Perovskite-based photovoltaic and 2D materials: fostering an innovative PV technology in an industrially relevant environment.

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Short Bio

Antonio Agresti is an Associate Professor at the Department of Electronic Engineering at the University of Rome Tor Vergata since 2019. His research activity mainly involves the design, engineering, fabrication, and electrical/spectroscopic characterization of hybrid and organic solar cells, and the use of graphene and transition metal dichalcogenides and emerging two-dimensional materials such as MXenes for perovskite solar cells, tandem devices, large-area modules, and panels. He has authored/coauthored more than 60 publications and has participated as an invited speaker to several conferences in the renewable energy field. He is currently the deputy leader of Horizon 2020 Spearhead 5—Graphene Core 3 project.

Abstract

Hybrid perovskite solar cells (PSCs) are one of the most promising technologies for new-generation photovoltaics due to outstanding semiconductor properties and low-cost solution processing methods for the fabrication. Indeed, PSCs dominated the PV scientific research in the last decade, by developing efficient and stable devices, produced by employing scalable and low-cost printing techniques, easily embedded in roll2roll or sheet2sheet production lines. However, PSC technology still requires to demonstrate the transfer from lab to fab, pushing the scientific community in finding brilliant solution for drawing a feasible and reliable route toward its commercialization. Moreover, the impressive potentiality of perovskite technology has been already demonstrated to compete on equal footing with traditional inorganic PV or to work in synergy with established silicon technology in tandem cell configuration.[1] As a matter of fact, the astonishing power conversion efficiency recently achieved by small area perovskite/silicon tandem solar cells (PCE>32%) demonstrated the technology potentialities to be appealing for the PV market.[2] However, such technology should keep the promise to be easily manufactured by employing the exiting silicon cell production line and by minimizing the Levelized Cost of Electricity (LCOE). Thus, the synergetic development of large area perovskite devices fitting the standard silicon wafer dimensions and the optimization of perovskite/silicon tandem architectures can definitively open up new horizons for winning the commercialization challenges. In this scenario, the use of interface engineering based on bi-dimensional (2D) materials is here proposed as an efficient tool for trap passivation and energy level alignment in perovskite devices, by mitigating the performance losses induced by the scaling-up process.[3] In particular, the successful application of 2D materials, i.e., graphene,[4] functionalized MoS_2,[5] and MXenes [6,7] in perovskite solar modules (PSMs) allowed to achieve PCE overcoming 17% and 14.5% over 121 and 210 cm^2 substrate area respectively. Moreover, an ad-hoc lamination procedure employing low temperature cross linking EVA (at 80°C-85°C) allowed to fabricate several 0.5 m^2 panels, finally assembled in Crete Island, in the first worldwide fully operating 2D material-perovskite solar farm.[8] The 2D material engineered structure employed for the opaque perovskite modules composing the solar farm, has been further modified and optimized for realizing small (0.54 cm^2) and large area semi-transparent modules (active area > 60 cm^2) suitable for tandem application, in two-terminal (2T) mechanically stacked architecture.[9] In the proposed tandem architecture, the two sub-cells are independently fabricated, optimized, and subsequently coupled by contacting the back electrode of the mesoscopic perovskite top cell with the texturized and metalized front contact of the silicon bottom cell. The possibility to separately optimize the two sub-cells allows to carefully choose the most promising device structure for both top and bottom cells. Indeed, semi-transparent perovskite top cell performance is boosted through the use of selected two-dimensional materials to tune the device interfaces,[3-8] gaining advantages from the experience maturated during the optimization of the opaque devices composing the solar farm. A textured amorphous/crystalline silicon heterojunction cell fabricated with a fully industrial in-line production process is here used as state of

art bottom cell. The perovskite/c-Si tandem device demonstrates remarkable PCE of 28.7%. Moreover, we demonstrate the use of a bifacial silicon bottom cell, as a viable way for overcoming the current matching constrain imposed by the 2T configuration, by promising top PCE overcoming 32%. Finally, here we propose a novel design for scaling the dimensions of tandem perovskite/Si lab cells up to panel size, by employing the voltage-matched (VM) configuration. Following this approach, the tandem panel can be realized by using commercial M2 (15.7x15.7 cm^2) silicon heterojunction (Si-HJT) cells provided by ENEL-3SUN company, while the perovskite solar modules can be independently optimized, realized and stacked atop the Si-HJT cells employing an ad-hoc developed lamination process. Among the advantages of the VM architecture, the much less sensitivity toward spectral variations allowed to employ bifacial Si-HJT bottom cell, gaining extra power output when exploiting the radiation reflected by the ground (albedo).

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