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Direct detection, high frame rate, radiation-hard CMOS monolithic pixels for high resolution Transmission Electron Microscopy

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CMOS monolithic active pixel sensors are rapidly becoming an established technology for digital imaging in Transmission Electron Microscopy. Direct electron detection, with sensitivity down to single electrons, benefits the sensor Detective Quantum Efficiency (DQE), while Modulation Transfer Function (MTF) and ultimately single point resolution are greatly enhanced by the thin sensitive layer and the small pixel dimensions achievable with deep-submicron feature size fabrication processes. It has also been demonstrated that sub-pixel resolution can be achieved by creating images from the digital superimposition of single electron hit positions, reconstructed by clustering and centroiding algorithms. Moreover, readout rates of several hundred frames per second (fps) are possible even for large area (megapixel scale) sensors.

Over the past year, and benefiting from the earlier LBNL development driven by the TEAM (Transmission Electron Aberration-corrected Microscope) project, we have developed a 16 megapixel, reticle scale CMOS imager optimized for 400 fps readout. The sensor is manufactured in a 0.18 μm commercial CMOS process, and implements pixels of 5 μm pitch featuring an advanced radiation tolerant layout which has been shown to be functional after 300 keV electron doses close to 100 Mrad, ensuring a long device lifetime. The sensor can be used both as an integrating device or as an electron counting device, and is currently being implemented in a commercial digital camera system.

The presentation will review this development, and report on the sensor detection and imaging performance, characterized in microscope columns with electrons of energies in the range of interest to TEM (80-300 keV), both under low dose illumination (i.e. single electrons) and high contrast imaging conditions. Further, a prototype chip implementing several novel pixel architectures and layout options will be introduced and evaluated comparatively, e.g. in terms of radiation hardness, in order to identify the best option for the next generation of electron imagers.

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