Project Synopsis

Silicon-Based 3D Position-Sensitive Scatter Detector with Integrated Amplification

In order to sense the direction from which radiation emanates with solid-state detectors, one typically measures the centroid position of the carrier clouds that result from particle impact, and from them, infers the initial direction from either Compton calculations or filtered back-projection algorithms. Our goal is to greatly enhance the directional resolution of semiconductor detectors by imaging the individual electron-hole pairs that are created via the passage of radiation through solids. From either the dynamics of the induced charge creation, or from the charge collection following drift, one can envision techniques in which the charge cloud formation indicates the direction of the incident radiation. For instance, if the charge cloud can be used to indicate the direction of the Compton electron, then the back-projected cone can be reduced to a point, enhancing image resolution. The resolution loss that accompanies reduced count rates in coded-aperture imaging can also be avoided if the individual photoelectrons can, in effect, be imaged.

In order to substantially enhance the capabilities of semiconductor detectors, we plan to develop a silicon imaging system via a phased development. In the proposed work, we will first seek to understand the solid-state physics that govern the electron behavior in the device, particularly focusing on contact and interface physics. For instance, we will seek to understand interface states, so that the factors that govern either avalanche or zener processes can be understood and controlled, in case we need additional device gain to image the charges. During these studies, our goal will be to develop a detailed theoretical understanding of the underlying processes that can be applied to other semiconductor materials, such as cadmium zinc telluride (CZT), mercuric iodide, and germanium.

These theoretical studies will be complemented by the empirical development of 3D sensitive silicon detectors, in which the interaction depth is sensed via drift time measurements, and the 2D lateral position measured via charge sharing techniques. We will use our long experience in silicon micromachining to build conventional amplification devices (such as field effect transistors) on-chip in order to minimize the noise that might limit the electron resolution, and apply stochastic noise control techniques if necessary in order to reach the desired performance.