ECAM–Image Sensor with Stacked a-Si:H Photodiodes

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We developed an image sensor with a-Si:H photodiodes stacked over the pixels. It will be used in conjunction with a photocathode in a second phase for ultra-low light imaging. Applications include scientific imaging and night-vision systems.

Image intensifiers are useful for a wide range of applications and markets, including surveillance, medical imaging and scientific imaging such as the rapidly growing field of fluorescence imaging. They are also used in night-vision instruments.

Traditional image intensifier systems combine a photocathode, a micro-channel plate, a phosphorous screen, a light guide and an image sensor. These multiple conversion stages introduce noise and a limited speed and spatial resolution due to the phosphorous screen.

The goal of this project is the development of a vision system for ultra-low light imaging with high photomultiplication gain which is much simpler than the above mentioned approach. The system, illustrated in Figure 1, consists of a vacuum envelope with a transparent front window. A photocathode which is deposited on the inner side of the window converts photons into electrons. These electrons are emitted by the photocathode and accelerated by a potential difference of a few kV directly onto the silicon sensor, which is kept at ground potential. Each electron impinging on the image sensor will generate a large number of electron-hole pairs, leading to a photomultiplier effect. Charges can then be collected by the individual pixels of the image sensor. The photocathode and the image sensor need to be encapsulated in a high vacuum.

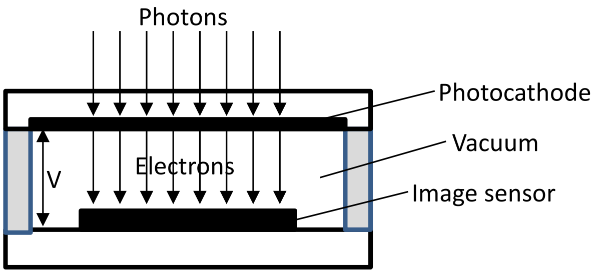

Figure 1: Image sensor module principle.

Whereas passivation and the several micrometer thick oxide are transparent for photons, they would stop electrons, thus preventing them from generating electron-hole pairs. To circumvent this problem, we have deposited on top of unpassivated pixels a layer of amorphous silicon (a-Si:H). In each pixel, the a-Si:H layer is connected to the pixel circuitry through the top metal layer, as illustrated on Figure 2. A layer of ITO (Indium Tin Oxide) deposited on top of the a-Si:H forms a transparent counter electrode.

An existing CSEM image sensor [1] with a pixels pitch of 14 µm has been modified to accommodate the a-Si:H layer. It contains pixels with Nwell to p substrate photodiodes with a fill factor of 20% and pixels with a-Si:H photodiodes with different metal contacting areas on the same chip for comparison purpose. Two types of junctions have been deposited: i-p and n-i-p.

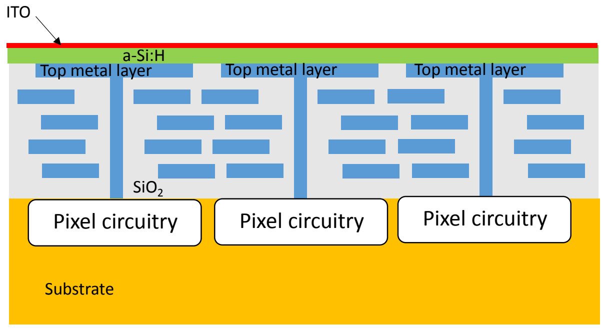

Figure 2: Image sensor module principle.

Figure 3 shows a microphotograph of the chip covered with a-Si:H and ITO. The areas with different metal contacting areas are clearly visible (right part of the pixel array with 3 × 3 rectangles), as well as the area with photodiodes (left part of the pixel array).

The characterization of the chip should be available in early 2017.

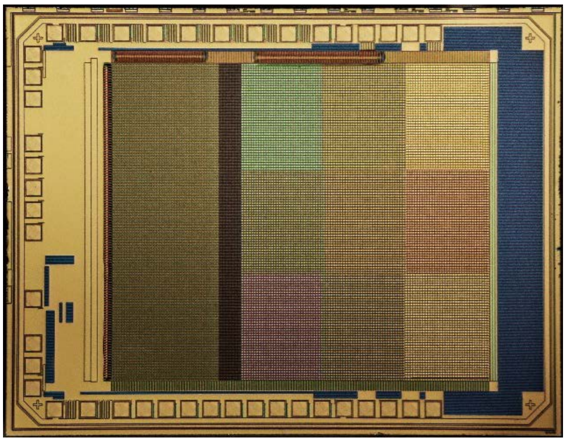

Figure 3: Microphotograph of the chip.

In addition to image intensifiers, the proposed approach can also be used for electron imaging, such as vacuum imaging of particles, electron microscopy, beam imaging and X-ray applications. It also offers benefits for standard visible light imaging. Depositing photodiodes on top of the read-out ASIC enables close to a 100% fill factor, while freeing space in the pixel for more electronics as there is no photodiode any more in the pixel.

[1] P. Heim, F. Kaess, P.-F. Rüedi, "High dynamic range versatile front-end for vision systems", CSEM Scientific and Technical Report (2007) 25.