Novel high-gain image sensors based on Si p-n APD.

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A novel solid-state imager in which a Si-avalanche photodiode (APD) is employed in charge storage mode operation, is proposed and studied.

First, the photo-electron conversion characteristic of the APD imager cell operating in the charge storage mode is analyzed. This analysis was separately conducted in below and above-breakdown voltage conditions.

In the below-breakdown voltage condition, photo-electron conversion characteristic was analyzed by use of an empirical relation between the multiplication gain and applied reverse bias in APD. The photo-electron conversion characteristic was divided into two regions, $\gamma = 1.0$ (linear region) and $\gamma = 0.5$ (sub-linear region). In the operation under the sub-linear region the light detection range is double compared with that of the conventional CCD. Moreover, in this operation region, responsivity variation of the APD array can be suppressed with the aid of self-quenching effect.

In the above breakdown condition, photo-electron conversion characteristic was discussed by employing the idea of carrier feedback. For extremely weak incident light range, it was found that the number of output counts observed over a certain constant period was in proportion to the number of incident photons.

Second, two kinds of the APD imager, the dual-gate construction and the capacitance-coupling construction, without avalanche discharge during read-out time were proposed and demonstrated by use of a test circuit. Photo-electron conversion characteristic of the experimental results was well explained by their analytical models. Design guidelines of the optimum construction for each type were also presented.

A five element APD liner array was fabricated to confirm the suppression effect of the output signal variation. As a result, a novel high-gain and wide-range image sensor without initial multiplication variation among pixels was achieved.