TCO bonding and optical management for III-V/Si tandem solar cells

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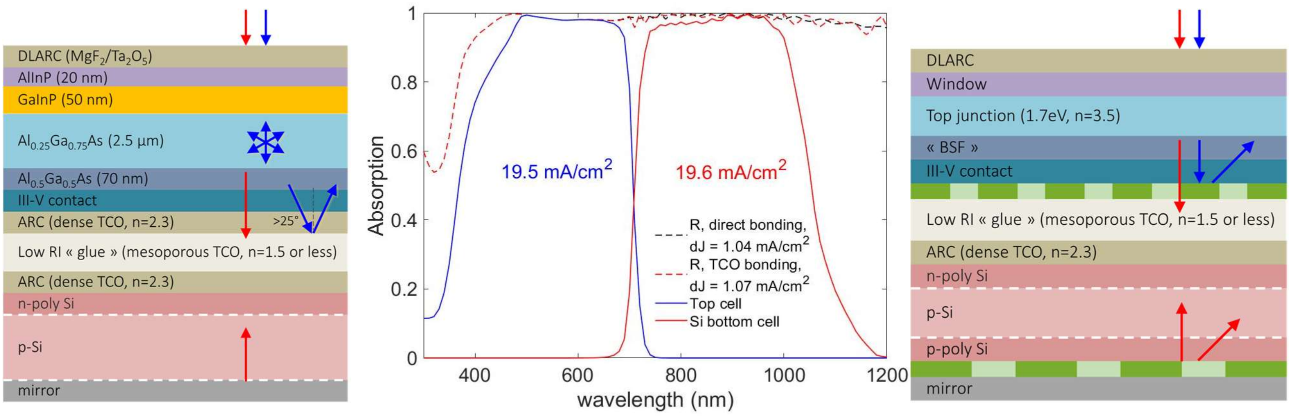
Photovoltaic market today is dominated by crystalline silicon single-junction solar cells. However, the record energy conversion efficiency of 26.7% for a c-Si solar cell recently demonstrated [1] is near to the theoretical maximum efficiency of 29.4% [2] for this technology. In order to overcome these limits, multi-junction solar cells represent a promising alternative. By combining several absorber materials, they enable a better use of the solar irradiance spectrum. If an ideal material combination is selected, a two-terminal tandem solar cell can reach an efficiency of 42.7% [3]. Today, research on III-V/silicon tandem solar cell attracts more and more attention. Record efficiencies (33.3%, 3 junctions, 2 terminals [4]) have been obtained with device fabricated by direct wafer bonding of III-V on Si. The main drawback of this technology is its cost and its difficult scalability.

In this study, we present the design of a GaInP/AlGaAs on Si tandem solar cell with a novel approach for wafer bonding using processes compatible with low-cost fabrication. We demonstrate the possibility of using TCOs with appropriate refractive indexes for bonding, allowing current matching (19.5 mA/cm^2 with a potential efficiency of 24.3% for the top cell without photon recycling) and with almost no additional losses. The design is presented in figure 1(a). The optical calculation results performed using Reticolo [5] combined with OPTOS [6] are shown in figure 1(b). One of the main advantages of this design is the potential photon recycling effect for the top cell provided by the low-refractive index gap (n = 1.5) while the ARC transmits incident red photons to the bottom cell [7]. We recently demonstrated efficient light trapping in an ultra-thin GaAs solar cell with an Ag/TiO_2 nanostructured back mirror [8]. We are now designing a new light trapping schema for spectrally selectively confining the light in the top and the bottom cell in order to reduce the thickness of both sub-cells (see figure 1(c)).



(a) (b) (c)

Figure 1. (a) Sketch of the tandem cell using TCO bonding. (b) Corresponding optical simulations and reflectance comparison with direct bonding. (c) Sketch of a tandem cell with light trapping.

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