On the cutting edge of semiconductor sensors: towards intelligent X-ray detectors

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Semiconductor device simulation

TCAD[1] software from Synopsis [122] is used to simulate the electrical characteristics of semiconductor devices.

The simulation programme calculates the electrostatic potential distribution and charge-carrier concentrations for user-defined semiconductor structures by numerically solving Poisson's equation and the electron and hole continuity equations. The the charge density in Poisson's equation,

$$\nabla^2 \psi = -\frac{\rho}{\epsilon} \,, \tag{B.1}$$

is given by the net sum of the free charge-carrier concentrations and that of the ionised n-type and p-type impurities:

$$\rho = q(p - n + N_d^+ - N_a^-) \,. \tag{B.2}$$

The electron and hole continuity equations are given by Equation 2.24.

In order to solve these equations for a given semiconductor device, the structure is typically approximated by dividing it into smaller, geometrically simple elements, a process is called meshing. Subsequently, the differential equations are applied to each element. By defining boundary conditions, e.g. potentials at each of the electrodes, the software finds the function that best approximates the solution to the equations for each element. This partial solution is determined such that the contribution to the total approximate solution outside the element equals zero. The total approximate solution is subsequently obtained by summing the partial solutions. The programme uses a numerical solver, which iterates repeatedly until the partial solution is accurate enough.

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[1]TCAD stands for Technology Computer-Aided Design

Figure B.1 depicts the corner of one of the p-type stop-ring sensor structures of Chapter 4 after meshing.
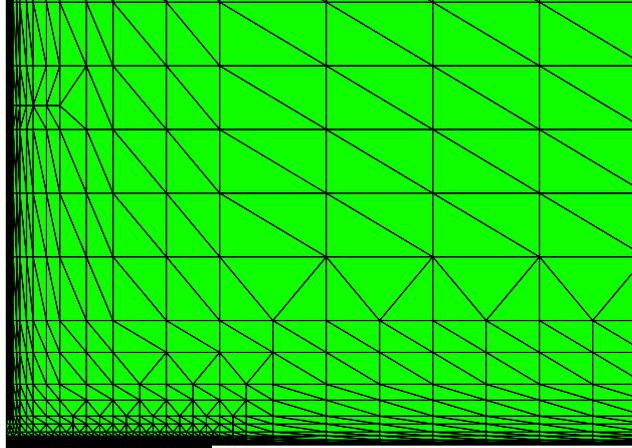
Figure B.1: Meshing

       A semiconductor structure is commonly meshed, which allows for finding an approximate solution to the equations by summing the simpler approximate partial solutions of smaller elements.