

LBIC MEASUREMENTS ON LOW COST BACK CONTACT SOLAR CELLS

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ABSTRACT: New crystalline silicon cell concepts like low cost back contact cells have a more complicated structure than appropriate for a simple device modelling. In order to increase the cell efficiency it is important to learn as much as possible about the inner mechanism of a solar cell. LBIC-measurements (Light Beam Induced Current) enable basic studies on the internal driving forces of a cell combined with a high spatial resolution. In the following we will present detailed LBIC investigations on low cost back contact cells. Both external contacts are located at the cell rear. The front emitter is connected through small laser drilled holes to the rear emitter contact (**E**mitter **W**rap **T**hrough). Despite the small absorption length of $30\ \mu\text{m}$ at $905\ \text{nm}$ the rear side structure of the cell is clearly visible in an LBIC scan. Especially the differences in the carrier collection probability of rear emitter and rear base contact can be investigated.
Keywords: back contact - 1: LBIC - 2: EWT - 3

1 INTRODUCTION:

The EWT cell design is very appropriate for low cost material with diffusion lengths smaller than the device thickness [1, 2, 3]. Emitter and base area at the cell rear are separated by a PECVD silicon nitride which acts as a diffusion barrier (Fig. 1). Contacts are screen printed, the hole process is a low cost process.

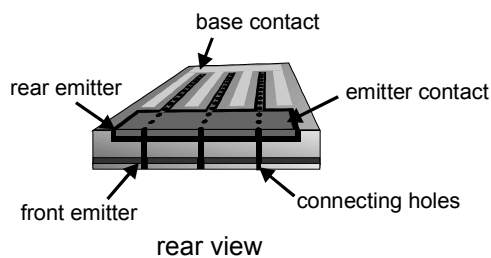


Figure 1: schematic view of the EWT cell design (rear view). Small laser drilled holes connect the front side emitter and the rear side emitter contact. Emitter and base region at the cell rear are separated by a diffusion barrier of silicon nitride.

The difference in the collection probability of rear emitter- and base regions is very well visible in an LBIC-scan. Depending on the base metallization paste the collection probability compared to the rear emitter differs. To a certain extend local shunts can be detected. The high spatial resolution allows an investigation of the effect of the vertical junction at the emitter covered edge of the connecting holes.

2 METHOD:

LBIC measurements were performed using diode lasers of 833 nm and 905 nm wavelength combined by a fiber optic coupler (Fig. 2). Using a fiber optic system a minimum spot size of $5\ \mu\text{m}$ FWHM is achieved. In order to operate the solar cells under low injection conditions, optical power of the lasers is reduced to $1.5\ \mu\text{W}$. Two lock-in amplifiers analyse I_{sc} and the reflection of the samples.

The electrical noise of the whole system is below 1 %, so rear contact effects on $300\ \mu\text{m}$ solar cells can be detected even with a $905\ \text{nm}$ laser (penetration depth $30\ \mu\text{m}$). For extended LBIC studies, a dedicated software with several display modes and numerical export functions was developed.

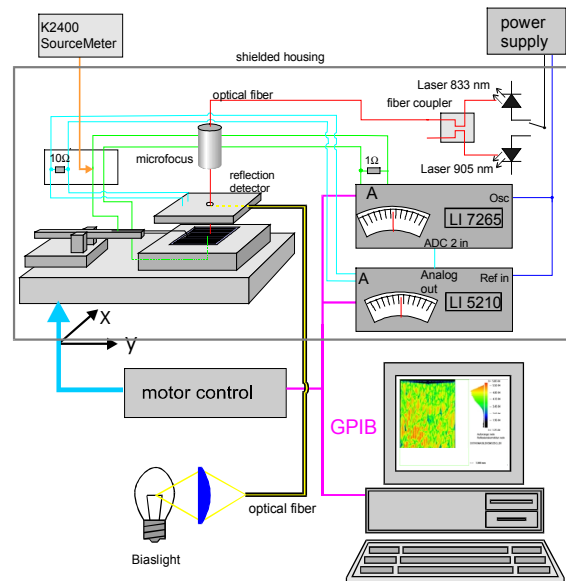


Figure 2: Experimental set-up of the LBIC system. The sample, the laser diodes and the lock-in amplifiers are placed in a double-shielded housing to prevent external interference. Optionally, a Keithly SourceMeter is used to operate the sample at a bias voltage from $-1\ \text{V}$ to $+1\ \text{V}$ and white biaslight may be applied. Motor controls allow a minimum step size of $0,5\ \mu\text{m}$. The computer controls the laser power and laser frequency, records the data from the lock-in amplifiers and places orders for moving the xy-tables after a successful point measurement.

3 RESULTS:

3.1 Rear side emitter

The enhanced collecting probability of the rear side emitter is very well visible in an LBIC scan. The base diffusion length L_{base} of the utilized Cz-silicon was determined to about 250 μm with spectral response measurements and fitting with IQE-1D. So L_{base} is smaller than the device width. The rear emitter increases considerably the collection probability of a minority charge generated in the base. Even at a wavelength of 905 nm, which corresponds to a penetration depth of 30 μm the difference in the LBIC signal between rear emitter and rear base region is about 15 % (Fig. 3).

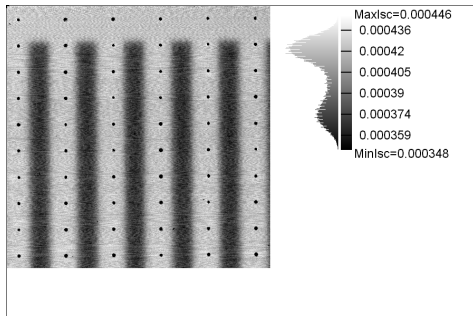


Figure 3: LBIC scan of a part of an EWT-cell. The increased carrier collection probability at the rear emitter area is clearly visible (front illumination at 905 nm). Despite an absorption length of only 30 μm and a cell thickness of 300 μm the rear side p- and n-structure causes a variation of about 15 % in the measured current.

3.2 Base metallization pastes

Two different base metallization pastes have been investigated. Paste A is less rich in Al content than paste B, but consists of a distinct fraction of silver which contributes to a low series resistance [4]. For conventionally processed cells with completely metallized rear surface J_{sc} is increased by about 9 % using paste B instead of paste A (Table I). This increase is due to an improved back surface field as well as to gettering properties of the aluminum. In addition the reflection of paste B is reduced in the long wavelength range (Fig. 5). Simulations with DESSISTM coincide with this increase in J_{sc} for paste B due to a substantial back surface field (BSF).

Table I: Short circuit current in experiment and simulation comparing conventionally processed cells and EWT cells with different base metallisation. Paste B has a higher Al fraction and therefore provides a better BSF. For unadulterated results no ARC was applied (Cz-Si 25 cm^2).

	I_{sc} [mA/cm^2] experiment	I_{sc} [mA/cm^2] simulation
conv. cell, paste A	21.1	21.5
conv. cell, paste B	23.0	22.8
EWT, A	24.3	23.8
EWT, B	24.6	25.1

For EWT-cells the difference in the LBIC signal between rear side emitter and base regions metallized with paste B is only half as high as for paste A. This is indicated in a line-scan through the cell (Fig. 4) where the laser induced current is plotted as a cut vertical to the fingers. In the middle of the base fingers metallized with paste B (Al-rich) even a small increase in the current can be detected

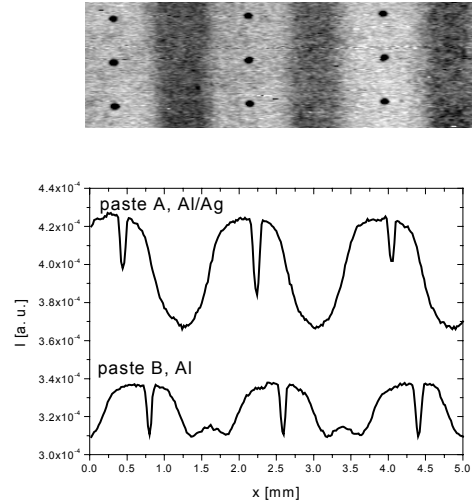


Figure 4: Cut through 2 different EWT-cells. The higher collection probability at the rear emitter area is visible. The dip at the tops is due to the connecting holes which naturally don't contribute to the current generation. The difference between rear n and p region is less distinct at the cell metallized with paste B (Al). For this cell even a small increase in the middle of the base finger can be observed. Current values can not be compared absolutely, so one graph was shifted for better analysis.

Reflection measurements of cells which are completely metallized at the rear by paste A or paste B differ only by 0.8 % at 905 nm, so that an optical effect can be excluded (Fig. 5).

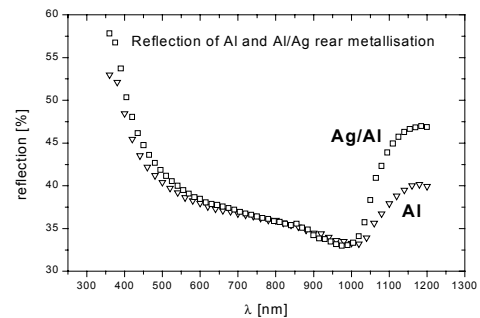


Figure 5: Reflection measurements of cells covered completely by paste A resp. paste B at the rear show only a very slight difference of 0.8 % in the reflection at 905 nm. So it can be excluded that the differences in the LBIC signal between n and p region arise from an optical effect (no ARC).

3.3 Shunt detection

Due to the spatial resolution of the LBIC-method locally restricted shunt resistances can be localised [4]. The laser generated current is reduced via the local shunt and the inevitable series resistance in the grid. Fig. 6 shows an example of a complete EWT cell where shunt resistances can be seen in the left upper and lower corner and on the first left upper finger.

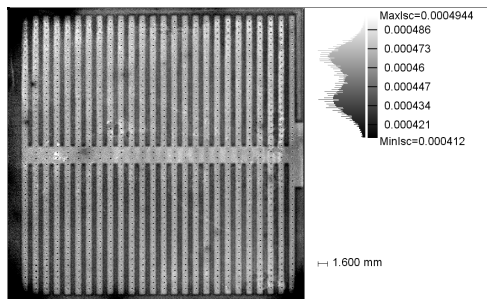


Figure 6: Shunt localisation via LBIC, the darker spots on the first upper left finger can be identified with some smearing of the base metallization paste at the cell rear.

3.4 Vertical emitter

The high spatial resolution (step size 0.5 μm) of the LBIC method allows an investigation of the effect of the vertical junction at the emitter covered edge of the connecting holes. Due to the width of the laser beam, part of the light is lost through the hole. Taking this into account a corrected signal was calculated (Fig. 7). The corrected signal is neither reduced by increased damaging nor increased by the vertical junction compared to the emitter area away from the hole.

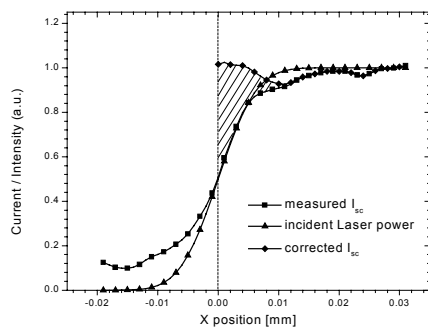


Figure 7: High resolution LBIC-linescan at the edge of a connecting hole. The corrected curve shows the same signal at the edge of the hole as at the other emitter area. So there's neither reduction by increased damaging due to the laser drilling, nor enhanced collection due to the vertical junction.

4 SUMMARY

The advantageous effect of the rear emitter in a low cost back contact cell (EWT-concept) was shown with an LBIC-mapping. Even under front illumination at a

wavelength of 905 nm the rear emitter increases the LBIC signal by 15 % compared to the base region. This increase depends also on the kind of base metallization paste: if using an Al-rich paste the increase reaches only 9 %.

The vertical junction at the edge of the holes does neither increase the LBIC signal nor does a possible damaging by the laser drilling reduce the signal.

5 ACKNOWLEDGEMENT

This work was supported by the German BMWI within the project „Neuartige kristalline Silizium Solarzellen“ and within the ACE designs project of the European Commission under contract number JOR3-CT98-0269.

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