ASIA-PACIFIC
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Contactless Photoconductivity Measurements for Photovoltaic Materials and Interfaces

Supriya Pillai[1,2], Nikos Kopidakis[1]
[1]*School of Engineering, Macquarie University, New South Wales - 2109*
[2]Australian Centre for Advanced Photovoltaics, University of New South Wales, Sydney, NSW 2052
E-mail: supriya.pillai@mq.edu.au

Charge carrier dynamics and photogeneration in new solar materials is gaining lot of interest not only from the fundamental understanding perspective but also due to its technological relevance. Some promising and emerging solar cell technologies have the ability to address the cost, efficiency and environmental impact of current solar technologies. However, there is a need to be able to screen the quality of such materials to select the most promising candidates for device optimization. We discuss the figures of merit that can be used to evaluate the quality of PV absorber and show how pump-probe techniques can be used to measure these quantities. We focus on microwave probes and show specific measurement configurations and the information they can provide. While specific configurations, like Time resolved Microwave Conductivity (TRMC), have been used for more than a decade to study the dynamics of charge carrier generation and recombination in PV materials, here we use extensive simulation and microwave expertise to demonstrate extensions to this technique that enable new measurement capabilities. For example, in addition to the rapid screening and selection of materials that would yield optimum PV properties, microwave-based probes can be used in line with roll-to-roll deposition methods to provide information about deposited layers in real time. This will allow identification of potentially new photovoltaic (PV) materials or technologies that could be upscaled and with high throughput.

The motivation for this work comes from multi-year materials characterization efforts using the TRMC technique, used to measure the transient change in the microwave reflectivity of a sample inside a microwave cavity in the dark and when pumped with light, usually a laser pulse. This change is a measure of the carrier generation or recombination in the bulk or at the interface. From these transient measurements one can deduce the carrier lifetime and mobility. The advantage of this technique is that it is a contactless and non-destructive technique that can be easily used to screen the quality of PV materials before any cell processing. There are a few advantages of operating in the MW regime. Due to the high frequency detection (GHz), the mobility obtained reflects transport across larger domains unlike macroscopic distances for other techniques. Also as no electrodes or DC electric fields are present, electric field dependant transport effects are excluded and provide more accurate measurements.[1] The success in using TRMC technique to understand the charge carrier dynamics and related photo-physics has previously been demonstrated using various organic materials [2]. In this study, we use the TRMC technique as a diagnostic tool to screen potential photovoltaic materials. We also utilize unique expertise in microwave design to demonstrate new measurement configurations that can include small single crystals or real-time characterization of roll-to-roll device architectures. These techniques can be easily extended to emerging PV materials like Organics, Perovskite, Quantum dots, Kesterites and Admantine.

The TRMC measurements are performed in the dark and under pulsed illumination using a pump-probe arrangement. This work utilises an X-band microwave (MW) waveguide cavity in the 8GHz-10GHz range to probe the photo response of different solar cell materials. An Nd-YAG 532nm laser is used to photo-excite or pump the samples. A vector network analyser records the scattering parameters from the waveguide. A schematic of the setup is shown in Fig.1. We will present some preliminary results from different PV materials using this technique. Computer Simulation Technology (CST) will be used to simulate our results and compare with experimental results.

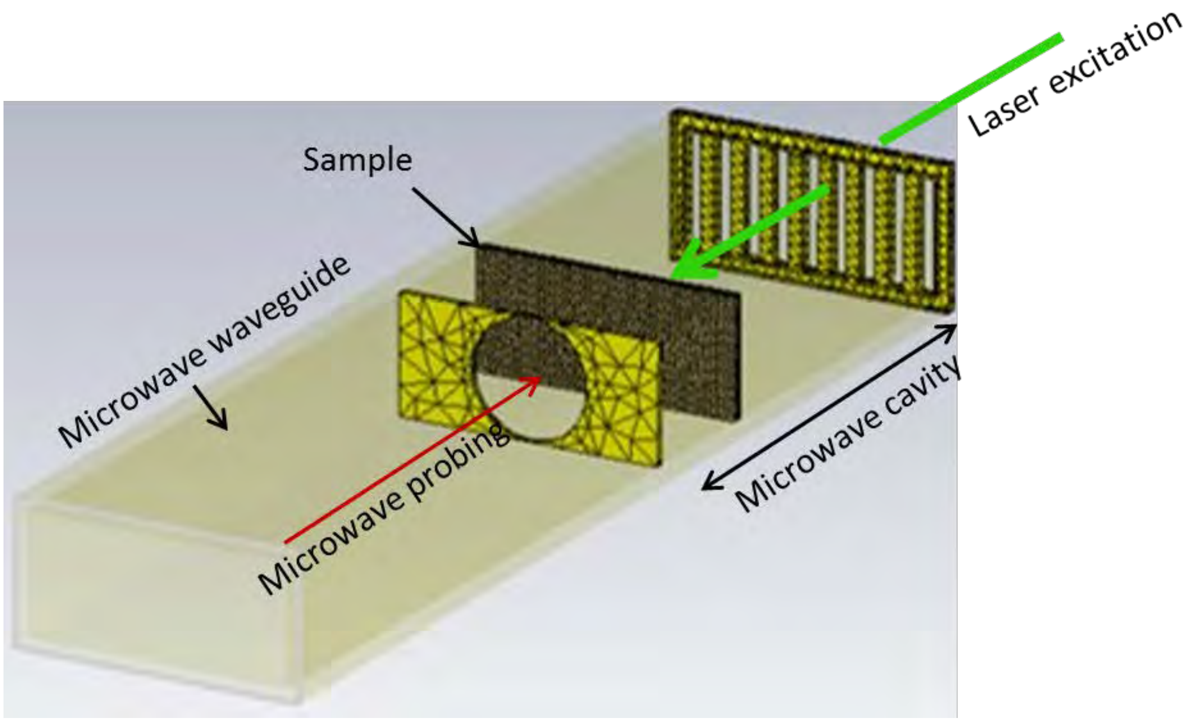

Figure 1. A schematic of the waveguide setup showing the cavity and the pump-probe arrangement

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References

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