Direct interface between c-Si and perovskite – study of materials' compatibility for tandem applications

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Efficiency of market leading c-Si solar cells is slowly approaching its limits. Mitigation of main losses in this type of solar cells, namely thermalisation of carriers excited by high energy photons, can be done by employing tandem geometry of solar cells, which consists of two sub-cells that absorb different part of the solar spectrum. Silicon as a matured technology and with its small bandgap of 1.12 eV is a perfect candidate for the bottom sub-cell, while halide perovskites can be used as absorber material in the top sub-cell due to their well-suited optoelectronic properties, such as band gap tuning via compositional engineering, high absorption coefficient and steep absorption edge with low sub-band gap absorption Indeed, such perovskite silicon tandem solar cells are currently showing efficiencies as high as 29.1% [1] with theoretical efficiencies that can potentially exceed 40%. Although technical considerations of perovskite-silicon tandem solar cell have been widely studied, the fundamental research of how this material system works is lacking and there have been only few studies dedicated to a direct investigation of perovskite silicon interfaces. While in practical solar cell devices these two materials are normally not in a direct contact, the knowledge of the carrier transport and band alignment between them would allow for a better understanding of their performance and compatibility as well as finding the best adapted interface and buffer layers.

In this study we used Kelvin force probe microscopy and photoemission spectroscopy to study the energetics of perovskite layer deposited directly on c-Si substrate of different doping type. It has been already reported that perovskite's Fermi level can shift according to the substrate and it's expected to be closer to the conduction band on n-type substrates and closer to a mid-gap position on p-type substrates [2][3][4]. The existing studies on this topic mostly consider perovskite on transparent conductive oxides or electron and hole transport materials. Our results reveal also a relative shift of the perovskite's Fermi level solely depending on the doping type of the silicon substrates. We also studied the wavelength and intensity dependent surface photovoltage of these samples, which allowed us to effectively vary the probe depth in the sample and discern the contribution from each interface to the overall effect measured under white light illumination.

Our results serve as a foundation to study the compatibility of perovskite and c-Si, elucidating band alignment, charge transport and light induced photovoltage of this interface, and thus guiding the development of perovskite-silicon tandem solar cells in monolithic device architectures.

References:

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