Rijksdienst voor Ondernemend Nederland

Openbaar eindrapport *BOBtandem*

Gegevens project

- Projectnummer: SOL18003
- **Subsity received from 'Ministerie van Economische Zaken en Klimaat'**
- Projecttitel: Band Offset Barrier Three Terminal perovskite on silicon high efficiency Tandem Solar Cell (BOBtandem)
- Penvoerder en medeaanvragers:
    - **Dr. James Connolly (GeePs CentraleSupelec/CNRS, France)**
    - Prof. Mohammad Nazeeruddin (EPFL, Switzerland)
    - Dr. Philippe Baranek (EDF R&D department, France)
    - Dr. Valentin Milailetchi, International Solar Energy Research Center Konstanz, Germany)
    - Dr. Olindo Isabella (Delft University of Technology, Netherlands)
- Projectperiode: 10/2019 – 09/2022
- Publicatiedatum openbaar rapport: 11/2022

Samenvatting van uitgangspunten, doelstelling en samenwerkende partijen

Background: Tandem solar cells can exceed the 30% efficiency barrier that forms a limit for conventional single junction devices. In recent years, especially the perovskite / silicon tandem has shown promising results. Most research thus far has focused on two- or four-terminal tandem designs. A less common approach is the three-terminal (3T) design, where the tandem has one contact at the front and two interdigitated contacts at the rear. Although this 3T tandem design is slightly more complex, it is a monolithic device that does not require current matching. Therefore it combines the advantages of the two- and four terminal designs into a single device.

Objectives: In the BOBtandem project the aim is to optimize the design of a 3T perovskite / silicon tandem by numerical simulations and then fabricate and test the optimized high efficiency 3T tandem design experimentally. An important challenge is the design of the band offset selective barrier, that connects top and bottom cell.

Collaborating parties:

Numerical simulations are performed in sequence. Atomistic simulations for perovskite material optimization are performed by **EDF R&D department** (FR). The obtained opto-electrical material properties are then used for the 3T tandem device simulations performed by **TU Delft** (NL) and **GeePs CentraleSupelec** (FR). Based on the optimized device characteristics, the annual energy yield is then calculated by TU Delft. To experimentally demonstrate the high efficiency 3T tandem, the project combines the perovskite top cell from **Ecole Polytechnique Federale de Lausanne** (CH) with the silicon bottom cell with interdigitated back contact from **International Solar Energy Research Center Konstanz** (DE).

Beschrijving van de behaalde resultaten, de knelpunten en het perspectief voor toepassing

- WP1: Coordination
- WP2: Silicon IBC subcell
  - The silicon bottom cell, based on the 'ZEBRA' design with interdigitated back contacts, was optimized for tandem applications. The conventional front-size texture was removed to create a flat deposition substrate for the perovskite sub-cell.
- WP3: Perovskite PSC subcell
  - The perovskite solar cell was first optimized as a single junction device and then methods were developed to enable deposition onto the silicon bottom cell.
- WP4: Tandem integration
  - The band offset selective barrier was designed and its charge selectiveness was tested experimentally. Top cell, bottom cell and band offset barrier were then finally integrated into a single device. Tandem devices were demonstrated experimentally and routes for further improvement were identified. The tandem showed surprisingly good performance at low-light conditions.
- WP5: Modelling
  - Atomistic simulation of perovskite materials were performed using density functional theory (DFT). Device optimization was performed by integrating the optical models developed by TU Delft with the advanced three-dimensional electrical models in Silvaco Atlas software. Simulations of complete PV modules identified potential issues with the interconnection of 3T cells, and developed interconnection schemes to mitigate these.
- WP6: Characterization
  - The opto-electrical properties of all device materials were measured and the current-voltage characteristic of the fabricated 3T perovskite / silicon tandems were measured, both a standard test conditions and at low-light conditions.

Beschrijving van de bijdrage van het project aan de doelstellingen van de regeling (duurzame energiehuishouding, versterking van de kennispositie)

This project has contributed to more knowledge and insight in three-terminal tandem device physics. Based on this, models have been developed for simulating the performance of tandem PV material, devices and even systems. These models can also be used in future projects for the optimization of other types of tandem. A 3T tandem demonstrator has been developed that could serve as the starting point for upscaling this new technology.

Spin off binnen en buiten de sector

Although the initial aim was outdoor applications, the excellent performance of the 3T tandem under low-light conditions might enable the use of this device in indoor applications as well.

Overzicht van openbare publicaties over het project en waar deze te vinden of te verkrijgen zijn

1. M.R. Vogt et al., *Introducing a comprehensive physics-based framework for tandem and other PV systems*, Solar Energy Material and Solar Cells **247** (2022) 111944. https://doi-org.tudelft.idm.oclc.org/10.1016/j.solmat.2022.111944
2. R. Santbergen et al., Ray-optics study of gentle non-conformal texture morphologies for perovskite/silicon tandems, Optics Express 30 (2022) 5608-5617. https://doi-org.tudelft.idm.oclc.org/10.1364/OE.448545

Meer exemplaren van dit rapport

Meer exemplaren van dit rapport kunnen digitaal worden verkregen via het hieronder genoemde contact.

Contact voor meer informatie

Meer informatie over dit project kan verkregen worden via:

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