Area 1: Crystalline and Thin Film Silicon PV

PROGRESS WITH POLYMER/SILICON HETEROJUNCTION SOLAR CELLS

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The passivated emitter and rear cell (PERC) concept is widely believed to become the dominant photovoltaic technology in the coming years. The key feature of the PERC technology compared to today's standard solar cell concept (Al-BSF) is the outstandingly low rear surface recombination velocity, which is typically realized by deposition of a dielectric layer stack of AlO_x/SiN_y, laser contact opening (LCO) and full-area screen-printing plus firing of Al paste. In our alternative approach (the so-called 'BackPEDOT' concept [1]), we implement the hole-conducting polymer PEDOT:PSS into an industrial-type solar cell fabrication sequence. The highly conductive PEDOT:PSS layer serves as effective rear surface passivation layer (as demonstrated by very low measured J_0 values < 50 fA/cm^2 [2]), thus, making the AlO_x/SiN_y rear surface passivation stack as well as the LCO step both obsolete, leading to a simplification of the overall process sequence. Figure 1 shows a photograph of the screen-printed front surface of our BackPEDOT solar cell and a container filled with the blue PEDOT:PSS liquid dispersion which is spin-coated or slot-die coated onto the solar cell rear. Importantly, our BackPEDOT cell process has the potential of being directly implementable into the existing Al-BSF production lines without the need of buying expensive additional production tools such as AlO_x/SiN_y deposition and laser systems.

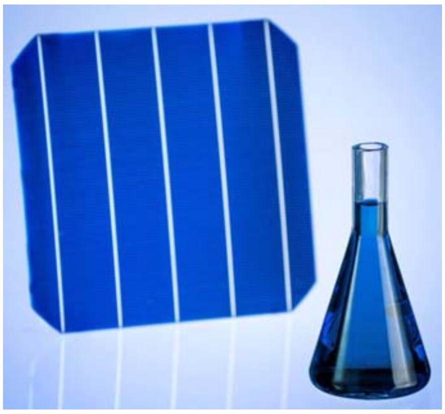

Figure 1: 20.2% efficient BackPEDOT solar cell fabricated on a large-area Cz-Si wafer (15.6 × 15.6 cm²) with a 5-busbar screen-printed front Ag grid. The container is filled with the non-toxic aqueous dispersion of PEDOT:PSS (~98% water), which is suitable for deposition methods based on aqueous solutions such as spin-coating, spray-coating or slot-die-coating.

In the present work, we apply the front surface of an industrial-type PERC solar cell with a phosphorus-diffused emitter and a 5-busbar screen-printed front metal grid [3]. As base material industrial-type Czochralski-grown 15.6 × 15.6 cm² silicon wafers are used. Since the firing sequence is made without a metal layer on the rear surface, we vary the set-peak temperature from 850°C to 890°C. The optimal set-peak temperature is determined to be 870°C, resulting in an average solar cell efficiency of (19.3 ± 0.5)%. Our best BackPEDOT solar cell achieves a short-circuit current density J_{sc} of 38.7 mA/cm² and an open-circuit voltage V_{oc} of 656 mV. Based on external quantum efficiency measurements we determine a maximum rear surface recombination velocity $S_{rear} < 100$ cm/s for the PEDOT:PSS-passivated rear surface of the cell. The low measured series resistance R_s of only 0.63 Ωcm² proves the excellent carrier transport across the PEDOT:PSS/c-Si junction, leading to high fill factors *FF* of 79.5% and a champion efficiency of 20.2%. Our simulations show that efficiencies well above 21% are achievable using the BackPEDOT approach.

[1] D. Zielke, A. Pazidis, F. Werner and J. Schmidt, *Organic-silicon heterojunction solar cells on n-type silicon wafers: The BackPEDOT concept*, Sol. Energy Mater. Sol. Cells **131**, 110-116 (2014).
[2] D. Zielke, C. Niehaves, W. Lövenich, A. Elschner, M. Hörteis and J. Schmidt, *Organic-silicon solar cells exceeding 20% efficiency*, Energy Procedia **77**, 331-339 (2015).
[3] T. Dullweber and J. Schmidt, *Industrial silicon solar cells applying the passivated emitter and rear cell (PERC) concept – a review*, IEEE J. Photovolt. **6**, 1366 (2016).