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Development of high speed, radiation hard CMOS monolithic pixels for high resolution Transmission Electron Microscopy

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CMOS monolithic active pixel sensors have been established in recent years as the technology of choice for new generation digital imaging systems for Transmission Electron Microscopy. With respect to conventional, optically-coupled CCD-based cameras, the advantages of this technology lie on one side in the possibility for direct detection with single electron sensitivity, which greatly benefits the sensor Detective Quantum Efficiency (DQE); on the other side, the thin sensitive layer and consequently reduced electron scattering, coupled with micrometer-level pixel sizes achievable with deep-submicron fabrication processes, dramatically improve spatial resolution through an enhancement of the Modulation Transfer Function (MTF) up to large spatial frequencies. Readout rates of several hundred frames per second (fps) are possible even for large area (megapixel scale) sensors, whose layout can be optimized to achieve a superior radiation tolerance and thus ensure a long device lifetime. This was recently demonstrated, in an effort driven by the Transmission Electron Aberration-corrected Microscope (TEAM) project [1] at the LBNL National Center for Electron Microscopy, with the development and commissioning of a 400 fps, 1-megapixel sensor manufactured in a 0.35 μm CMOS process on a 9.5 μm pixel pitch [2]. The search for higher spatial resolution and radiation hardness, without compromising readout speed, prompted us to evaluate finer feature size processes. Through the design and testing of a prototype sensor manufactured in a 0.18 μm CMOS process, we identified an architecture for a 5 μm pitch pixel that demonstrated radiation hardness to 300 keV electron doses close to 100 Mrad [3]. This ultimately led to the development of a 16-megapixel, 400 fps readout, reticle scale CMOS imager which is currently being commissioned in a commercial digital camera system. The presentation will review this development, and introduce our search for a next generation architecture through the evaluation of a recently manufactured prototype sensor implementing novel variants for the pixel architecture and layout. Sensor detection and imaging performances, as characterized with electrons of energies in the range of interest to TEM (80-300 keV) will be reported and evaluated comparatively with the present state-of-the-art architecture.

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