4th International Symposium on
Energy Challenges & Mechanics
- working on small scales

11-13 August 2015
Aberdeen, Scotland, UK

Engineering of the window layer for optimum performance of thin film silicon solar cells

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Accepted for publication on 15th April 2015

The abundance of non-toxic ZnO in comparison to In and Sn makes it a more economic and environmentally friendly option than indium tin oxide (ITO) and tin oxide (SnO_2) as a contact for thin film silicon solar cells. However, despite its high conductivity, it produces a Schottky barrier with a-Si:H(p) and a-SiC:H(p). This Schottky contact is often ignored in solar cell modeling, regardless of its detrimental impact upon power conversion. Our Current – Voltage – Temperature measurements of diode structures reveal the Schottky barrier height of the ZnO/a-Si:H(p) interface to be higher than 0.7 eV, whereas an ohmic contact can be achieved for a ZnO/μc-Si:H(p) structure. However, the use of μc-Si:H(p) compromises the open circuit voltage (V_{OC}) of the cell due to a misalignment of energy bands with the intrinsic region.

Optimization of the window layer is achieved by 1) facilitating tunneling transport mechanism through the Schottky barrier via an adjustment of the boron doping concentration of a-Si:H(p) and by 2) modifying the ZnO/a-Si:H(p) interface to a ZnO/μc-Si:H(p)/a-Si:H(p) structure. The effect of tunneling for barrier heights greater than 0.5 eV is demonstrated in our circuit model with the inclusion of the Schottky junction ideality factor n_2, whereas barrier heights lower than 0.5 eV do not impact the solar cell performance. Our interface engineering validated via TCAD simulations shows that a 4nm/11nm thick μc-Si:H(p)/a-Si:H(p) window layer can improve the 1 sun A.M. 1.5 initial conversion efficiency by 9% with a typical ZnO/a-Si:H(p) window layer. This μc-Si:H(p)/a-Si:H(p) mixed window layer allows to create an ohmic contact with ZnO without compromising the contact with the intrinsic region. The results obtained here can be extended to other solar cell technologies with Schottky contacts and represent a great opportunity for the fabrication of efficient heterojunction solar cells without the need of contacts with indium.

Keywords: Amorphous silicon, Schottky diode, thin film solar cells, tunneling transport.