Hybrid lead halide perovskite as a non-excitonic triplet sensitiser for triplet fusion upconversion

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Sensitised triplet fusion upconverters are photonic systems based on organic chromophores, which output significantly anti-Stokes shifted photoluminescence at potentially mild excitation densities. Triplet fusion occurs upon the encounter of two triplet excitons diffusing within the upconverting medium, which is usually a dense film or solution of polycyclic aromatic hydrocarbon derivatives [1]. Populating the triplet manifold of the system is the task of the triplet sensitiser. This is invariably a nanomaterial, such as a metal-organic complex or a metal chalcogenide nanocrystal, in which the excited state photophysics are exciton-dominated. Exciton mobility is thus a central concern in sensitised triplet fusion upconversion. The low exciton mobility of many organic materials can be an impediment to producing efficient systems [2].

In a new approach for photonic upconversion, we found that photoexcited carriers in thin film methylammonium lead iodide perovskite (MAPI) could generate triplet excitons in a surface coating of rubrene, a common triplet fusion upconverter. The triplet sensitisation mechanism does not rely on the existence of an exciton in the sensitiser material, proceeding instead by the sequential transfer of nongeminate charge carriers. The result is that highly mobile photoexcited charge carriers in MAPI are harnessed to drive the exciton-reliant process of triplet fusion upconversion in rubrene.

Thin film MAPI samples were prepared using solution processing, then treated with spin-coated layers of small molecule organic semiconductors, including rubrene. After encapsulation in nitrogen, samples were characterised using time-resolved photoluminescence. Changes in the MAPI photoluminescence decay after coating with an organic semiconductor film were assigned to charge carrier extraction and exciton formation at the organic layer. Pumping MAPI resulted in delayed fluorescence emanating from the molecular layer, with a pump power dependence indicative of triplet fusion upconversion modified by density-dependent carrier diffusion in the MAPI film.

The described mechanism for triplet sensitization enables an energy-funneling effect, sidestepping the exciton mobility problems endemic to nanomaterial triplet sensitisers. Optimised versions of the MAPI-organic dye upconverters reported here should therefore permit efficient upconversion conditions to be obtained at very low irradiance. The efficient interconversion of excitons and charges at the MAPI-organic dye interface is also of potential interest for other optoelectronic applications, such as lasing [3].

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