Advances and challenges for ultrathin solar cells

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Single-junction solar cells have reached efficiencies close to the theoretical Shockley-Queisser limit. They currently use relatively thick absorber layers, more than 100 µm for silicon and several microns for thin-films (GaAs, CIGS, CdTe), and rely on single-pass light absorption. However, optical path enhancement using light-trapping can dramatically reduce their thickness. Ultrathin solar cells could then offer a unique potential to convert efficiently solar energy into electricity while enabling material savings, shorter deposition times, and improved carrier collection in defective or degraded absorber materials. Nevertheless, several challenges must be overcome to go from the ideal concept of an ultrathin solar cell to a working device.

In this contribution, we propose an overview of recent advances for ultrathin solar cells made of silicon (c-Si), gallium arsenide (GaAs) and $Cu(In,Ga)(S,Se)_2$ (CIGS). Using a broad literature survey, we will present benchmarks of light-trapping performances of numerous devices as a function of their thickness (see an example Fig. 1), and we will discuss most recent advances. We will highlight current limitations and challenges in multiple aspects, from efficient light-trapping to charge carrier collection. We will also review technological routes for the fabrication and patterning of ultrathin absorber layers, and we will provide perspectives to combine photonic and electrical constraints into complete architectures envisioned for ultrathin solar cells.

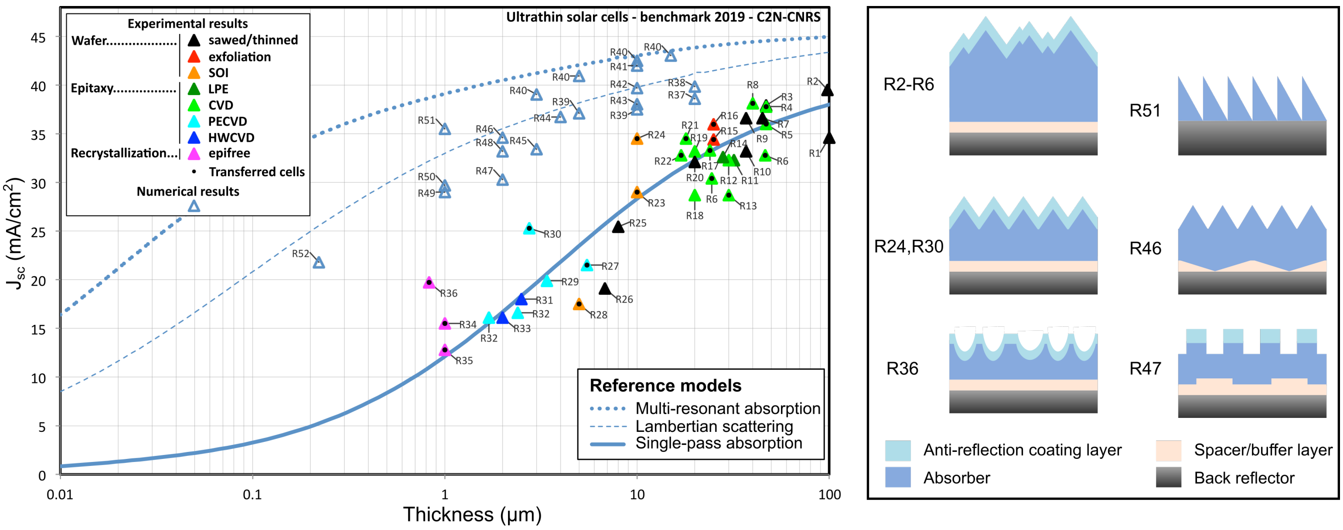

Figure 1. State-of-the-art of ultrathin monocrystalline Si solar cells. (a) Short-circuit current density (Jsc) of thin (20 µm ≤ t ≤ 100 µm) and ultra-thin (< 20 µm) monocrystalline silicon (c-Si) solar cells as a function of the absorber thickness. Filled colored symbols: experimental results obtained with different fabrication processes (inset). The use of a layer transfer process is shown with a black dot. Open symbols: Jsc values from numerical calculations and absorption measurements. All reported values are compared to reference models (curves). (b) Sketches of notable light-trapping schemes used in state-of-the-art thin and ultrathin c-Si cells: micron-scale random pyramids, front inverted nanopyramid arrays, amorphous ordered nanopatterning, slanted cones, front and back nanocone arrays and photonic crystals.