Materials Science & Engineering Thesis Defense

Understanding Solar Cell Contacts through Simulations

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Abstract

The maximum theoretical efficiency of a terrestrial non-concentrated silicon solar cell is 29.4%, as obtained from detailed balance analysis. Over 90% of the current silicon photovoltaics market is based on solar cells with diffused junctions (Al-BSF, PERC, PERL, etc.), which are limited in performance by increased non-radiative recombination in the doped regions. This limitation can be overcome through the use of passivating contacts, which prevent recombination at the absorber interfaces while providing the selectivity to efficiently separate the charge carriers generated in the absorber. This thesis aims at developing an understanding of how the material properties of the contact affect device performance through simulations. The partial specific contact resistance framework developed by Onno et al. aims to link material behavior to device performance specifically at open circuit. In this thesis, the framework is expanded to other operating points of a device, leading to a model for calculating the partial contact resistances at any current flow. The error in calculating these resistances is irrelevant to device performance resulting in an error in calculating fill factor from resistances below 0.1% when the fill factors of the cell are above 70%, i.e., for cells with good passivation and selectivity. Further, silicon heterojunction (SHJ) and tunnel-oxide based solar cells are simulated in 1D finite-difference modeling package AFORS-HET. The effects of material property changes on device performance are investigated using novel contact materials like Al0.8Ga0.2As (hole contact for SHJ) and ITO (electron contact for tunnel-oxide cells). While changing the bandgap and electron affinity of the contact affect the height of the Schottky barrier and hence contact resistivity, increasing the doping of the contact will increase its selectivity. In the case of ITO, the contact needs to have a work function below 4.2 eV to be electron selective, which suggests that other low work function TCOs (like AZO) will be more applicable as alternative dopant-free electron contacts. The AFORS-HET model also shows that buried doped regions arising from boron diffusion in the absorber can damage passivation and decrease the open circuit voltage of the device.

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