Semiconductor Physics Documentation

Y.G

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1.2 Basic equations

In this section, we introduce some basic equations related to semiconductor devices.

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1.2.1 Poisson equation

The electrostatic potential can be calculated with the corresponding charge distribution ρ with Poisson equation.

$$\nabla \cdot (\varepsilon_s \nabla \psi) = -\rho, \tag{1.1}$$

where ε_s is the dielectric permittivity and $\varepsilon_s = 11.9\varepsilon_0$ for Si. ψ is the electrostatic potential. The electric charge density in a semiconductor is given by the summation of the electron charge density n, the hole charge density p, and the ionized impurity doping density D. Therefore,

$$\rho = q(n - p + D), \tag{1.2}$$

where q is the elementary charge. Note that D consists of the ionized acceptor and donor type impurity densities, which mean $D = N_A - N_D$.

Thus, (1.1) can be expressed as following,

$$\nabla^2 \psi = -\frac{q(n - p + N_A - N_D)}{\varepsilon_s}. \tag{1.3}$$

The left side can be rewritten in the orthogonal coordinate system,

$$\nabla^2 \psi(x, y, z) = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2}. \tag{1.4}$$