Rijksdienst voor Ondernemend Nederland

Public final report Antilope

Project details

- Project number: TEID215011
- Project title: Advanced n-Pasha – bifacial passivated contact cells
- Project manager and participants:
  Project manager: Tempress Systems BV
  Participants:
  - Levitech BV
  - Meyer Burger (Netherlands) BV
  - ECN Solar Energy
  - Eindhoven University of Technology
  - Delft University of Technology
  - M4Si BV
  - Yingli Energy (China)
  - ~~Jinko Solar (China)~~
- Project duration: 2 years: 01.01.2016 – 31.12.2017
- Date of publication public report: 30 April 2018

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Project summary

Combining passivated contacts with a bifacial front and rear contacted solar cell is an attractive way to improve the efficiency of existing (bifacial) n-type cells that are now in (pilot) production. In the Antilope project the partners have researched and developed a new, bifacial, n-type cell architecture based on passivated contacts and with a target efficiency of 22.5%. This novel cell concept has been named PERPoly and is designed for industrial size, 6 inch crystalline silicon wafers. A cross section of the PERPoly cell is shown in Figure 1.

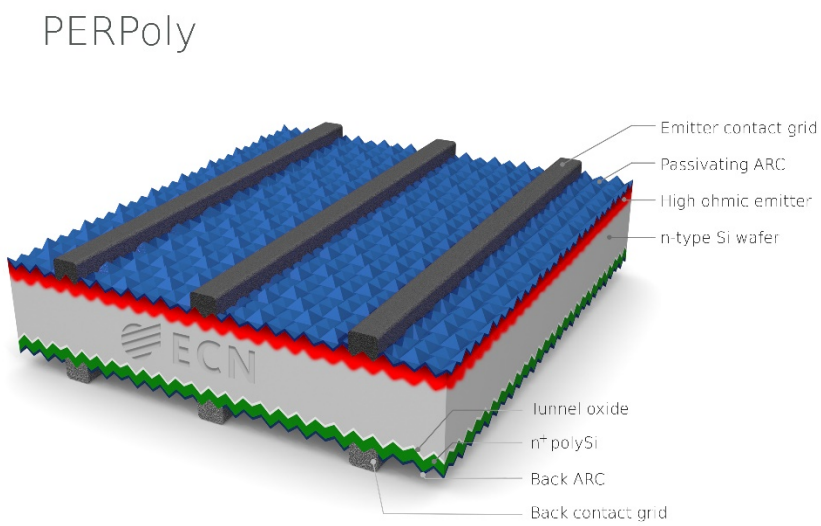

Figure 1: The PERPoly solar cell that has been designed and developed in the Antilope project

Boundary conditions for the PERPoly cell processes that have been researched in the Antilope project are low cost, reduction in silver consumption and readiness to implement into industry. To assess the latter, the cell concept has been evaluated in a pilot production line at Yingli Solar in China.

The main objective of the Antilope project was to develop a new solar cell architecture (and processes to make this cell) based on passivated contacts at the rear with a target efficiency of 22.5%. The process flow should be based on Dutch equipment and (partly proprietary) processes. Boundary conditions for these processes were low cost, reduction in silver consumption and readiness to implement into industry.

Sub-goals, specific to parts of the cell design were:

- A diffused, selective boron emitter on the front side with $J_{0\_front} < 25 – 30$ fA/cm2 enabling $V_{oc} > 700$ mV
- Passivated contacts at the rear using tunneling oxide and a n^+ poly silicon layer, with $J_{0\_rear} < 10$ fA/cm^2 enabling implied $V_{oc} > 720$ mV
- Reduced metal coverage to around 5% at both front and rear, which in combination with adjusted poly-Si layer between the rear contacts, will enable a bifacial cell with rear response around 95% of the front.
- Front J_{sc} above 40 mA/cm^2
- Reduction in total silver consumption to below 100 mg Ag per cell, while still obtaining a FF above 80%

The WP structure of the project and its high level targets are summarized in Figure 2.

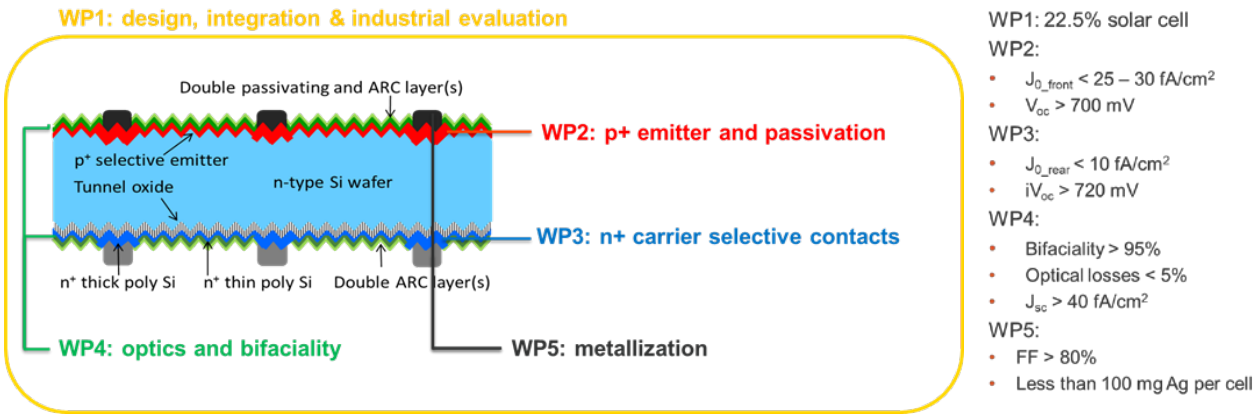

Figure 2: The workpackage structure and high level goals of the Antilope project

In the project, all partners worked on various and different aspects of the PERPoly solar cell: The technical universities TU/e and TUD focused on the fundamental aspects of surface and contact passivation and optical processes and their interactions on cell and module level. The equipment manufacturers Tempress, Levitech and RRBV developed and optimized tools for specific processing of selective emitters, poly-Si passivated contacts, passivation and optical dielectric layers. For front and rear metallization, a novel, simultaneous n+ and p+ nickel plating process has been evaluated by ECN and M4SiBV. ECN has designed and integrated the new processes into the final PERPoly cell concept. The cell manufacturer Yingli has evaluated the developed processing steps and assessed challenges and bottlenecks for the industrialization.

Project results, highlights and bottlenecks

With respect to the technical results, highlights that can be mentioned are:

- Increased understanding of underlying physics of the n+ polysilicon passivating contact and the dependency of the passivating contact properties on process parameters and solar cell design
- Improved passivation of high ohmic emitters
- Investigation and understanding of the optics on cell and module level
- Reduced Ag consumption using stencil print and busbarless cells.
- The implementation of the PERPoly cells in the pilot line at Yingli and in the SiCC baseline process at ECN shows the industrial feasibility of the cell concept that has been developed in the Antilope project.

Work has been done and reports have been made on all 16 deliverables of the project, 13 of which have been fully met. All 9 milestones in the project plan have been achieved. Finally the 22.5% cell efficiency has not been obtained, although 22.1% has been reached by TUD on 9cm^2 polyIBC samples. At ECN, 21.6% has been reached on large size (6 inch) industrial cells, still an increase of 0.8% from the starting point at the beginning of the project (20.8%). The main limiting factor remained the front side (contact) recombination, but unfortunately the consortium has so far not been successful in finding a good solution for boron selective emitters to mitigate these losses. (although three different approaches have been tried in the course of the Antilope project). And although results of the initial plating test to form simultaneous NiSi contacts on n+ and p+ doped surfaces were quite promising, implementation on cell level was finally not successful in this project.

With respect to the objectives of the project, most of them have been obtained:

WP1: 22.5% solar cell

- 21.6% achieved at ECN (D1.2), 22.1% achieved at the TUD (D4.3). The path towards >22% PERPoly cells has been defined.

WP2: Front emitter and its passivation

- J_{0_front} < 25 – 30 fA/cm^2 has been reached (D2.3)

- V_{oc} > 700 mV: iV_{oc} > 700 mV achieved (D2.3)

WP3: Rear passivating contact
- J_{0_rear} < 10 fA/cm^2 has been reached (D3.2, D3.3)
- iV_{oc} > 720 mV achieved (D.3.3)

WP4: Optics and bifaciality
- Bifaciality > 95%: 88% has been reached (D4.2)
- Optical losses < 5% achieved (D4.2)
- J_{sc} > 40 mA/cm^2: J_{sc} = 39.8 mA/cm^2 has been reached (D1.2 and D1.4)

WP5: Metallization
- FF > 80% reached (D5.1 and D1.4)
- Less than 100 mg Ag per cell: <60 mg on front achieved with BB-less cells (D5.1)

Only one major change has been made during the execution of the project: After the initial agreement in the proposal phase and signing of the project agreement, Jinko Solar did not respond to any attempts of communication from Tempress or ECN anymore. This may have had to do with a change of management at Jinko Solar, and leave of the person who originally arranged the contact between Jinko Solar and the project partners. After several attempts, finally the partners decided to end the collaboration with Jinko Solar. There was already a very good and close collaboration with Yingli Solar in the project, and they could take over the tasks on evaluation of industrial feasibility that were originally foreseen for Jinko. The fact that Jinko Solar was no longer a project partner did not have any effects on the outcome or results of the project.

Contribution to program targets

This project was part of the TKI Urban Energy program line 1, and contributed to its target to increase the efficiency of PV products (towards >24% module efficiency), and its target to reduce the overall costs of electricity generation by PV (reduce cost/Wp). The higher efficiencies achieved for the bifacial PERPoly cells in this project will not only result in lower cost/Wp but also in a (much) lower levelized costs of electricity (LCoE). Using the bifaciality of these cells and bifacial modules the production of energy can be further increased by > 20%, especially in locations such as the NL with a lot of diffuse light. This will result in a higher kWh/Wp for reduced LCOE in the Netherlands.

The Antilope project has brought the PERPoly solar cell one step closer to industrialization, and its TRL has progressed from about 4 to 6. During the Antilope project the process flow has been further refined and found to be much more stable (in efficiency) than the n-Pasha process flow for different crystalline Si material qualities as well as base doping. This means that the process will have a smaller spread in efficiency due to material variation, and probably will also have a smaller run-to-run variation

Spin-off

Further finetuning and optimization of the PERPoly process up to TRL8 will be done by Tempress, Levitech and ECN (together with Veco for stencil metallization) within the granted POLARIS project in the Hernieuwbare Energy Regeling. In this project, the standard homogeneous boron emitter will be optimized, and target efficiency is 22%. POLARIS will start in May 2018.
Further developments and research on a selective boron emitter or its alternative, passivated front p+ contacts is ongoing by Tempress and ECN in the TKI toeslag project Beacon. Beacon has started in September 2017.

The results of the consortium have been presented at various conferences, workshops and solar-tradeshows and drawn international attention. Especially the fact that the PERPoly solar cell process is a simple upgrade from existing n-PERT processing with fire-through screen printing, makes industrial implementation relatively straightforward and many (Asian) manufacturers already expressed their intention to do so.
Conference contributions typically also resulted in publications. A list of these is given in paragraph 2.5

Publications

Date	Title	Authors	Conference / medium
22-03-2018	poly-silicon carrier selective contacts for high efficient c-Si IBC solar cells	G. Yang, P. Guo, P. P. Moya, G. Limodio, A. Weeber, O. Isabella, M. Zeman	SiliconPV 2018 (paper and persentation)
28-11-2017	Ion-implanted carrier-selective passivating contacts for high-efficiency c-Si solar cells	G. Limodio, G. Yang, H. Ge, Y. Zhang, A. W. Weeber, O. Isabella, M. Zeman	MRS-fall, 2017 (paper and Presentation)
13-11-2017	Poly-Si(O)x passivating contacts for minimizing parasitic absorption in IBC cells	G. Yang, P. P. Moya, Y. Zhang, A. Weeber, O. Isabella, M. Zeman	IEEE PVSEC-27, 2017 (Abstract and Presentation)
08-11-2017	Highly transparent carrier-selective passivating contacts based on poly-SiOx for c-Si solar cells	R. Santbergen, G. Yang, P. Procel, A. Weeber, O. Isabella and M. Zeman	OSA-congress 2017 (Paper and Presentation)
23-10-2017	Contact recombination of polySiLICON passivating contact with fire-through screen-printed metallization	Maciej K. Stodolny, Hande Ciftpinar, Bart Geerligs and Ingrid Romijn	7th Workshop on Metallization & Interconnection for Crystalline Silicon Solar Cells
28-09-2017	Material properties of LPCVD Processed n-type Poly-Si Passivating Contacts and Application in PERPoly Industrial Bifacial Solar Cells	Maciej K. Stodolny, John Anker, Bart L.J. Geerligs, Gaby J.M. Janssen, Bas W.H. van de Loo, Jimmy Melskens, Rudi Santbergen, Olindo Isabella, Jurriaan Schmitz, Martijn Lenes, Jan-Marc Luchies, Wilhelmus M.M. Kessels, Ingrid Romijn	EU PVSEC 2017 (paper & presentation)
28-09-2017	Ultrathin silicon oxide: what makes it suitable as interlayer in passivating contacts for silicon solar cells?	J. Melskens, J. Palmans, S. Karwal, G. Yang, M. Stodolny, I.G. Romijn, G.J.M. Janssen, M. Creatore, W.M.M. Kessels	EU PVSEC 2017 (oral presentation)
27-09-2017	Opimized IBC c-Si solar cells based on poly-Si(Ox) carrier-selective passivating contacts	G. Yang, P. P. Moya, Y. Zhang, G. Limodio, A. Weeber, O. Isabella, M. Zeman	Asian PVSEC 27 (paper & presentation)
24-09-2017	Information session on industrialization of the PERPoly cell concept, with three different presentations. Audience consisted of all major (tier1) solar cell manufacturing companies	Gaby Janssen (theory of passivating contacts), Maciej Stodolny (contact recombination in industrial passivating contacts), Ingrid Romijn (industrialization of PERPoly	IRP Day ECN

23-09-2017	Material properties of LPCVD processed n-type polysilicon passivating contacts and its application in PERPoly industrial bifacial solar cells	Maciej K. Stodolny, John Anker, Bart L.J. Geerligs, Gaby J.M. Janssen, Bas W.H. van de Loo, Jimmy Melskens, Rudi Santbergen, Olindo Isabella, Jurriaan Schmitz, Martijn Lenes, Jan-Marc Luchies, Wilhelmus M.M. Kessels, Ingrid Romijn	Proceedings of the 7th International Conference on Silicon Photovoltaics, SiliconPV 2017, Energy Procedia 124 (2017) 635–642
03-04-2017	poly-silicon carrier selective contacts for high efficient c-Si IBC solar cells	G. Yang, P. P. Moya, Y. Zhang, A. Weeber, O. Isabella, M. Zeman	SiliconPV 2017 (persentation)
27-10-2016	Bifacial aspects of industrial n-Pasha solar cells	Kees Tool	PVSEC-26 Singapore, 27 October 2016 (presentation)
27-10-2016	An energy yield model for bifacial photovoltaic systems	Gaby Janssen, Anna Carr, Koen de Groot, Bas van Aken, Ingrid Romijn	PVSEC-26 Singapore, 27 October 2016 (presentation)
30-06-2016	Atomic-layer deposited passivation schemes for c-Si solar cells	B.W.H. van de Loo, B. Macco, J. Melskens, M.A. Verheijen, W.M.M. Kessels	Proceedings of the 43rd IEEE Photovoltaic Specialists Conference, Portland, OR, USA, pp. 3655-3660, 2016
20-06-2016	n-type Polysilicon passivating contacts for industrial bifacial n-PERT cells	M.K. Stodolny, M. Lenes, Y. Wu, G.J.M. Janssen, I. Romijn	EU PVSEC 2016 (paper & presentation)
07-03-2016	Extraction of recombination properties from lifetime data	Gaby Janssen, Yu Wu, Kees Tool, Ingrid Romijn, Andreas Fell	Silicon PV Conference, 7-9 March 2016 (paper & poster)

Patents

ECN has requested two patents on the integration of the cell concepts. Patent number are available upon request.

Extra copies of this report

Digital copies of this report can be requested via the below mentioned contact persons.

Contact for more information

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Rijksdienst voor Ondernemend Nederland

Subsidy

"Het project is uitgevoerd met subsidie van het Ministerie van Economische Zaken, Nationale regelingen EZ-subsidies, Topsector Energie uitgevoerd door Rijksdienst voor Ondernemend Nederland."