Capacitance measurements of defects in solar cells: Checking the Model Assumptions

Justin Davis, Thaddeus Cox, Dr. Jennifer Heath.
Department of Physics, Linfield College

Abstract

Capacitance measurements of solar cells are able to detect minute changes in charge of the material. For that reason, capacitance is used in many methods to electrically characterize devices. Standard interpretations of capacitance rely on many assumptions, which, if wrong, can skew the results. We have focused on a non-ideal back contact and the additional capacitance it adds to the cell. We work to distinguish the influence of a back contact from that of a thermally activated trap state on capacitance data. We find the DLCP method most clearly distinguishes between the contributions of the trap state and the back contact barrier.

Introduction

Solar Cells are composed of semiconductor material which converts solar energy into electrical energy. Thin film cells, including those we have analyzed, are relatively cheap to make in terms of time, energy, and materials. However, thin film materials have many imperfections, or defects, which can trap charge. We study these traps using differential capacitance. Capacitance, which is sensitive to minute changes in charge in the material, allows us to determine the origin and location of trap states in the bandgap. However, other non-ideal device responses can also behave as trap states. For example, the series resistance and capacitance can combine to make a low pass filter. Or, the non-ideal interface can create a thermally activated barrier at the back contact.

Admittance Spectroscopy

- \( C(T) \rightarrow \) Trapping time, energy: \( e_n = \gamma \sigma_{\text{me}} T^2 \exp \left( \frac{-E_{\text{trap}}}{kT} \right) \)
- Measuring \( C \): Apply \( V_{ac} \) measure \( I_{ac} \)
- \( C = \frac{dV}{dT} = \frac{dV_{ac}}{dV} \)
- Defects that release charge fast enough contribute to \( C \).

Drive Level Capacitance Profiling

- Technique which determines carrier and trap density from a purely AC measurement: \( N_{DL} = \frac{\eta + \rho x}{\sigma \Delta x} \frac{dE}{dx} \)

Back Contact Modeling

- DLCP allows the capacitance step to be associated with trap state. Or, a series resistance and capacitance can combine to make a low pass filter. Or, a non-ideal interface can create a thermally activated barrier at the back contact.

Conclusions

- Samples clearly show both a bad back contact and a trap in the bulk material.
- DLCP allows the capacitance step to be associated with a trap state. Shift in \( E \) with DC bias suggests a non-uniform density of states, a shift in trap energy as the quasi-Fermi energy moves, or overlap between the trap energy and back barrier energy.
- Numerical models of DLCP would be useful for further analysis.

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References: