Multifunctional and reliable bonding layer for cost-effective 2-Terminal III-V on Si tandem solar cells

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ABSTRACT:

Silicon solar cells dominate the photovoltaics market, but their record efficiencies are now close to the theoretical efficiency limit of 29.4 % [1]. This has stimulated strong interest in Si-based hybrid tandem cells in a 2-terminal (2-T) configuration, which aim to surpass this limit while remaining low-cost. The III-V/Si combination holds the current efficiency record at 36.1% under 1 sun for a 2-junction III-V on Si configuration [2] but relies on direct wafer bonding, a costly process requiring high vacuum and chemical-mechanical polishing [3]. In this work, we present our latest advancements in the development of a rapid, reliable and affordable bonding process for 2-T tandem cells, suitable with Si bottom cells featuring moderate surface roughness (100-200 nm).

Our innovative bonding layer architecture consists of a 6 µm-thick transparent photoresist, patterned through photolithography, followed by the spin-coating of a thin layer of conductive polymer (PEDOT:PSS). This design aims to resolve the trade-off between transparency, conductivity, and Si surface planarization. A conformal deposition of the PEDOT:PSS layer is ensured. An aging test showed stable optical transmission and no delamination after 42 days at 85% humidity and 85 °C, demonstrating the long-term stability of the bonding layer. We have successfully bonded III-V/Si tandem stacks over areas up to 2.2 × 2.2 cm² without visible defects after III-V substrate removal, using an easy and affordable bonding method (low temperature, low vacuum, no polishing needed).

We fully processed tandem cells (AlGaAs cell on top of TOPCon Si cell) incorporating our novel patterned bonding structure. The III-V cell active area is 1 cm² while the Si cell covers a larger area (no MESA etching performed on the Si). The use of a 1 cm² aperture mask under the solar simulator to block parasitic absorption revealed better performance from the top III-V cell than from the Si bottom cell. We can currently achieve a high V_{OC} of 1.80 V and an efficiency of 8.01 % (without anti-reflective coatings). Ongoing investigations aim to identify the origin of the series resistance, currently the main limitation of our cells, and develop strategies for its reduction.

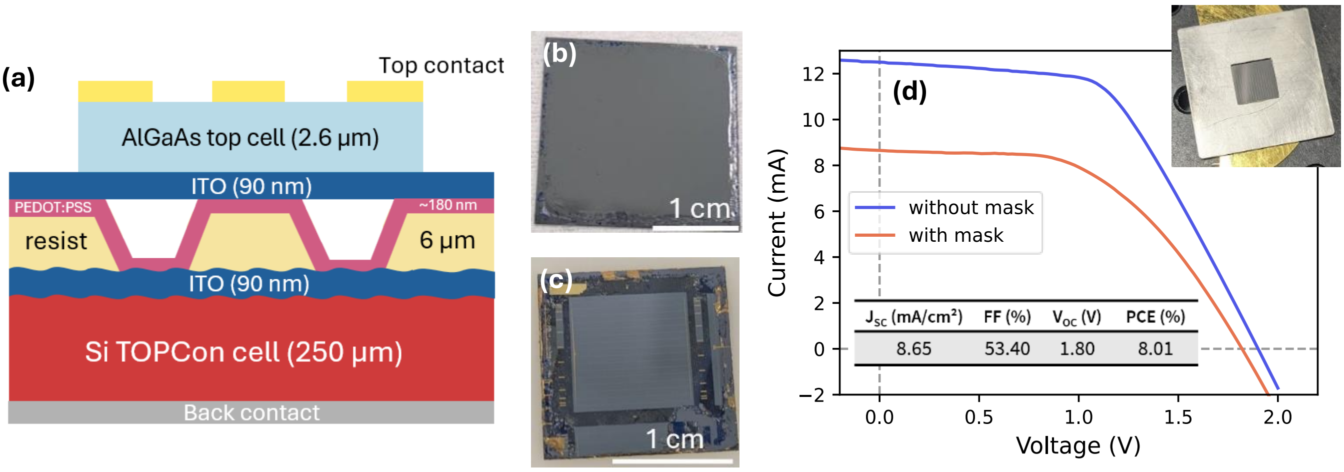

Fig. (a) Scheme of the bonded tandem III-V on Si cell (both sub-cells provided by the Fraunhofer ISE). **(b)** Tandem stack after bonding and III-V substrate removal. **(c)** Fully processed tandem cell. **(d)** IV curve of tandem cell in (c) with and without mask. Inset 1: Cell covered with the mask. Inset 2: Performances of the tandem cell with the mask.

[1] Richter et al., IEEE Journal of Photovoltaics, vol. 3, no. 4, pp. 1184-1191, Oct. 2013.
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[3] K. A. Horowitz et al., NREL/TP-6A20-7 2103, Nov. 2018.