

# A CMOS Image Sensor with a Stacked Quantum Dot Photon Absorber for Wide-spectral Imaging

P.-F. Rüedi, R. Quaglia, A. Paracchino, P. B. Cruz, H.-R. Graf, J.-D. Decoppet, C.-M. Zhang

In the framework of the Clean Sky 2 SWISSMODICS project, a CMOS image sensor made of a readout circuit (ROIC) with a stacked quantum dot photon absorber for wide spectral imaging has been developed. The chip, realized in a 180-nm 1-poly 6-metal CMOS technology, has an area of  $12.5 \times 13 \text{ mm}^2$ , containing an array of  $512 \times 512$  pixels with a pixel size of  $22.5 \times 22.5 \mu\text{m}^2$ .

The requirement of image sensors for applications in which silicon has low quantum efficiency (QE) has resulted in the development of CMOS readout integrated circuits (ROICs) combined with different photon absorber materials. One possible option is to deposit layers of absorption materials directly on top of an ROIC. While exploiting the superior QE of innovative materials, this solution keeps the advantages of modern CMOS technologies such as optimal pixel density and circuitry, low power consumption, and complex readout electronics. Additionally, this offers a much cheaper solution than bump bonded photon absorbers, while offering a fill factor close to 100%.

In recent years, quantum dot materials have gained attention as photon absorbers. Their excellent properties, including a high absorption coefficient, a long carrier diffusion length, and low-temperature compatible deposition, make them suitable candidates for the detection of photons in multiple bands of the spectrum (such as visible, near infrared, and X-ray). This has been exploited to develop a wide spectral range image sensor. Figure 1 shows the concept with a quantum dot layer deposited on top of a CMOS chip. The top metal of the CMOS process is used as the in-pixel bottom electrode to contact the stacked quantum dot photon absorber. The common top electrode is made of a transparent conducting layer.

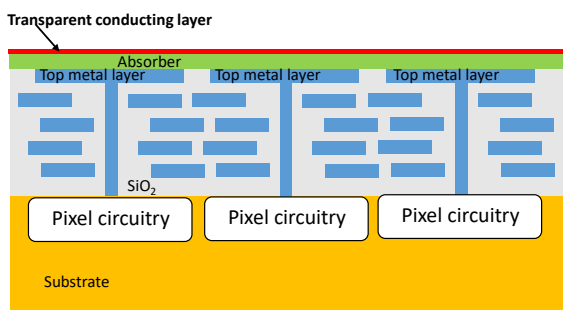


Figure 1: Cross-sectional view of the device with a stacked quantum dot photon absorber.

The chip has been designed in a standard 180-nm 1-poly 6-metal CMOS process. Figure 2 shows a micrograph of the chip. The chip area is  $12.5 \times 13 \text{ mm}^2$  including an active imaging region with a resolution of  $512 \times 512$  pixels and a pixel size of  $22.5 \times 22.5 \mu\text{m}^2$ . Each pixel can collect electrons or holes and has a programmable integration capacitor, making the chip compatible with different material stacks and photon energies (X-ray versus visible/infrared).

Figure 3 shows the structure of the quantum dot-based photon absorber layer deposited on top of the chip. The absorber is made of a  $120 \mu\text{m}$  thick layer of PbS quantum dots. The absorber has been developed and deposited by QDI, a Dutch start-up. Deposition is done by spray coating. The  $120 \mu\text{m}$  thick layer of quantum dots in addition to being a very good x-ray absorber is also sensitive out of the visible to wavelength up to 1300 nm.

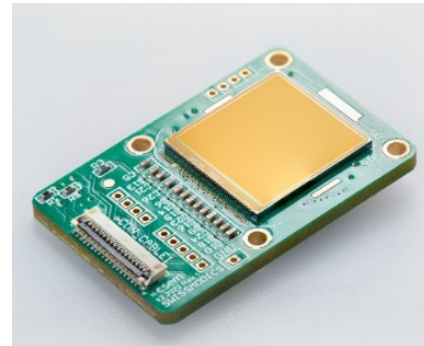


Figure 2: Micrograph of the chip hosted in a dedicated board.

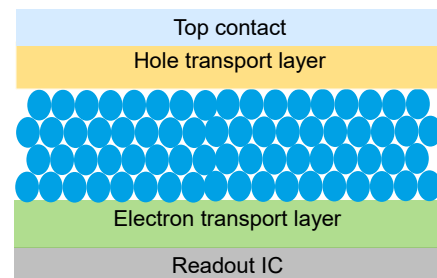


Figure 3: Structure of the photon absorber.

Figure 4 shows an X-ray image of a screw in a plastic tube acquired with the processed chip including a stacked quantum dot absorber.

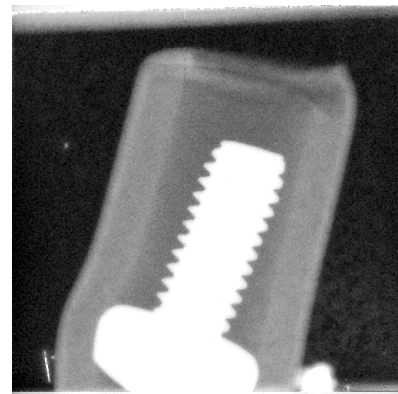


Figure 4: X-ray image acquired with the Swissmodics sensor. Courtesy of QDI.

The present development shows better resolution and sensitivity than scintillator-based X-ray detectors and opens the door to low-cost, wide spectral range and highly efficient image sensors usable for a wide range of applications.

This work, which is led by CSEM, receives the support of the European Union Clean Sky 2 program under grant 887192.

We thank QDI ([www.qdisystems.com](http://www.qdisystems.com)) for their collaboration.