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Dark-Current Estimation Method for CMOS Image Sensor in Mixed Radiation Environment

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Nowadays, CMOS image sensors (CIS) are more and more used in a wide variety of applications, especially in satellite systems, high energy physics setups, where they are exposed to mixed radiation sources. The sensors suffer from radiation-induced dark-current degradation that the dark-current mean value and non-uniformity increase, which results in the signal-to-noise-ratio (SNR) decrease affecting the image quality. Especially, for long working period, dark-current degradation has been proved to be the dominant noise issue for high SNR imaging. Needless to say, it's very important to assess the possible dark current degradation of a given CIS before it is selected for a specific application in radiation environment.

Previous reports illustrated that charge trap density in Si/SiO_2 is proportional to the ionizing dose, which helps building a linear relationship between dark-current and ionizing dose. Also, it has been reported that displacement damage dose induced dark-current in silicon could be reasonably fitted to a power-law function of the particle's energy. Based on the knowledge above, it's able to illustrate the dark-current probability density function (PDF) of the whole pixel array under the radiation of single kind of particles. However, the models cannot be used when there is more than one radiation source in the environment, which is a more common situation.

In order to estimate the CIS dark-current behavior in mixed radiation environment, we propose using probability operation to estimate the pixel array's dark-current PDF, assuming that particles incident events are uncorrelated. Simulations are implemented upon a set of data (dark images derived under γ-rays(10 Krad) and protons ($\Phi_p = 10^{10}\ p/cm^2$, E=40 MeV)).The results show that the dark-current mean-value and non-uniformity calculated using the proposed method almost equal to the simulation results under γ-proton mixed radiation, with errors no more than 4% and 5%,respectively.

Further validation of the proposed method will be implemented through radiation experiment this autumn. Once the proposed method is validated in practice, It can do great help in CIS dark-current estimation under sophisticated radiation environment where the devices are exposed, at the same time, to more than one kind of radiation particles.

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