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Simulating and Optimizing a 3D Neutron Imaging Sensor

Neutron imaging provides complementary information to X-ray imaging due to the different interaction mechanisms of the two radiations. This technique is particularly relevant in nuclear engineering and non-destructive diagnostics.

Within the INFN HYDE2 project, an innovative thermal neutron detection and imaging device has been developed. The sensor exploits a 3D microstructure design: it is based on a standard planar n-on-p pixel structure, but the backside is processed with Deep Reactive Ion Etching (DRIE) to create $\sim$25 μm-deep narrow cavities, later filled with ^{6}LiF or ^{10}B converter. The device features a 256×256 pixel matrix with 55×55 μm^2 pixels, fully compatible with Timepix electronics.

The study aims to optimize cavity geometry (radius and spacing) to maximize neutron detection efficiency. This requires considering neutron capture, transport of reaction products, and charge collection —a non-trivial task.

The workflow integrates multiple simulation tools. First, GEANT4 provides the energy deposition maps of charged particles from neutron capture. Then, TCAD Sentaurus simulations deliver the device's electrostatic properties (weighting potential, electric field, doping). While transient TCAD runs allow CCE (Charge Collection Efficiency) evaluation, they are too computationally demanding for large parameter scans. To overcome this, the Allpix2 framework is employed: TCAD outputs are imported, charge deposition is modeled according to GEANT4, and a modified TransientPropagation module accounts for the HYDE2 geometry. The computed CCE is benchmarked against selected TCAD transients, ensuring accuracy.

Finally, combining all results enables the identification of the optimal geometry for maximizing neutron detection efficiency. Moreover, a first outlook on preliminary measurements performed on dedicated test structures will also be presented.

Title

Topic

Solid state sensors

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