Graphene and Perovskite: a New Paradigm for Photovoltaics

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In the context of new generation photovoltaics, perovskite solar cells have recently attracted the scientific community attention due to the surprising power conversion efficiency surpassing 22% on small area devices.[1] Moreover the possibility to tune electrical and optical properties of perovskite crystals combined with low cost solution-based manufacturing processes encouraged the research in scaling-up the perovskite technology from lab-scale cells (active area lower than 0.1 cm2) to large area modules. However, the possibility to reach high efficiency on large area device is still limited by the poor control of large scale perovskite film deposition penalizing the active film morphology and eventually its light harvesting and charge collection properties. In particular, the poor morphology and poor stability under real working conditions of the perovskite/charge transport layers interfaces still represent a bottle neck for perovskite devices when compared with the already developed thin film technology such as CdTe or CIGS.[2] In that context, graphene and 2D related materials (GRMs) are here proposed as a powerful tool to improve the morphology control of perovskite layer during the deposition process and to stabilize the resulting interfaces between the stacked device layers. More in detail, in a typical mesoscopic structure (glass/FTO/compact TiO2 (cTiO2)/mesoporous TiO2/perovskite/spiro-OMeTAD/gold), GRMs have been inserted at both photo and counter electrodes (PE and CE) as dopant or interlayer. At the PE side, graphene flakes [3] have been used as dopant for the mTiO2 precursor while lithium-neutralized graphene oxide (GOLi)[4] has been synthetized to be inserted as interlayer at the mTiO2/perovskite interface. Time-resolved photo-luminescence (PL) measurements revealed an improved morphology of perovskite crystals wrapped into the mTiO2 layer that led to an improved negative charge injection and collection at the cell PE.[5] This allowed madding a record efficiency perovskite-graphene module showing 12.6% power conversion efficiency (PCE) over an active area above 50cm2.[6] At the same time, advanced structural analyses (such as XPS depth profiling and ToF-SIMS analysis) revealed a remarkable reduction of iodine diffusion within the mesoporous layer when graphene nanoflakes are embedded, by even stabilizing the mTiO2graphene/perovskite interface and eventually enlarging the device lifetime under prolonged light soaking. On the CE side, the insertion of molybdenum disulphide (H-MoS2) layer at perovskite/spiro-OMeTAD interface was demonstrated to further improve the cell PCE by speeding-up the holes collection.[7] Moreover it acts as an effective blocking layer for gold atom diffusion from the metallic CE toward the active layer during the working condition by enlarging the device lifetime. In summary, GRMs engineered devices with the following structure (glass/FTO/cTiO2)/mTiO2+graphene/perovskite/MoS2/spiroOMeTAD/gold) showed remarkable PCE above 17% and improved stability, by retaining more than 60% of initial performance after 24 hours of prolonged stress test.

The demonstrated stability improvement of GRMs-based perovskite solar cell together with the feasibility of a reproducible scaling-up procedure are here proposed as a viable route to make perovskite technology ready to satisfy the efficiency, stability and cost targets required by the photovoltaic market.

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