The emerging role of 2D materials in perovskite solar cell technology.

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The emerging of perovskite solar cell (PSC) technology has been disruptive in the last few years by demonstrating power conversion efficiency (PCE) comparable with that of thin film technologies and manufacturing processes compatible with roll2roll massive production.[1] The intrinsic instability of the hybrid lead halide perovskites with the standard formula $CH_3NH_3PbI_3$ (MAPI) has be successfully addressed by employing mixed cation hybrid lead halide perovskites showing superior robustness under prolonged light soaking condition.[2] Despite that, the perovskite/charge transport layer (CTL) interfaces still remain the weakest part of complete device by limiting both the device overall stability and scalability on large area module.[3] In fact, as soon as the device dimensions increase, the impact of charge recombination at perovskite/CTLs interfaces badly affects the overall device performance and stability by still limiting the diffusion of perovskite as a real alternative to the existing photovoltaic technologies. In this work, we propose several device structure modifications by embedding 2-dimensional (2D) materials as interlayer between active and transport layers and/or doping for the CTLs. In particular, the mesoscopic nip structure has been modified by doping both compact and mesoporous TiO_2 layers with the addition of graphene into the precursor solutions [4-7] while several molybdenum disulphide (MoS_2) derivatives have been employed as effective interlayer at perovskite/HTM (hole transporting material) interface.[8,9] The device structure engineering based on 2D materials allowed to realizing record PCE (PCE>20%) MAPI-based mesoscopic devices with enlarged lifetime.[9] Moreover, the easily large scale production of 2D materials in the form of ink by liquid phase exfoliation [10] allowed to easily scale up the 2D-material engineered device structure by small area cell to large scale module. [11-12] The optimization of mixed-cation perovskite precursor formulation, the renewed module layout design and the insertion of 2D-materials into the module structure allowed to move from 12.6% to 13.4% PCE by enlarging the module active area from 50 to 108 cm^2. The presented structure, combined with a next replacement of the standard HTM with a more stable counter electrode, pave the way for a marketable and cheap photovoltaic technology replacing the existing silicon-based ones.

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