Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 124 (2017) 161–165

Energy Procedia

www.elsevier.com/locate/procedia

7th International Conference on Silicon Photovoltaics, SiliconPV 2017

CELLO photo-impedance-spectroscopy on PERC solar cells: Separation of bulk and rear surface defects

Andreas Schütt*

CELLOscan GbR, Gravelottestr. 5, 24116 Kiel, Germany

Abstract

Thin PERC type solar cells are wait in the wings to take over from Al-BSF solar cells. However, the impact of (bulk) material and rear surface (contact) quality to the efficiency is found to be quite hard to measure on a processed solar cell. We will show with this paper that CELLO (solar **cel**l **lo**cal characterization) photo-impedance-spectroscopy measurements are capable of separating bulk from rear side effects on locally resolved maps. This allows cell manufacturers to better understand, analyze and control processing parameters and related defects like parasitic shunting, rear contact formation and passivation, gettering and other forms of degradation. As a result cell efficiencies and revenues can be boosted.

Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.

Keywords: bulk lifetime; rear surfacerecombinationvelocity, gettering, degradation, series resistance

1. Introduction

It is well known that PERC solar cells with a rear surface passivation scheme and local Al-contacts is a hot candidate to replace the standard of full area Al-BSF solar cell, because PERC solar cells promise potentially higher conversion efficiencies. However, there are still a lot of material- and process issues to solve, before the full potential of PERC solar cells can be harnessed: A better understanding and control of gettering and degradation of multi- and mono-material will be as essential then the formation of the rear Al-contact.

* Corresponding author. Tel.: +49(0)1737600436.
E-mail address: asc@celloscan.de

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.
10.1016/j.egypro.2017.09.318

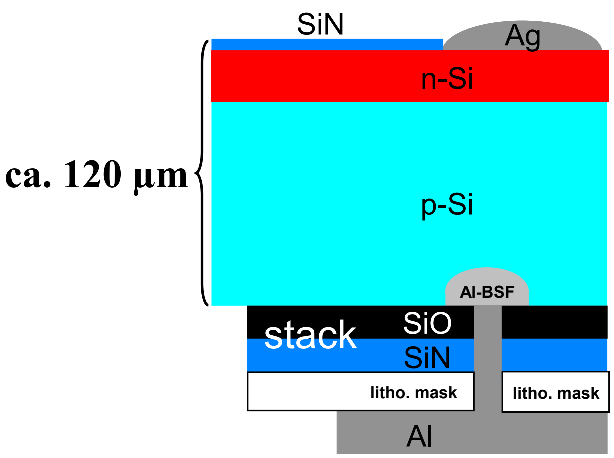
The solar **cell lo**cal characterization technique (CELLO) is a tool that yields local parameter maps of solar cell parameters that allow to identify local losses and thus helps technicians, engineers and scientists to optimize solar cell materials and processes.

E.g. CELLO photo-impedance measurements of Al-BSF cells helped to optimize the co-firing process and thus gettering, contact formation (series resistance R_{SER}), and Al-BSF formation (rear surface recombination velocity Sb) [1].

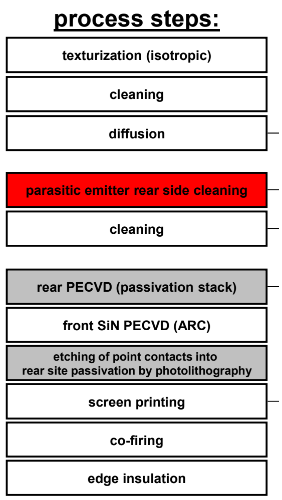
For PERC cells, this separation is especially challenging, since injection level dependencies of the bulk lifetime and S_B, and the parasitic shunting [2] make locally resolved measurements difficult. In this paper we will present the successful separation of bulk lifetime and S_B influences of PERC solar cells with the CELLO photo-impedance technique.

2. PERC solar cell sample

The cells investigated in this study originate from several neighboring 150 µm thick multicrystalline wafers that went through an industrial-like cell process in a research line [3, 2, 4]. Fig. 1 a) displays the schematic of the cell architecture and Fig 1 b) shows the corresponding processing sequence steps. Key processes steps are: After the PSG-etching step, a back-etching step of the parasitic emitter follows to remove 3-6µm material on the rear side. Then both sides were chemically cleaned, an ARC-SiN was deposited on the front side and a SiO/SiN-stack on the rear side via a PECVD process. A photolithographic step with subsequent etching forms contact holes at the rear. These holes were filled with Al-paste by a simple screenprinting and co-firing process. After all etching steps the final thickness of the cells is around 120 µm.



a)



b)

Fig. 1. PERC cell architecture a) and processing scheme b)[4].

3. CELLO photo-impedance-spectroscopy

3.1. Set-up and measurement details

The CELLO set-up is described in full detail elsewhere [4, 5]. In short: Three different lasers are intensity-modulated by four different frequencies and the amplitude and phase shift of the linear response is recorded, while a potentiostat keeps short circuit conditions. The set-up allows a laser focus range from 50 µm to 2000 µm, and various gray-filters for adjusting the local light injection density. As global illumination halogen lamps with a power of 1/3 sun are also available.

3.2. Data preparation and fit

For a typical measurement, 48 maps were recorded and processed. After a "current-correction" routine that compensates for small none-linearities of the set voltage of the potentiostat the final 24 maps are obtained. These amplitude and phase shift maps were fit to a model called "tSRC3*3"that is explained in detail elsewhere [5]. Global fit parameter are set: Minority diffusion coefficient D=28 cm²/s (a common value for multicrystalline-material) and 120 µm wafer thickness. The resulting maps of the local fit parameters are minority carrier lifetime τ (µs), diffusion length L (µm), rear surface recombination velocity S_B (cm/s), and for the three lasers the $R_{SER}C$-time constants (ns).

4. Results and discussion

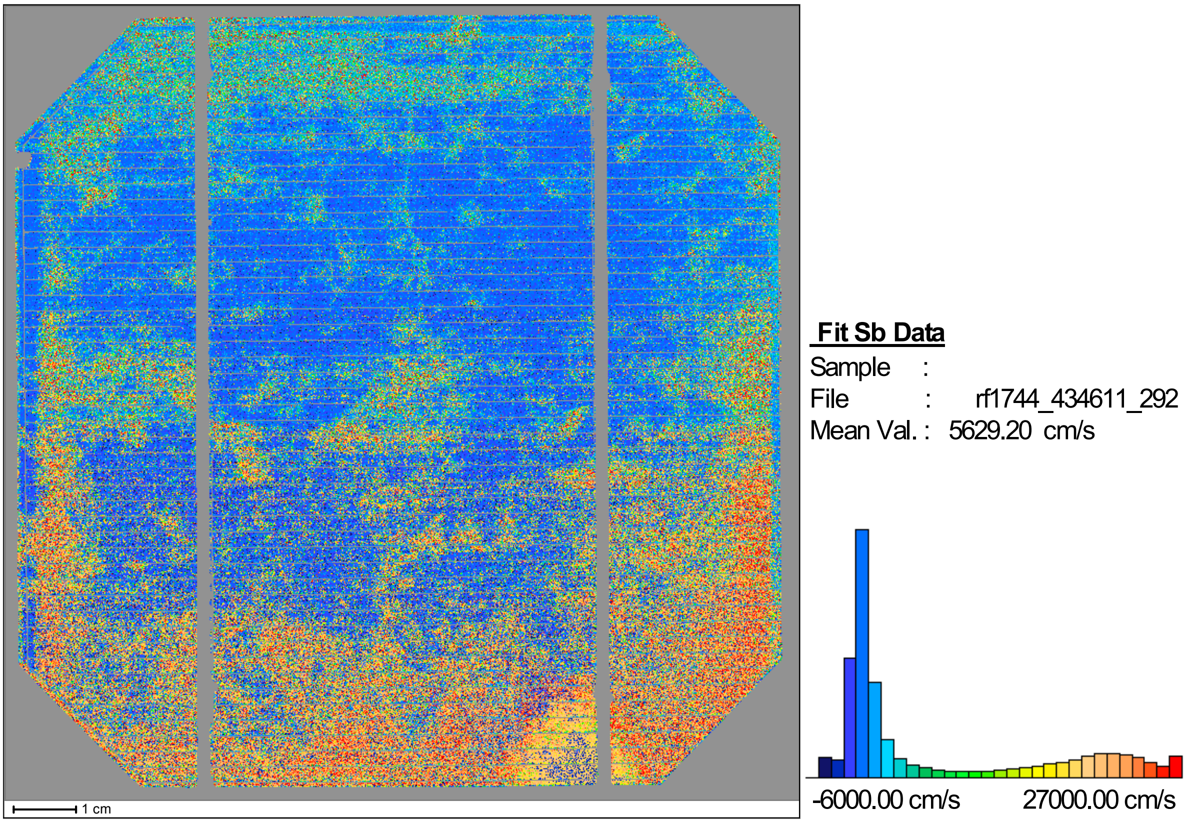


Fig. 2. S_B -map.

Here an overview of the findings. L and S_B maps were found to be very suited to separate between bulk and rear side surface effects. As visible in Fig. 2: Large areas show an excellent S_B. The negative sign of good S_B areas is just attributed to the current flow under the measurement conditions. But tendency is valid: the smaller S_B the better. The L-map in Fig. 3 is quite homogeneous and reflects nicely the expected L value of around 120 µm that is similar to the mean value of the map. Note: a good separation of series resistance effects with the $R_{SER}C$ -map of Fig. 4 is possible, reflecting R_{SER} inhomogeneities due to not optimal co-firing conditions.

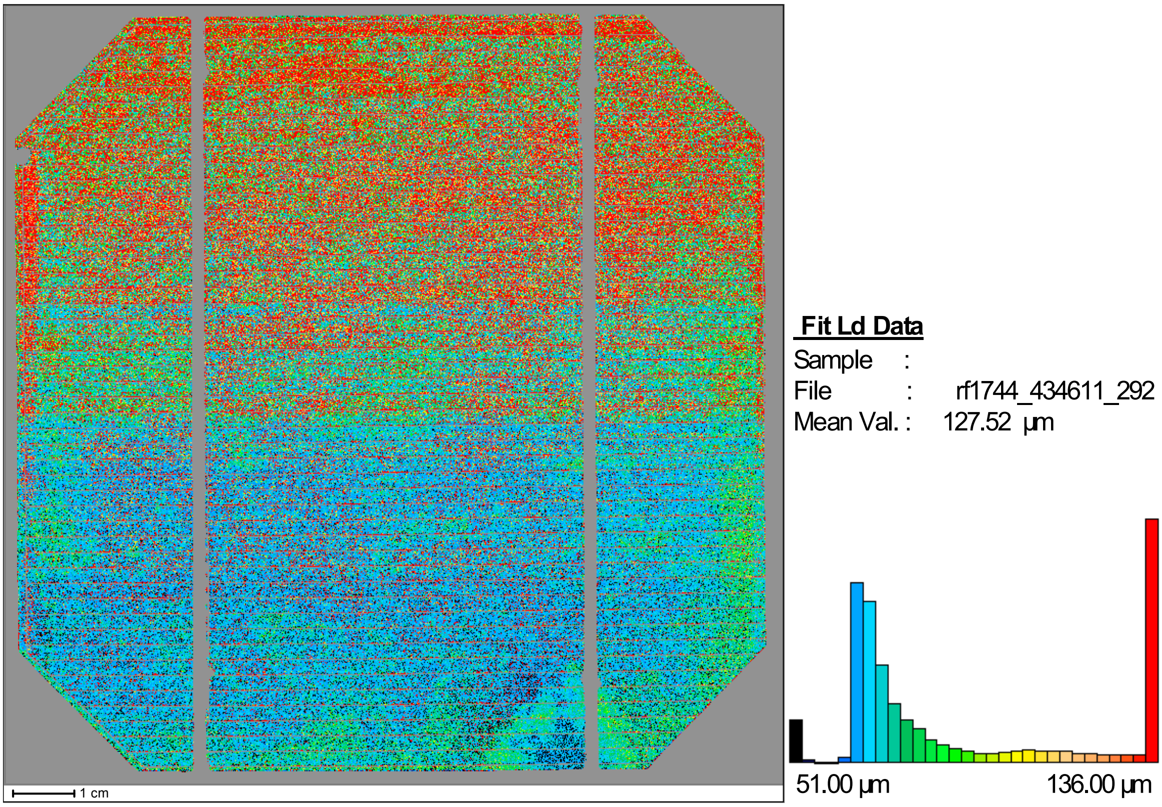

1 cm
Fit Ld Data
Sample :
File : rf1744_434611_292
Mean Val. : 127.52 µm
51.00 µm
136.00 µm

Fig. 3. *L*-map.

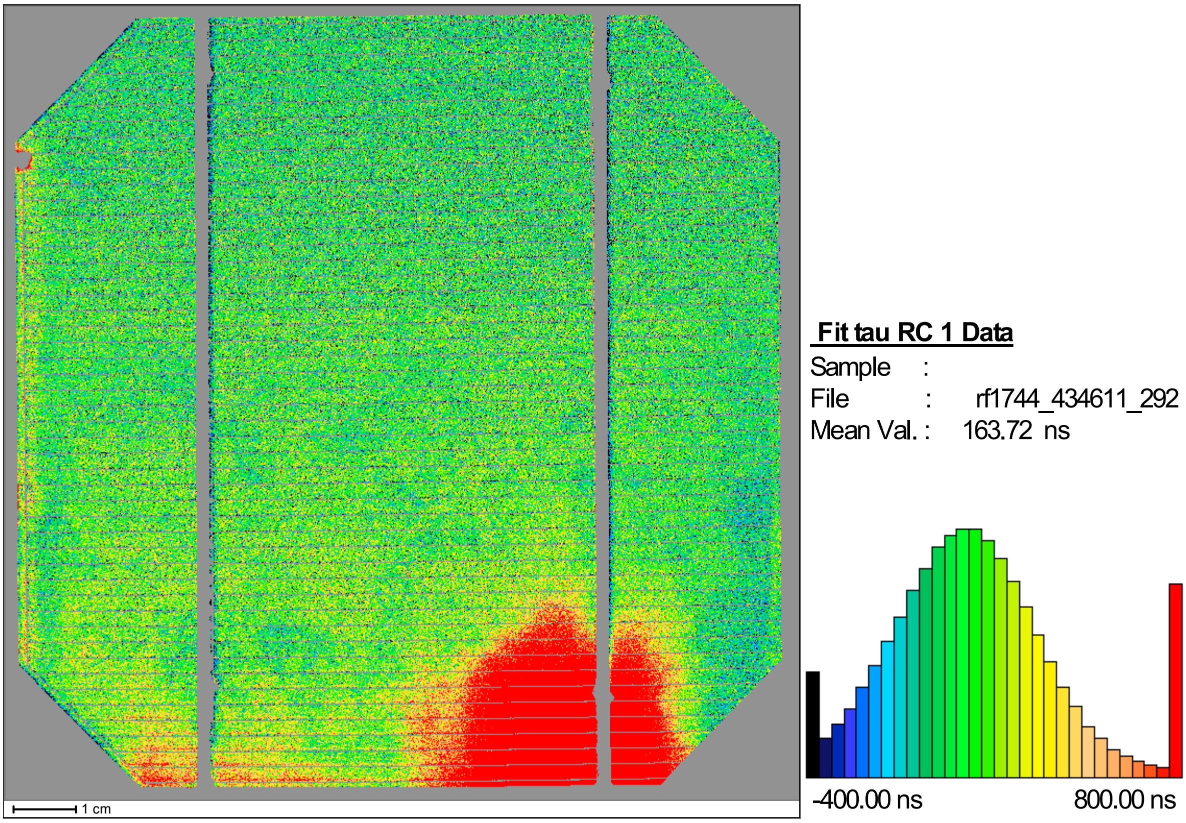


Fig. 4. $R_{SER}C$ -map of the IR laser (830nm).

5. Importance and outlook

The CELLO set-up allows the variation of various measurement parameters. That allows to modify the measurements in such a way that local dependencies can be resolved. As simple example, the photocurrent map with and without global illumination show the local impact of parasitic shunting. Additionally, adjustable conditions of the local injection level (change in perturbation frequency, focus size and grey filters) are necessary for the description and analysis of typical PERC “challenges”, i.e. effects like injection level dependencies of τ and S_B, and effects on L like any kind of degradation and gettering.

6. References

[1] Schütt A, Carstensen J, Wagner JM, Föll H, Local characterization of co-firing-induced inhomogeneities of conventional mc-Si solar cells. 28th EUPVSEC, contribution 2CV.3.13, Paris (2013).

[2] Schütt A, Carstensen J, Föll H, Keipert-Colberg S, Borchert D. CELLO analysis of solar cells with silicon oxide/silicon nitride rear side passivation: parasitic shunting, surface recombination, and series resistance as rear side influences. 27th EUPVSEC 2BV.5.14, Frankfurt (2012).

[3] Keipert-Colberg S, Barkmann N, Streich C, Schütt A, Suwito D, Schäfer P, Müller S,. Borchert D. Investigation of PECVD silicon oxide/silicon nitride passivation system concerning process influences. 26th EUPVSEC, contribution 2BV.3.61, Hamburg (2011).

[4] Schütt A. Ortsaufgelöste Charakterisierung in der Photovoltaik mit der CELLO-Technik (Solar Cell Local Characteriszation), Dissertation, CAU Kiel, 2015.

[5] Wagner JM, Schütt A, Carstensen J, Föll H. Series resistance contribution of majority carriers in CELLO impedance analysis: Influence of wafer thickness variation. Solar Energy Mater. Solar Cells 146, 129 (2016).