A path toward 25%-efficient ultrathin GaAs solar cells

Bérengère Frouin[a], Andrea Cattoni[a,d], Hung-Ling Chen[a], Oliver Höhn[c], David Lackner[c], Gerald Siefer[c], Marco Faustini[e], Frank Dimroth[c] and Stéphane Collin[a,b]

(a) Centre for Nanoscience and Nanotechnology (C2N), CNRS, Université Paris-Saclay, Palaiseau, France
(b) *Institut Photovoltaïque d'Ile-de-France (IPVF), Palaiseau, France*
(c) *Fraunhofer Institute for Solar Energy Systems (ISE), Freiburg, Allemagne*
(d) Ecole Polytechnique de Milan, Milan, Italie
(e) *LCMCP, Sorbonne Université, CNRS, Collège de France, Paris, France*

GaAs is at the forefront of high efficiency PV, however, the cost of III-V raw materials still significantly limits its industrial throughput. Hence, reducing the absorber thickness of at least one order of magnitude while maintaining equivalent efficiency is key for the development of photovoltaics and saving scarce material. Therefore, light trapping strategy is required to compensate for the low single-pass absorption in very thin films. In 2019, a record 19.9%-efficient GaAs solar cell with an absorber thickness of only 205 nm has been demonstrated by our team using multi-resonant absorption (1st generation of ultrathin GaAs solar cells: Jsc=24.6 mA/cm^2, Voc=1.02 V, FF=79 %). Fabricated with a low-cost nanoimprint lithography process, a TiO_2/Ag nanostructured mirror was designed at the rear side of the solar cell enabling multiple overlapping resonances.

In this contribution, we will present our strategy to overcome this 20% efficiency limit based on a comprehensive analysis of the optical and electrical losses. We explore two possible ways to get a step closer to the Lambertian scattering model in terms of short-circuit current (Jsc).

First, we propose to modify the back side architecture with a high index contrast diffraction grating associated with a planar mirror to reduce parasitic losses in the metallic mirror (2nd generation). This leads to a theoretical Jth net increase of 2.6 mA/cm^2 compared to the first generation as shown in Figure 1. Experimentally, we demonstrate functional devices with state-of-the-art Voc and FF, and EQE exhibiting a multi-resonant behavior. The Jsc is still slightly below the theoretical value, but can be easily improved confirming the advantages and the potential of this new back architecture.

While keeping and adapting the optical part at the rear side, we then propose an alternative stack of semiconductor layers based on a 250 nm-thick GaAs/AlGaAs heterostructure (3rd generation), resultings in a maximum Jsc of 28.9 mA/cm^2. Our first experimental results show the effect of the doping and thickness of the GaAs layer, and lead to improvements of the electrical properties of these ultrathin solar cells (Voc=1.05 V, FF=83 %). The fabrication of devices with an optimized nanostructured back mirror is in progress.

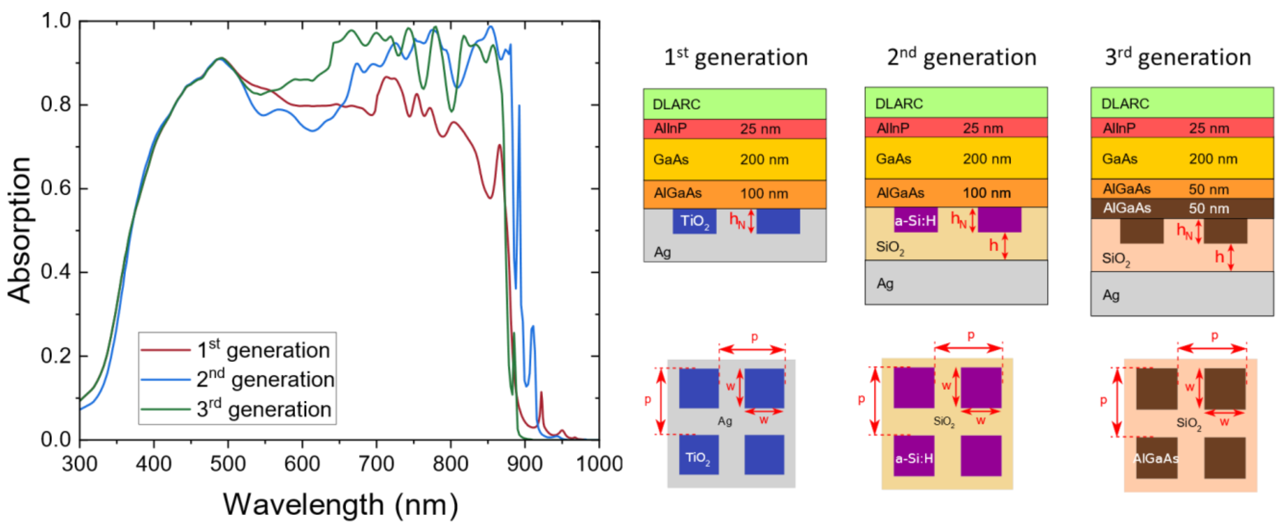

Figure 1: (a) Absorption spectra in the GaAs absorber for three different generation of ultrathin solar cells with optimized rear side design (simulations). (b) Corresponding schemes of the ultrathin solar cells.