Nanocomposites of a nematic liquid crystal doped with magicsized CdSe quantum dots

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Electronic Supplementary Information – ESI

1) Absorption Spectra for QD1 – QD3



Fig. S1 Absorption spectra of magic-sized quantum dots QD1 (blue), QD2 (green), and QD3 (red) in toluene. Note the exact identical absorption maxima and FWHM.

2) Additional FCPM Images



Fig. S2 Fluorescence confocal polarising microscopy image of a sample obtained by adding 0.007% (by weight) of the dichroic fluorescent dye BTBP to the 2.5wt% **QD3** in **LC1**. Illumination (only green channel; emission of dye) with (a) circularly polarised light, (b) linearly polarised light (*E* along *y*), and (c) linearly polarised light (*E* along *x*), respectively.



Fig. S3 Fluorescence confocal microscopy images of LC1 in polyimide-coated ITO test cells (4 micron spacers): (a) 5wt% QD1 (compare to image in Figure 2f in the main text), and (b) 2.5wt% QD2 (compare to image in Figure 3e in the main text). Only the blue (QDs) and the transmission channel are observed in both images. These images highlight that the QDs are only to some extent responsible for the point-like defects observed by POM in planar cells.

3) Permittivities measured on cooling



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-9

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4) Resistivities



5) Frequency dependence

Experimental setup:

The electro-optical measurements were performed on a Leica Ortholux II POL-BK microscope with a white light source and a green interference filter (541 nm). All samples were positioned in the beam path under an angle of 45° between crossed polarizers. To apply voltages, an Analogic 2030 waveform synthesizer and a Krohn-Hite model 7500 amplifier were used. The light intensity was detected using an Oriel photomultiplier tube and a Keithley 197 DMM. Both signals (voltage and intensity) were averaged (8 to 256 circles) and stored on a Gould 4064 oscilloscope.

Results:

The electro-optical response was measured at different frequencies (0.1 Hz, 1 Hz, 5 Hz, 10 Hz, 50 Hz, 100 Hz, 500 Hz and 1000 Hz). To point out differences or unusual effects due to nanoparticle doping, we first measured the electro-optic response of the pure LC. The results for pure LC1 are plotted below, followed by the QD-doped samples:

Pure LC1 (Felix)





voltage (V)







voltage (V)







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0.0 |- -80

-60 -40

0 voltage (V)

20 40

60 80

-20



QD1 2.5wt%











voltage (V)







voltage (V)

40





0.0 |- -80

-60



voltage (V)

-20

-40

20

40 60 80



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QD3 2.5wt%





0.0 -80

0 voltage (V)

20

40

60 80

-40 -20

-60















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6) Transmission vs. applied voltage



7) Comparison of ultrasonication using sonotrode (internal sonication) vs. sonication bath (external sonication)



Fig. S4 Photograph of vials under UV light irradiation ($\lambda_{exc} = 366$ nm) showing the effect of sonication conditions for LC1 doped with QD1 (as a representative example) at 5wt% 10 minutes after sonication: (left vial) using 5 minutes regular sonication bath, and (right vial) using 5 minutes ultrasonication (Sonics VCX 750 Watts, Frequency 20 kHz) in pulse mode (5 seconds *On* followed by 5 seconds *Off* at an amplitude of 21%). Note the improved homogeneity of the mixture on the right.

8) XPS

XPS analysis of the QD samples was performed using a Kratos AXIS ULTRA spectrometer with a 300 W monochromated Al K α source and a delay line detector. The survey and high-resolution scans were recorded with pass energies of 160 and 40 eV, respectively. All spectra were collected at 90° take-off angle and referenced to the C 1s peak set at 285 eV. The background pressure in the analyzer chamber was ~10⁻⁹ Torr. For quantitative analysis sensitivity factors supplied by the instrument manufacturer were used.

QD1 (CdSe)



Peak	Туре	Position	FWHM	Raw Area	n RSF	Atomic	Atomic	Mass
		BE (eV)	(eV)	(cps eV)		Mass	Conc %	Conc %
Cd 3d	Reg	405.323	1.163	109032.4	6.623	112.422	2 82.83	87.29
Se 3d	Reg	54.023	1.593	2507.3	0.853	78.982	17.17	12.71

QD2 (CdSe)



QD3 (CdSe(a)Zn) \rightarrow Zn-rich surface (surface doping)



Peak	Туре	Position	FWHM	Raw Area	RSF	Atomic	Atomic	Mass
]	BE (eV)	(eV)	(cps eV)		Mass	Conc %	Conc %
C 1s	Reg	285.002	1.234	109850.9	0.278	12.011	88.99	74.48
0 1s	Reg	532.002	1.639	31933.9	0.780	15.999	8.17	9.11
Cd 3d	Reg	405.502	1.330	31809.6	6.623	112.422	1.02	8.01
Se 3d	Reg	54.602	1.547	431.7	0.853	78.982	0.13	0.69
Zn 2p	Reg	1022.502	2.003	61732.0	5.589	65.387	1.69	7.72
Peak	Type	Position	FWH	M Raw Ar	ea RSI		ic Atomi	r Mass
reak	турс	RF (AV)	(eV)	(cns eV)		Mass	Conc %	Conc %
				(cps cv)		Mass	Conc 70	COILC /0
Cd 3d	Reg	405 502	1 3 3 0	31809	6 6 6 2	3 112.42	22 89 10	92.09
Se 3d	Reg	54.602	1.547	431.7	0.853	3 78.982	2 10.90	7.91
56.54	1005	0 11002	110 17	1011/	01000	, , , , , , , , , , , , , , , , , , , ,	10170	, , , , ,
Peak	Туре	e Positior	n FWH	M Raw Ar	ea RSF	Atomic	Atomic	Mass
		BE (eV)	(eV)	(cps eV))	Mass	Conc %	Conc %
Cd 3d	Reg	405.502	1.330	31809.6	6.623	112.422	2 35.98	48.79
Se 3d	Reg	54.602	1.547	431.7	0.853	78.982	4.40	4.19
Zn 2p	Reg	1022.50	2 2.003	3 61732.0	5.589	65.387	59.62	47.02

9) TEM

A discussion on the synthesis and characterization including detailed TEM analyses of QD1 and QD2 can be found in earlier publications by Yu et al. (see references [29] and [30] in the main text). A high-resolution TEM image for QD3 is shown on the right (TEM was performed on a JEOL JEM-2100F electron microscope operating at 200 kV and equipped with a Gatan UltraScan 1000 CCD camera. A TEM sample was prepared by depositing a dilute dispersion of a purified sample in toluene onto a 300 mesh carbon-coated TEM copper grid and dried in air.) On TEM grids, some aggregation after solvent evaporation leads to larger QD assemblies, which can be



broken up by re-dispersing them in toluene or hexane.