ETHZ RW MSc candidate Stefano Weidmann,
Potential MSc thesis starting date: 1st March 2019

Title:

## Frequency Domain 2D+1D FEM Simulation of Solar Cells

Abstract:

Fluxim develops and commercializes simulation software for OLEDs in displays and lighting as well as for next generation solar cells. Fluxim already has experience in modelling small cells in both direct current (DC) and alternating current (AC) operation and large cells in DC operation, using numerical methods for the solution of partial differential equations, see the publication list further below. New frequency-domain calculation methods need to be developed and applied to large-area cells and modules in AC operation. Fluxim's large-area simulation software Laoss is based on an electro-thermal 2D+1D simulation approach where the electric potential and the temperature within two 2D domains (the electrodes) are simulated with the finite element method (FEM) and coupled via a 1D non-linear coupling law (in the semiconductor stack) [1-5]. This is currently possible for DC operation only.

The objective of this project is thus to extend the FEM solver to the frequency domain. A simulation method shall be developed for calculating the electrical impedance spectra of state-of-the-art silicon photovoltaic (PV) modules, that is the response of the device to a voltage modulation superimposed over an offset voltage. For this, a sinusoidal small-signal analysis shall be carried out which also considers the frequency-dependent capacitance and conductance of the 1D coupling law between the 2D domains. The code to be implemented shall be written in C++ together with some prototypes in Matlab or Python. If feasible, a time-dependent FEM solver shall also be developed that computes transient signals which may be Fourier-transformed for benchmarking the frequency-domain results.

With the developed prototype it shall be checked if typical defects have a significant influence on the impedance spectra of solar modules. It is of interest whether different types of cell defects have a distinct fingerprint in the resulting AC response. A circuit-level model shall be employed for the transition from cells to modules which contain serially connected cells, because it is of additional interest whether PV modules show signatures of individual cell defects, too. Additional aspects relevant for PV module characterization are the modeling of the AC response in the presence of illumination as well as the calculation of spatial maps that may possibly be compared to experimental imaging results for quality control (e.g. electroluminescence or infrared images). In that respect, an extension of the electrical AC simulation method to coupled electro-thermal simulation shall be evaluated. For this study realistic cell contacting layouts need to be considered when setting up the simulation domain.

[1] M. Diethelm, L. Penninck, S. Altazin, R. Hiestand, C. Kirsch, B. Ruhstaller, „Quantitative analysis of pixel crosstalk in AMOLED displays", J. of Inf. Display, 1-9, (2018)

[2] T. Lanz, M. Bonmarin, M. Stuckelberger, C. Schlumpf, C. Ballif, B. Ruhstaller, „Electrothermal finite-element modeling for defect characterization in thin-film silicon solar modules", IEEE JSTQE, 19 5 1, (2013)

[3] S. Altazin, R. Hiestand, M. Fontenlos, F. Pschenitzka, B. Ruhstaller, „Simulation-based optimization for solar cells and modules with novel silver nanowire transparent electrodes", 32nd European Photovoltaic Solar Energy Conference and Exhibition, Munich, (2016)

[4] C. Kirsch, S. Altazin, R. Hiestand, T. Beierlein, R. Ferrini, T. Offermans, L. Penninck, B. Ruhstaller, "Electrothermal simulation of large-area semiconductor devices", Intl. Journal of Multiphysics 11 (2), 127-136, (2017)

[5] P. Losio T. Feurer, S. Bücheler, B. Ruhstaller, „Evolutionary Optimization of TCO/Mesh Electrical Contacts in CIGS Solar Cells", 32nd European Photovoltaic Solar Energy Conference and Exhibition, Munich, (2016)