CMOS Camera-On-A-Chip

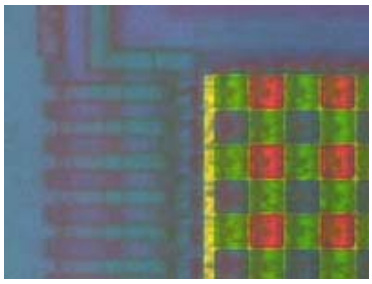
Ruth DeJule, Associate Editor -- Semiconductor International, 4/1/1999

CMOS active-pixel digital image sensors (APS) may offer an alternative to charge-coupled devices (CCD), a mainstay in video and still-camera applications for the past 30 years. The CMOS camera-on-a-chip technology was invented at NASA Jet Propulsion Laboratory to overcome the limitations of power, size and mass of CCD-based camera systems for interplanetary spacecraft. More importantly, APS technology uses the same manufacturing platform as most microprocessors and memory chips, making them more cost-effective and easier to manufacture.

CCDs are manufactured using specialized processes that optimize optical characteristics and charge transfer efficiency. The need to enhance efficiencies with high electric fields makes CCDs incompatible with state-of-the-art CMOS devices and circuits. Since the early '70s, efforts to merge CCD and CMOS processes have not been economically viable, noted Dr. Eric Fossum, chief scientist at Photobit (Pasadena, Calif.). Fraught with large power dissipation and requiring a large number of system components, CCDs are not well suited for portable applications.

Developed at Photobit, CMOS camera-on-a-chip is a system-on-a-chip that integrates an array of image-capturing pixels, pixel selection logic, digital timing generator, analog signal processing electronics, analog-to-digital converter (ADC), digital signal processing and interface functions. Applications range from computer-based video teleconferencing and digital cameras to bar code scanners and cell phones.

At the heart of the camera-on-a-chip is the CMOS active pixel sensor (APS). Each pixel contains the photodetector element, transistor circuitry for readout of the pixel signal and transistors for selecting and resetting the photodetector. A pixel ranges in size from 5 mm to 12 mm so that it is appropriate for 0.25 mm to 0.5 mm CMOS technology. The photodetector element can be a simple photodiode, PIN photodiode or photogate.



The corner of a CMOS active pixel sensor displays an RGB color filter array deposited on the pixels. [Source: Photobit]

In addition to power, size and cost advantages over CCDs, the CMOS camera-on-a-chip has several functional advantages, in particular, random accessibility, increased system robustness, faster design cycle times for camera manufacturers, lowered production costs and increased reliability as a result of having fewer components. The pixels in the array can be individually addressed in an X-Y fashion, permitting the readout of only pixels of interest. In contrast, CCDs access pixels sequentially from left to right and top to bottom in a raster-scan.

The challenges addressed in CMOS APS fabrication are primarily those posed by surrounding circuitry. Here, processes require the support of mixed analog/digital circuits. Though standard mixed signal processes are commonly available at most fabrication facilities, applications to APS processing were non-trivial. Another issue is junction leakage current. As with CCDs, the dark current must be carefully controlled and reduced to very low levels and matching of photodetector aperture across a large array, >1 million pixels is critical to uniform image quality. Finally, white spots, a common problem caused by a combination of low level contamination and process-induced defects, must be controlled.

Despite these constraints, the reduced cost of implementing an imaging system in CMOS and the functional advantages offered by such a camera-on-a-chip have extended the appeal of APS technology to nearly all terrestrial imaging applications. Future generations of CMOS image sensors will most likely be fabricated using a standard CMOS process platform with extra process modules to optimize sensor performance, Fossum commented. Over time, companies will likely develop specialized processes to enhance the performance of their CMOS sensors. Although this has the advantage of improved image sensor performance, it has the disadvantage of moving image sensor fabrication away from the mainstream and, thus, away from the benefits associated with leveraging off of the ongoing multi-billion dollar process development. Camera-on-a-chip technology may prove a viable alternative.