Coupled Optoelectronic Frequency Domain Spectroscopy for Thin Film Device Characterisation

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Mass-deployed crystalline silicon solar cells will maintain their efficiency for more than 30 years. However, the aging of novel thin-film solar cells (CIGS, Perovskite etc.) remains less understood, particularly in niche environments like floating PV and agrivoltaics. Previous approaches to understanding degradation phenomena in-situ tend to focus on standard optical and electrical characterization techniques such as I-V measurements and photoluminescence. Here, alternative characterisation techniques are used to provide deeper insight into the evolution of materials and interfaces in photovoltaic devices as they age. Two such techniques are modulated photoluminescence (MPL) and admittance spectroscopy (AS). These frequency domain characterization techniques are capable of determining defect densities, positions, and cross sections as well as carrier lifetime in the devices. MPL and AS were used to characterize CIGS solar cells and the optical (MPL) and electrical (AS) responses were correlated, with AS extracting capture cross sections, activation energies, and defect distributions for the majority carrier in the device (Fig. 1 a, b) and MPL corroborating these results and adding insight to the minority carrier dynamics (Fig. 1 c). This suggests different defects will be more efficiently analysed by a combination of these two techniques, with majority carriers (close to EV) suiting AS and minority carriers (close to EC) suiting MPL. It was shown that both techniques provide useful insight into defect properties and that their coupling can bring unique insight to material characterization, making them promising tools for future degradation studies.

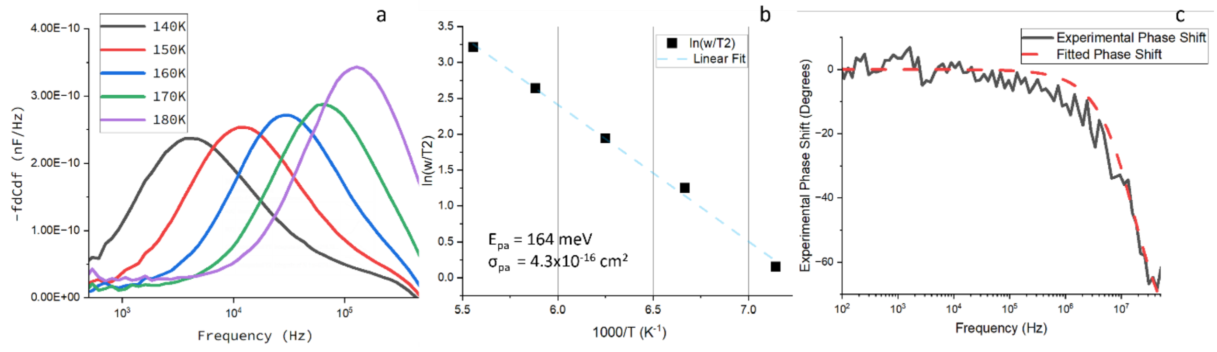

Figure 1: -fdC/df as a function frequency for the temperature range 140K-180K (a), Arrhenius plot of peak positions extracted from (a) to extract cross section (\sigma) and activation energy (E_q) (b), and MPL phase-shift as a function of frequency with a theoretical fitted curve, using the values extracted from (b) superimposed.