Color Tunable Perovskite Metamaterials

G. Adamo,[1] B. Gholipour,[2] K. C. Lew,[1] D. Cortecchia,[3,4] H. N. S. Krishnamoorthy,[1] J. K. So,[1] M. D. Birowosuto,[5] N. I. Zheludev[1,2] and C. Soci[1]

[1] *Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, 21 Nanyang Link, Singapore 637371*
[2] *Optoelectronics Research Centre & Centre for Photonic Metamaterials, University of Southampton, SO17 1BJ, UK*
[3] *Interdisciplinary Graduate School, Nanyang Technological University, Singapore 639798*
[4] *Energy Research Institute @ NTU (ERI@N), Nanyang Technological University, 50 Nanyang Drive, Singapore 637553*
[5] *CINTRA UMI CNRS/NTU/THALES 3288, 50 Nanyang Drive, Singapore 637553*
E-mail address: g.adamo@ntu.edu.sg

Abstract: We show that subwavelength nanostructuring of solution-processed organolead halide perovskite films generates optical resonances whose position can be controlled by design. Perovskite metamaterial create color tuning and strong enhancement of photo- and cathodo-luminescence of the films.

Metal halide perovskites attract increasing interest as solution-processable materials with outstanding optoelectronic properties for applications such photovoltaic energy conversion, light-emitting diodes and lasers, owing to their low cost and ease of processing. The field of metamaterials has demonstrated the ability of engineering resonant response in numerous material platforms, both metallic and dielectric, via nanostructuring, enabling unprecedented control of light absorption and emission properties of materials.

Here we show that all-dielectric metamaterials obtained by nanopatterning methylammonium lead iodide perovskite ($CH_3NH_3PbI_3$) thin films enable structural colour tuning (Fig. 1a) and luminescence enhancement. We also show hybridization of perovskites with metamaterials, leading to tunability of the light emission in the perovskite films. We report a five-fold enhancement in cathodoluminescence (Fig. 1b) and three-fold increase of the photoluminescence with comparable reduction in the decay time for the nanostructured perovskite in comparison with unstructured films.

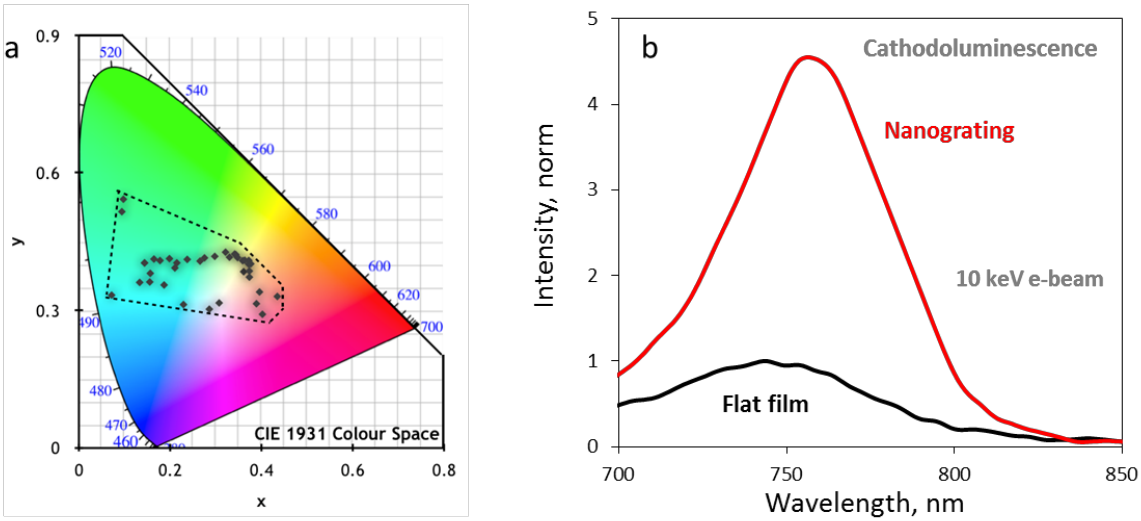

Fig. 1 a) Color tuning of the reflection spectra of all-dielectric perovskite metamaterials; b) Cathodoluminescence of perovskite nanograting of 350 nm period, showing five-fold enhancement when compared to an unstructured film, using unpolarised detection.

Perovskite films of 150 nm thickness were spin-coated on quartz substrates and their optical constants estimated experimentally from ellipsometry measurements. Nanograting and nanoslit metaterials were milled into the perovskite film by focused ion beam (FIB), browsing through a wide parameter space to obtain tuning of the resonances across the entire visible range.

This first demonstration of all-dielectric, solution processed perovskite metamaterials, with tunable structural colour and radiative emission properties engineered on-demand, paves a new way to increase the efficiency, control the electroluminescence spectrum, and possibly improve light extraction and directivity of hybrid perovskite light-emitting devices.

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