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

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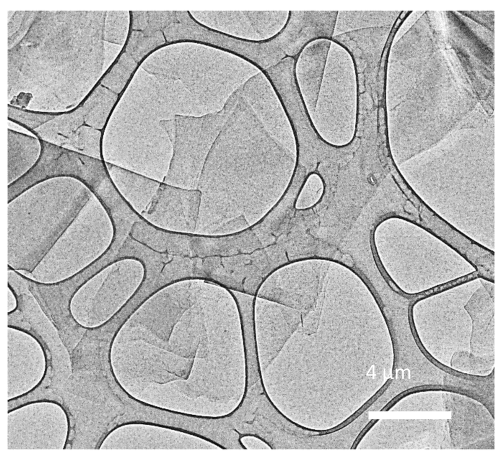
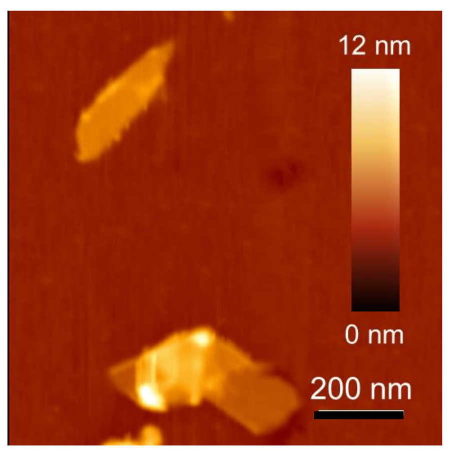
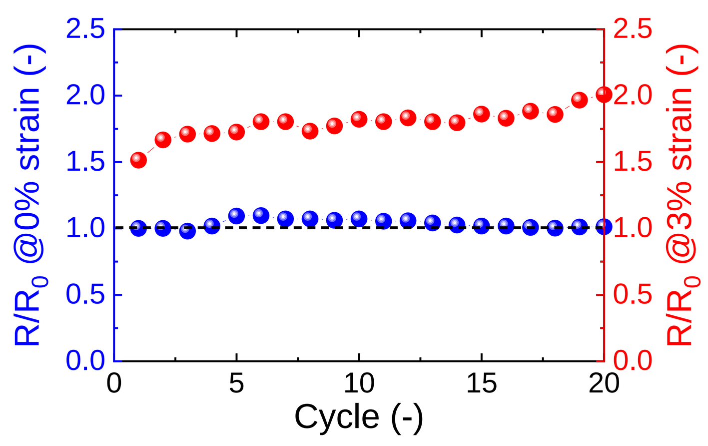
INTRODUCTION

Gold films are typically used as the back electrode of the most efficient certified perovskite solar cells (PSCs)[1], arising severe concerns for their future industrialization. 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 film causes severe instability effects under operating conditions, decreasing the PSC lifetime[2]. In this work, we show a very simple way to replace the gold of PSC back electrode with nanocarbon films based on graphene flakes without altering the underlying structure of the traditional mesoscopic. Our low-temperature graphene-based pastes are currently implemented in advanced mesoscopic PSCs[3,4] and perovskite solar modules (PSMs)[5] including graphene-doped TiO_2 ETL and 2D transition metal dichalcogenides interlayer[6] to overcome the "gold" PCE and reach the state-of-the-art performance through viable large-scale manufacturing processes.

GRAPHENE-BASED ELECTRICALLY CONDUCTIVE ADHESIVES

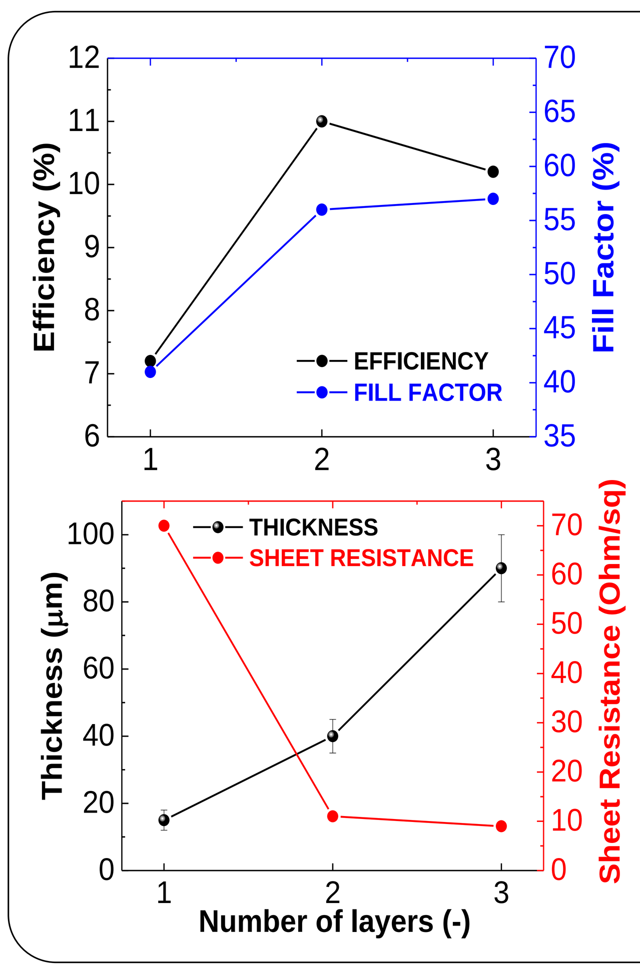






Metal-free electrically conductive adhesives (ECAs) are formulated by using single-/few-layer graphene flakes produced through wet-jet milling exfoliation. Our ECAs show optimal electrical properties (sheet resistance < 20 Ω/sq for thickness < 30 µm) and mechanical strength.

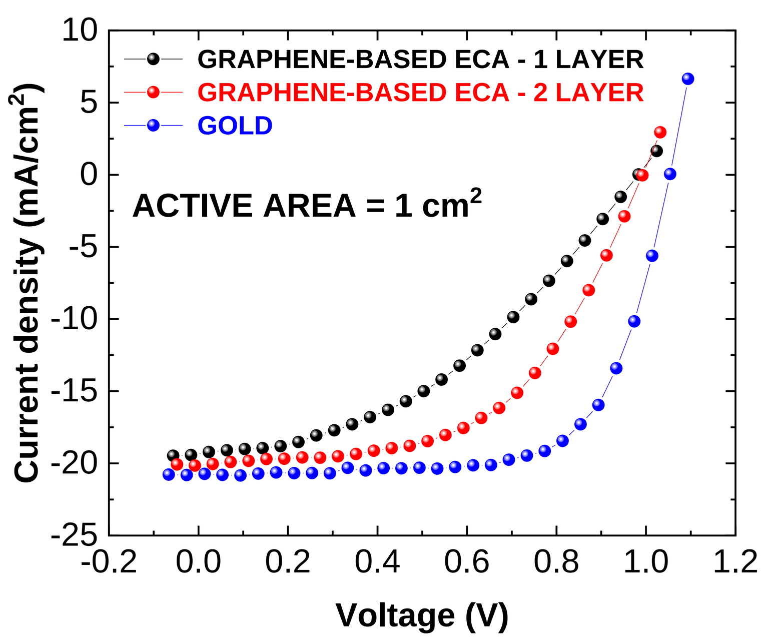
THICKNESS AND SHEET RESISTANCE



We determined both the thickness (µm) and the sheet resistance (Ω/sq) of the deposited graphene-based ECA. The sheet resistance decreases with increasing the thickness.

LAYERS	THICKNESS (µm)	SHEET RESISTANCE (Ω/sq)
1	15 ± 3	73
2	40 ± 5	11
3	90 ± 10	9

OPTIMIZATION OF THICKNESS

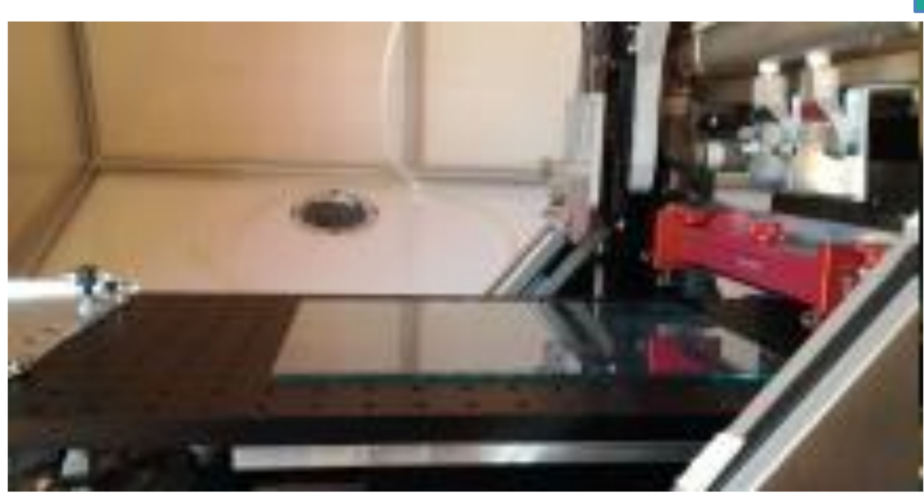


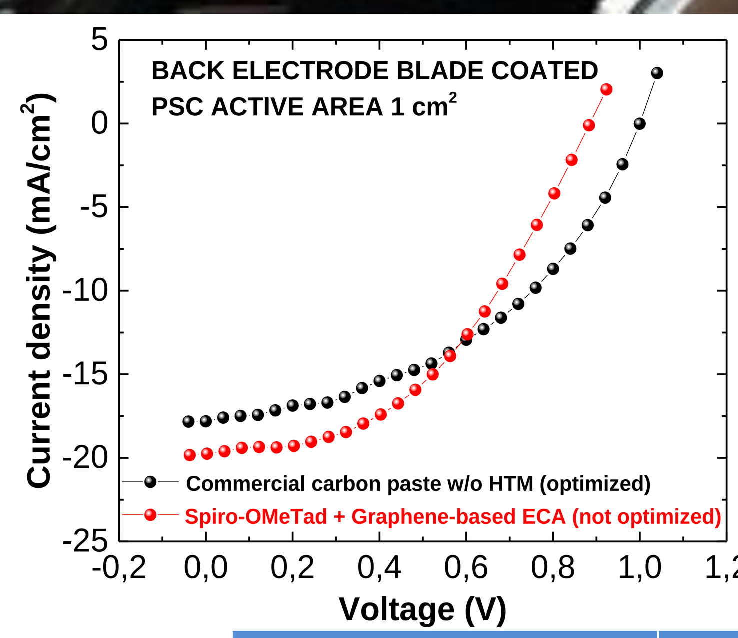
The optimization of the thickness of the spin-coated graphene-based ECA increases the photovoltaic performance of our PSCs by 30%.

+ 30%

Counter Electrode	V_{oc} (V)	J_{sc} (mA/cm²)	FF (%)	PCE (%)
GRAPHENE-BASED ECA - 1 LAYER	0.98	-19.4	40.5	7.7
GRAPHENE-BASED ECA- 2 LAYERS	0.99	-19.7	55.6	11.0
GOLD	1.05	-20.7	68.4	15.0

BLADE COATING TECHNIQUE





Blade coating technique has been established for he upscaling of the PSC technology [7].
The deposition of graphene-based ECA through blade coating paves the way towards the large-scale PSC manufacturing, while avoiding material waste occurring using other depositions techniques, such as spin-coating.

PASTE	V_{oc} (V)	J_{sc} (mA/cm²)	FF (%)	PCE (%)
Commercial carbon paste (optimized)	1.00	-17.3	45.6	8.0
Graphene-based ECA (not yet optimized)	0.90	-19.4	46.0	8.0

CONCLUSIONS

- ✓ **Large-area cell (1 cm² active area) reached a PCE of 11%**
- ✓ **Optimized graphene-based ECAs shows a sheet resistance < 10 Ω/sq for thickness > 40 µm.**
- ✓ **Graphene-based ECAs deposited by blade coating enable efficient large-area PSCs.**

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