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TCAD simulation of 3D silicon sensors for thermal neutron imaging

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Thermal neutron imaging is a powerful technique providing information on materials and structures otherwise opaque to X-rays, and is widely used in different applications, such as non-destructive industrial diagnostics, nuclear engineering, archaeology and cultural heritage, forensic science, to cite but a few. To increase the detection efficiency, we have developed hybrid 3D pixel detectors compatible with the Timepix read-out chip (256×256 pixels of 55×55 m^2 size), with encouraging results from laboratory tests with α particles. The device structure is largely simplified as compared to standard 3D sensors (see Fig. 1): it features planar n^+ pixels on a p^- substrate on the front-side, and deep (˜25 μm) and narrow cavities (from ˜2 to ˜ 15 μm, compatible with ^{10}B and ^{6}Li neutron converters) on the back-side, with different distances between them. The back-side surface is p^+ doped with boron and coated with an Aluminium layer before performing Deep Reactive Ion Etching to establish a good ohmic contact. By doing so, the cavities remain undoped: while this minimizes the dead-layer for reaction products, the residual damage from DRIE could be an issue. Thus, a thin (tens of nm) layer of Al_2O_3 is deposited which, due its expected negative fixed charge, should result in the accumulation of a layer of holes at the Si/Al_2O_3 interface, reducing generation/recombination effects. However, the density of fixed negative charge in Al_2O_3 strongly depends on the deposition and annealing conditions, and it is difficult to be controlled, with possible impact on the leakage current and the charge collection efficiency. This motivated the present study, which is aimed at assessing the sensitivity of the 3D sensors performance to the properties of the Si/Al_2O_3 interface for future optimization of the device. We will report on TCAD simulations of the different geometries of interest in the presence of different Si/Al_2O_3 interface conditions in terms of fixed charge density and recombination velocity, also using results from Geant4 simulations as an input to better describe the ionization profiles in silicon caused by neutron reaction products.

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