Hybrid UV Imager Containing Face-Up AlGaN/GaN Photodiodes

An alternative approach offers potential advantages over the flip-chip approach.

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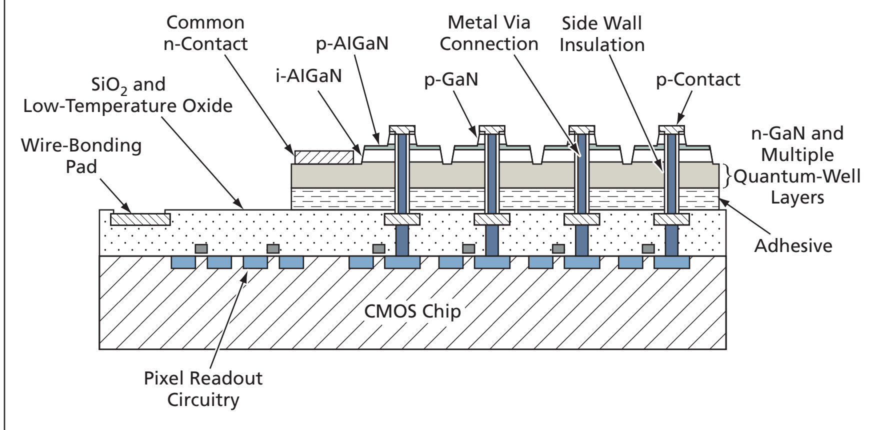
A proposed hybrid ultraviolet (UV) image sensor would comprise a planar membrane array of face-up AlGaN/GaN photodiodes integrated with a complementary metal oxide/semiconductor (CMOS) readout-circuit chip. Each pixel in the hybrid image sensor would contain a UV photodiode on the AlGaN/GaN membrane, metal oxide/semiconductor field-effect transistor (MOSFET) readout circuitry on the CMOS chip underneath the photodiode, and a metal via connection between the photodiode and the readout circuitry (see figure). The proposed sensor design would offer all the advantages of comparable prior CMOS active-pixel sensors and AlGaN UV detectors while overcoming some of the limitations of prior (AlGaN/sapphire)/CMOS hybrid image sensors that have been designed and fabricated according to the methodology of flip-chip integration.



The **Proposed Hybrid Image Sensor** would comprise a planar membrane array of face-up AlGaN/GaN photodiodes adhesively bonded to a CMOS readout-circuit chip, with a metal via connection in each pixel.

AlGaN is a nearly ideal UV-detector material because its bandgap is wide and adjustable and it offers the potential to attain extremely low dark current. Integration of AlGaN with CMOS is necessary because at present there are no practical means of realizing readout circuitry in the AlGaN/GaN material system, whereas the means of realizing readout circuitry in CMOS are well established. In one variant of the flip-chip approach to integration, an AlGaN chip on a sapphire substrate is inverted (flipped) and then bump-bonded to a CMOS readout circuit chip; this variant results in poor quantum efficiency. In another variant of the flip-chip approach, an AlGaN chip on a crystalline AlN substrate would be bonded to a CMOS readout circuit chip; this variant is expected to result in narrow spectral response, which would be undesirable in many applications. Two other major disadvantages of flip-chip integration are large pixel size (a consequence of the need to devote sufficient area to each bump bond) and severe restriction on the photodetector structure.

The membrane array of AlGaN/GaN photodiodes and the CMOS readout circuit for the proposed image sensor would be fabricated separately. The AlGaN/GaN membrane would be separated from its fabrication substrate by use of laser lift-off or perhaps some other technique that works as well. A temporary holder would be used for lifting off the AlGaN/GaN membrane, transferring this membrane to the CMOS circuit chip, and keeping the front surface of the membrane facing up in the process. The AlGaN/GaN membrane would be bonded to the CMOS chip by use of an adhesive, which could be a polyimide or other, similar material. After curing of the adhesive, the portion of the membrane outside the area of the photodiode arrays would be removed by dry etching. Then the metal via connections between the photodiodes and the CMOS readout circuit would be made in all the pixels.

The performance of the proposed image sensor in solar-blind or visible-blind UV imaging would exceed that achievable in flip-chip integration in two ways:

The face-up orientation of the photodiodes would make it possible for UV photons to be detected at the top layer of the photodetector, where the quality of the photodetector material usually exceeds that of the inner layers. As a result, it should be possible to achieve high quantum efficiency, wide and tailorable spectral response, and low dark current.

The metal via connections in the proposed configuration could be made much narrower than the tens-of-microns-wide bonding bumps of a typical flip-chip configuration. The elimination of the need to devote so much pixel area to bump bonds would enable the design and fabrication of much smaller pixels. Hence, it would be possible to achieve greater spatial resolution of the image and to fit more pixels into a given image area.

This work was done by Xinyu Zheng and Bedabrata Pain of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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