3D-Hybridized MAPS and Readout ASIC Pixel Detector for Soft X-Rays with In-Pixel A-to-D Conversion

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FLORA (Fermilab-LCLS CMOS 3D-integRated detector with Autogain) is a large dynamic range and continuous, fast readout rate pixel detector conceived to exploit the high repetition rate operation at LCLS-II with focus on soft X-rays. The detector can fulfill the needs of the new storage rings and its concept extended to tender and harder X-rays. The target for the FLORA device is a sensitivity to X-ray photon energies from the range from 250 eV to 2 keV, allowing detection of a single photon and extending the dynamic range to 10^4 photons per pixel per frame. The FLORA detector structure is planned for large area coverage in a form of up to 10×10 cm^2 tileable modules arranging in a structure with a central hole and high vacuum compatible. The detector module is a hybridized device, in which the structural support function is fulfilled by a sensing layer to which readout integrated circuits are bonded using the high-density interconnect technology. The sensor is a monolithic active pixel sensor (MAPS) built on high resistivity silicon that is operated in depletion with the first processing stage allowing optimized, separate processing of weak and strong signal built in. The individual fabrication yield of MAPS can be expected high due to the larger feature size of electronic devices and interconnects, allowing reticule stitching, and orders of magnitude smaller number of active devices than typically encountered in the readout integrated circuits. The hybridization used in FLORA is oriented on maximization of its fabrication yield that is to be achieved through bonding of so called known-good-dies to the sensor layer preferably using the low-temperature direct bonding technology. Other design specification parameters for the FLORA detector are small pixel size on the order of 50×50 μm^2; $\sim$10 e$^-$ ENC for single photon sensitivity at the lowest energy, that is achieved through correlated-double-sampling-based filtering in the front-end; no-dead-time and exceeding the 10 kfps frame readout processing and readout rate with the in-pixel 10-bit digitization of integrated signal yielding digital-only readout. The FLORA_V1.0 ASIC is a prototype that is intended to demonstrate the concept of the low-noise front-end processing adapted to the MAPS sensors and the in-pixel 10-bit digitization fitting into the 50×50 μm^2 footprint of the pixel together with the efficient reading out of the results. The ASIC has been submitted for fabrication in a 65-nm process in January 2018 and testing is scheduled to start in late Mach 2018. The device dimensions are 5×5 mm^2 and it features an array of 64×64 pixels grouped in four quadrants each equipped with a separate digital serial output. The in-pixel ADC is the charge redistribution successive approximation register type circuit that uses two capacitors tuned digitally with a some-tens-of-attofarads precision. The prototype FLORA_V1.0 ASIC is also intended for hybridization with a diode-only sensor. This is the first step in the FLORA sensor's development in order to work-out calibration with the actual X-ray signals. The presentation will include measurements of the front-end chain including detailed characterization of the ADCs with emphasis on statistical variations of the circuit's parameters, their uniformization and calibration.