Perovskite/Silicon Tandem Solar Cells and Modules

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In recent years the power conversion efficiency of solar cells based on metal halide perovskite materials was tremendously enhanced to over 22% due to the outstanding optoelectronic properties of semiconductors such as methylammonium lead iodide. In addition, the ease of fabrication when utilizing perovskites paves the way towards very low production costs. Furthermore, the optical band-gap and energy levels can be tuned by changing the composition, rendering this material highly interesting as a partner for silicon in multi-junction solar cells, where each sub-cell absorbs a different portion of the solar spectrum. We present recent developments of 4-terminal and monolithic (figure 1a) perovskite/silicon tandem solar cells on their way to outperform record silicon single junctions. We review the most promising device designs, especially parasitic absorption in contact layers for different device polarities and highlight the obstacles necessary for realizing their full efficiency potential of over 30%. Furthermore, we discuss needs for industrialization such as long term stability, upscaling of film processing and integration into tandem modules. With that, we show how perovskites can be implemented as a drop-in technology on top of silicon solar cells to potentially speed up the development of PV in becoming the cheapest and most ubiquitously applied energy source.

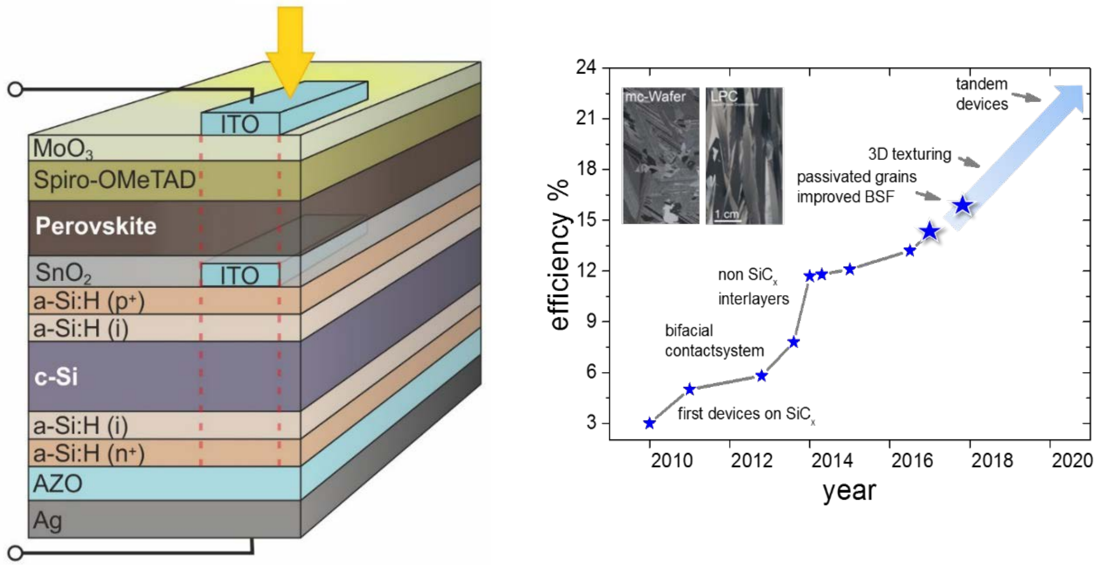

Figure 1: a) Schematic illustration of a monolithic perovskite/silicon heterojunction tandem solar cell. b) Efficiency progress for liquid phase crystallized silicon on glass & roadmap.

Finally, we present our recent developments in liquid phase crystallization (LPC) of silicon on glass. This technology enables wafer equivalent silicon films on glass and can be an ideal partner for future tandem concepts due to excellent open circuit voltages up to 661mV. For LPC, silicon is evaporated on a dielectric coated glass and subsequently crystallized using a line shaped energy source. Due to directional solidification we achieve a multi-crystalline wafer like film on glass that can be processed into cells and modules using established wafer-PV know-how such as texturing, passivation or hetero-junction techno-logy. Based on a rapid development during the past six years (figure 1b), we are now able to show a conversion efficiency up to 15.9% on full emitter test cells and 14.2% on full-featured IBC cells for a 13 micrometer thin poly-crystalline solar cells on glass. LPC is a scalable technology and combines the advantages of wafer- and thin-film PV. It opens up the ability to reduce the specific silicon consumption by a factor of 10 to 20. While we target at a conversion efficiency goal of 18% for a single-junction IBC module, based on numerical device simulations, we demonstrate that a perovskite/silicon tandem has the potential to deliver conversion efficiencies above 23% in the near future.