

**THE BURIED EMITTER SOLAR CELL CONCEPT:
INTERDIGITATED BACK-JUNCTION STRUCTURE
WITH VIRTUALLY 100% EMITTER COVERAGE OF THE CELL AREA**

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ABSTRACT:

The buried emitter back junction back contacted solar cell combines large area emitter allocation with effective insulation of emitter region by means of a base-type surface region. We present experimental results for two different concepts of the buried emitter solar cell. The first “partial” approach features 80% emitter coverage in combination with 50% metallization fraction for emitter and base without the need for an additional insulation layer. Our second “full area” approach combines the large area emitter with an efficient boron emitter passivation realized by an oxidized n^+ -surface region. Our recent experimental result for the “partial” buried emitter solar cell shows 21.0% efficiency and a short circuit current density of 41.0 mA/cm², which confirms the efficient current collection of the large area emitter coverage. The high fill factor of 79.8% indicates that trap-assisted tunneling is not a relevant loss mechanism of this solar cell despite large areas of n^+p^+ overlap. For the “full area” buried emitter solar cell we report a maximum conversion efficiency of 21.8%.

KEYWORDS: back-junction solar cell, buried emitter, double diffusion, high-efficiency

1 INTRODUCTION

In back-junction solar cells, the partition on the rear side is usually a trade off between optimisation for maximum short circuit current and low series resistance in the metallization fingers, especially for the base metallization. For optimum short circuit current the emitter coverage should be as high as possible whereas for metallization base and emitter fingers should have equal dimensions. The buried emitter concept meets this challenge using an emitter diffusion that is buried underneath base-type diffusion which isolates the emitter region from the rear wafer surface [1, 2].

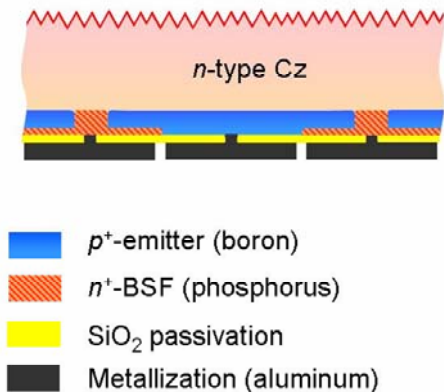


Figure 1: Schematic of the partial buried emitter solar cell concept: The boron p^+ -emitter is extended over virtually the entire rear side of the device whereas the emitter is insulated from the base metallization by an n^+ -surface layer. The Base and emitter metallization each take area fractions of 50% for minimization of series resistance.

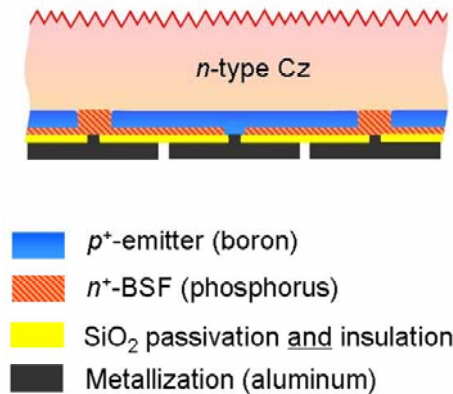


Figure 2: Schematic of the “full area” buried emitter solar cell: large area emitter coverage is combined with an efficient boron emitter passivation by a thermally oxidized n^+ -surface region.

In this article we present experimental results for two different approaches of buried emitter solar cells. Figure 1 provides a cross sectional sketch of the first one, the “partial” buried emitter solar cell. It exhibits a large area emitter that covers practically the complete rear side of the solar cell. Only point-like BSF diffused regions interrupt the otherwise continuous emitter. The n -type surface regions serve as isolation between the base metallization regions and the emitter. A 19.5% efficient “partial” buried emitter solar cell was already fabricated using laser structuring techniques [2].

In the second approach, the “full area” buried emitter solar cell concept, the n -type surface region passivated by thermal oxide is extended over nearly the entire rear surface of the device (Figure 2) [3]. In this way we can achieve on the full area an efficient surface passivation of the p -type emitter [2,4]. Therefore the extended full area buried emitter solar cell structure circumvents the problem that at present there are no cost-efficient

industrial methods available for passivation p -type emitters in large-scale PV-production. In return, this “full area” buried emitter solar cell requires a dielectric insulation layer.

In the following we report on our recent experimental results on buried emitter solar cells for both, the “partial” and the “full area” buried emitter concept.

2 EXPERIMENTAL

We process both buried emitter solar cell structures (Figures 1 and 2) on n -type Czochralski grown silicon wafers ($2.6 \Omega \text{ cm}$).

The rear side diffusion design was realized using Inkjet printing of an etch resist and subsequent HF treatment. Thermal oxide layers serve as local diffusion barrier during boron and phosphorus diffusion steps. The experimental boron-phosphorus double diffusion profile is shown in Figure 3. The buried boron emitter diffusion has a sheet resistance of about $89 \Omega / \text{sq}$ which is a well-suited value for carrying a lateral current within the emitter. The thin (and ideally weakly-doped) phosphorus surface layer exhibits a sheet resistance of about $150 \Omega / \text{sq}$ that can be well passivated by a thermally grown silicon dioxide.

The total boron emitter coverage is at present about 80 %. This value can be further increased, depending on the accuracy of the structuring techniques for producing the emitter and base contact regions.

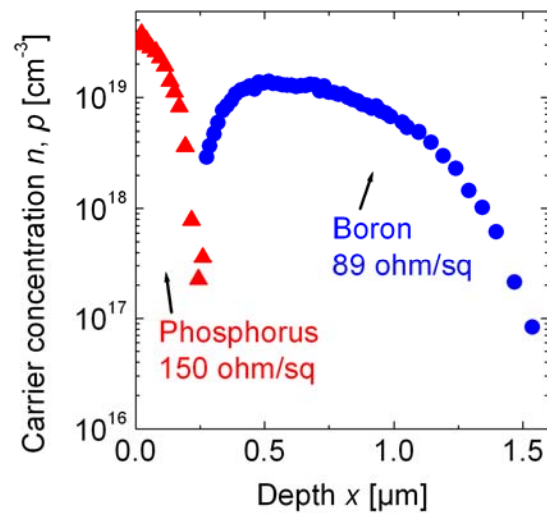


Figure 3: Majority carrier concentration profile of our n^+p^+ double-diffused surface regions.

The front side of our buried emitter solar cells is passivated by an oxidized phosphorus front surface field diffusion, that is covered by a SiN_x AR-coating. The rear sides of the devices are passivated with thermal silicon dioxide. Contact openings in emitter and base regions are formed by Inkjet printing of etch resist and subsequent etching. The base and emitter metallization fingers are both $800 \mu\text{m}$ wide.

The processed buried emitter solar cells have an active cell area of 3.97 cm^2 and were characterized by current voltage measurements (1 sun illumination intensity).

3 RESULTS AND DISCUSSION

The solar cell results of our “partial”- and “full area”-buried emitter solar cells are shown in Figures 4 and 5. The “partial” buried emitter solar cell has the following output parameters:

V_{oc} :	642 mV
J_{sc} :	41.0 mA/cm^2 ,
FF:	79.8 %
Efficiency:	21.0%

Despite the fact that about 50% of total cell area is covered by buried emitter regions, i.e. areas of n^+p^+ overlap, we achieve very high fill factors.

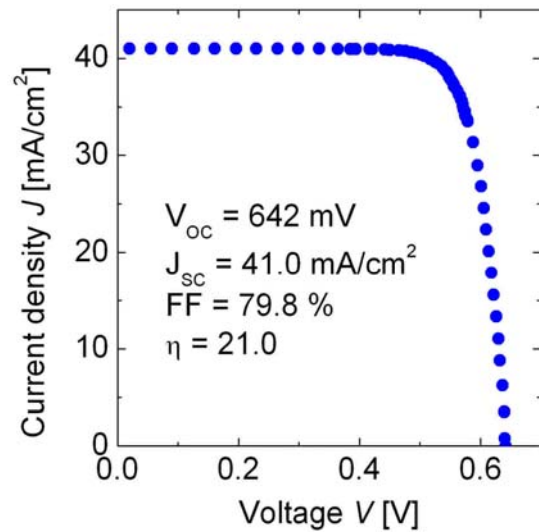


Figure 4: IV characteristics of our present “partial” buried emitter solar cell. The short circuit current of 41.0 mA/cm^2 demonstrates the excellent current collection properties of the large area boron emitter.

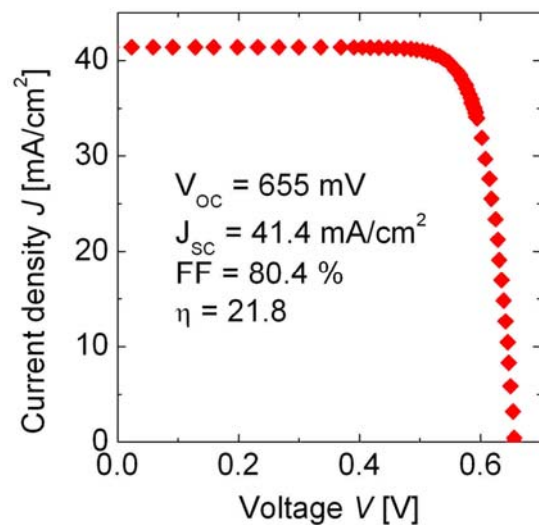


Figure 5: IV characteristics of our present “full area” buried emitter solar cell. The high fill factor demonstrates both, the good insulating properties of the dielectric insulation layer and the absence of excessive trap-assisted tunneling.

In particular, the I - V -characteristics do not show any shunting-type behaviour. This is a strong indication that trap-assisted tunneling is not a significant loss mechanism for these devices [5]. As can be seen from the very high short circuit current density the large area boron emitter shows excellent current collection.

The current-voltage characteristics of our second solar cell structure, the “full area” buried emitter concept, is shown in Figure 5. With this type of solar cell we have presently achieved the following solar cell parameters:

V_{OC} :	655 mV
J_{SC} :	41.4 mA/cm ² ,
FF:	80.4 %
Efficiency:	21.8%.

Corresponding to the large area emitter coverage we obtain very high short-circuit currents for the “full area” buried emitter solar cell.

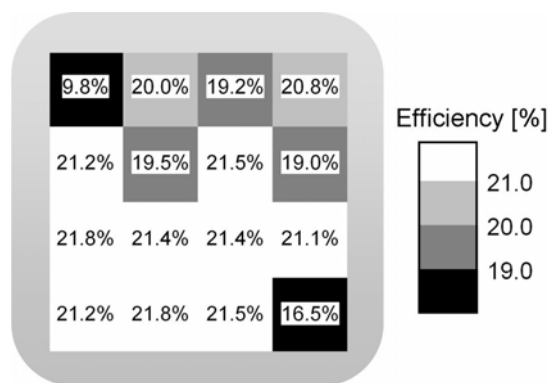


Figure 6: Distribution of efficiencies for our present “full area” buried emitter solar cells on the processing wafer. The devices were fabricated on a $12.5 \times 12.5 \text{ cm}^2$ pseudo square wafer and cut into single solar cells ($2.5 \times 2.5 \text{ cm}^2$, active area: 3.97 cm^2) after processing.

The solar cells presented were processed on $12.5 \times 12.5 \text{ cm}^2$ pseudo square wafers. To evaluate the robustness of the solar cell structures we give an overview of the cell efficiencies for the “full area” buried emitter solar cell. As can be seen from Figure 6, over 50% of the devices exhibit efficiencies over 21%. These data indicate that this solar cell concept can produce high solar cell efficiencies not only on small area devices but also demonstrates potential for larger area high efficiency solar cells.

4 SUMMARY

We provide experimental results for two variants of buried emitter solar cells featuring a large area n^+p^+ -overlap: The “partial” buried emitter solar cell and the “full area” buried emitter solar cell. Both types of solar cells feature a large-area emitter coverage that can be close to 100% of the total cell area. The experimental realisations of the buried emitter solar cells reported here, have an emitter coverage of about 80%.

The “partial” buried emitter solar cell combines high current collection with an efficient insulation of emitter

region from the base metallization by an n^+ -surface layer. For this solar cell structure we achieve a short-circuit current density of 41.0 mA/cm^2 and a solar cell efficiency of 21.0%.

In the “full area” buried emitter solar cell the regions of n^+p^+ overlap are extended to almost the entire emitter area. This rear side design offers an efficient passivation for boron emitters by an oxidized n^+ -type surface layer. Our experimentally realised solar cells have a maximum efficiency of 21.8%.

4 ACKNOWLEDGEMENTS

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6 REFERENCES

- [1] N.-P. Harder patent pending
- [2] N.-P. Harder, V. Mertens, R. Brendel, *phys. stat. sol. (RRL)*, 2(4), 148-150 (2008).
- [3] N.-P. Harder, V. Mertens, R. Brendel, *Prog. Photovolt.* 17, 253-263 (2009).
- [4] J. Benick, O. Schulz-Wittmann, J. Schön, S. W. Glunz, *phys. stat. sol. (RRL)* 2, No. 4, 145 (2008).
- [5] G.A.M. Hurkx, D.B.M. Klaassen, and M.P.G. Knauers, *IEEE Trans. Electron Devices*, ED-39, 331-338 (1992).