Nanopatterning-Enhanced Perovskite Luminophores

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We demonstrate that nanopatterning of solution-processable metal-halide perovskite films can be used to control their luminescence spectra and lead to up to five-fold increase of luminescence yield.

Metal halide perovskites have recently emerged as a class of solution-processable semiconductor materials which enable a wide range of photovoltaic and photonics applications thanks to their unique properties such as broad absorption spectrum, long charge diffusion length, tunable bandgap, high charge carrier mobility, high absorption coefficient. Here we focus on their light emitting properties and show that their optical response can be engineered using metamaterial design concepts. As a proof of principle we fabricated all-perovskite dielectric metasurfaces and hybrid metal-perovskite metamaterials with significantly enhanced luminescence emission and controlled spectral response throughout the visible region.

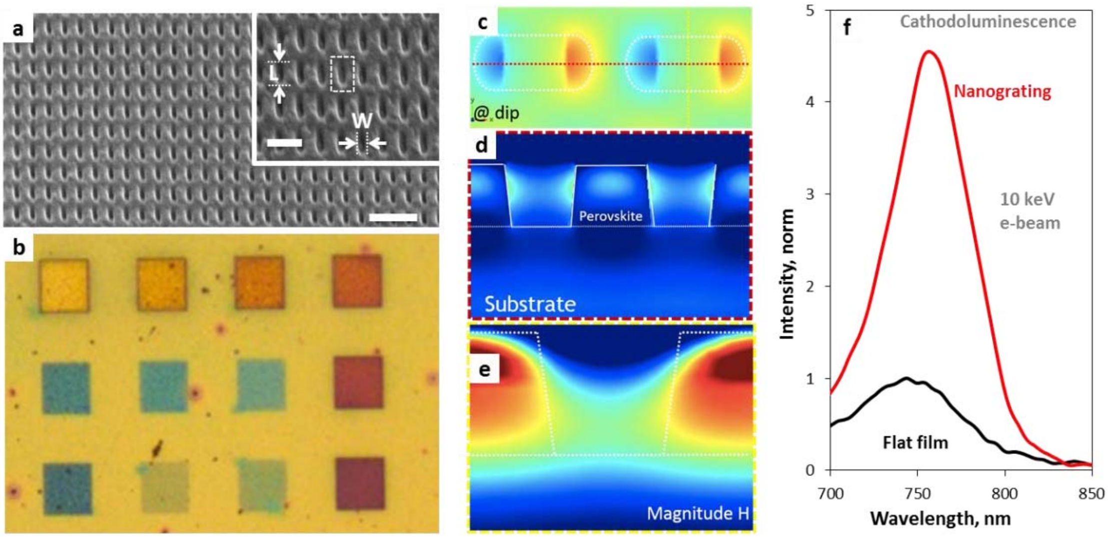

Fig. 1 a) Secondary electron image of an all-dielectric ($CH_3NH_3PbI_3$) perovskite nanoslits array b) Color tuning on the reflection spectra of all-dielectric perovskite metamaterials with varying milling depth; c-d) Simulated electric and e) magnetic field distributions on the nanoslits for TE polarised incident light f) cathodoluminescence of perovskite nanograting with 350 nm period, showing five-fold enhancement when compared to an unstructured film, using unpolarised detection.

All dielectric metsurfaces were engraved by focused ion beam (FIB) milling (Fig. 1a) onto thin films of methylammonium lead iodide perovskite ($CH_3NH_3PbI_3$) spin-coated on quartz substrate. Nanogratings and nanoslits metamaterials arrays show vivid structural color tuning (Fig. 1b) and strong field enhancement (Fig. c-e) as function of varying, period, widths and milling depth. This is manifested by up to a five-fold Purcell enhancement of both photo- and cathodo-luminescence emission (Fig. 1f) compared to the unstructured films.

We will also discuss hybrid designs including metal-semiconductor-metal plasmonic slab waveguides and strongly coupled plasmonic nano-resonators which allow a larger degree of control the perovskite light emission and extraction properties.

Our results prove that nanostructuring and hybridization of perovskites with metamaterials are viable routes to engineer tunable structural colour and radiative emission properties on-demand, thus defining a new paradigm to increase the efficiency, control the electroluminescence spectrum, and improve light extraction and directivity of light-emitting devices.

References:

[1] B. Gholipour, G. Adamo, D. Cortecchia, H. N. S. Krishnamoorthy, M. D. Birowosuto, N. I. Zheludev, C. Soci, Adv. Mater. 2017, 1604268.

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