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SUPPORTING INFORMATIONS

Nanohybrids as a tool to control the dispersion of organic emitters in solution-processed electroluminescent layers

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Experimental Part

Experimental Part - General

All experiments were performed under an atmosphere of dry argon using standard Schlenk techniques. Commercially available reagents were used as received without further purification. The synthesis of the emitter L was done following the procedure from our previous work.¹ The ZnO nanocrystals were prepared as published elsewhere.² Solvents were freshly purified using MBRAUN SPS-800 drying columns.. UV-Visible spectra were recorded at room temperature on a VARIAN Cary 5000 spectrophotometer. The UV-Vis emission and excitation spectra measurements were recorded on a FL 920 Edimburgh Instrument equipped with a Hamamatsu R5509-73 photomultiplier for the NIR domain (300-1700 nm) and corrected for the response of the photomultiplier. AFM measurements: the tip comes from Mikromasch referenced HQ -NSC15 / AI - BS, while the AFM comes from Digital Instruments (Bruker) Multimode SPM equipped with a type E scanner (XY = $10\mu m$, Z = $2.5\mu m$) and a Nanoscope IIIa controller. The software Gwyddion ensures the processing of collected datas. Morphology roughness RMS (root mean square) is analyzed on Glass /ITO /PEDOT :PSS / active layer sample. The layers including nanohybrids were characterized by HR-TEM (JEOL 3010, acceleration voltage of 300 kV). Holey carbon coated copper grid were used. Sacrificial layer of spincoated PEDOT:PSS on ITO substrate was used before deposition of the nanohybrids containing matrix (see main text). Layer thickness were measured using a profilometer type Dektak XTS (Bruker, Germany) equipped with a stylus of 2 μ m radius.

LED fabrication – Methods

The OLED devices were fabricated onto indium tin oxide (ITO) glass substrates purchased from Xin Yang Technology (90 nm thick, sheet resistance of 15 Ω/\Box). Prior to organic layer deposition, the ITO substrates were cleaned by sonication in a detergent solution, rinsed twice in de-ionized water and then in isopropanol solution and finally treated with UV-ozone during 15 minutes. The OLEDs stack is: Glass / ITO/ PEDOT:PSS/ Matrix including nanohybrids/ BCP/ Alq₃/ LiF/ Al prepared in inert atmosphere (Ar-filled glovebox) with spin-coated PEDOT-PSS (40nm), following evaporation deposition (deposited at a rate of 0.2 nm/s under high vacuum of 10^{-7} mbar) of the other layers: BCP, Alq₃ before a thin layer of lithium fluoride is used as

¹ J. Phelipot, N. Ledos, T. Dombray, M.P. Duffy, M. Denis, T. Wang, Y. Didane, M. Gaceur, Q. Bao, X. Liu, M. Fahlman, P. Delugas, A. Mattoni, D. Tondelier, B. Geffroy, P. Bouit, O. Margeat, J. Ackermann, M. Hissler, Highly Emissive Layers based on Organic/Inorganic Nanohybrids Using Aggregation Induced Emission Effect, Adv. Mater. Technol. 2100876 (2021) 2100876. https://doi.org/10.1002/admt.202100876.

² A.K. Diallo, M. Gaceur, N. Berton, O. Margeat, J. Ackermann, C. Videlot-Ackermann, Towards solution-processed ambipolar hybrid thin-film transistors based on ZnO nanoparticles and P3HT polymer, Superlattices Microstruct. 58 (2013) 144–153. https://doi.org/10.1016/j.spmi.2013.03.012.

electron injection layer sequentially capped with a 100 nm thick layer of aluminum as cathode. Polyvinylcarbazole (PVK) and an oxadiazole derivative (2-(4-tert-butylphenyl)-5-(4-biphenyl-yl)-1,3,4oxadiazole) including nanohybrids as electroluminescent blends were spin coated at a speed of 4000 rpm for 45 seconds, the layers were then annealed on a hot plate at 150°C for 5 minutes. The active area of the devices defined by the Al cathode was 0.3 cm². After deposition, all the measurements were performed at room temperature under ambient atmosphere with no further encapsulation of devices. The current– voltage–luminance (I–V–L) characteristics of the devices were measured with a regulated power supply (ACT100 Fontaine) combined with a multimeter (Keithley) and a 1 cm² area silicon calibrated photodiode (Hamamatsu). Electroluminescence (EL) spectra and chromaticity coordinates of the devices were recorded with a PR650 SpectraScan spectrophotometer, with a spectral resolution of 4 nm.



Figure S1. TEM images of the layers (a) M:N₅, (b) M:N₅:OA, (c) M:N₁₅ and (d) M:N₁₅:OA.



Figure S2. TEM (a) and AFM (b) images of the layer $M:N_{10}:OA_{0.4\%}$. TEM (c) and AFM (d) images of the layer $M:N_{10}:OA_{0.6\%}$.



Figure S3. SEM image of a cross-section of the layer **M:N**₁₀**:OA** spin-coated on a substrate. The 50 nm thick layer is present above the dashed line, and the brighter spots within the layer are attributed to the homogeneously dispersed nanohybrids.



Figure S4. AFM images at $10x10\mu$ m scale of the layer (a) M:N₅, (b) M:N₅:OA, (c) M:N₁₅ and (d) M:N₁₅:OA.



Figure S5. Absorption spectra of layers of M:L, M:N₁₀ and M:N₁₀:OA deposited on glass substrate.

	Sample name	M:N ₁₀ :OA _Y
PLQY (%)	Y = OA (0.2% v/v)	35 +/-3
	Y = OA (0.4% v/v)	33 +/-3
	Y = OA (0.6% v/v)	35 +/-3

Table S1. Photoluminescence quantum yields for three amounts of OA in $M:N_{10}:OA$ layers.



Figure S6. Electroluminescent spectra measured at 50 mA·cm⁻² of ITO/PEDOT:PSS/**M:OA**/BCP/Alq₃/LiF/Al devices (inset: photograph image of the device).



Figure S7. J-V curves for various thicknesses of the electroluminescent layer M:N₁₀:OA in ITO/PEDOT:PSS/M:N₁₀:OA/BCP/Alq₃/LiF/Al devices.

M:N ₁₀ :OA layer thickness (+/- 5nm)	40 nm	50 nm	65 nm	100 nm
Threshold voltage (V)	4.5	4	6	9
EQE (%)	0.72	0.71	0.34	0.38
Power efficiency (lm/W)	0.77	0.82	0.27	0.11
Luminance efficiency (cd/A)	2.05	1.84	1.32	0.67

 Table S2. Device performances for various thicknesses of the electroluminescent layer

 M:N₁₀:OA in ITO/PEDOT:PSS/M:N₁₀:OA/BCP/Alq₃/LiF/Al devices.



Figure S8. J-V curves for various amounts of OA in the electroluminescent layer M:N₁₀:OA in ITO/PEDOT:PSS/M:N₁₀:OA/BCP/Alq₃/LiF/Al devices.

OA amount (%) in M:N:OA	0.05 % v/v	0.1 % v/v	0.2 % v/v	0.4 % v/v	0.6 % v/v
Threshold voltage (V)	6	6	4	6	7
EQE (%)	0.58	0.66	0.71	0.65	0.34
Power efficiency (lm/W)	0.36	0.56	0.82	0.61	0.27
Luminance efficiency (cd/A)	1.81	1.98	1.84	1.91	1.32

Table S3. Device performances for various amounts of OA in the electroluminescent layerM:N10:OA in ITO/PEDOT:PSS/M:N10:OA/BCP/Alq3/LiF/Al devices.