Graphene-based counter-electrode for large area gold-free perovskite solar devices

Paolo Mariani,
L.Najafi[2,3], S.Bellani[2,3], M.I. Zappia[3,4], G.Bianca[2], N.Yaghoobi Nia[1], S.Pescetelli[1], A. Agresti[1], F. Bonaccorso[2,3] and Aldo Di Carlo[1,5]
[1]Department of Electronic Engineering, University of Rome "Tor Vergata", via del Politecnico 1 00133 Rome – ITALY / CHOSE- Centre for Hybrid and Organic Solar Energy, Viale Pietro Gismondi snc 00133 Roma- ITALY
[2]Graphene Labs, Istituto Italiano di Tecnologia, via Morego 30, 16163 Genova, Italy
[3] BeDimensional Spa., Via Albisola 121, 16163 Genova, Italy
[4] Department of Physics, University of Calabria, via P. Bucci cubo 31/C, 87036 Rende, Cosenza, Italy
[5] Istituto di Struttura della Materia, CNR-ISM, via Fosso del Cavaliere 100, 00133 Roma, Italy
paolo.mariani@uniroma2.it

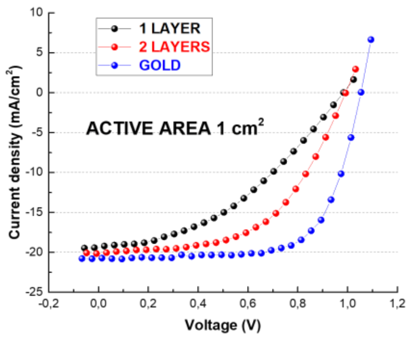
Gold films are typically used as the back electrode of the most efficient certified perovskite solar cells (PSCs) [1], arising severe concerns for industrialization purposes. In fact, on one hand, both gold cost and deposition through energy-consuming vacuum evaporation negatively affect the levelized cost of energy (LCOE) of the mesoscopic PSC technology. On the other hand, gold ion migration toward either the hole-transporting layer (HTL) or the perovskite causes severe instability effects under operating conditions, decreasing the PSC lifetime [2]. In this work, we report solution-processed electrically conductive adhesive (ECAs) based on graphene flakes to replace the gold in PSC back electrode without altering the underlying structure of the traditional mesoscopic devices. Our ECAs are formulated by mixing carbon nanomaterials with different topological morphologies, including wet-jet milling-produced pristine (not oxidised) single-/few-layer graphene flakes. Thanks to the peculiar properties of pristine graphene, our ECAs show optimal electrical properties (sheet resistance < 20 Ω/sq for thickness < 30 μm) and mechanical strength. The ECAs are deposited in form of counter-electrode for large-area PSCs. By optimizing the thickness of spin-coated graphene-based ECAS, we have increased the photovoltaic performance of our PSCs by 30%. In particular, optimal ECA thickness of ~40 μm resulted in a sheet resistance of ~10 Ω/sq. Afterwards, we investigated the ECA deposition through blade coating technique, aiming to scale-up our PSC technology [7]. Beyond to provide an effective method to fabricate large-area PSCs, blade coating efficiently reduce material waste compared to other depositions techniques, such as spin-coating. Our preliminary tests proved that our graphene-based PSCs can overcome the performances obtained with market-ready c carbon pastes.

Our ECAs are currently implemented in advanced mesoscopic PSCs [3,4] and perovskite solar modules (PSMs) [5], using graphene-doped TiO_2 electron-transporting layers (ETLs) and two-dimensional (2D) transition metal dichalcogenides interlayers [6] to surpass the "gold" PCE and reach the state-of-the-art performance through viable large-scale manufacturing processes.

REFERENCES

[1] Green, M.A. et al. Prog Photovolt Res Appl. (2020); 28:3–15.
[2] Domanski, K. et al. ACS Nano (2016), 10 (6), 306-6314.
[3] Taheri B. et al. 2D Materials (2018), vol 5,4
[4] Lamanna E. at al. Joule, vol 4, 4, (2020), 865-881
[5] Agresti, A. et al. ACS Energy Lett. (2019), 4, 8, 1862-1871
[6] Najafi L. et al. ACS Nano (2018), 12, 11, 10736-10754
[7] Park N., Zhu K. Nat Rev Mater 5, 333–350 (2020)

FIGURES



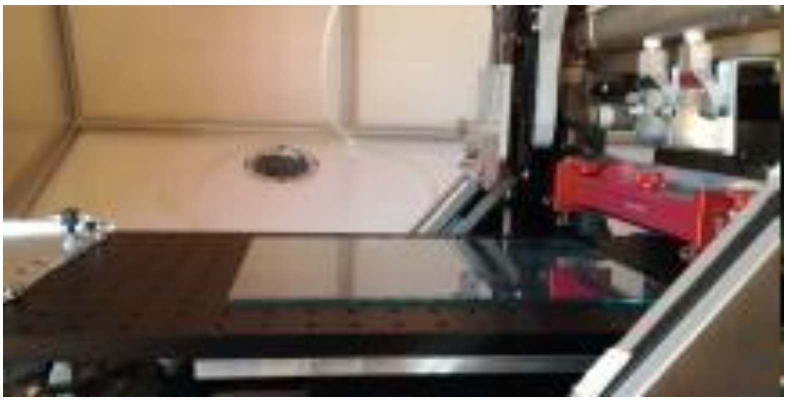


Figure 1: on the left, J-V curves of graphene-carbon based PSCs. On the right: blade coating equipment