Editorial: Perovskite materials for light-emitting devices

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Over the past decade, great effort in the metal halide perovskite society has been devoted to the perovskite lighting field. The sky-rocketing external quantum efficiencies (EQEs) of perovskite lighting-emitting diodes (PeLEDs) from less than 1% to over 20% make perovskite emitters successfully join the solid-state lighting community (Chen et al., 2021a; Wu et al., 2021). The huge diversity of perovskite emitters with various compositions and dimensionality contributes to a colourful world of PeLEDs that their emission can be continuously tuned from violet to near-infrared, as well as white (via colour combination) (Chen et al., 2021a; Chen et al., 2021b).

The goal of this Research Topic is to show a wide range of possibilities of perovskite emitters for various functional light-emitting devices, to meet the requirement of potential applications in the future. Four original papers about the engineering of different types of perovskite emitters (including excitonic and non-excitonic systems), which are the core of PeLED devices, are collected here.

Excitonic perovskites, generally referred to low-dimensional perovskites such as two-dimensional (2D)/quasi-2D perovskites and perovskite quantum dots (QDs)/nanocrystals (NCs), are the most popular system and have established a large community in the perovskite light-emitting field, due to their outstanding optoelectronic properties like large exciton binding energy, low trap density, and high radiative efficiency. The tailoring of low-dimensional perovskites, via organic ligand engineering, perovskite compositional engineering, and controlling synthetic methods, is a powerful approach to modulating their nanostructure (e.g., multi-quantum wells and crystal sizes/shapes) as well as optoelectronic properties [e.g., emission colours and photoluminescence quantum yields (PLQYs)] (Dey et al., 2021; Zhang et al., 2021).

For instance, Wang et al. reported a simple strategy to improve the overall quality of quasi-2D perovskites. They found that in o-FPEA CN x Pb F Br 1 system (m ≥ 1, and o-F-PEABr = o-fluorophenylethylammonium bromide), the modulation of 2D perovskite
layer thickness was important for the improvement of PLQY. A
~60% PLQY was achieved in the m = 3 quasi-2D perovskite,
while much lower PLQYs (<10%) in the m = 1 and 2 quasi-2D
perovskites were obtained. This phenomenon was attributed to
the strong electron-phonon coupling that caused non-radiative
recombination (Chen et al., 2021a). Furthermore, using mixed
ligands of o-F-PEABr and 2-aminoethanol hydrobromide
(EOABr) to modulate the properties of m = 3 quasi-2D
perovskite contributed to a ~80% PLQY. The improvement
from signal-ligand samples to dual-ligand samples, such as
PLQYs (from ~60% to 80%) and EQEs (from ~5% to 10%),
reflects that dual-ligand control is a feasible method to obtain
high-quality perovskite emitters. However, more investigation
is needed to fully understand the in-depth mechanism.

As another type of low-dimensional perovskite, perovskite
QDs/NCs generally have sharp emissions and high colour
purity. Interestingly, broad emissions are also achievable via
ion doping, such as incorporating alkaline Earth metals or
purity. Interestingly, broad emissions are also achievable
via ion doping, such as incorporating alkaline Earth metals or
rare-earth ions into the perovskite lattice (Dey et al., 2021).
In fact, Wang et al. successfully demonstrated broad-
emission perovskite NCs by doping Mn2+ into CsPbCl3
(i.e., Mn:CsPbCl3), which generated a combined emission
of a shape emission from CsPbCl3 (~410 nm) and a broad
emission from Mn2+ (~600 nm). Moreover, they found that
using 3-thienylboronic acid (TBA) to passivate the surface
traps of Mn:CsPbCl3 NCs could suppress the non-radiative
recombination, resulting in a huge improvement of PLQY
from 46% (non-passivated one) to 93%. Another bonus for the
TBA passivation was the significantly improved stability
(including heating/moisture stability, storage stability, and
purification stability) of the perovskite NCs. Both the
enhanced PLQY and stability of Mn:CsPbCl3 NCs prove
that surface passivation is an effective strategy to further
strengthen the perovskite QD/NC quality.

Although PeLEDs based on excitonic perovskite systems
operate efficiently at low charge-carrier density regions, they
suffer from obvious efficiency droop at high charge-carrier
density regions. In contrast, non-excitonic perovskite system
like three-dimensional (3D) perovskites works reversely that
better device performance can be achieved when charge-
carrier density is high, because the radiative recombination
rate (or bimolecular recombination rate) is proportional to the
charge-carrier density in 3D perovskites (Xing et al., 2017).
Therefore, 3D perovskites are proper choices for high-
brightness PeLEDs which need to be injected with a large
amount of current. For instance, Yuan et al. have
demonstrated high-brightness green PeLEDs with a
maximum luminance of 72,082 cd/m², based on CsPbBr3-
Cs4PbBr6 hybrid perovskites. They found that the excessive
CsBr on the surface of the perovskite film could react with
partial 3D CsPbBr3 to form Cs4PbBr6, which could modify the
film morphology and passivate the crystal surface. More
importantly, they successfully demonstrated a hole-
transport-layer-free device based on a unique device
architecture of ITO/Perovskite/LiF (8 nm)/Bphen (60 nm)/
LiF (1 nm)/Al, and with which a device half-lifetime of
1,000 min was achieved. This report reflects that
composition engineering is an effective strategy to optimise
the 3D perovskite crystals and films for better light emission.

Regarding near-infrared emission, in terms of emission
wavelength, 3D perovskites are also better candidates than low
dimensional perovskites that tend to have bluer emission. The
substitution of Pb2+ with Sn2+ in the perovskite lattice can lead
to redshifts of emission to the near-infrared region
(−1,000 nm) (Liu et al., 2019). Moreover, the choice of
A-site cations for these Sn/Pb mixed perovskites is also
critical for their emission properties. Liu et al. has
investigated how A-site cations of MA+, FA+, and Cs+
affected the quality of perovskites of ASnxPb1-xI3 (x = 0, 0.2,
0.4, 0.6, 0.8, 1). They found that MASnPb1-xI3, FASnPb1-
xI3, and CsSnPb1-xI3 had bandgaps ranging from 1.2 to 1.5
5 eV, 1.2–1.5 eV, and 1.3–1.7 eV, corresponding to near-
infrared emission of 766–980 nm, 800–965 nm,
716–960 nm, respectively. However, only MASnPb1-xI3 and
FASnPb1-xI3 perovskites were considered promising for
lighting applications as CsSnPb1-xI3 perovskites showed
weak emission, poor stability, and poor film morphology,
which might relate to their small tolerance factor of the
lattice (~0.81).

In conclusion, in this Research Topic, we show three types of
perovskite emitters (i.e., 0D perovskite QDs/NCs, 2D/quasi-2D
perovskites, and 3D perovskites) with various optoelectronic
properties for different lighting applications. We believe these
reports could provide the perovskite lighting field with more
inspiration and guidelines for the future development of
perovskite light-emitting devices.

Author contributions

All authors listed have made a substantial, direct, and
intellectual contribution to the work and approved it for
publication.

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Conflict of interest

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