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THERMAL MANAGEMENT OF CONCENTRATED PHOTOELECTROCHEMICAL ENERGY STORAGE AND CONVERSION DEVICES

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ABSTRACT Heat transfer is a key phenomena in energy conversion and storage devices. Solar energy conversion and storage is especially important as solar radiation is the most abundant energy source available. However, solar energy is distributed and intermittent, thereby necessitating its conversion and storage. The understanding of heat transfer is crucial in devices which convert and store solar energy. In this talk I will introduce a photoelectrochemical (PEC) approach for the direct conversion of solar energy into fuels. This technology is relevant as our society relies largely on energy-dense fuels for short and long-range mobility. Predictive modelling frameworks are relevant for the design and optimization of such PEC energy conversion and storage devices. However, the multi-physical nature of PEC approaches poses significant challenges when developing a PEC modelling frameworks. PEC reactors use the high-energy photons of the solar radiation to generate electron-hole pairs in the semiconductor component. These charge carriers are used for the electrochemical reactions at the catalytically active sites. While the semiconductor performance decreases with high temperature, the chemical reaction is enhanced at higher temperatures. Consequently, a smart rector design will ensure that the heat transfer between the two components is optimized. Cost competitive approaches to PEC reactors utilize concentrated irradiation [Dumortier 2015], which further intensifies the heat management requirement. I will present our modelling framework which allows for design and optimization of such concentrated PEC reactors, schematically shown in figure 1 [Tembhurne 2016a, 2016b].

a) b)

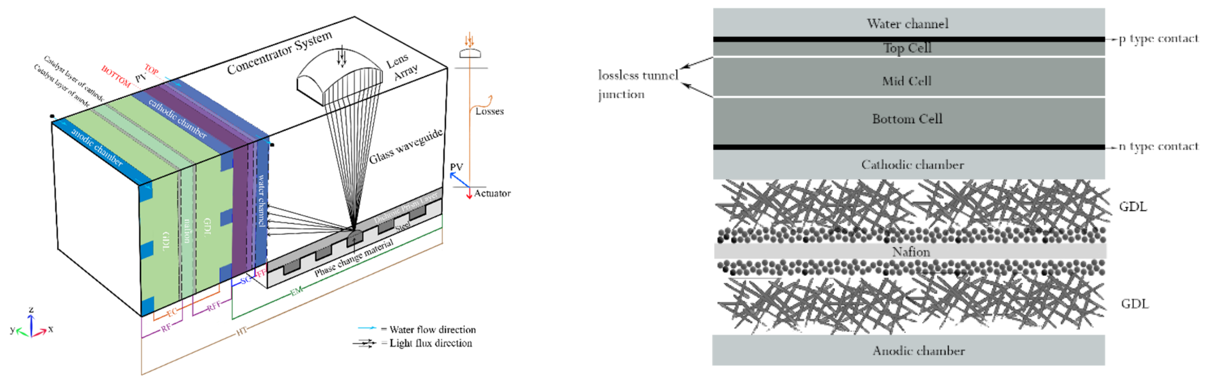

Figure 1. a) Schematic (not to scale) of the 3D structure of the concentrated PEC device. b) Schematic (not to scale) of a 2D cut with details of the device (*xy*-plane in 3D structure).

The model accounts for charge generation and transport in the triple junction solar cell and the components of the integrated electrolyzer (polymeric electrolyte and solid electrode), electrochemical reaction at the catalytic sites, fluid flow and species transport in the channels delivering the reactant (water) and removing the products (hydrogen and oxygen), and radiation absorption and heat transfer in all components. The various heat source/sink term calculations were treated in detail to ensure accurate energy conservation and to allow for subsequent effective thermal management. I will show how the framework can be exploited for the formulation of design guidelines of concentrated PEC device designs and their operating conditions.

Furthermore, I will show how multi-scale approaches can be used to further refine the models and better identify and understand the performance-limiting transport phenomena.

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