Electronic Supplementary Information

Simultaneous Mobility Reduction and Conductivity Enhancement of SnO_2 Nanoparticles *via* Fluorine Doping for Balanced Charge Transport in High-Performance Quantum Dot Light-Emitting Diodes

Xin Su, Chen Lin, Mengxin Liu*, Xinan Shi*, and Daocheng Pan*

State Key Laboratory of Featured Metal Materials and Life-cycle Safety for Composite Structures; Guangxi Key Laboratory of Processing for Non-ferrous Metals and Featured Materials; Guangxi Key Laboratory of Advanced Rare Earth Materials; School of Resources, Environment and Materials, Guangxi University, Nanning 530004, China

*E-mail: mxliu@st.gxu.edu.cn; xashi@gxu.edu.cn and dcpan@gxu.edu.cn

Table S1. Summary of the band gap, VBM/CBM positions, electron mobility, and conductivity of doped SnO_2 NP thin films.

SnO_2	Band gap (eV)	VBM (eV)	CBM (eV)	Mobility ($cm^2 V^{-1} s^{-1}$)	Conductivity ($S cm^{-1}$)	Reference
10 at% F	4.02	-7.56	-3.54	6.00×10^{-4}	2.51×10^{-6}	This work
5 wt% In	4.05	-7.87	-3.82	1.62×10^{-4}	2.03×10^{-6}	Ref. 1
3.5 at% Ga	4.02	-7.95	-3.93	2.53×10^{-5}	6.37×10^{-7}	Ref. 2
7.5 at% Zn	3.98	-7.64	-3.66	1.08×10^{-4}	8.30×10^{-6}	Ref. 3
0.45 at% Sb	3.93	-7.47	-3.54	1.60×10^{-3}	$\sim 1 \times 10^{-6}$	Ref. 4

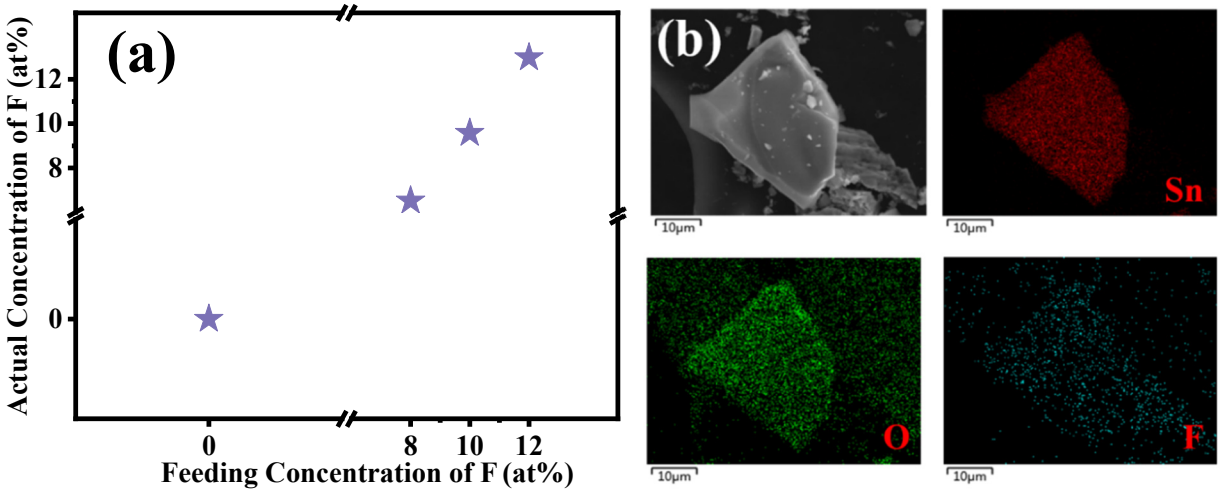

Figure S1. (a) Plot of actual F doping concentration measured by EDS versus the feeding concentration of F ions; (b) SEM elemental mapping images of 10% F-doped SnO_2 nanoparticles.

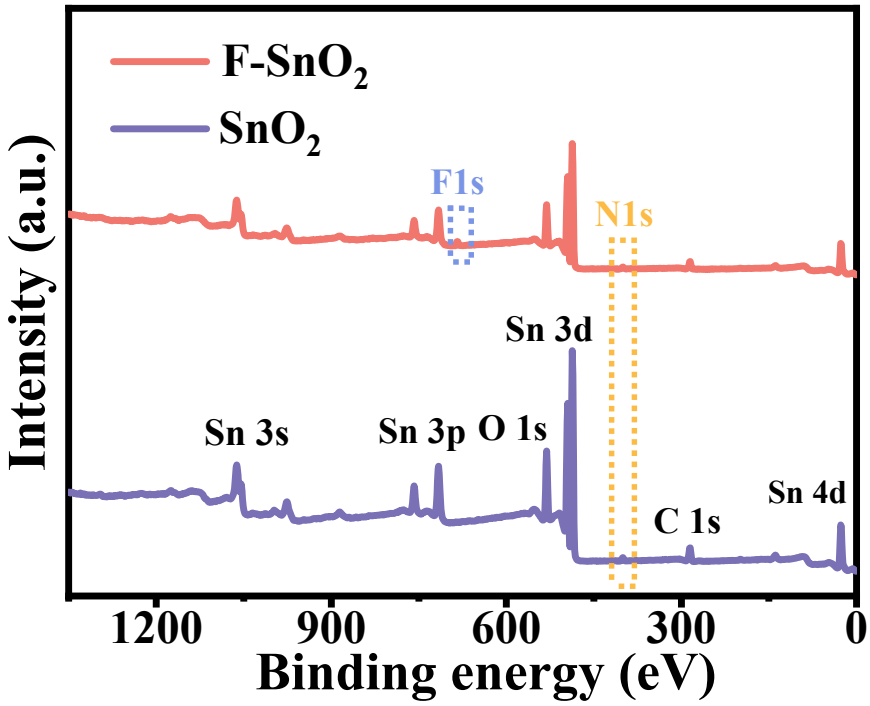

Figure S2. XPS survey spectra of pristine SnO_2 and 10% F-doped SnO_2 nanoparticles.

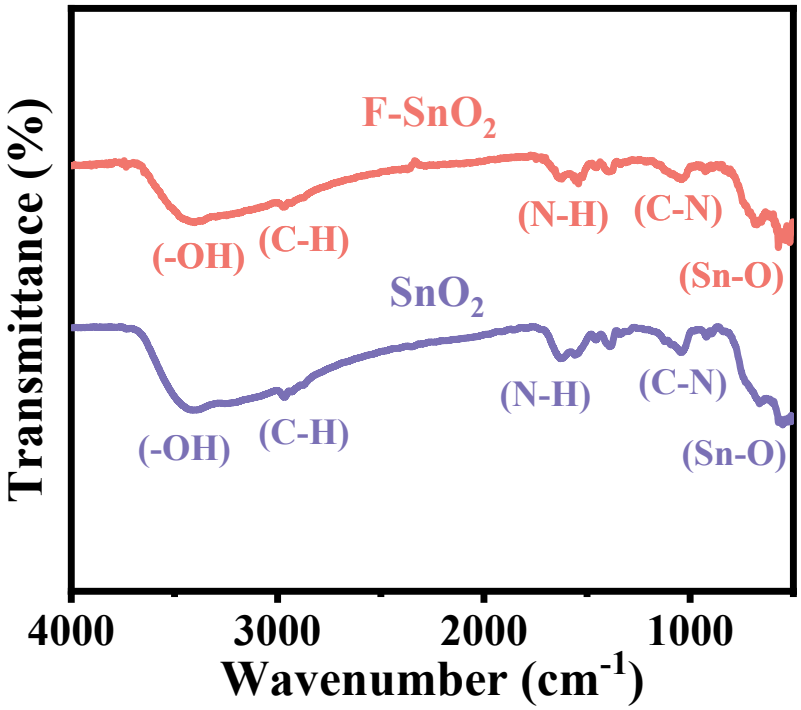

Figure S3. FT-IR spectra of undoped SnO_2 and 10% F-doped SnO_2 nanoparticles.

Table S2. PL decay parameters of QDs onto the glass substrate, F-doped SnO_2 and undoped SnO_2 thin films.

Samples	A_1	τ_1 (ns)	A_2	τ_2 (ns)	τ_{avg} (ns)
QDs/glass	0.81	5.68	0.15	150.46	125.94
QDs/F-SnO_2	0.85	4.32	0.12	95.06	72.96
QDs/SnO_2	0.87	3.18	0.12	47.52	33.04

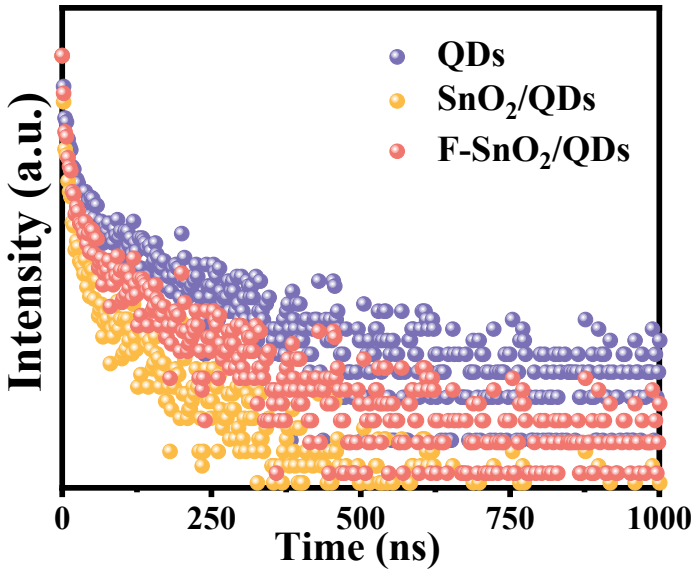

Figure S4. TRPL decay curves of CdSe QDs onto glass, undoped SnO_2 and F-doped SnO_2 NP thin films.

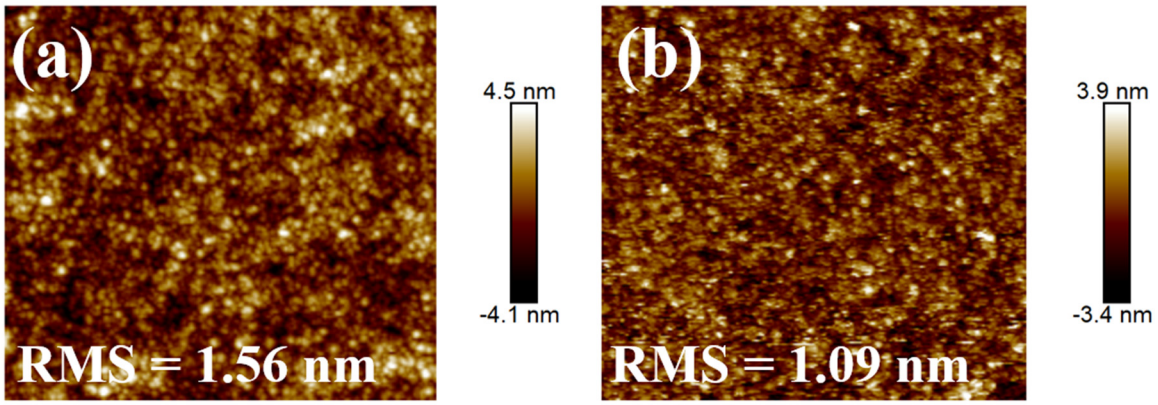

Figure S5. AFM images of (a) undoped SnO_2 and (b) 10% F-doped SnO_2 nanoparticle thin films.

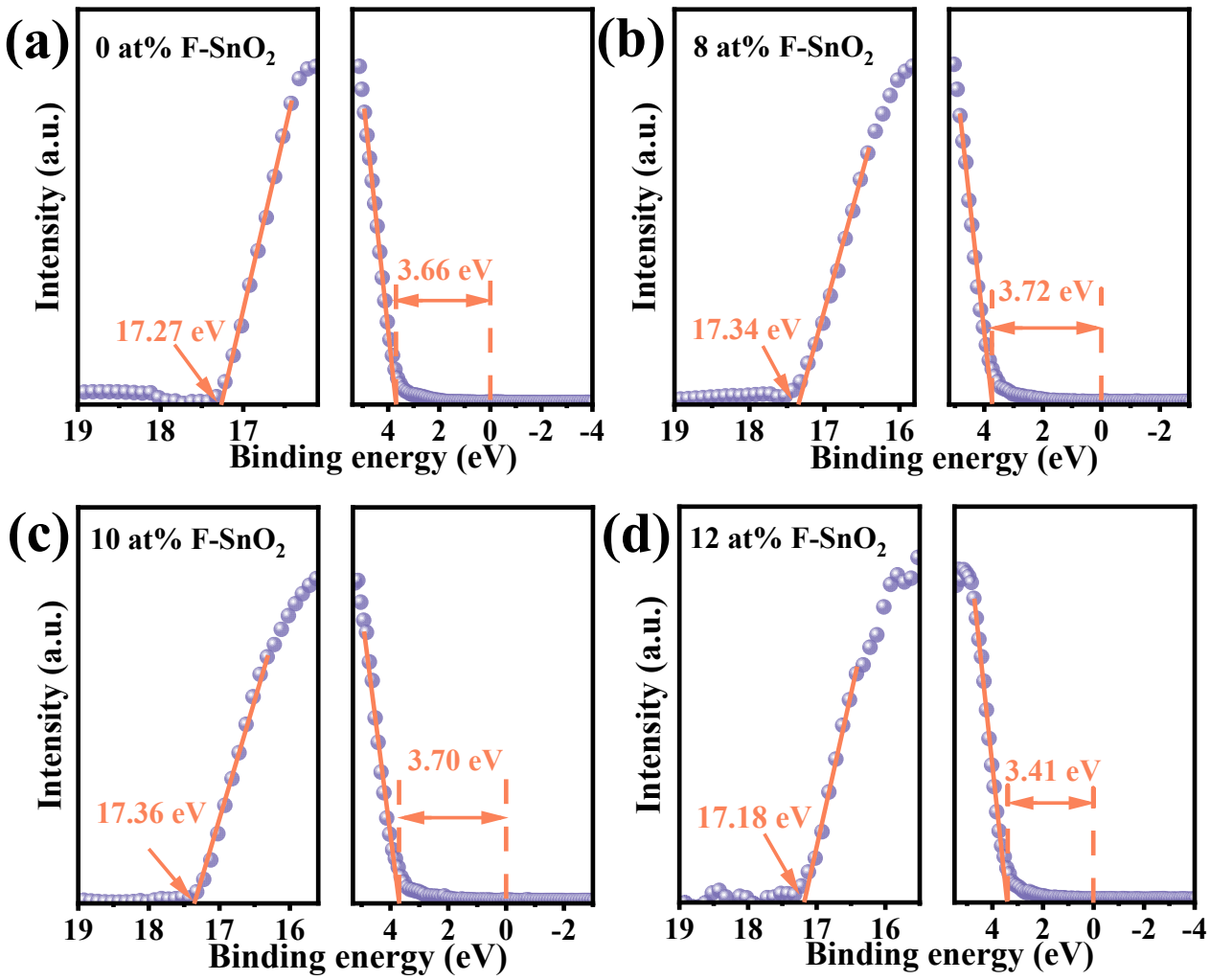

Figure S6. UPS spectra of (a-d) *x* at% F-doped SnO_2 nanoparticle thin films (*x* = 0, 8, 10, 12).

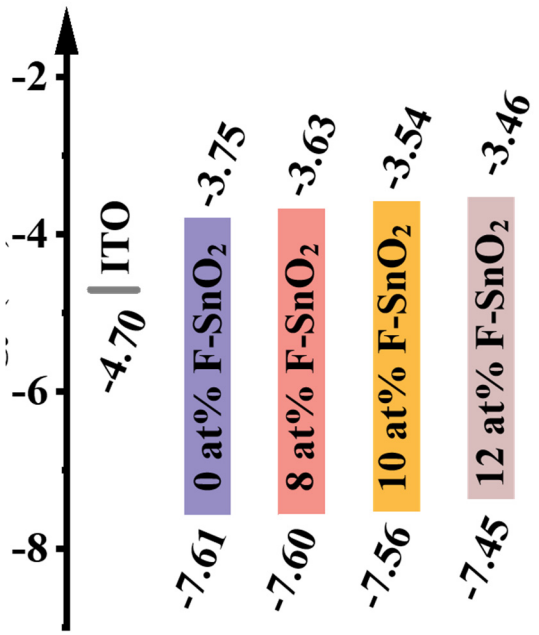

Figure S7. Energy level diagrams of *x* at% F-doped SnO_2 nanoparticle thin films.

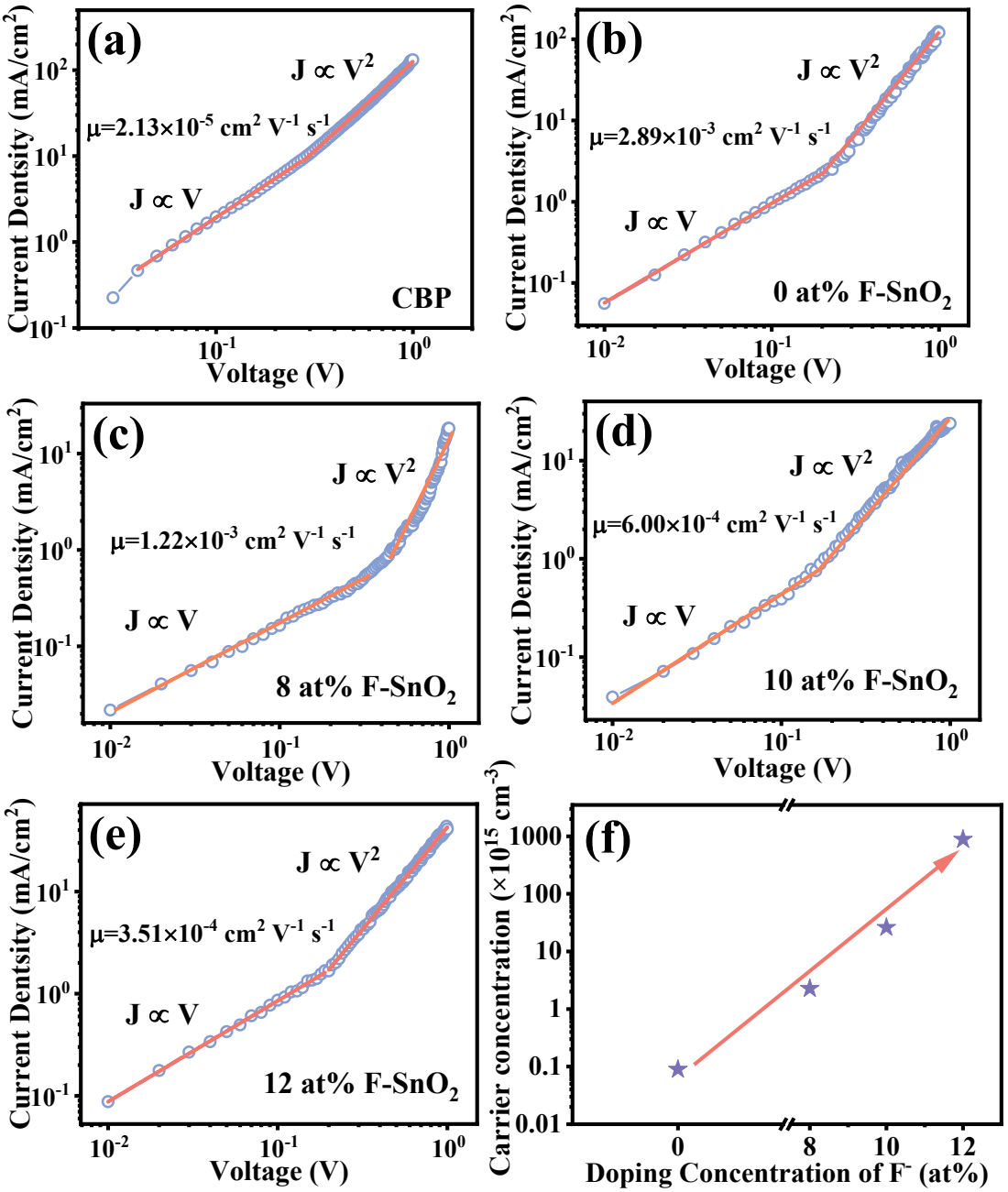

Figure S8. Current density-voltage curves of (a) ITO/CBP/MoO_3/Al device and (b-e) ITO/*x* at% F-doped SnO_2 NP thin films (*x* = 0, 8, 10, 12)/Al devices; (f) The effects of F doping concentrations on the net carrier concentrations of F-doped SnO_2 NP thin films.

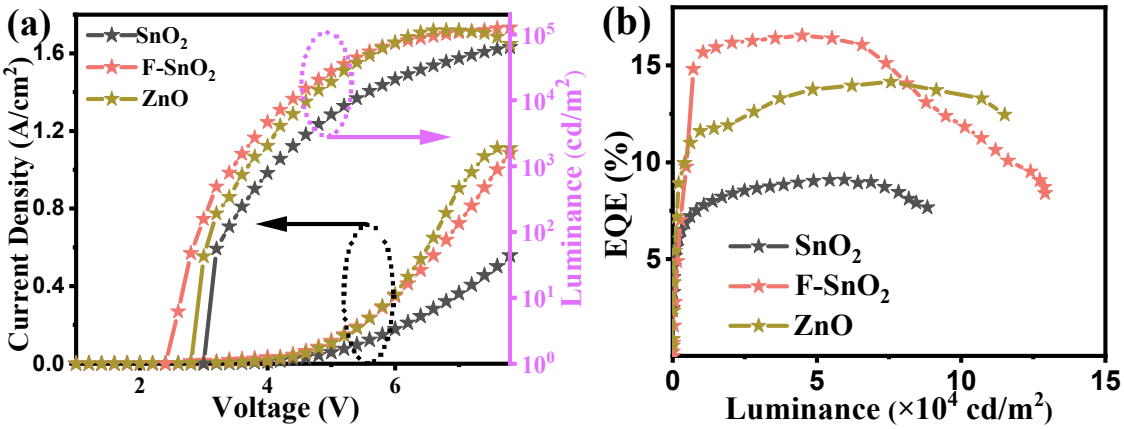

Figure S9. (a) *J-V-L* and (b) *EQE-L* characteristics of QLED devices based on ZnO, undoped SnO_2, and 10 at% F-doped SnO_2 ETLs.

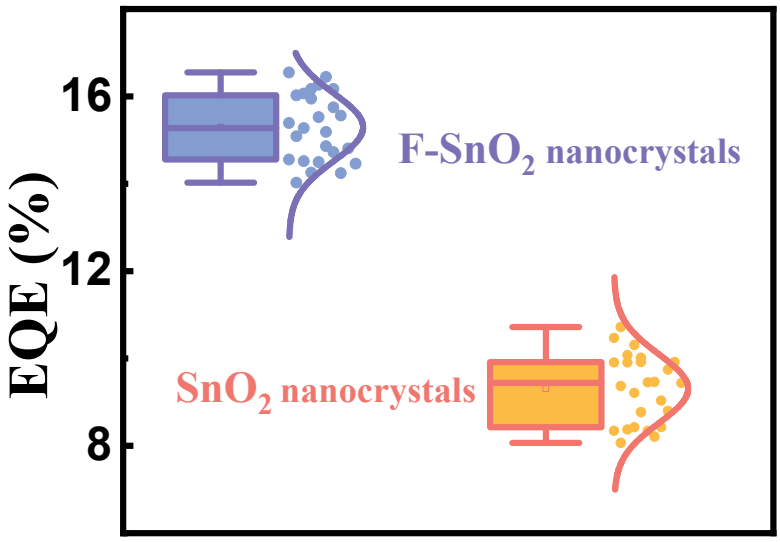

Figure S10. EQE distribution boxplots (calculated from 25 devices) for undoped SnO_2 and 10 at% F-doped SnO_2 QLED devices.

References for Supporting Information

1. C. Lin, M. Liu, Y. Liu, X. Shi and D. Pan. *Dalton Trans.*, 2025, **54**, 5511–5520.

2. C. Lin, M. Liu, Y. Liu, X. Su, X. Shi and D. Pan. *Adv. Opt. Mater.*, 2026, **14**, e02968.

3. M. Liu, C. Lin, H. Li, J. Pan, Y. Liu, X. Su, X. Shi, H. Zhang, B. Zou and D. Pan. *Adv. Funct. Mater.*, 2026, **36**, e15270.

4. X. Xia, X. Chen, J. Xie, X. Li and S. Chen. *Laser Photonics Rev.*, 2025, **19**, 2401755.