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PEROVSKITES

Highly efficient perovskite LEDs

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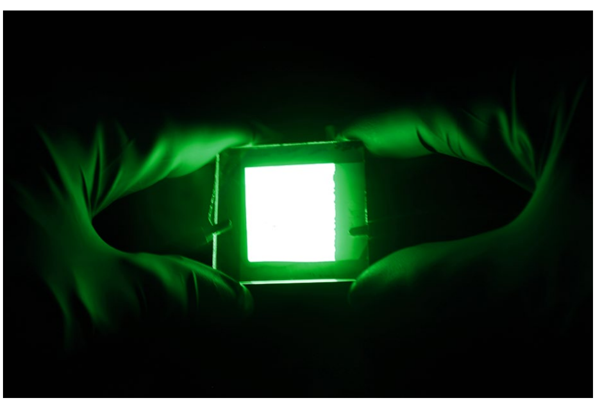
Perovskite light-emitting diodes (LEDs) benefit from both high colour purity and low-cost solution processability. However, to enable their use in practical devices, further improvements in their electroluminescence efficiency are needed. One strategy towards this goal, as reported by Young-Hoon Kim, Sungjin Kim, Arvin Kakekhani, Andrew Rappe, Tae-Woo Lee and colleagues in *Nature Photonics*, consists of employing a one-dopant alloying strategy that enables the synthesis of monodisperse perovskite nanoparticles with high efficiency.

“Inorganic quantum dots are widely used emitters with high colour purity, but do not meet the requirements of REC.2020, the new colour standard for ultra-high-definition television, on top of suffering from size-dependent colour purity and wavelength,” explains Lee. “Therefore, metal halide perovskite emitters, which have high colour purity and satisfy REC.2020, aroused great attention as promising light emitters for future displays.”



Credit: Tae-Woo Lee, Seoul National University

To maximize the electroluminescence efficiency of perovskite emitters, one ideally needs to simultaneously increase the radiative recombination rate and suppress the non-radiative recombination rate. A successful strategy to enhance radiative recombination consists in spatially confining the charge carriers in small crystals, whereas non-radiative recombination can be reduced by passivating defects, particularly those at the surface.

The researchers incorporated a guanidinium (GA) cation in formamidinium (FA) lead bromide ($FAPbBr_3$) perovskite nanocrystals, obtaining small, uniform colloidal nanocrystals. “In the theoretical part of the study we established that the GA dopants are sparingly soluble in $FAPbBr_3$, and that the remainder of the GA resides on the surface,” says Rappe. “As a result, choosing a particular GA/FA ratio fixes the surface-to-volume ratio, enhancing the monodispersity of the particles; moreover, the GA has an extra amine group, so its presence at the surface stabilizes surface Br ions, reducing defects and non-radiative recombination.”

In particular, as the amount of GA increases, the bulk enthalpy of the nanocrystals increases owing to GA’s large size, destabilizing the bulk crystals, so that only low concentrations of GA can be introduced in the structure. The rest of the GA segregates to the nanocrystal’s surfaces. The result is that the size of the particles decreases and the surface-to-bulk ratio increases to compensate for the increase of bulk enthalpy. The presence of GA on the surface also hinders nanocrystal growth, leading to the formation of smaller crystals. These processes result in an increased confinement of charges. Finally, the GA on the surface effectively passivates surface defects by increasing the number of hydrogen bonds.

“As a result, we manufactured a perovskite LED with the world’s highest external quantum efficiency (23.4%) and current efficiency (108 cd A^{-1}),” notes Lee. “This is the highest device efficiency among perovskite LEDs reported so far and is comparable with even the highest current efficiencies of conventional III–V and II–VI inorganic quantum dot LEDs.” This strategy can also be extended to perovskites with other halides and cations.

Before perovskite LEDs can be used in commercial devices, however, their operating stability needs to be improved, which can be done through various strategies. “First, we intend to gain better control of perovskite compositions and surface ligands, and modify the interlayers in devices,” states Lee. “Then, inspired by the development history of organic LEDs and quantum dot LEDs, we will try various materials engineering concepts for the emitting layers and push forward to achieve higher efficiency, longer lifetimes and fast progress toward more commercially viable devices.”

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