

Electronic supplementary information (ESI)

Facile In-situ Synthesis of Stable Luminescent Organic-Inorganic Lead Halide Perovskite Nanoparticles in a Polymer Matrix

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Supporting Figures

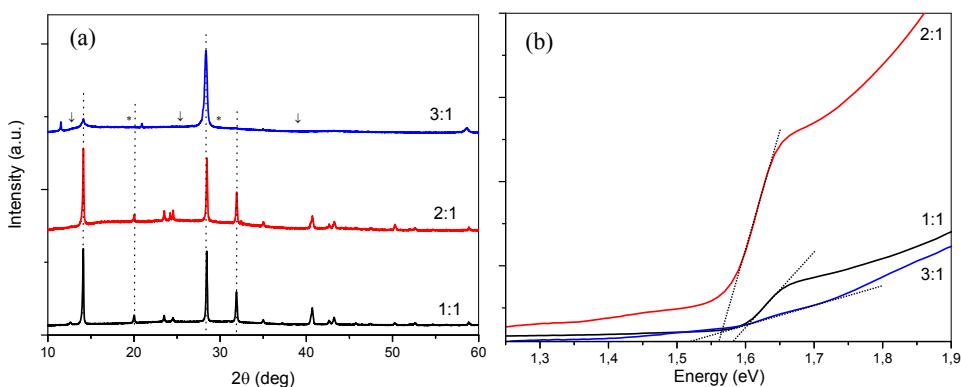


Fig. S1. XRD patterns from (a) perovskite nanoparticles with initial molar ratios of MAI and PbI₂ of 1:1, 2:1 and 3:1. The nanoparticles were annealed at 130 °C for 20 min. Note: The dotted lines indicate the changes after changing composition. Stars (*) show the peak positions from bare MAI as showed in the Main Text. Downward arrows (↓) show the peak positions of bare PbI₂. (b) Tauc plots of MAPbI₃ perovskite nanoparticles for the same three molar ratios of MAI to PbI₂. This shows that the optical band gap (E_g) changes when the molar ratio of the precursors is changed.

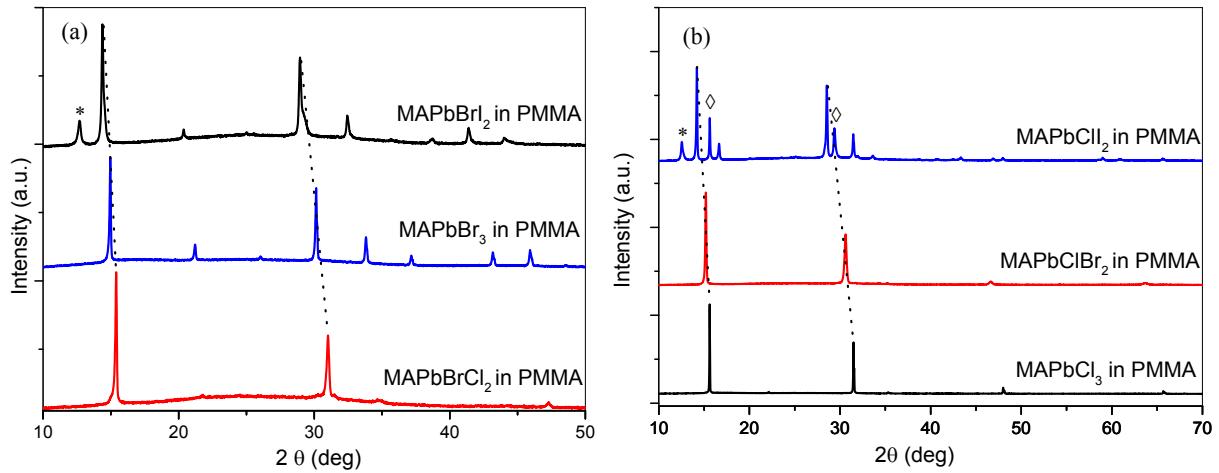


Fig. S2. XRD patterns from (a) MAPbBr_2 and (b) MAPbCl_2 nanoparticles in a PMMA matrix after annealing at 130 °C for 20 min. The perovskites are named based on the starting precursors added. In this case we added MAX and PbX_2 in equal molar ratio in the solution. The dotted lines indicate the peak shift. Peaks labeled with asterisks are related to lead halide or mixed halide, e.g., PbICl , while peaks labeled with diamonds are related to MAPbCl_3 .

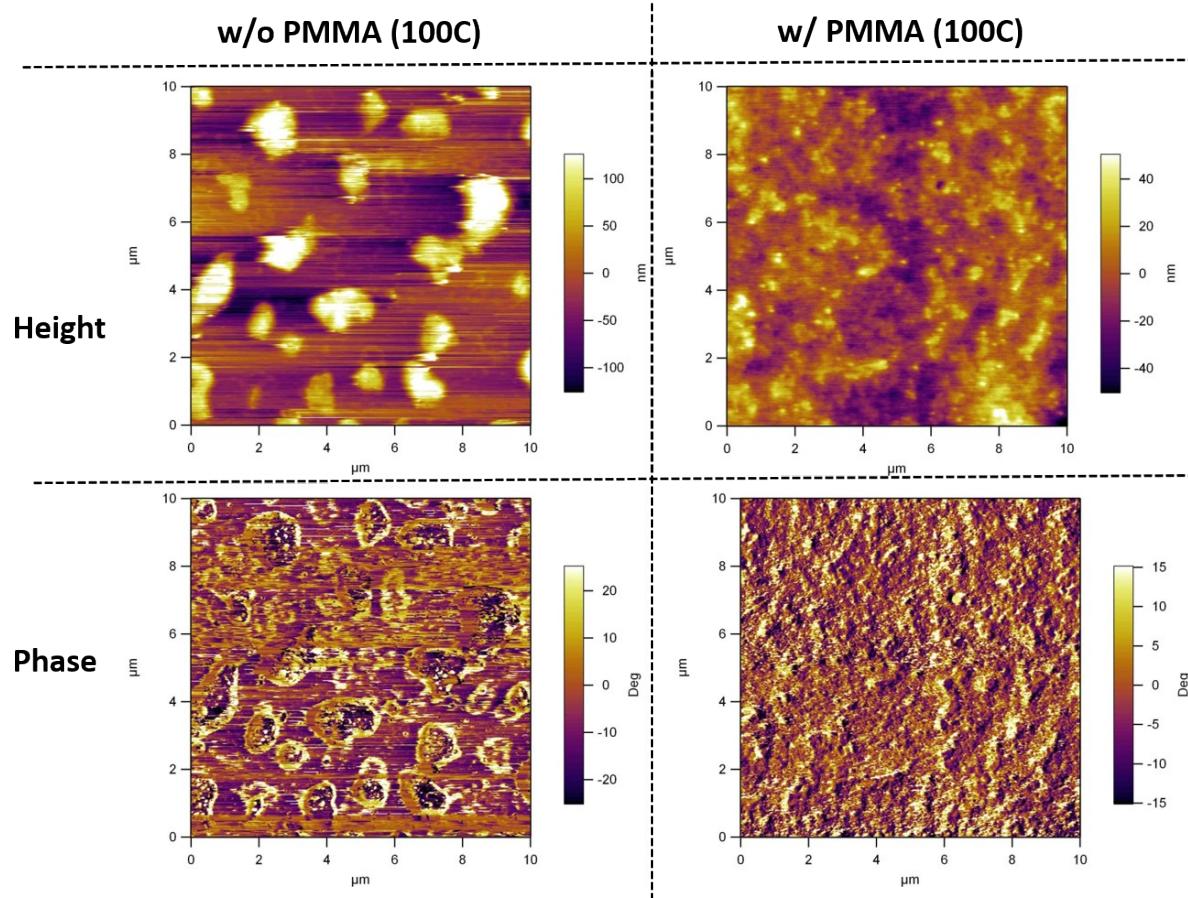


Fig. S3. Atomic force microscope (AFM) phase and height images of MAPbI_3 prepared with and without the PMMA matrix. These images show that the pure film without PMMA appears rough with big crystals (or aggregates) and a surface roughness of 60 nm. On the other hand, in the presence of PMMA, the nanoparticle matrix film is fairly smooth with surface roughness of 14 nm. This huge difference in surface roughness could be due to the restriction of molecular movement of the perovskite materials to crystallize or aggregate when polymer molecules are present or simply PMMA molecules flowing around the nanoparticles filling the gaps between particles, or a synergistic effect of both.

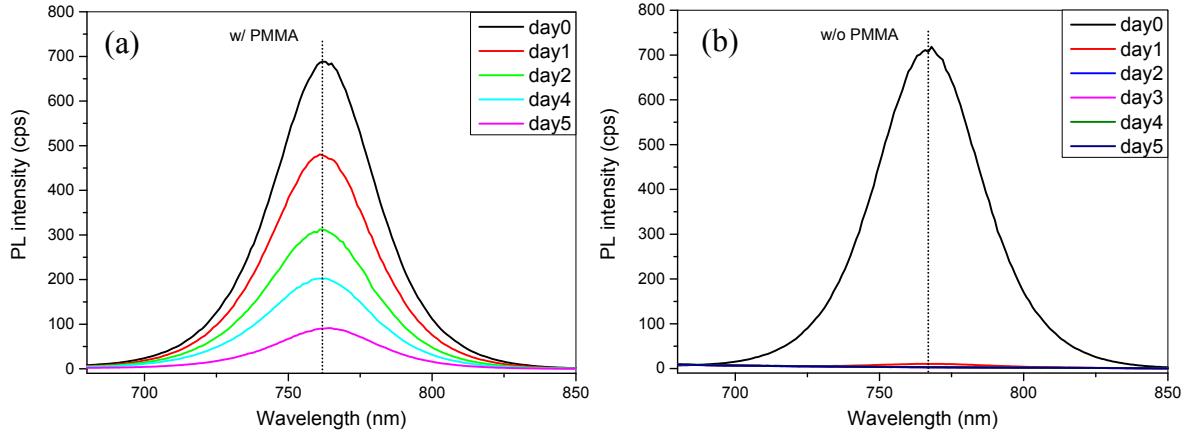


Fig. S4. PL spectra of MAPbI₃ NPs in (a) PMMA and (b) without PMMA. The samples were aged in humid ambient (RH = 70-80%) up to 5 days and the measurement was performed at one-day interval. The PL measurement was performed with an excitation wavelength of 405 nm. Note: we omitted the day 3 PL spectrum in PMMA due to abnormal low intensity.

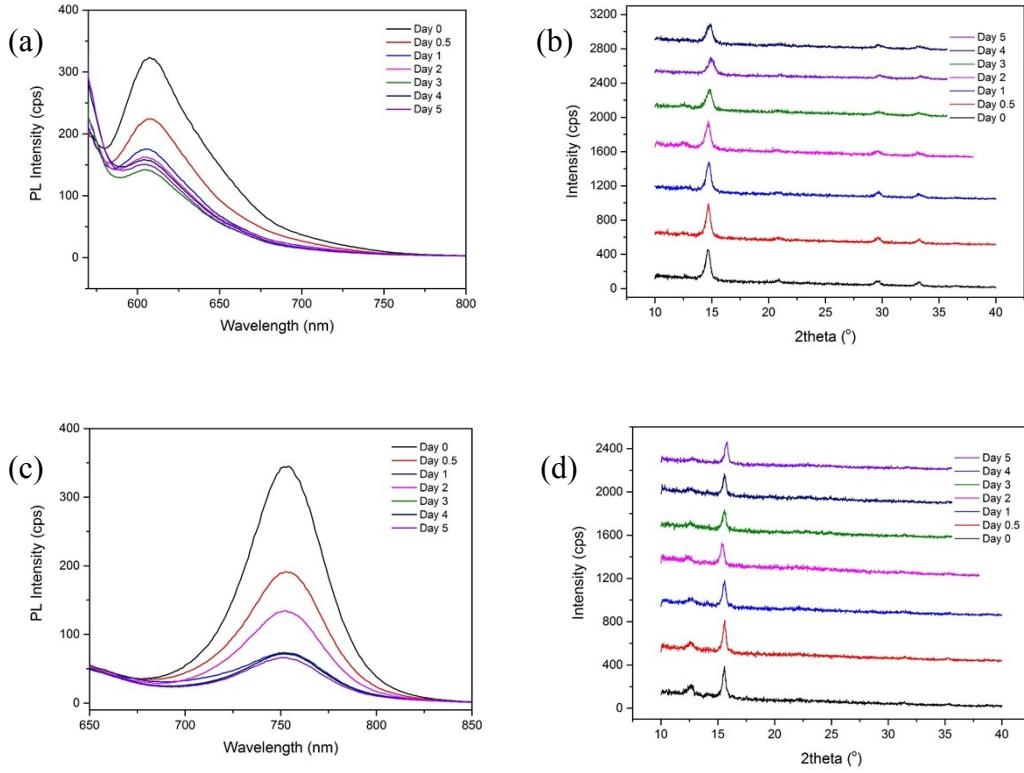


Fig. S5. PL spectra (a,c) and XRD patterns (b,d) of MAPbIBr₂ (a,b) and MAPbICl₂ (c,d) NPs in PMMA. The samples were aged in humid ambient (RH = 70-80%) up to 5 days and the measurement was performed at one-day interval. The PL measurement was performed with an excitation wavelength of 405 nm. The tail in the lower wavelength (in Fig. S5a) can be caused by a mixed perovskite phase of MAPbIBr_x, where x is between 0 to 2.

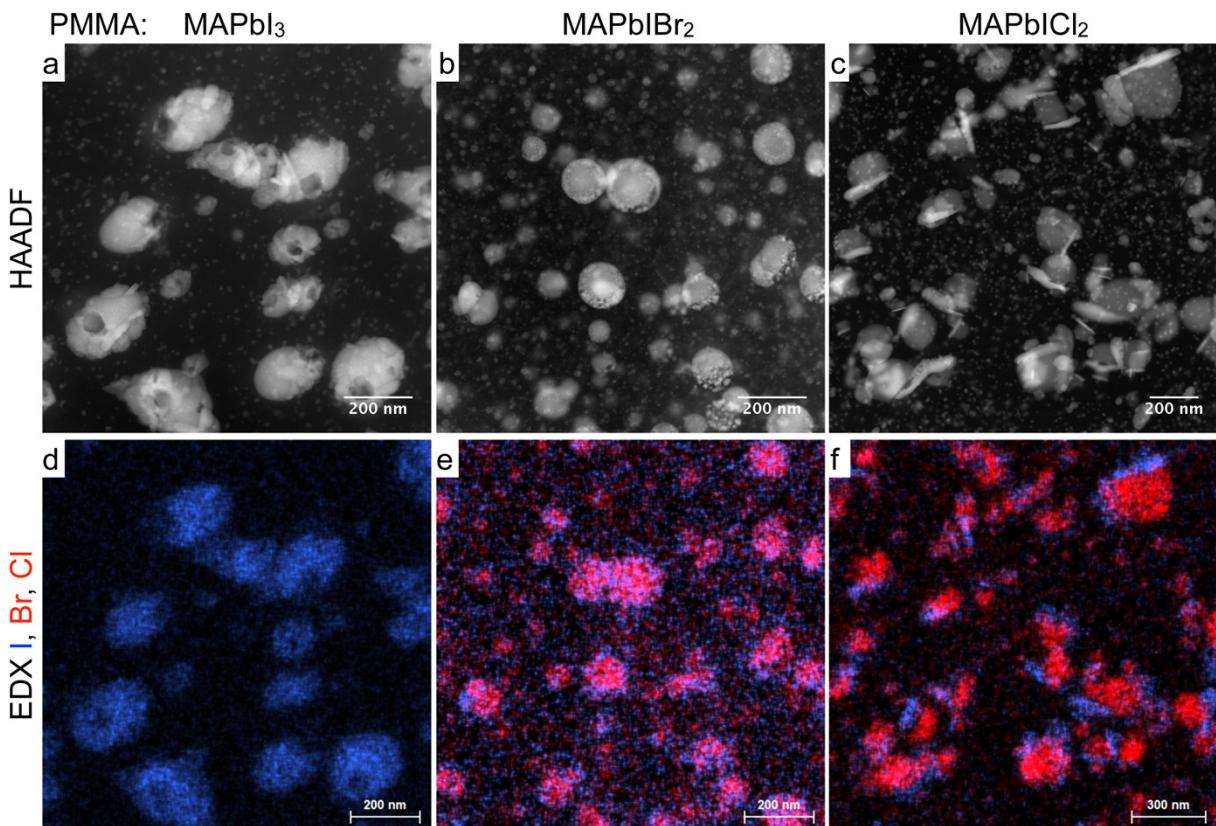


Fig. S6. (a-c) Detailed scanning transmission electron microscopy (STEM) high-angle annular dark-field (HAADF) images and (d-f) energy dispersive X-ray (EDX) maps obtained from MAPbI-X₂ NPs in the PMMA matrix. I is shown in blue in (d-f) while Br and Cl are both shown in red in (e) and (f). Thus pink indicates a mixture of I and Br in (e) or I and Cl in (f).

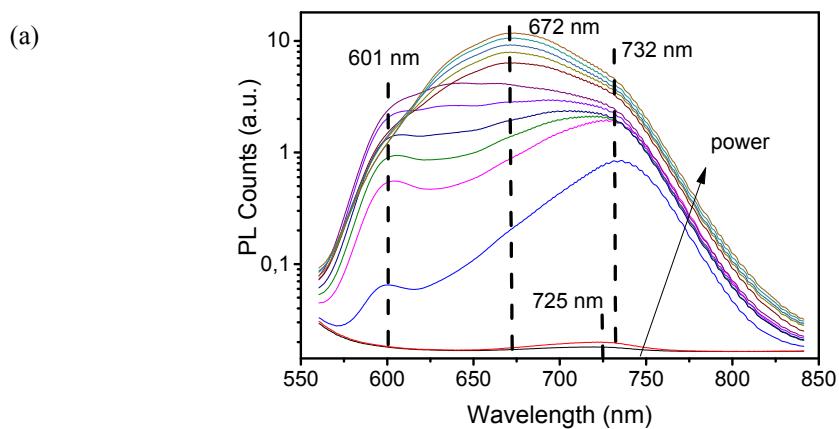


Fig. S7. Evolution of photoluminescence with increasing excitation laser power from MAPbIBr₂ NPs in PMMA.

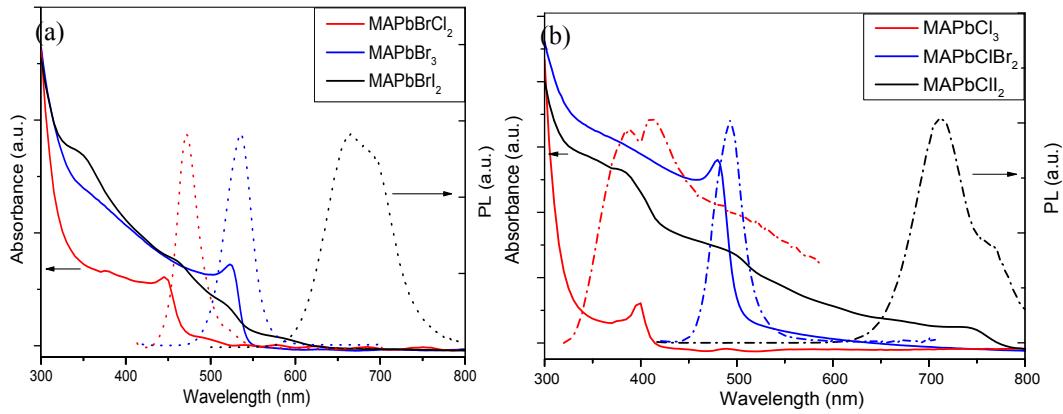


Fig. S8. Normalized UV-Vis and PL spectra from (a) MABr-PbX₂ and (b) MACl-PbX₂ in PMMA after annealing for 20 min at 130 °C. In (b) the weak absorption peak at 375 nm corresponding to the PL peak at 390 nm from MAPbCl₃ nanoparticles in a polymer matrix is due to the formation of PbCl₂ precipitates. In the PL spectrum from MAPbClI₂ nanoparticles in a polymer matrix, there are two overlapping peaks. The peak at 710 nm is probably due to the hump at 675 nm in the absorption spectrum. It is related to the locally rich phase, e.g. MAPbICl₂.