Efficient and Spectrally Stable Perovskite Light Emitting Diode (peLED) via Metal Doping

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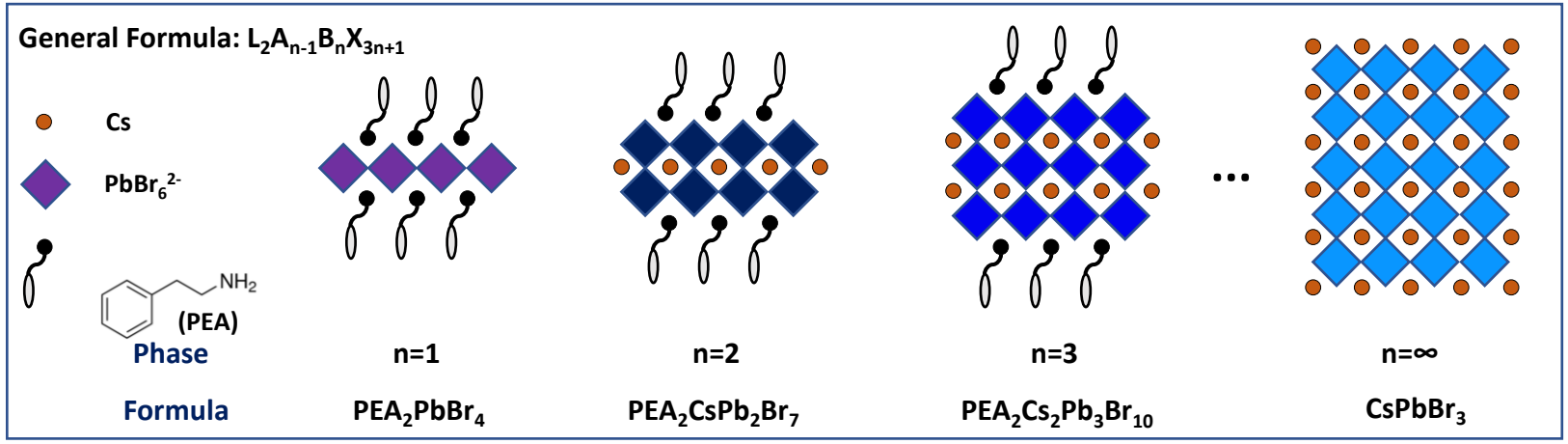
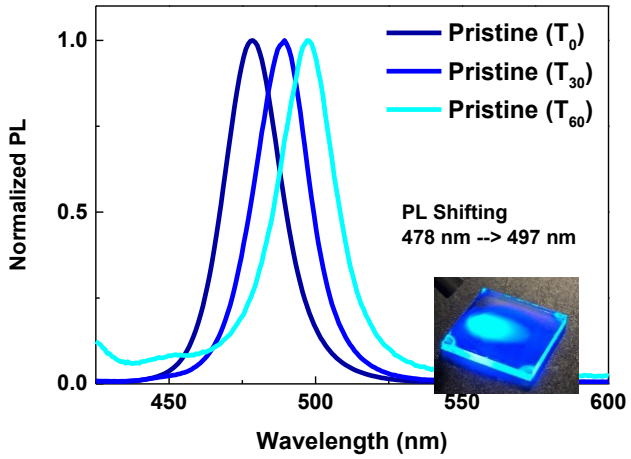
PEA based quasi-2D perovskites

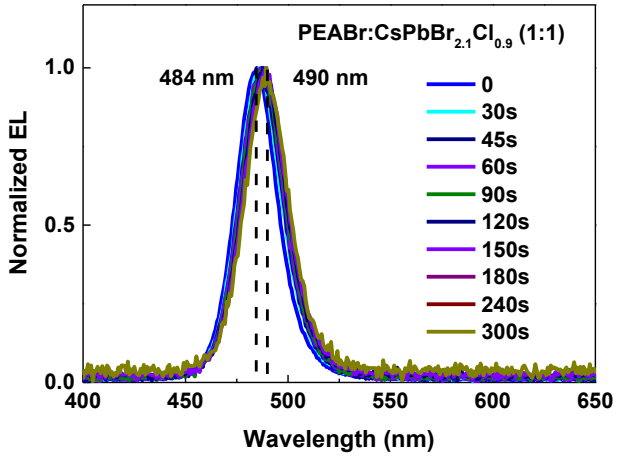


- Quasi-2D perovskite was first applied in the solar cells for higher device stability[1].
- The concept was transferred to first near IR LED, then to RGB.[2,3]
- Adding bulky cation - "spacer" to the 3D perovskites are key strategy in achieving good EQE and brightness in blue peLED.

Good efficiency (EQE) and brightness, however…



Photoluminescence (PL)



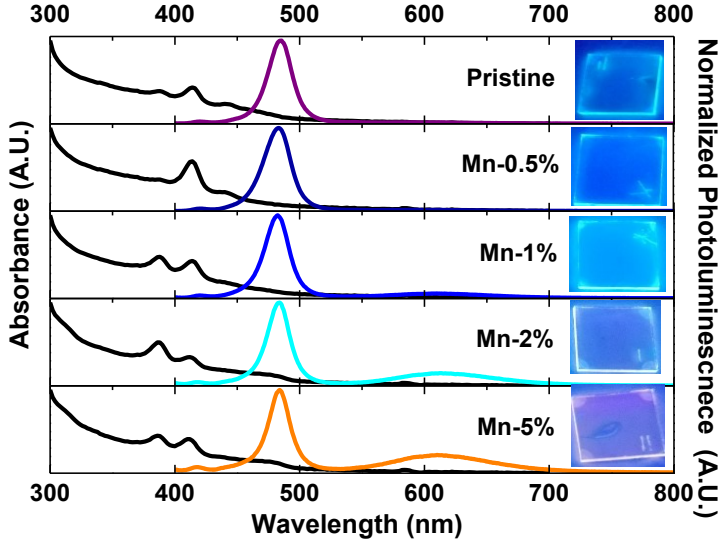
Electroluminescene (EL)

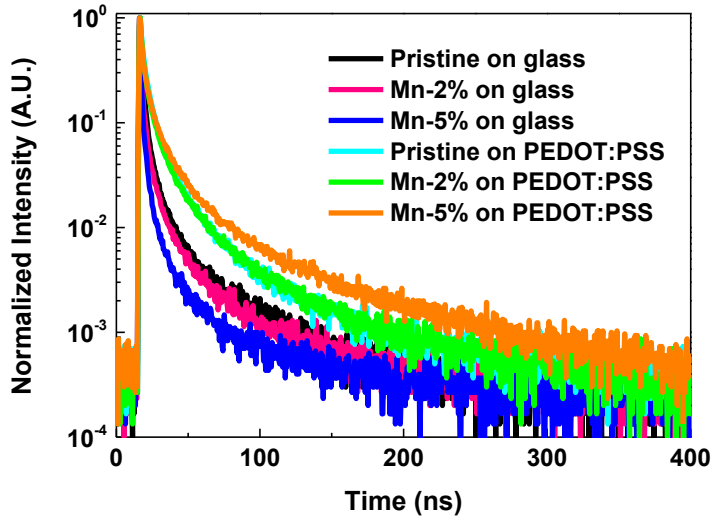
Shift in the Emission Peak

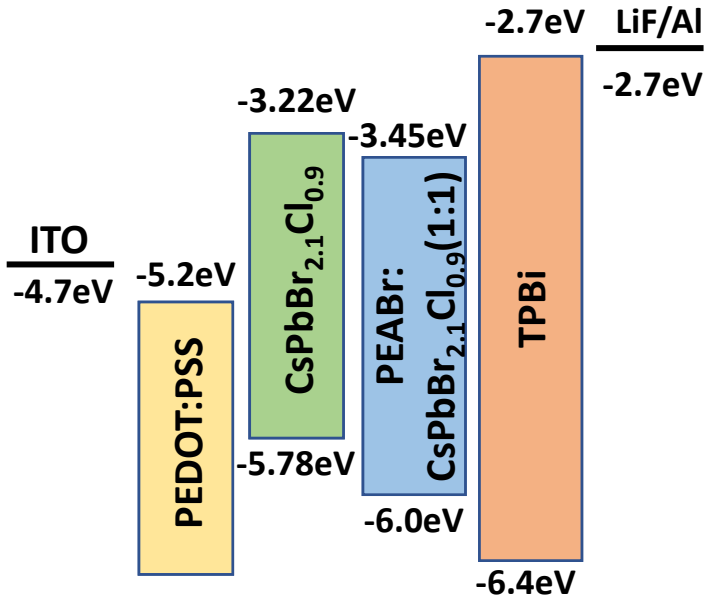
- Spectral stability issue arises from ion-migration and phase segregation in mixed halide system (Br/Cl), especially under photo-excitation and electric potential.
- **Metal-doping** is a promising strategy on boosting efficiency[4] and enhancing spectral stability.

[1]*Angew. Chem*. **2014**, *53*, 11232–11235.
[2]*Nat. Photon.* **2016**, *10*, 699-704.
[3]*Chem. Mater.* **2019**, *31*, 1, 83–89
[4]*Nat. Commun.* **2019**, *10*, 5633

Thin-film and device characterization – Mn optimizations

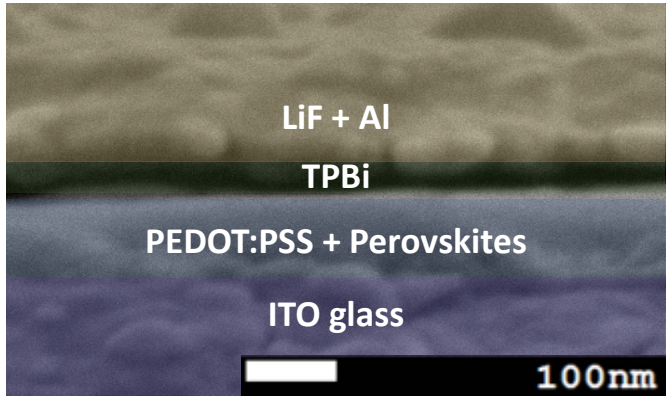


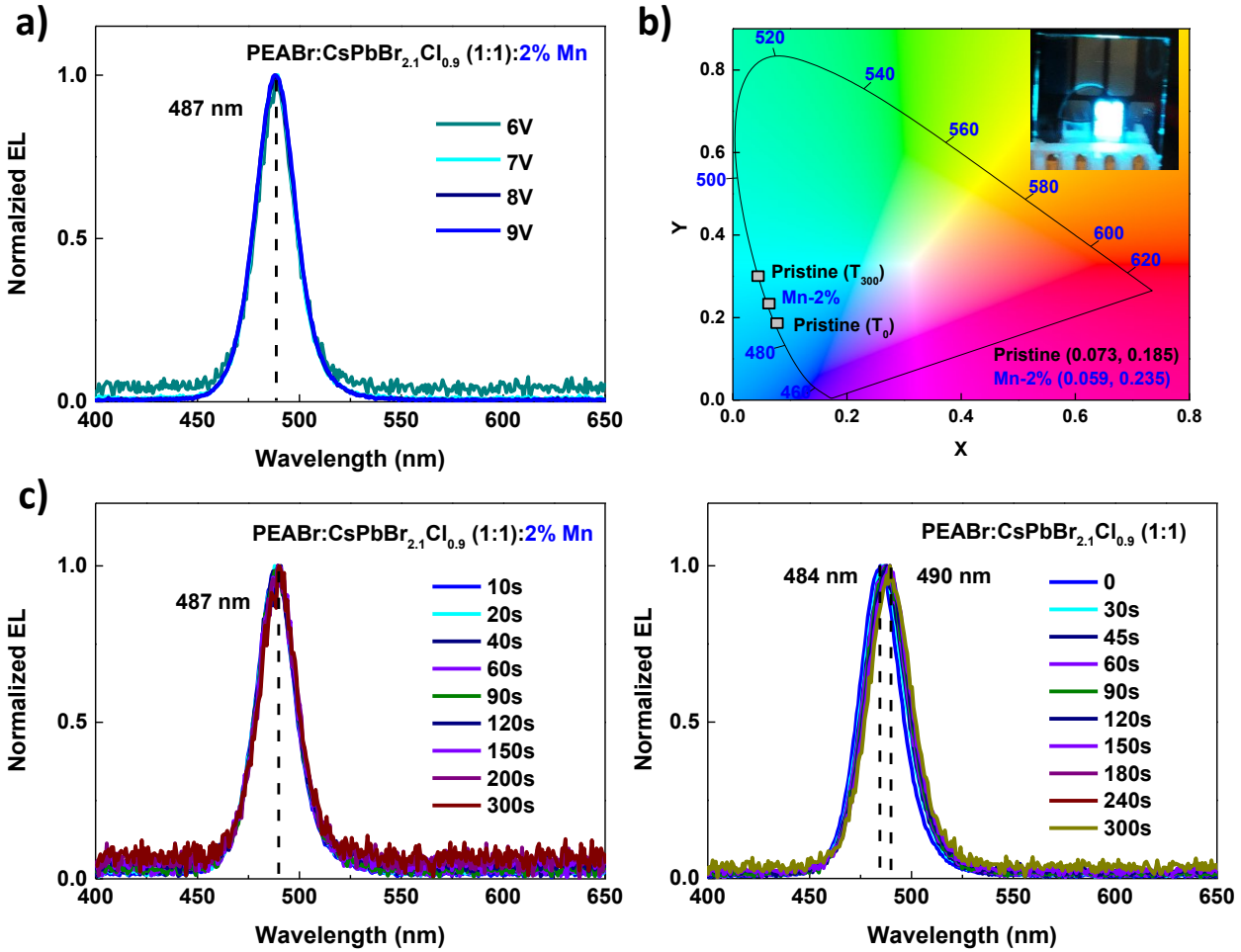




Metal (%)	EL position (nm)	Max. EQE (%)	Max. Brightness (cd/m^{-2})	Max. Current Efficiency (cd/A)	Turn-on voltage (V)
Pristine*	484	4.35	711	1.47	5.1
Mn-0.5%	486	7.46	409	2.33	4.5
Mn-1%	487	4.56	348	1.55	5.3
Mn-2%	487	6.38	473	2.21	4.5
Mn-5%	490	5.71	900	2.01	4.6
Mn-10%	491	3.15	587	1.19	6.1

*Pristine refers to PEABr:$CsPbBr_{2.1}Cl_{0.9}$ in (1:1) ratio

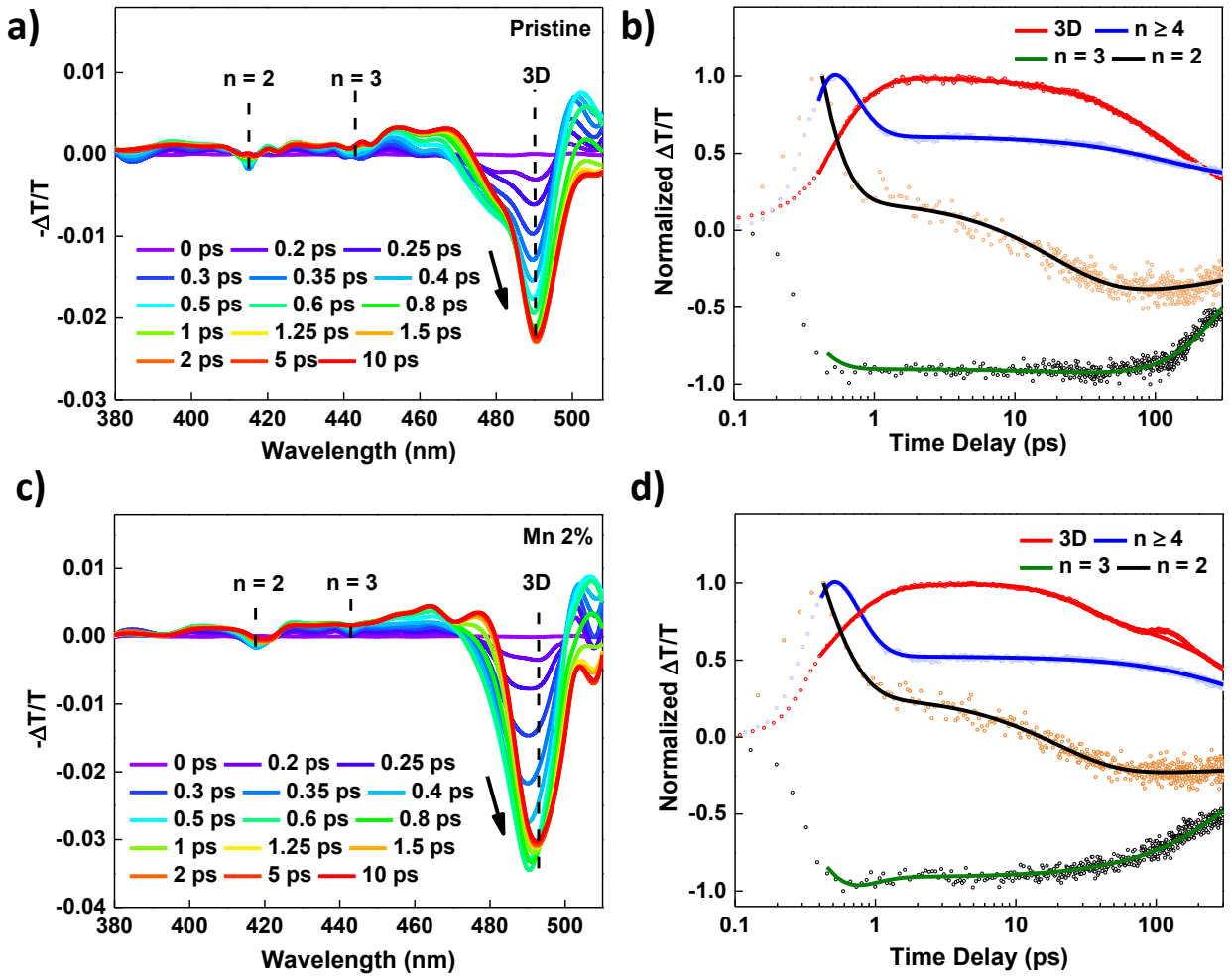




Spectral Stability of Mn-doped peLEDs

a) Spectral stability of Mn-2% doped device at 487 nm, up to 9V.
b) Commission Internationale de l'Eclairage (CIE) plot showing the position of pristine and doped sample, with inset Mn-2% device photo.
c) Spectral stability of Mn-2% device at fixed voltage 6.8 V, EL peak **remains at 487 nm**.
d) Comparison of pristine device at fixed voltage 6.8 V, note the **drifting** from 484 nm to 490 nm.

All the samples are measured in ambient air, without encapsulation



Transient Absorption (TA) Spectroscopy

1. "Energy funneling" [1] was observed in both sample, carrier transfer from lower order phase <n>, to higher phase, then to 3D phase for emission.

2. For Mn-doped sample, the transfer from n ≥ 4 to 3D is more efficient compare to pristine.

$$\frac{\Delta T}{T} = A_1 \cdot e^{-\frac{t}{\tau_1}} + A_2 \cdot e^{-\frac{t}{\tau_2}} + B_1 \cdot e^{-\frac{t}{\tau_3}} - B_2 \cdot e^{-\frac{t}{\tau_4}}$$

A_1, A_2, B_1, B_2 - amplitude
t_1, t_2, t_3 - decay time constant
t_4 - increase time constant

[1]Nat. Photon. 2016, 10, 699-704

Conclusion

- Metal (Mn^{2+}) doping in quasi-2D peLED has shown enhanced EQE, brightness and spectral stability.
- The EL peak drifting problem are solved with doped sample, with steady emission at 487 nm
- The carrier transfer of n≥4 phases to 3D phase are more efficient in doped sample, which may explained the enhanced EL performance.
- Further studies are need to study the improvement mechanism.

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