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Design study and spectroscopic performance of SOI pixel detector with a pinned depleted diode structure for X-ray astronomy

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We have been developing silicon-on-insulator pixel detectors with a pinned depleted diode structure, named "XRPIX", for X-ray astronomy. XRPIX, using a reverse-biased p-type substrate, has a pinned, undepleted p-well at the back-gate surface under the buried oxide layer and a depleted n-well underneath the p-well. The latter has two important roles: one is to prevent leakage current from the p-well to the substrate (punch-through) creating a potential barrier, and the other is to improve charge collection efficiency creating lateral electric field toward the n+ charge sensing node. Optimization of the dopant concentration of the n-well is the key ingredient to finalize XRPIX because higher dopant concentration could result in a higher potential barrier but make it harder to deplete the n-well, and vice versa. Based on TCAD simulations, we fabricated five candidate chips having different n-well dopant concentrations and configurations. We successfully found out the best candidate chip, which showed a satisfactory X-ray spectroscopic performance and suppressed a large leakage current. Too high or too low dopant concentration chips showed a degraded X-ray spectroscopic performance or a large leakage current as expected from the TCAD simulations. We also evaluated the dependency of X-ray spectroscopic performance on the n-well dopant concentration and configuration. In this presentation, we will report the above design study and spectroscopic performance of XRPIX.

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