Quantum SOLUTIONS

Perovskite Quantum Dots Application Guide

THE NEXT GENERATION MATERIAL FOR OPTOELECTRONICS:

1. The narrowest FWHM among all types of QDs (<20-25 nm)
2. Near unity PLQY (up to 100 %)
3. Broad absorption (from X-rays) and tunable wavelengths emission (450 – 685 nm)

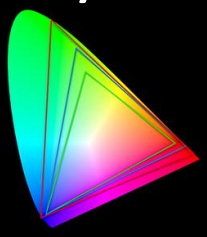
About Quantum Solutions:

We are a manufacturer of PbS and Perovskite QDs. We have large scale production capabilities with the high standards of quality control. We benefit from expertise in QD optoelectronic devices prototyping and testing.

APPLICATION EXAMPLES:

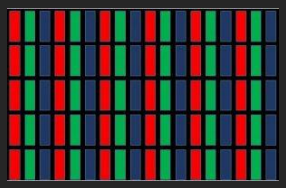
QD LCD displays

Enhances color gamut for HDR displays



QD LEDs

Ultimate solution for displays with the widest color gamut and highest contrast



UV sensors

Increases UV sensitivity of Si based photodetectors

X-ray scintillation

High-efficiency scintillator material for X-ray detection

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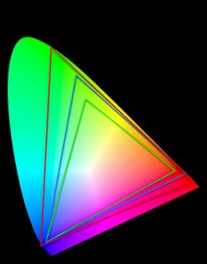
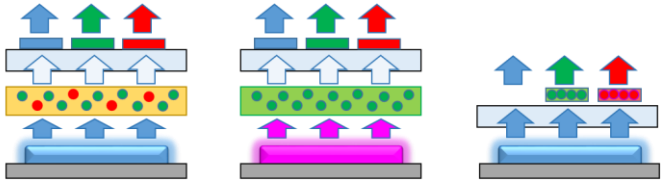
Perovskite Quantum Dots for LCD Displays



Quantum dots extend the color gamut of LCD displays, making them present more vibrant colors with better contrast in TVs, laptops and tablets. This is an ideal solution for HDR displays to meet Rec2020 standard. On top of that, QDs help to reduce the energy consumption. Nowadays, many TV makers adopted this technology. QUANTUM SOLUTIONS offers novel green Perovskite QDs for LCD application ("LCD backlighting" and "LCD color filters"). These materials have high photoluminescence efficiency (up to 100 %), narrow band emission (< 20-25 nm). This makes them a better quality and more environmentally friendly alternative to the current CdSe and InP QDs.

BENEFITS:

- Emission for Rec2020 and beyond: 510-530 nm
- The narrowest FWHM among all QDs (< 20-25 nm)
- High PLQY up to 100 %
- High absorption coefficient of the blue light
- RoHS compliant for LCD backlighting, cadmium free
- High reliability (RA) to thermal and photo exposure



LCD backlighting with blue light source and green+red QDs layer

LCD backlighting with magenta light source and green QDs layer

LCD green+red color filters with blue light source

PERFORMANCE for LCD backlighting:

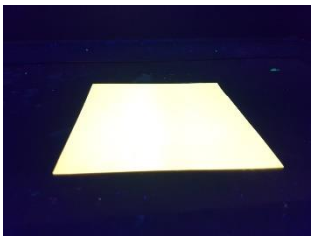
LUMAR™ $CsPbBr_3$ QDs in a polymer film: polymer type – IBOA, QDs content - 0.5 wt %, film thickness - 100µm	
Emission	510 – 530 nm (tunable)
FHWM	< 20-25 nm
PLQY	> 60-70 %
RA@85 ^{0}C, blue light 10 mW/cm^2	1,000 hours (70-80 % of initial PL)
RA@60 ^{0}C, blue light 10 mW/cm^2, 90 % relative humidity	1,000 hours (80 % of initial PL)
PL quenching at 100 ^{o}C	65-70 % of initial PL (reversible)

Products portfolio:

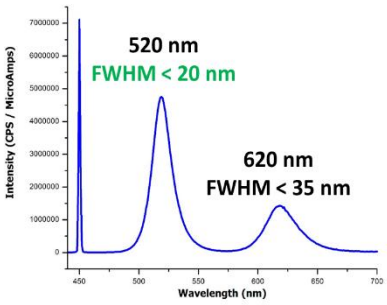
- **LUMAR™ $CsPbBr_3$ Quantum Dots**

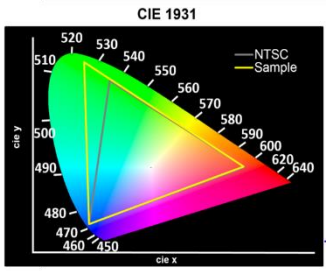
Perovskite QDs $CsPbBr_3$, 510-530 nm emission peaks, high thermal and photo stability for LCD

EXPERIMENTAL DATA for LUMAR™ $CsPbBr_3$ QDs in a polymer film:



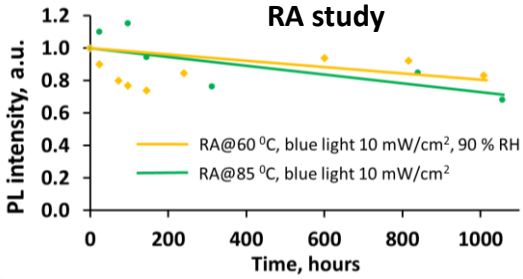
LUMAR™ $CsPbBr_3$ QDs can be used as a green emissive material in combination with red QDs (CdSe or InP QDs based) for LCD backlighting.





120 % of NTSC area

Due to narrow FWHM of emission, LUMAR™ $CsPbBr_3$ QDs makes LCD to exceed NTSC standards and get it closer to Rec.2020. Our special QDs shelling enables to achieve high thermostability and photodegradation resistivity according to industrial standards to QDs.



RELATED LITERATURE (with our contribution):

1. Lutfan Sinatra et al. **SID Symposium Digest 2018**, 1681-4
2. Jun Pan et al. **SID Symposium Digest 2017**, 83-86.

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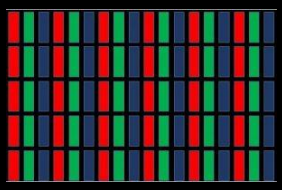
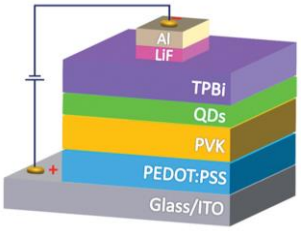


Perovskite Quantum Dots for QD LEDs

QD LEDs is an emerging technology that promises to enhance current OLED displays with higher brightness, durability and color purity. It will be an ultimate solution for flexible and curved displays in TVs, mobile and wearable devices, virtual and augmented reality glasses, automotive displays and signage. Perovskite Quantum Dots show a promise in that field alongside with InP and CdSe quantum dots. $CsPb(Cl/Br)_3$ and $CsPbBr_3$ QDs are especially efficient for blue and green QD LEDs.

BENEFITS:

- High brightness (from 500 Cd/m^2 for blue and from 1000 Cd/m^2 for green lights)
- High EQE (from 2% for blue and 5% for green)
- Short decay time (≈ 5-20 ns)
- Solution processable



PERFORMANCE:

	QD-P-450	QD-P-510
Emission	450 nm	510 nm
FHWM	< 20 nm	< 20-25 nm
Decay time	≈ 5-20 ns	≈ 5-20 ns
EQE max	> 2 %	> 5 %
Luminance max	> 500 Cd/m^2	> 1000 Cd/m^2

EXPERIMENTAL DATA for QD-P-450 and QD-P-510 (Perovskite $CsPb(Cl/Br)_3$ and $CsPbBr_3$ QDs):

QD LED based on green QD-P-510 exhibits strong electroluminescence at 510 nm with FWHM 18 nm. EQE max is > 5 % with luminance max > 1000 Cd/m^2. QD LED based on blue QD-P-450 demonstrates the emission at 450 nm with FWHM 20 nm. It has relatively high EQE max over 2 % with exceptional brightness 500 Cd/m^2.

Products portfolio:

- **Perovskite Quantum Dots (QD-P)**

Perovskite QDs $CsPbX_3$, oleic acid and oleylamine capped, 450-685 nm emission peaks

- **LUMAR™ $CsPbBr_3$ Quantum Dots**

Perovskite QDs $CsPbBr_3$, 510-530 nm emission peaks, high thermal and photo stability for LCD

- **Ink for $CsPbBr_3$ thin film**

Ink for $CsPbBr_3$ thin film, solution in DMSO, high thermal stability

RELATED LITERATURE (with our contribution):

1. Jun Pan et al. **Adv. Mater**, 28, 8718–8725 (2016).
2. Emre Yassitipe et al. **Adv. Funct. Mater**, 26, 8757–8763 (2016).
3. Jun Pan et al. **J. Am. Chem. Soc.** 2018, 140, 562–565 (2018).

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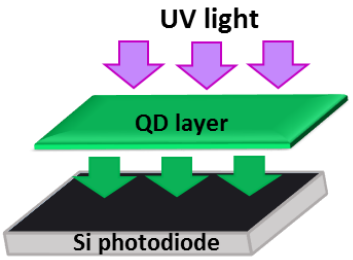
Perovskite Quantum Dots for UV Sensors

Silicon photodiode is the most widely used commercial device to capture light in a broad range of applications, from imaging to light sensors. Due low penetration depth of high energy UV photons in the silicon-based layer, these sensor are not sensitive enough for UV light with the wavelengths below 400 nm. Perovskite Quantum Dots can be utilized as the color-converting layer to enhance the UV light sensitivity of Si-based photodectors.

BENEFITS:

- High photoconversion of UV light into visible light (PLQY up to 100 %)
- Short decay time (≈ 5-20 ns) allowing high-speed UV light detection
- High absorption coefficient of UV light
- Tunable emission 450-685 nm

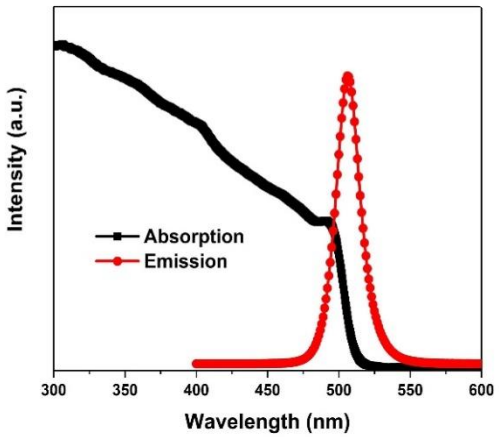


PERFORMANCE:

	QD-P-510
Emission	510 nm
PLQY at UV light excitation	Up to 100 %
FHWM	< 20-25 nm
Decay time at UV light	≈ 5-20 ns
UV light absorption range	100-400 nm

EXPERIMENTAL DATA for QD-P-510 (Perovskite $CsPbBr_3$ QDs):

Perovskite Quantum Dots $CsPbBr_3$ with the catalog number QD-P-510 has a broad absorption profile and can capture UV light and re-emit at 510 nm.



High PLQY of QD-P-510 allows to convert UV light into lower energy green light where Si-based photodetectors have a high sensitivity. QD-P-510 can be used in the form of QDs in a polymer film or a spin coated layer on top of the Si-sensor.

Products portfolio:

- **Perovskite Quantum Dots (QD-P)**

Perovskite QDs $CsPbX_3$, oleic acid and oleylamine capped, 450-685 nm emission peaks

- **LUMAR™ $CsPbBr_3$ Quantum Dots**

Perovskite QDs $CsPbBr_3$, 510-530 nm emission peaks, high thermal and photo stability for LCD

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