Role of Contacts in Capacitance Measurements of Solar Cells

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Abstract

The electronic properties of low cost, thin-film solar cells are complicated by the non-ideal nature of the semiconductor layers. Typically, the fundamental electronic properties of such materials are evaluated using current-voltage and capacitance-voltage measurements. However, in these devices, it is common for the back contact to be non-ohmic. We are exploring the impact of such a back contact on the outcome of standard capacitance-based characterization techniques. We compare computer models of capacitance response with measurements of simple model electronic circuits, and of solar cell devices.

Introduction

A Solar Cell is a photo-active diode which converts light into electrical energy. With multi-crystalline cells, ideal characteristics are no longer observed, complicating the solar cell model.

Figure 1: Solar Cells on TJ Day Hall of Linfield College, McMinnville Campus

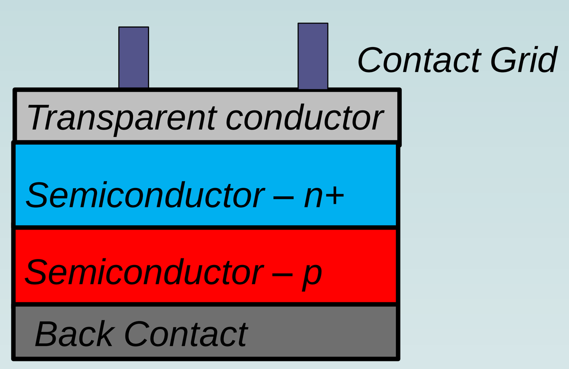


Figure 2: layers in a typical solar cell.

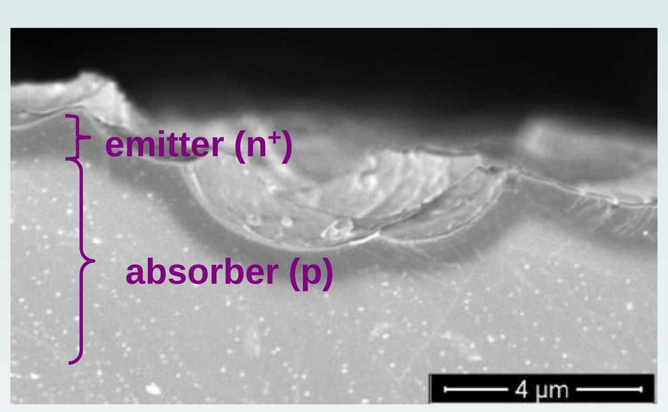


Figure 3: SEM cross-section of a single crystalline silicon solar cell, showing secondary electron contrast (note that the surface is textured to enhance light absorption.)

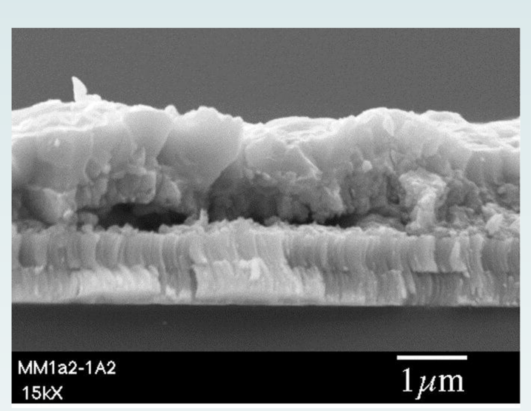


Figure 4: Cross-section of a thin film Cu(In,Ga)Se_2 solar cell. Reproduced from [2].

PN Junction

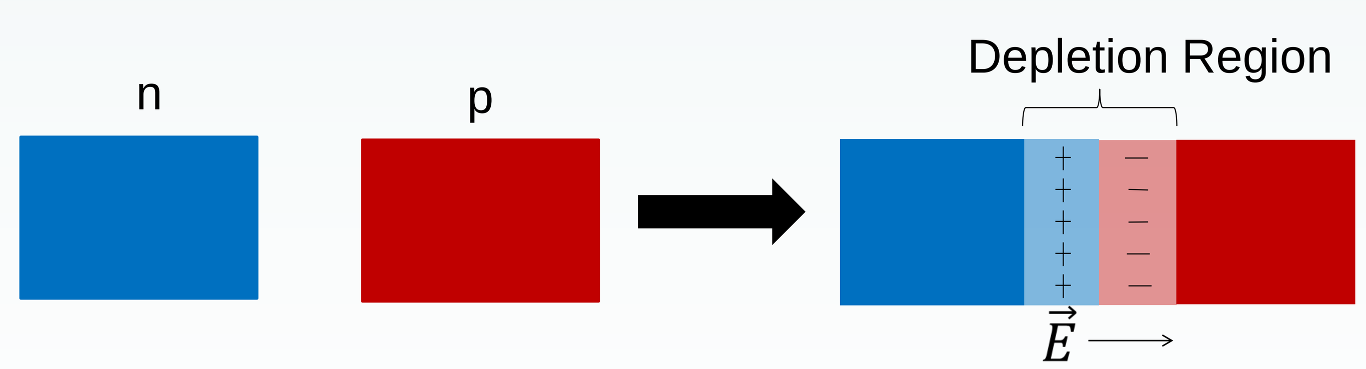


Figure 5: Schematic of the p-n junction at the heart of the solar cell. Diffusion of free carriers across the p-n junction forms a charged region near the junction, resulting in an electric field and counteracting drift current. In equilibrium, these effects balance, creating a fixed region depleted of free carriers, the 'depletion region', of width W.

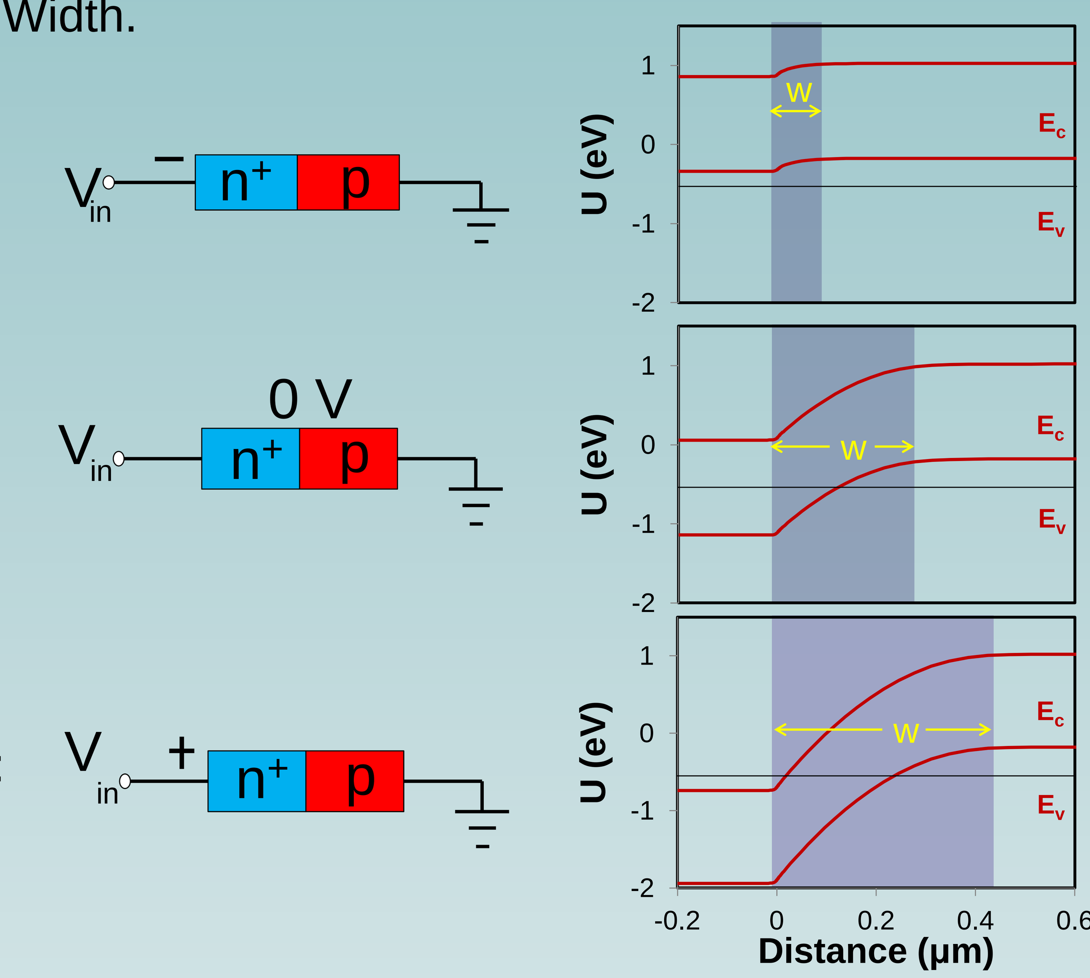
Experimental Techniques

Differential Capacitance: $$C = \frac{dQ}{dV} = \frac{\varepsilon A}{W} \quad (1)$$

Capacitance-Voltage measurements:

Ideal C-V data provides:

- Doping Densities.
- Depletion Width.
- V_{bi} of cell.



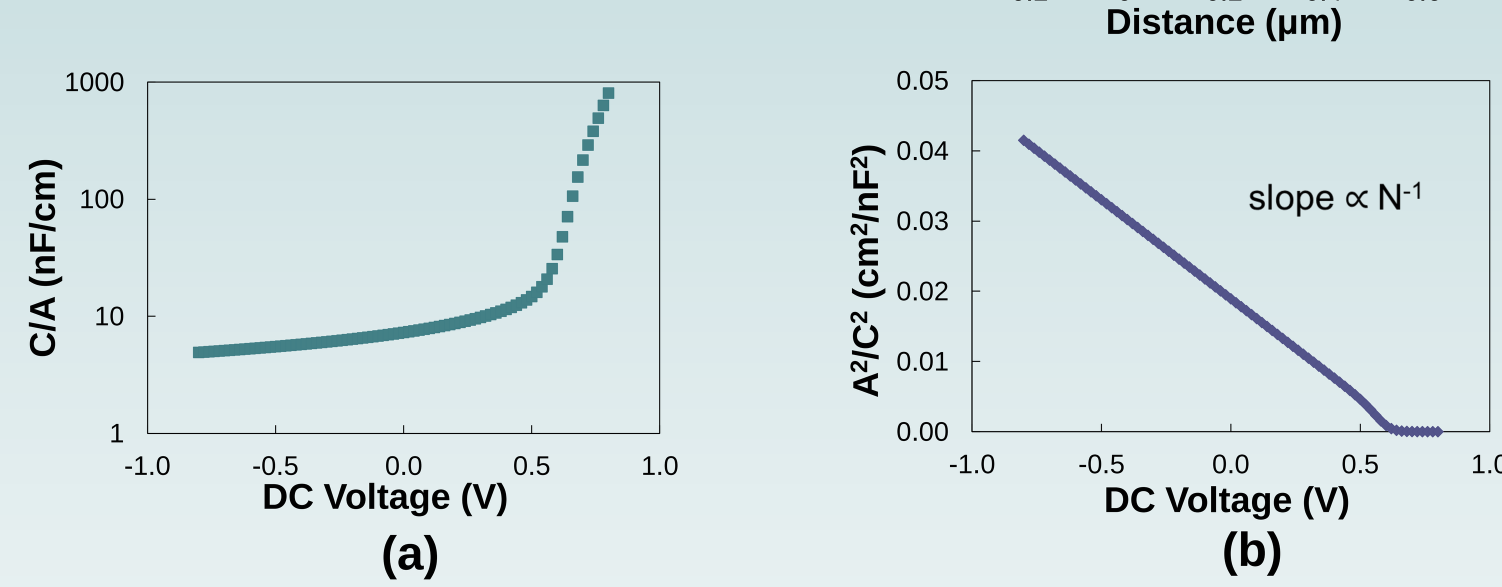


Figure 6: **(a)** C-V data for a simple n^+-p junction created with SCAPs [1]. Positive DC voltage corresponds to forward bias, decreasing the depletion width, and increasing capacitance. **(b)** Theoretically, $\frac{1}{C^2} \propto V$, and the slope is related to the doping density N.

Numerical Models

After seeing the theoretical capacitance with an ohmic contact, it is interesting to analyze the effect a bad back contact has upon solar cells. A bad back contact resists the flow of current from the cell.

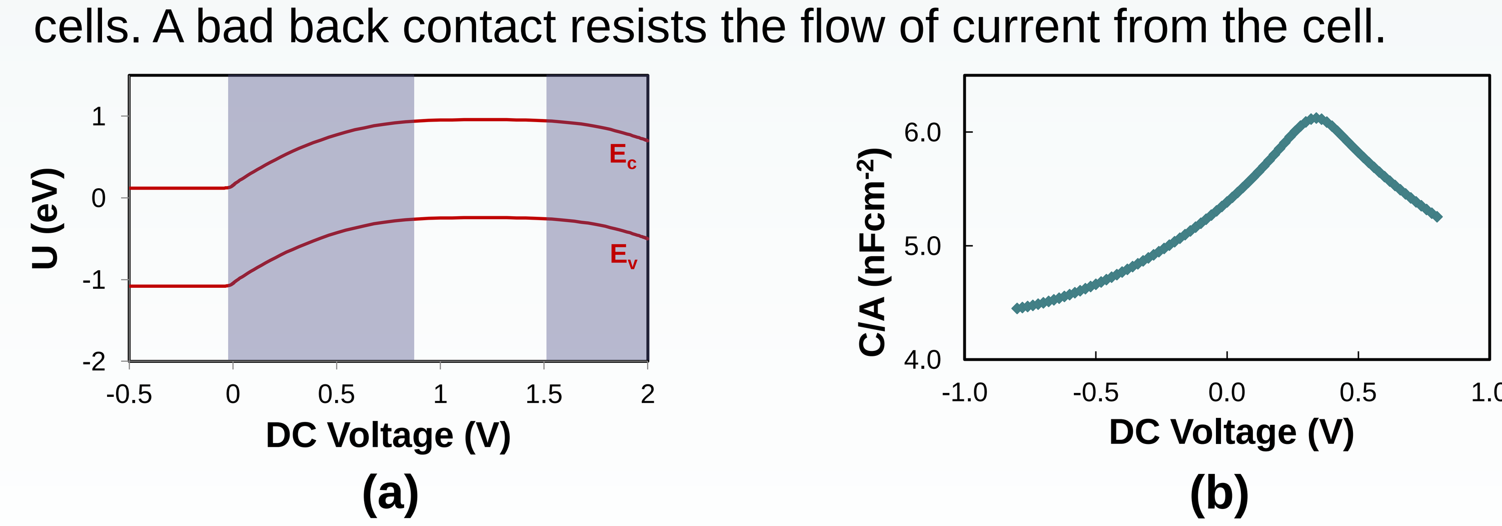


Figure 7: **(a)** An example of a band diagram for the semiconductor material with a back contact barrier. In order to model this, a voltage difference from the cell and contact was used. Model created with SCAPS [1]; **(b)** Numerical modeling for CV data using the model shown in (a).

Circuit Results

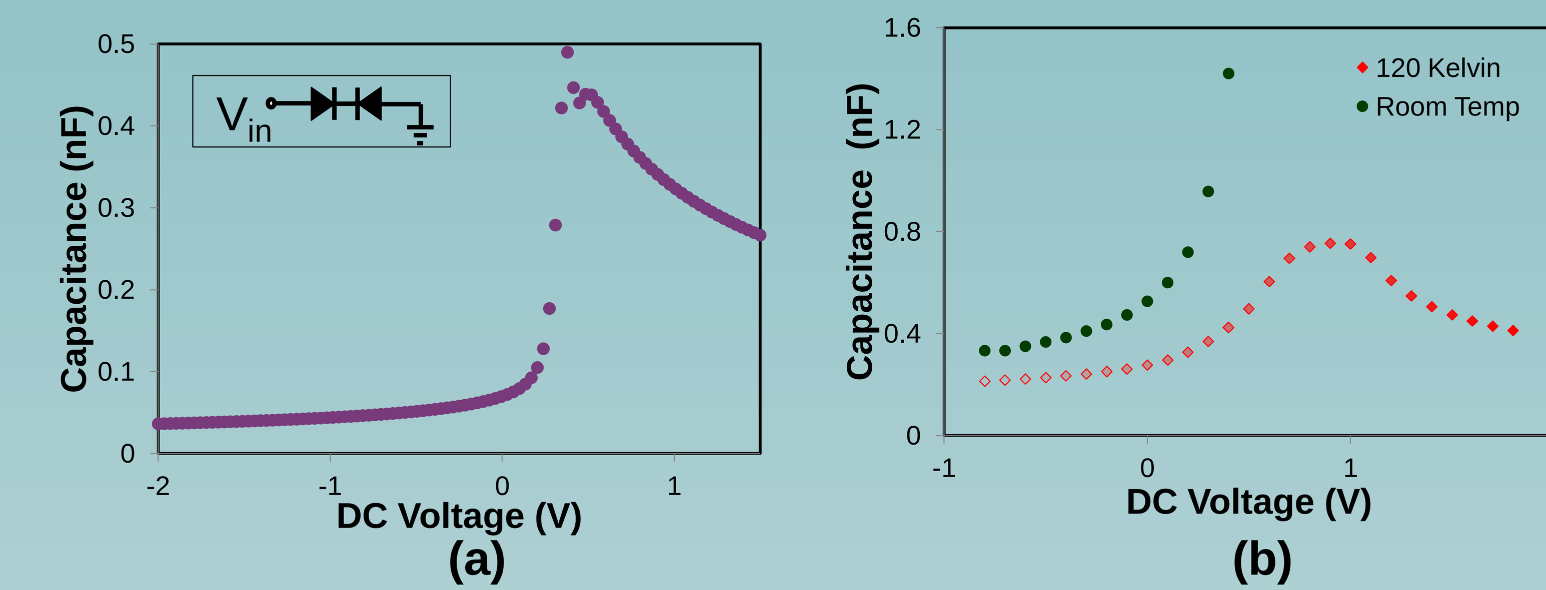


Figure 8: **(a)** Results for a circuit model of a bad back contact; two back-to-back diodes. Inset: circuit diagram. **(b)** Recorded data for CIGS solar cell at 120K and room temperature. A bad back contact likely explains the low temperature results.

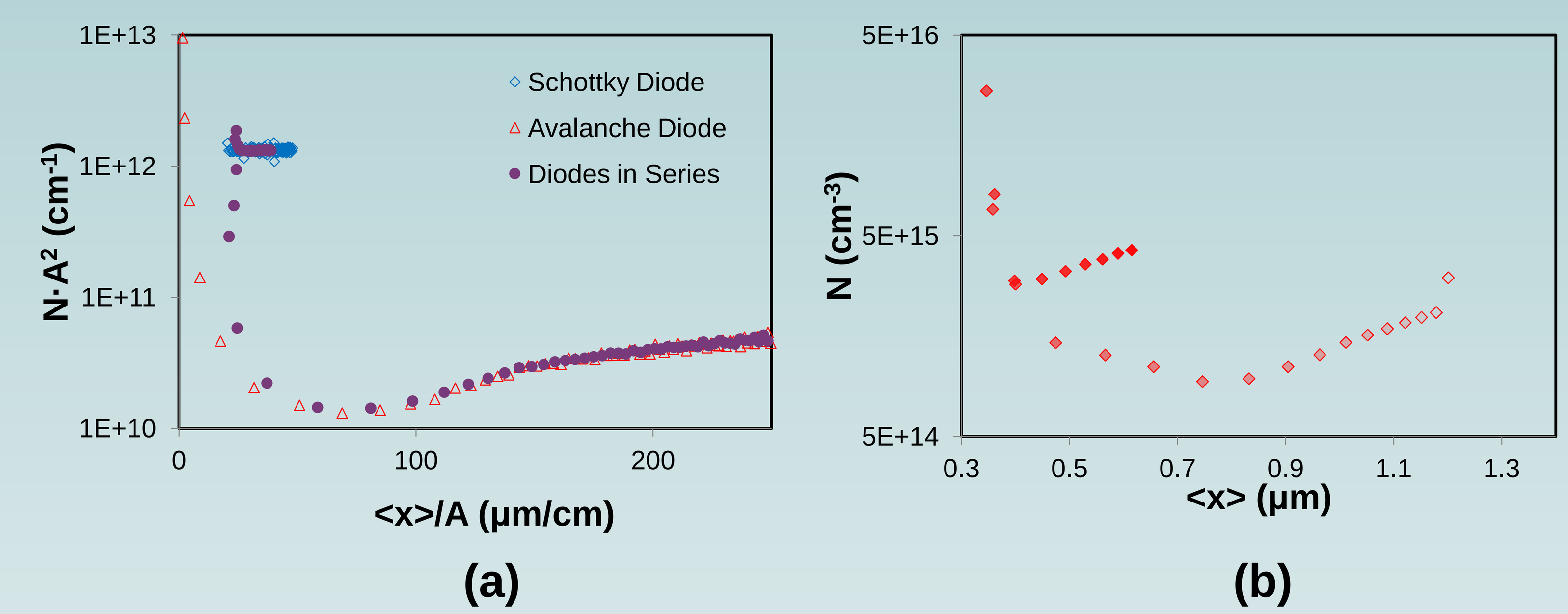


Figure 9: Analysis of data from Fig. 8, using the standard C-V analysis illustrated in Figure 6. **(a)** Results for each individual diode, and the back-to-back diodes show that the individual diode results can be recovered from back-to-back diode data at appropriate values of bias. **(b)** Results from the solar cell at 120K may illuminate differences between the top and back of the absorber layer.

Future Work

- More sophisticated modeling of current transport in a device.
- Explore the nature of the back contact including the height, the dependence of temperature, and sample fabrication details.

Acknowledgements

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References

[1] M. Burgelman, et al., *Thin Solid Films*, **361**, 527 (2000).
[2] Rockett, et al., Thin Solid Films **372**, 212 (2000).
[3] T. Eisenbarth, et al., J. Appl. Phys. **107**, 034509 (2010).

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