CQD-SWIR:
Low-Cost SWIR Sensors for Broadband, High-Resolution Imaging

Novel sensor architecture and production method to enable range of applications

Features

- SVGA format
- 640 x 512 pixels
- 15 µm pitch
- Broad spectral response
- Sensitive from 400 nm to 1700 nm
- Room temperature operation
- Low noise
- Non-ITAR (EAR 99 Classification)
- Global shutter
- XVGA format (1280x1024 pixels) – available in spring 2017

The Problem: Prohibitively Expensive InGaAs-based SWIR Sensors

Presently, commercially available, short-wave infrared (SWIR) imagers are based on costly, high-purity semiconductor materials such as indium-gallium-arsenide (InGaAs) that are grown on specialized substrates, such as indium phosphide (InP). In order to form electrical connections between each photodiode (i.e., pixel) and the corresponding Si ROIC input, the two devices are joined, one detector at a time, by metal-to-metal bonding. This time-consuming process, known as hybridization, is carried out by forming an array of indium bumps on the detector die, bringing this bumped array into contact with an array of metal bumps on the ROIC die, and then reflowing the bonds in order to form the electrical connections. The hybridization process imposes limitations on array size, pixel size, and sensor resolution.

Introducing CQD-SWIR: Low-Cost, Monolithic SWIR Sensors

RTI International has developed CQD-SWIR, a SWIR imaging sensor platform that provides low noise and broad spectral sensitivity in a low-cost architecture. CQD-SWIR is a monolithic device fabricated by building a colloidal quantum dot photodiode structure directly on the surface of silicon (Si) CMOS circuitry, bypassing the hybridization process required by conventional SWIR sensors. The techniques used in the fabrication of CQD-SWIR sensors are standard high-throughput processes found in the commercial CMOS industry. The use of these high-throughput processes, coupled with the low-cost materials employed in the diode structure, enables the fabrication of CQD-SWIR sensors that are more than an order of magnitude lower cost than existing SWIR sensors.

Images generated by a RTI-CQD SWIR image sensor with a 640 x 512 format array with 15 µm pixel pitch. (Top Left) Full-spectrum daylight image with no optical filtering. (Top Right) Daylight image obtained using a 900 nm optical long pass filter to block visible light. Both images were taken using a 4 ms integration time. (Bottom Left) Full-spectrum daylight image. (Bottom Right) Daylight image take with 1050 nm-long pass filter. Subject is holding a 1550 nm LED.

Sensor Applications

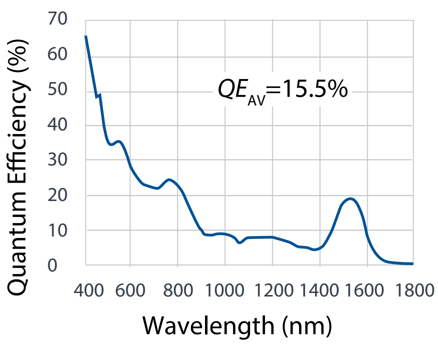
Low-cost CMOS-SWIR sensors enable imaging and remote sensing in a range of industries, including:

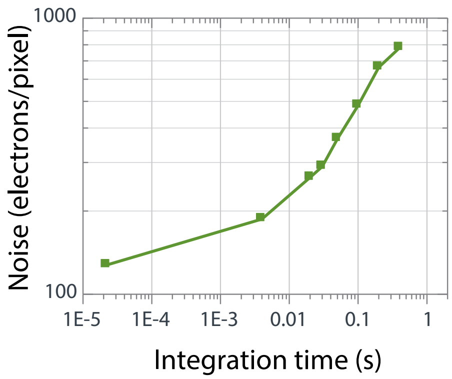
- safety, security, and defense
  - chemical sensing
  - gas leak detection
  - explosives detection
- automotive
  - day/night vehicle collision avoidance
  - autonomous navigation
- industrial automation
  - machine vision
  - quality inspection
  - process control
  - moisture detection
  - fill level inspection
  - plastics sorting
- agriculture
  - crop health monitoring
  - water stress and moisture measurement
  - irrigation control
  - food sorting

CQD Detectors

At the core of RTI's imaging sensors are tiny semiconductor crystals, CQDs, that are deposited from solution. The innovation in this approach is the device stack, which provides high extraction efficiency, linearity, response time, and low dark current using a heterojunction formed between the CQDs and a fullerene layer. The device structure has a broad spectral response with sensitivity across the visible and SWIR bands.

Parameter	Value	Comments
Part number	RTI CQD 640_1	
Format	640 × 512	
Pixel pitch	15 µm	
Active area	75% fill factor	3 µm spacing between pixels
Max frame rate	60 fps	
Spectral response	400 to 1700 nm	See QE plot
Peak response wavelength	400 nm	
Quantum efficiency	15%	Average from 0.4 to 1.8 µm
Total noise	280 electrons rms (30 ms integration time)	Room temperature, see total noise plot
Noise equivalent irradiance at 1550 nm	6×10^9 photons/cm2/s (33 fps)	Room temperature
Operability	99%	Typical
Dynamic range	2100:1	Typical





(Left) Plot of the FPA spectral QE. QE shown is the mean response for the array under monochromatic illumination. The FPA exhibited an average QE of 15% across the spectral range shown. (Right) Total per pixel RMS noise electrons as a function of integration time plotted on a log-log scale.

RTI International is an independent, nonprofit research institute dedicated to improving the human condition. Clients rely on us to answer questions that demand an objective and multidisciplinary approach—one that integrates expertise across the social and laboratory sciences, engineering, and international development. We believe in the promise of science, and we are inspired every day to deliver on that promise for the good of people, communities, and businesses around the world. For more information, visit www.rti.org.

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For More Information

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