Area 2: Thin-Film Compound Semiconductor PV

NUMERICAL MODELING OF SHADING-INDUCED BREAKDOWN IN CIGS PHOTOVOLTAIC DEVICES

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Shading-induced failure is a critical issue for the wide-scale commercial adoption of low-cost Copper Indium Gallium Selenium (CIGS) photovoltaic (PV) devices [1]. Full or partial shading of cells in a module results in a reverse voltage bias scenario and junction breakdown which occurs at weak spots with relatively low breakdown voltage. The nature of those weak spots and reverse breakdown in general for CIGS devices remains poorly understood because they exhibit unique characteristics in terms of the dependence of the breakdown voltage on light intensity, photon energy, buffer layer material, and temperature [2]. For example, our recent work [3] indicates that some of the most prevalent reverse breakdown charge transport mechanisms, such as impact ionization, band-to-band tunneling, and trap-assisted tunneling with Poole-Frenkel enhancement cannot quantitatively describe the available data.

In this work, a theoretical analysis of two potential breakdown mechanisms is undertaken. Optimum channel hopping conduction and electric field enhancement at metallic protrusions within the p-n junction (junction shunts). Analytical and numerical methods are employed. The numerical methods cover the spatial scales of micron-scale diodes and meter-scale modules; examples of each are shown in Figures 1 and 2. Micron-scale diodes are modeled with 2D semiconductor device simulation using the finite element method customized with the software COMSOL Multiphysics®. Coupled electro-thermal, time-dependent modeling is used at the module scale to investigate the effects of shading, weak spots, and thermal runaway. This module simulation methodology was recently demonstrated and will be employed in this work to study various shading and operational scenarios. The ultimate goals of this work are to better understand the basic physics of charge transport in CIGS junctions, the effects of shading on module failure, and to provide suggestions for mitigation measures and improved reliability.

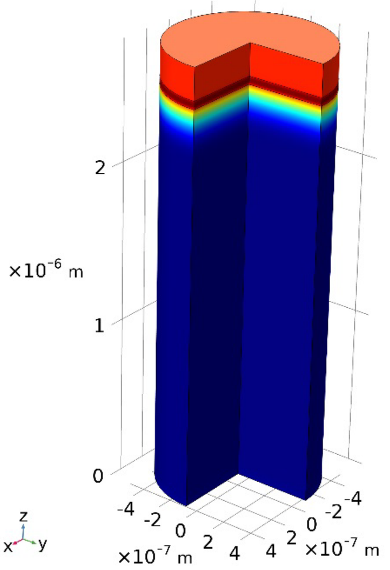

Figure 1: Micron-scale simulation of CIGS device showing electric potential distribution in Volts. Bottom layer is CIGS (2.5 μm), middle layer CdS (50 nm) and top layer ZnO (200 nm).

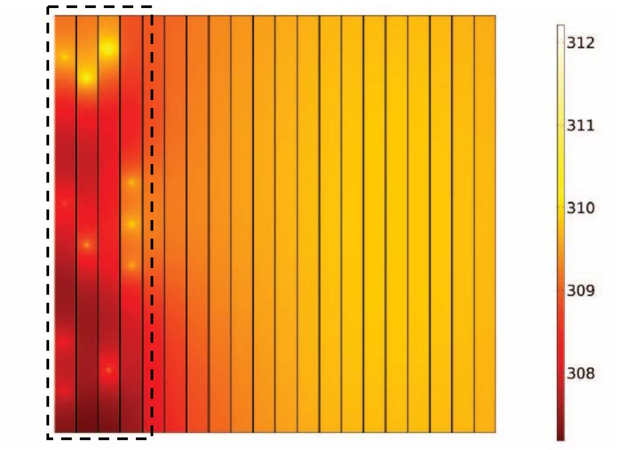

Figure 2: CIGS mini-module (10 x 10 cm^2) simulation of temperature distribution (K). Dashed region is shaded with rest under 1-sun light. Weak spots exhibit higher temperature due to Joule heat.

[1] I. Kozinsky, B. Bob, and R. Jones-Albertus, MRS Advances, FirstView, 1 (2016).
[2] M. Nardone and S. Dahal, MRS Advances 1 (2017).
[3] P. Szaniawski, J. Lindahl, T. Törndahl, U. Zimmermann, and M. Edoff, Thin Solid Films **535**, 326 (2013).