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Published in:
Data in Brief

DOI:
10.1016/j.dib.2016.12.031

Published: 01/04/2017

Document Version
Publisher's PDF, also known as Version of record

Please cite the original version:
Huang, H., Lv, J., Bao, Y., Xuan, R., Sun, S., Sneck, S., Li, S., Modanese, C., Savin, H., Wang, A., & Zhao, J. (2017). Data of the recombination loss mechanisms analysis on Al_2O_3 PERC cell using PC1D and PC2D simulations. *Data in Brief*, *11*, 27-31. https://doi.org/10.1016/j.dib.2016.12.031

Data in Brief 11 (2017) 27–31

Contents lists available at ScienceDirect

Data in Brief

journal homepage: www.elsevier.com/locate/dib

Data Article

Data of the recombination loss mechanisms analysis on Al_2O_3 PERC cell using PC1D and PC2D simulations

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ARTICLE INFO

Article history:
Received 18 November 2016
Received in revised form
13 December 2016
Accepted 15 December 2016
Available online 21 December 2016

ABSTRACT

This data article is related to our recently published article (‘20.8% industrial PERC solar cell: ALD Al_2O_3 rear surface passivation, efficiency loss mechanisms analysis and roadmap to 24%’, Huang et al., 2017 [1]) where we have presented a systematic evaluation of the overall cell processing and a cost-efficient industrial roadmap for PERC cells. Aside from the information already presented in Huang et al., 2017 [1], here we provide data related to Sectin 3 in Huang et al., 2017 [1] concerning the analysis of the recombination losses' mechanisms by PC1D V5.9 and PC2D simulations (Clugston and Basore, 1997, Basore and Cabanas-Holmen, 2011, Cabanas-Holmen and Basore, 2012 and Cabanas-Holmen and Basore, 2012.) [2–5] on our current industrial Al_2O_3 PERC cell. The data include: i) PC2D simulations on J_{02}, ii) the calculation of series resistance and back surface recombination velocity (BSRV) on the rear side metallization of PERC cell for the case of a point contact, and iii) the PC1D simulation on the cumulative photo-generation and recombination along the distance from the front surface. Finally, the roadmap of the solar cell efficiency for an industrial PERC

DOI of original article: http://dx.doi.org/10.1016/j.solmat.2016.11.018

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http://dx.doi.org/10.1016/j.dib.2016.12.031

technology up to 24% is presented, with the aim of providing a potential guideline for industrial researchers.

Specifications Table

Subject area	Physics
More specific subject area	Silicon solar cells, device simulations
Type of data	Figures, simulation graph
How data was acquired	Series resistance of the Si solar cell and surface recombination velocity were calculated based on Fisher's and Plagwitz's model [6–9]. Cell performances were simulated by PC1D V5.9 or PC2D. Cumulative photo-generation and recombination along the distance from the front surface were simulated by PC1D V5.9. Roadmap to solar cell efficiency was based on the analysis in Ref. [1].
Data format	Raw and analyzed
Experimental factors	–
Experimental features	The basic parameters settings for the recombination loss mechanisms analysis by PC1D and PC2D are described in Table 8 and Fig. 21 in Ref. [1].
Data source location	(1) China Sunergy, No.123. Focheng West Road, Jiangning Zone, Nanjing, Jiangsu, 211100, China (2) Aalto University Department of Micro and Nanosciences, Tietotie 3, 02150 Espoo, Finland
Data accessibility	Data is within this article and in Ref. [1]

Value of the data

- The concurrent application of both PC1D Version 5.9 and PC2D simulations to industrial PERC cells provides a deeper insight into the optimization of the processing parameters.
- The PC1D simulations on the cumulative photo-generation and recombination as a function of the distance from the front Si surface give an indication for the front surface passivation levels required for an optimized performance of the PERC cell.
- The roadmap for cell efficiency to 24% is calculated from measured industrial performances and can therefore provide a valuable reference base for further development and optimization in the production processes.
- The data presented is collected from an extensive database from industrial PERC cells, and can thus be used as a benchmark for industrial performances.

1. Data

The dataset of this article provides additional information to Ref. [1]. PERC cell performances are reported in Table 1, the recombination as a function of the distance from both front and rear side is reported in Figs. 1, 2. The roadmap to PERC technology to 24% at an industrial level is shown in Table 2.

Table 1
Cell performances of the current industrial PERC cell as a function of J_{02}.

J_{02} (A cm^{-2})	V_{oc} (mV)	J_{sc} (A cm^{-2})	FF (%)	η_{cell} (%)
1.0E-09	661.5	38.62	80.98%	20.69%
1.0E-10	661.7	38.62	81.11%	20.73%
1.0E-11	661.8	38.62	81.12%	20.73%

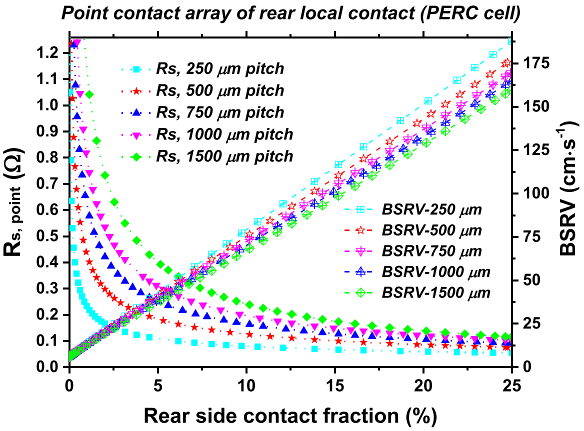

Fig. 1. R_s and BSRV (point contact array) as a function of rear contact fraction and pitch.

2. Experimental design, materials and methods

PC2D simulations were performed to confirm the effect of J_{02} on the current industrial PERC cell performance, and the results are reported in Table 1. The detailed parameters settings can be found in Table 8 and Fig. 21 in Ref. [1]. The data show that the cell efficiency will gain 0.04% with J_{02} decreasing from $1 \cdot 10^{-9}$ to $1 \cdot 10^{-10}$ A cm^{-2}, which is mainly related to the gain in fill factor (0.13%).

The series resistance (R_s) and the back surface recombination velocity (BSRV) and their relation with rear side metallization geometry were calculated for a point contact array geometry for the rear local contacts, as a function of the rear contact fraction and pitch (Fig. 1). The calculations are based on Fisher's and Plagwitz's model [6–9]. The data show that rear point or segment local contact arrays give lower total series resistance and thus lower BSRV with lower contact fraction.

A representative example of the cumulative photo-generation and recombination as a function of the distance from the Si front surface is shown in Fig. 2. The data were simulated by PC1D Version 5.9 and it can be seen that the cumulative photo-generation profiles among different front n^+ emitters with different front surface recombination velocities (FSRV) coincide. Note that the data can also be used to calculate the collection efficiency along the depth from the front Si surface, as the collection efficiency is the ratio between the cumulative recombination and cumulative photo-generation.

A roadmap for industrial PERC cell technology to achieve efficiency up to 24% is shown in Table 2, which is based on the simulation data presented above and on the results on cell efficiency loss mechanisms presented in Ref. [1]. In particular, the recombination losses analysis was carried out with PC1D and PC2D simulations.

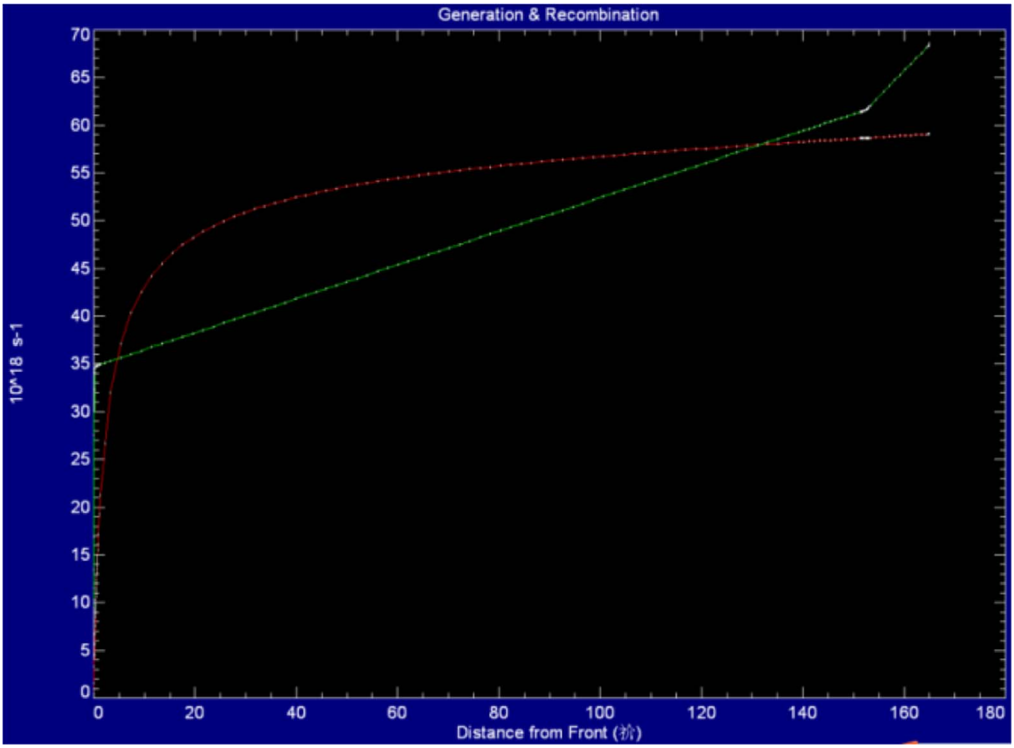

Fig. 2. The cumulative photo-generation and recombination as a function of the distance along the Si from the front surface (Erfc (error function complement) profile "2": surface n^+ concentration $= 1.0 \cdot 10^{20}$ at cm^{-3}, X_j: ~0.4 μm, $R_\square$: 90 Ω/□, FSRV $= 5000\ cm\ s^{-1}$, BSRV $= 25\ cm\ s^{-1}$).

Table 2
Roadmap for industrial PERC technology up to 24%.

No.	Research topic	Key factor	New cell process or design	Challenge
1	Current	NA	NA	NA
2	Front emitter and passivation	To decrease $J_{01,\ front\ n^+\ emitter\ region}$ to $\leq 5 \cdot 10^{-14}\ A\ cm^{-2}$	More advanced emitter process to tailor emitter profile such as ion implantation	★★★☆
3	Front metallization engineering	To decrease $J_{01,\ front\ contact\ region}$ to $\leq 2.5 \cdot 10^{-13}\ A\ cm^{-2}$	Screen printing Ag paste development, metallization pattern optimization (multi-busbar or free busbar schemes)	★★☆
4	LBSF+Rear local metal contact recombination	$J_{01,\ rear\ local\ metallization}$ down to $\leq 3 \times 10^{-13}\ A\ cm^{-2}$	To continue R&D on screen-printed local BSF Al paste	★★
5	Rear side metallization pattern optimization	Metallization array dimension decreased, keeping fraction unchanged or a suitable value	Laser ablation and Al paste development	★★☆
6	Light trapping	Front and rear optical structure optimization	Texture process, ARC process	★★★☆
7	Bulk diffusion length improvement	To increase bulk lifetime to ≥ 400 μs (diffusion length ≥ 1100 μm)	To improve Si ingot technique	★★★
8	Rear side passivation	To decrease $J_{01,\ rear\ passivation\ region}$ down to $\leq 5 \times 10^{-15}\ A\ cm^{-2}$	Al_2O_3 process optimization	★★★☆
9	Cell structure update from PERC to PERL	$J_{01,\_rear\ local\ metallization} < 1 \times 10^{-13}\ A\ cm^{-2}$, rear side p^{++} local BSF	PVD Al process, local p^{++} heavy boron doping process (laser doping/ inkjet print doping/ selective ion implantation doping)	NA

Acknowledgements

The research work is based on the China-Finland International R&D Cooperation project "Improved cost-efficiency in crystalline silicon solar cells through Atomic Layer Deposited Al_2O_3", Project No. 40843 (Chinese Project No. S2013GR0622), 2013.05-2016.05. The work has been partially funded through the European Research Council under the European Union's FP7 Programme ERC Grant Agreement No. 307315.

Transparency document. Supporting material

Transparency data associated with this paper can be found in the online version at http://dx.doi.org/10.1016/j.dib.2016.12.031.

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