Ultra-Bright Perovskite Nanocrystals from a Novel Spray Synthesis

A spray-synthesis method to produce novel perovskite nanocrystals (NC) shows an unprecedentedly stable absolute quantum yield ≈ 100% for photoluminescence in both solution and neat solid films. The highly emissive NC films exhibited a pure green emission with Commission Internationale de l'Eclairage (CIE) coordinates (0.161, 0.769).

Nanocrystals (NC) are nano-materials of length less than 100 nm in all three dimensions; their optical, electric and magnetic properties vary with their size. NC of many kinds emit bright light; their bandgaps can be tuned through a wide spectrum simply on modifying their size or composition during synthesis. NC technology has become popular for display and imaging because of the outstanding photoluminescent quantum yields (PLQY), narrow width (full width at half maximum, FWHM) in the emission spectrum and widely tunable emission wavelengths.

Perovskite NC show promising optical properties and simple synthesis. The synthesis of organometallic lead-halide perovskite NC typically involves an injection of the precursors dissolved in an appropriate solvent into poor solvents; the perovskite NC then crystallize in the poor solvents. The NC formed with this method generally possess irregularly spherical shapes[1] and non-ideal PLQY values. The group led by Hao-Wu Lin (National Tsing Hua University) reports a new perovskite NC spray-synthesis method (**Fig. 1**) utilizing a traditional perovskite NC synthesis in conjunction with spray pyrolysis.[2] The resulting organometallic lead-halide perovskite NC showed a highly crystallized cubic shape with absolute PLQY 100% in the solution form. In addition, negligible quenching was found in neat films, which showed a saturated green emission at 526 nm of narrow width and an absolute PLQY up to 100%. The morphology of the NC was investigated with images from a transmission electron microscope (TEM). These spray-synthesized NC showed an almost perfect cubic shape, which was previously observed in only high-performance Cs-based inorganic perovskite NC.[3] Grazing-incidence wide-angle X-ray scattering (GIWAXS) at **TLS 23A1** was performed to reveal a single crystal-like NC film structure; with grazing-incidence small-angle X-ray scattering (GISAXS) an average size 14 nm of NC was determined. The high crystallinity and size range of NC are consistent with those observed in the TEM images and their fast-Fourier-transform (FFT) patterns. The structure and morphology of a film at varied scales are illustrated in **Fig. 2**.

Because of the excellent PLQY of NC films, Lin's team applied them as color-conversion films for optoelectronic applications. The pixelated color conversion was demonstrated utilizing the NC-organic light-emission display (ccNC-OLED) structure of color-conversion type, which is shown in **Fig. 3**. The pixelated still image can be converted by the large-area NC thin films to green images with a highly saturated

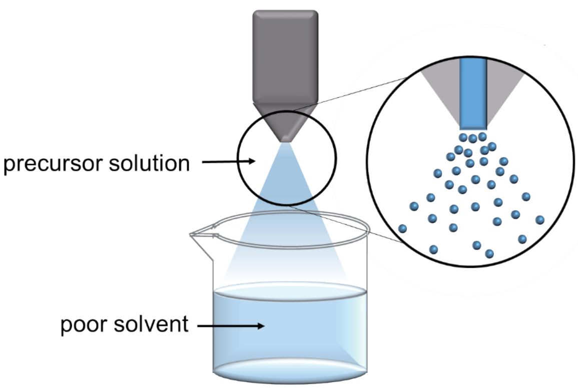

Fig. 1: Illustration of the spay-synthesis method. The droplets of precursor solution of micrometer size are sprayed into a poor solvent to increase the contact surface area between the precursor solution and the poor solvent, which synthesizes high-quality perovskite NC. [Reproduced from Ref. 2]

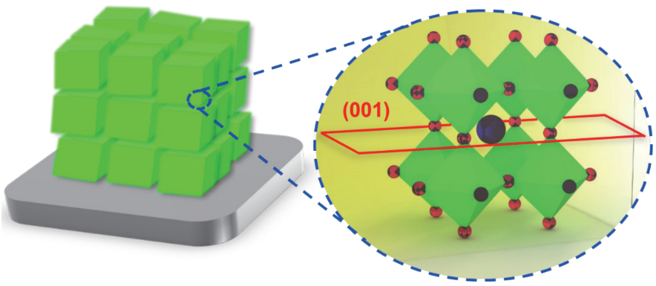

Fig. 2: Schematic representation of the nanomorphology and crystal orientation of cubic-shaped NC thin films. [Reproduced from Ref. 2]

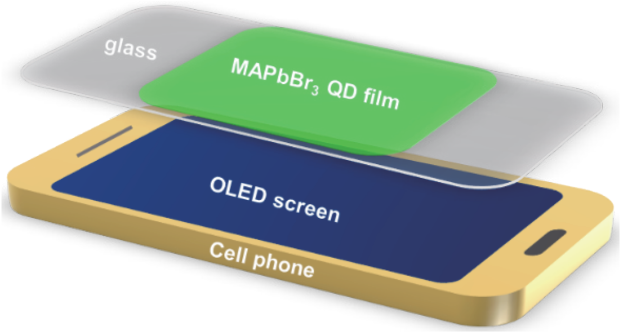

Fig. 3: Illustration of the hybrid ccNC-OLED display. The spray-synthesized NC film was bar-coated on a thin glass substrate and the substrate was attached onto a cellular telephone with an OLED screen. [Reproduced from Ref. 2]

color. The color gamut displayed a 15% increment compared with a state-of- the-art OLED display because of the saturated green emission, which corresponds to a wide color gamut up to 119% National Television System Committee (NTSC) or 123% Digital Cinema Initiatives-P3 (DCI-P3) standard.

In conclusion, Lin's group demonstrated a novel spray method to synthesize highly emissive cubic-shaped NC, which are not merely scalable, highly stable and extremely emissive even in neat solid films, but widely applicable in ccNC-OLED hybrid devices. The stable and highly emissive thin films also have properties for useful applications in optical-type sensors, bioimaging and luminescent solar concentrators. (Reported by Hao-Wu Lin, National Tsing Hua University)

This report features the work of Hao-Wu Lin and his co-workers published in Adv. Mater. ***30****, 1705532 (2018).*

TLS 23A1 IASW – Small/Wide Angle X-ray Scattering
- GIWAXS, GISAXS
- Materials Science, Perovskite Nano-crystals

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Human-Made Photonic Crystals Superior to a Butterfly's Wings

Human-made bioinspired three-dimensional gyroid-structured photonic crystals reflect desired visible light in a range over the full visible wavelengths, which is superior to a butterfly's wings found in nature. Through novel trapping of structural coloration (TOSC), unique flexible gyroid-structured reflectors were first-time and efficiently fabricated, possessing diverse performance for applications as energy-efficient window, sensor and optical device.

Unlike typical colors from pigments, photonic crystals from self-assembled biomaterials can exhibit a fantastic and brilliant structural coloration due to coherent reflection by inner long- or short-range ordered periodic microstructures, which formed more than 500 million years ago. Three-dimensional (3D) network-structured photonic crystals such as single and double gyroids, single and double diamonds, as well as 3D rod-connected amorphous diamond (RCD) microstructures have attracted much attention because of the ease of achieving a complete photonic bandgap that can implement the complete reflection of incident light in a desired wavelength range without angular dependence or iridescence. In theory, the reflectance wavelength of the photonic crystal is similar to the dimension of the inner microstructure. For this reason a visible-wavelength photonic crystal (400–800 nm) should have a periodicity of its microstructure ranging from 133 to 267 nm based on an efficient refractive index (n_{eff}) 1.5. This periodicity for the 3D network microstructure is difficult to make by top-down optical interference or lithographic methods. Difficulties in fabricating such a network microstructure with a periodicity matching the visible wavelength have prompted scientists to replicate self-assembled network microstructures found in nature. For example, butterfly wings (**Fig. 1(a)**) and macaw feather bards have been