Quantum SOLUTIONS™

QDot™ PbS Quantum Dots Application Guide

THE NEXT GENERATION MATERIAL FOR OPTOELECTRONICS:

1. Superior photoelectrical properties in NIR range
2. Broad absorption through all UV-visible and tunable in NIR range (from 700 to 2300 nm)
3. Device grade QDs with high purity, surface cleanliness and narrow particle size distribution

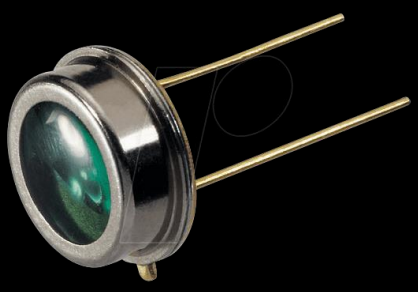
About Quantum Solutions:

Quantum Solutions develops and manufactures quantum dot materials and technology for image sensors and displays. Our innovative QDot™ materials can be found in industrial devices around the world.

MAIN APPLICATION AREAS:

NIR IMAGE SENSORS

For VIS-NIR image sensors on silicon CMOS substrate, used for cameras in machine vision, automotive and consumer electronics

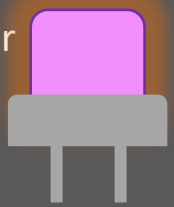


SOLAR CELLS

Increases the efficiency of silicon based solar panels

NIR QD LEDs

Active material for NIR LEDs in 900-2300 nm range



X-RAY IMAGING

Next generation active material for X-ray scanning

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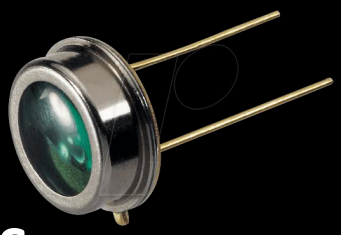
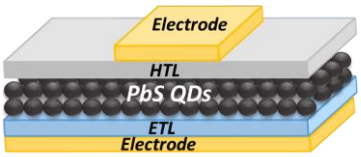


QDot™ PbS Quantum Dots for NIR Image Sensors

Near infrared sensing is getting very important in such applications as machine vision (for goods quality inspection and control), automotive (for 3D aerial and geographic mapping, advanced driver-assistance systems at night and adverse weather conditions (mist/fog/snow)), smartphone cameras (for biometrics and 3D photography), AR and VR headsets (for eye tracking), in night vision and surveillance. Current cameras with such NIR absorbers, such as InGaAs and Ge, have high production costs, are bulky and have limited camera resolution. QDot™ PbS QDs have high sensitivity, wider absorption range and compatibility with silicon CMOS read out integrated circuits (ROIC) making them an ideal solution for economical, high resolution and broadband cameras.

BENEFITS:

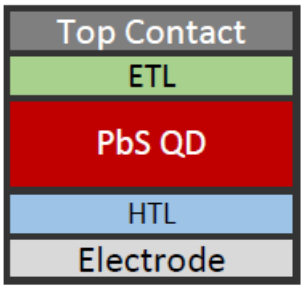
- Broad tunable absorption in NIR (SWIR) range from 700 to 2500 nm
- Superior photoelectrical properties with high devices EQE and detectivity, low dark current
- Easy integration with silicon CMOS by printing and spin-coating manufacturing processes



Photodiode structure with QDot™ PbS QDs

DEVICE EXAMPLE:

QDot™ PbS QDs with 1420 nm absorbance (QDot™ PbS-1420-abs) were used as an active layer on CMOS ROIC chip to make the NIR camera with a sensitivity range of 400 – 1500 nm, 768x512 px resolution with 5 µm px pitch.

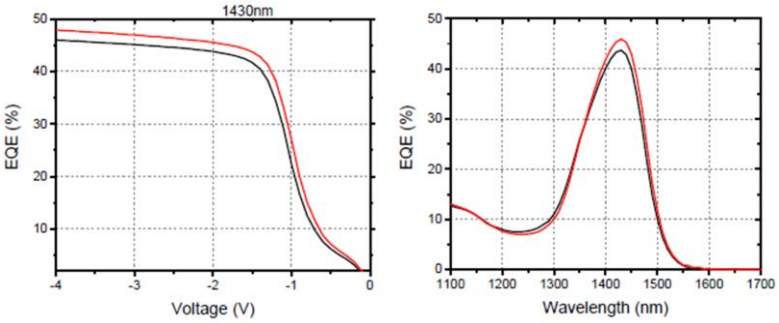


The device pixel pitch structure

SENSOR PERFORMANCE:

Parameter	Typical values
Sensitivity range	300 – 2500 nm (tunable)
EQE	> 30-40 %
Specific detectivity	Up to $1x10^{11}$ cm·$Hz^{1/2}$/W (Jones)
Dark current	100 – 1000 nA/cm^2
Response time	< 50 µs
Pixel pitch	< 2 µm
Cooling requirements	Room temperature or TEC

The typical EQE reached over 40 % at the first excitonic absorption peak 1420 nm with the specific detectivity is up to $1x10^{11}$ Jones and the dark current 100 – 1000 nA/cm^2.



The device EQE

Products portfolio:

- **QDot™ PbS Quantum Dots**

PbS Quantum Dots, oleic acid capped, 700-2300 nm emission/excitonic absorption peaks

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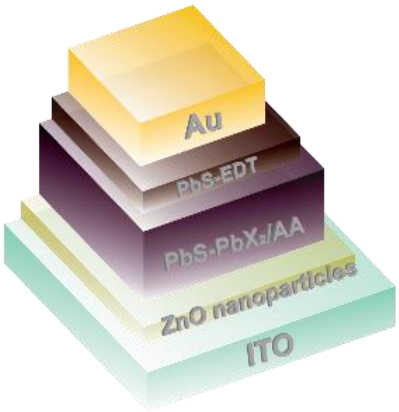
QDot™ PbS Quantum Dots for Solar Cell

QDot™ PbS QDs can be utilised in solar cells to capture more solar spectrum in the near infrared range. The QDs' absorbance wavelength in the NIR range can be tuned, making the QDs promising for tandem solar cells made with other materials, such as silicon or perovskite solar cells. Current development of a stand alone PbS solar cell has already achieved 10% certified efficiencies.

BENEFITS:

- Broad tunable absorption in near infrared range from 700 to 2300 nm
- Enables solution and room temperature processable solar cells
- Can be used in tandem with other solar cell technology such as silicon or perovskite, adding up to 5% to the total power conversion efficiency.

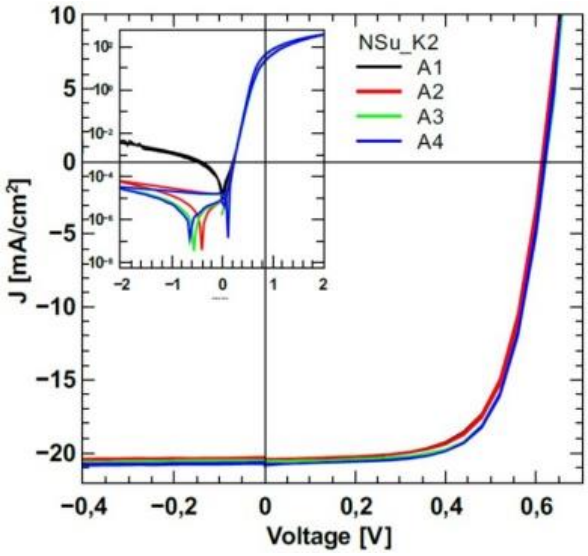
Solar cell structure with QDot™ PbS QDs



DEVICE EXAMPLE:

QDot™ PbS QDs with absorption 920 nm (QDot™ PbS-920-abs) were used as an active layer in the solar cell with gold electrodes and a ZnO electron transporting layer. QDot™ PbS QDs treated with PbI2/PbBr2 and ammonium acetate were deposited by spin coating as an active layer. For a hole transporting layer, layer processing consisted of ligands exchanged QDot™ PbS QDs with 1,2-EDT was used.

The device absorbs the light through all visible spectra up to NIR light. The solar cell produced using using QDot™ PbS QDs shows promising power conversion efficiencies of up to 8.77%.



SOLAR CELL PERFORMANCE:

Parameter	Typical values
Absorption range	Through all visible up to NIR (tunable from 700 nm to 2500 nm)
PCE	8-9 %

Measurement	Jsc	Voc	FF	PCE	Area
A-1	20.66	0.62	0.66	8.45	0.10
A-2	20.54	0.61	0.67	8.45	0.10
A-3	20.68	0.62	0.68	8.69	0.10
A-4	20.88	0.62	0.68	8.77	0.10

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