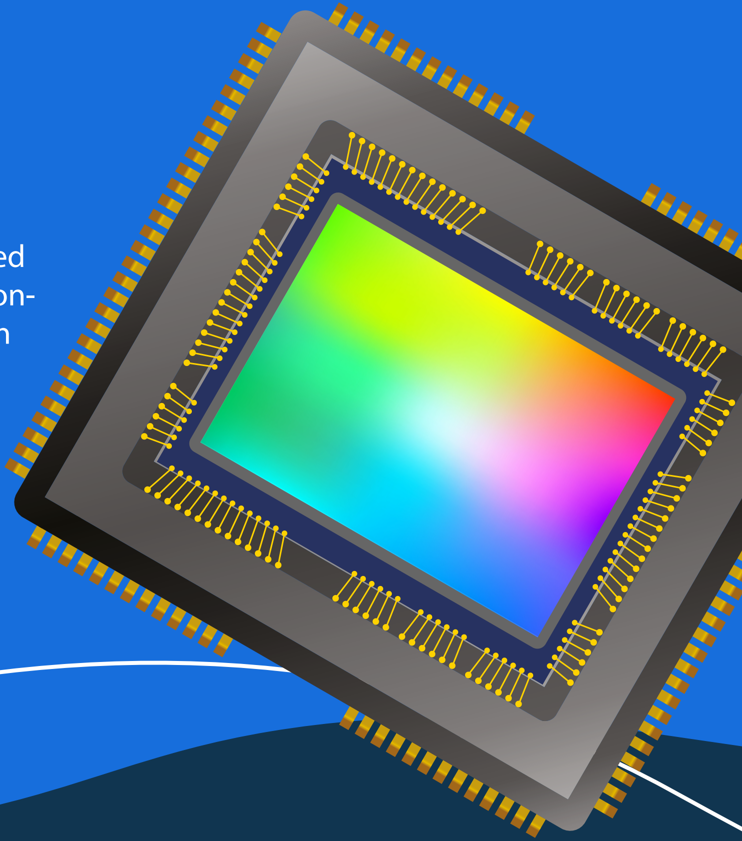
Q.Dot™ stack materials for SWIR photodetectors & image sensors

Application Notes

SWIR (short-wave infrared) sensing is becoming increasingly important in various applications such as:



Machine vision
for quality inspection and control of goods

Automotive
for 3D aerial and geographic mapping, advanced driver-assistance systems in adverse weather conditions like mist, fog, and snow, and night vision

Smartphone cameras
for biometrics and 3D photography

AR and VR headsets
for eye tracking

Surveillance

However, current SWIR sensors that use absorbers like epitaxially grown InGaAs and HgCdTe (MCT) compound semiconductors are expensive to produce, and have limited camera resolution. Quantum Solutions offers a range of materials that can be used for fabricating a Q.Dot™ photodiode stack for sensing applications, including Q.Dot™ quantum dot absorbers, Q.Dot™ ETL, and HTL materials.

BENEFITS

Wide Range

Q.Dot™ quantum dot absorber with broad tunable absorption in SWIR range from 700 to 2500 nm and superior photoelectrical properties with high devices EQE and detectivity, low dark current

Full Stack

Carefully designed Q.Dot™ ETL (electron transport layer) and Q.Dot™ ETL (hole transport layer) semiconducting materials to be used in combination with Q.Dot™ quantum dots with various energy levels choices

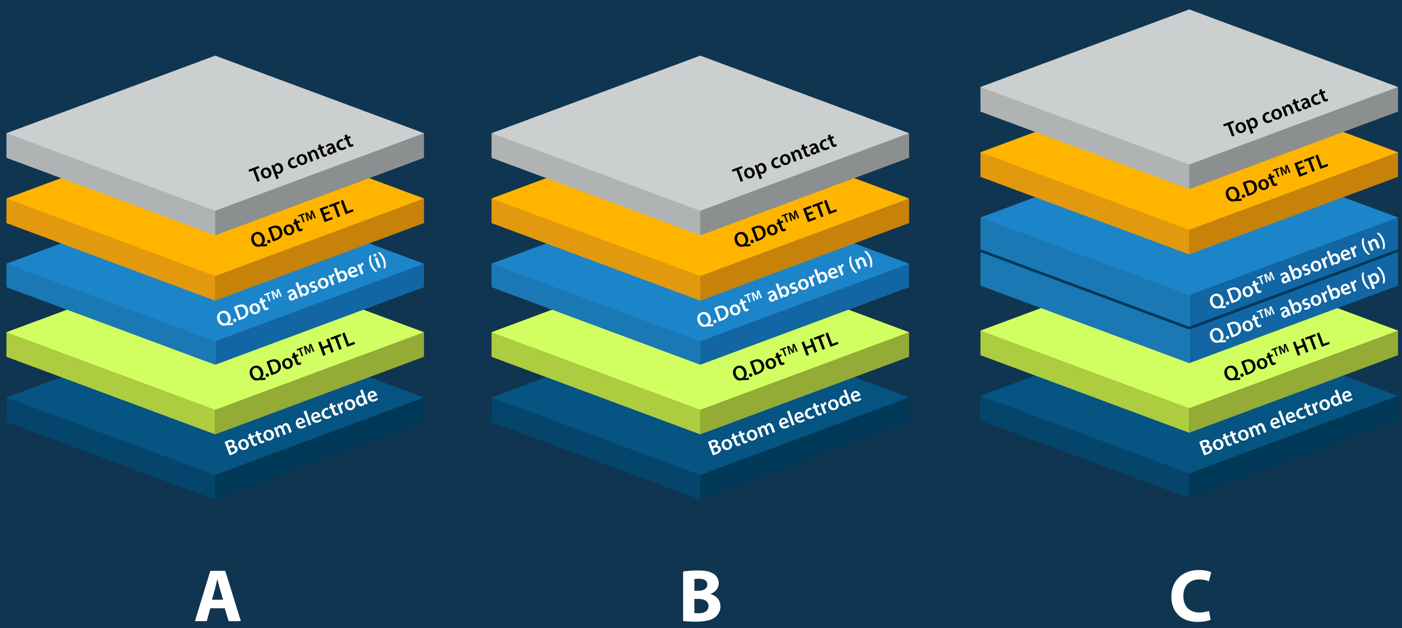
Solution-processable

Easy integration on substrates (glass, silicon, or CMOS wafers) by spin-coating or other printing processes, guaranteeing affordability and manufacturability.

DEVICE ARCHITECTURE EXAMPLES

The Q.Dot™ stack architecture can vary in the implementation and Q.Dot™ layer types, sequence, thicknessaes, and spin-coating conditions, depending on the required specifications of the photodiode performance, such as sensitivity range, EQE, dark current, response time, reliability, etc.

For example, there are several options for the sequence implementation of Q.Dot™ layers.



Type (A) represents the typical photodiode stack with the bottom Q.Dot™ HTL, followed by absorber Q.Dot™ quantum dots (i-type), Q.Dot™ ETL, and the top electrode.

Type (B) represents the photodiode structure where the absorber is Q.Dot™ quantum dots (n-type).

Type (C) demonstrates an example where the Q.Dot™ PbS layer includes two types: n and p types within the same stack.

Further details can be found in the following articles: [1], [2], [3], [4], [5].

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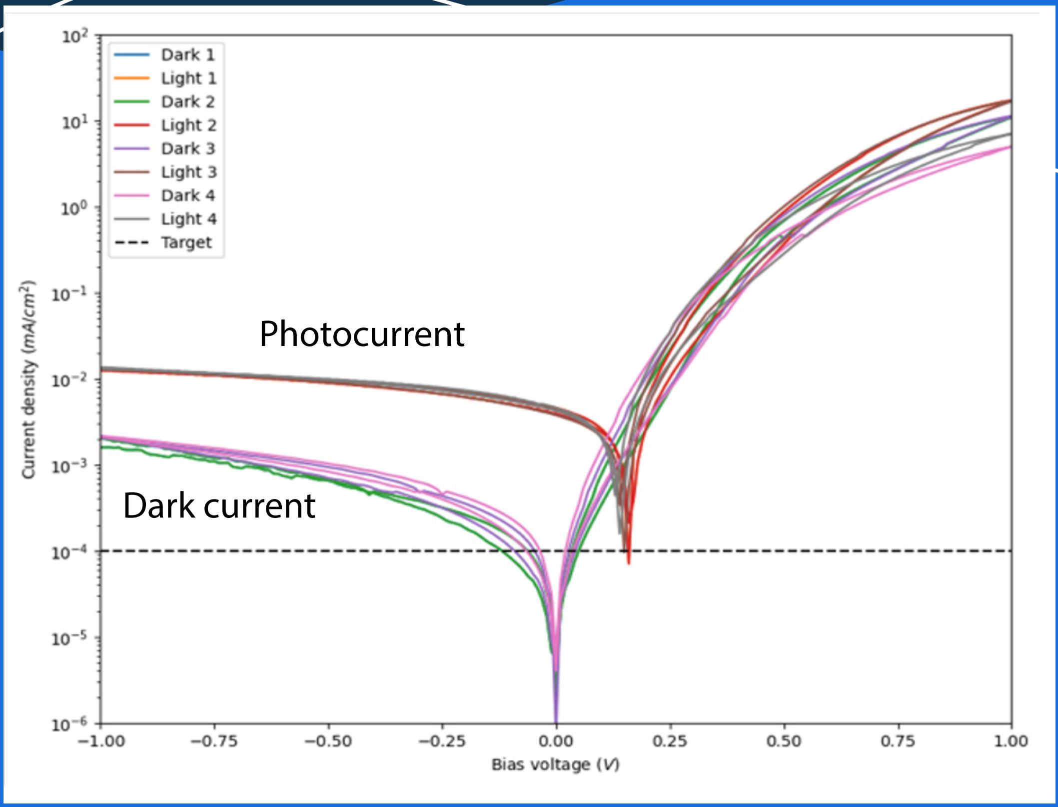
CASE STUDIES

Q.Dot™ InAs quantum dots, capped with fatty acids and featuring an absorption wavelength of 1200 nm (Q.Dot™ InAs-1200-abs), were used as the absorber layer in the SWIR photodiode device employing the type (A) quantum dot stack architecture (see page 3). The Q.Dot™ InAs-1200-abs layer was post-processed using a solution-phase ligand exchange technique to produce an n-type ink absorber layer [6]. Q.Dot™ ETL-ZnO was used as the electron transport layer, and Q.Dot™ HTL-PbS was used as the hole transport layer.

Depending on the thicknesses of the ETL and HTL layers, the EQE of the device can vary by up to 35–50% at 1200 nm. The dark current can be minimized to a value as low as 300 nA/cm^2 at a 0.5 V bias. Examples of I–V curves for some variants are presented in Figure 1.

1



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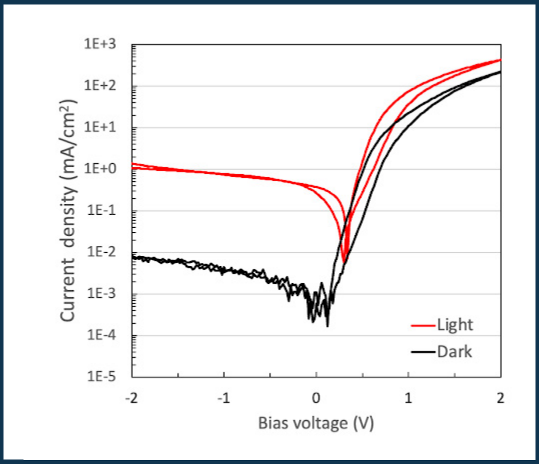
CASE STUDIES

2

Q.Dot™ PbS quantum dots, oleic acid capped, with an absorption wavelength of 1420 nm (Q.Dot™ PbS-1420-abs) were used as the absorber layer in the SWIR photodiode device with the type (A) Q.Dot™ stack architecture. The Q.Dot™ PbS-1420-abs layer was deposited using spin-coating and solid ligand exchange techniques to create i-type absrober layer [7]. Depending on the choices and thicknesses of the Q.Dot™ ETL and HTL, the EQE can be varied by up to 40-60% at 1450 nm. The dark current can be minimized to the range between 100 to 1,000 nA/cm^2 at 0.5V bias. Examples of I-V curves for some variants are presented in the Figures 2 and 3. The variant (1) utilizes Q.Dot™ ETL-ZnO and Q.Dot™ HTL-PbS, while the variant (2) exploits Q.Dot™ ETL-ZnO and Q.Dot™ HTL-POL.



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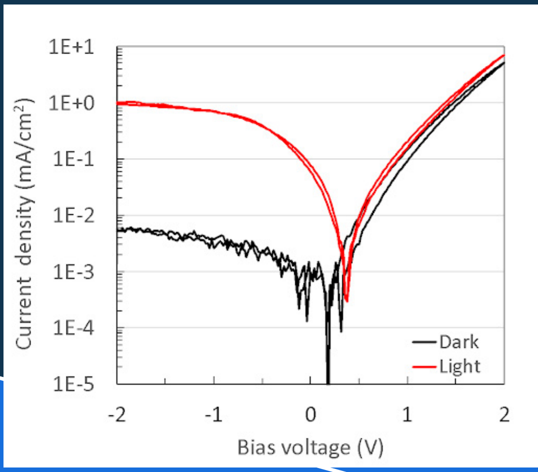
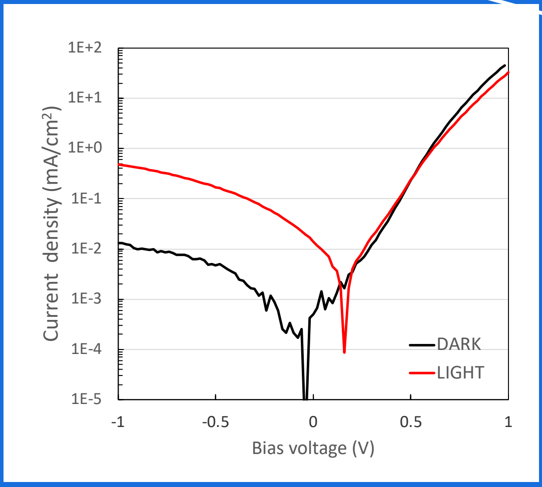


4

Q.Dot™ PbS n-type ink, with an absorption wavelength of 1420 nm (Q.Dot™ PbS-1420-abs n-ink), was used as the absorber layer in the SWIR photodiode device with a type (B) stack architecture that included Q.Dot™ ETL-ZnO and Q.Dot™ HTL-PbS. The Q.Dot™ PbS-1420-abs layer was deposited by a simple spin-coating process, involving 3 deposition steps to create a thick absorber layer of 300 nm. This deposition process did not require any solid ligand exchange. The EQE reached 50-60% at 1450 nm, with a dark current of 13 μA/cm^2 at a 0.5V bias (Figure 4). The dark current can be reduced to values below 1 μA/cm^2 by using the type (C) architecture, which additionally incorporates a p-type quantum dot absorber.



PRODUCTS PORTFOLIO

Q.Dot™ PbS Quantum Dots, oleic acid capped

Q.Dot™ InAs Quantum Dots, oleic acid capped

Q.Dot™ PbS Quantum Dots, n-type ink

Q.Dot™ ETL and HTL materials

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