Simultaneous Optical & Electrical In-Situ Characterisation of Solar Cell Aging

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A key consideration for upscaling renewable energy technologies is device lifetime. For photovoltaics (PV), the durability of mass-deployed silicon technology exceeds 30 years. However, novel thin-film solar cells are still an unknown quantity, particularly in niche environments like floating PV and agrivoltaics. Previous approaches investigating degradation in these technologies usually focus on one characterisation technique and pre-/post-mortem analysis surrounding accelerated ageing tests, making it difficult to pinpoint the causes and kinetics of degradation. In-situ characterisation using several complementary techniques allows degradation to be tracked in real-time and the pathways to be fully explored, giving insight into the physio-chemical processes taking place. Consequently, a coupled IV-photoluminescence (PL) characterisation bench has been developed inside a climate chamber, facilitating the periodic acquisition of PL spectra and IV curves during accelerated ageing. Using this, it was possible to observe disparities between the evolution of a solar cell's optical and electrical performance.

It then becomes imperative to relate accelerated ageing to outdoor kinetics. This was achieved using time-independent parameter-space analysis, where experimental degradation signatures were compared to simulated degradation processes. Finally, time-resolved characterisation of defect states was explored as an addition to the bench. Modulated PL (MPL) and admittance spectroscopy (AS) optically and electrically probe carrier traps in thin-film solar cells. It was seen that MPL is better suited to characterising minority carrier traps in the absorber material, while AS focusses on deep traps, probing various depths of the device and its interfaces. Thus, it was possible to characterise different defect states in thin-film devices.