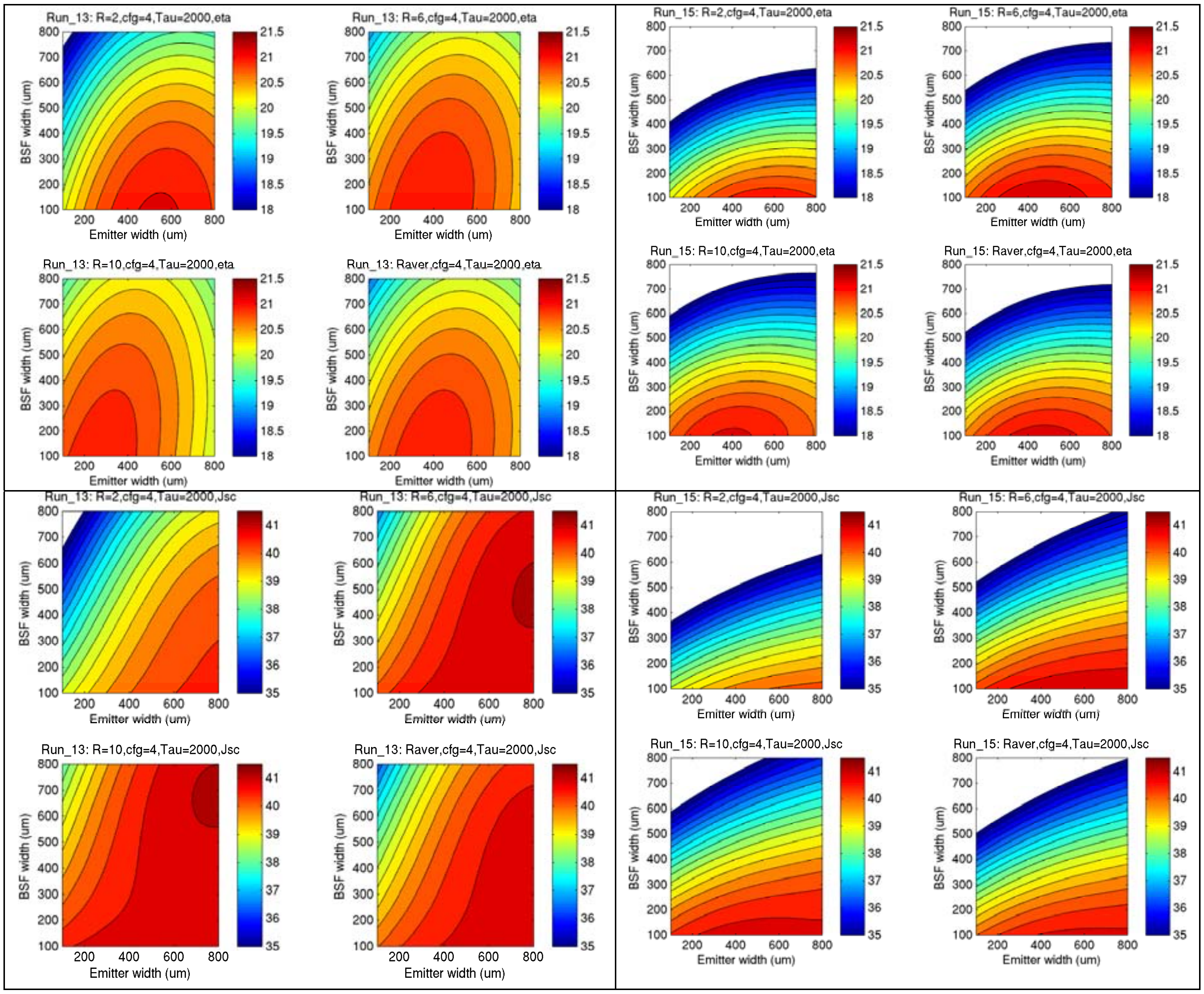

Fig 3:contour plots of Effiency (top row), Jsc (bottom row) for FFE (left) and FSF (right). There are contour plots for R_{bulk} of R=2 Ω-cm (top left) R=6 Ω-cm (top right), R=10Ω-cm (bottom left) and ingot averaged (Raver, bottom right).

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