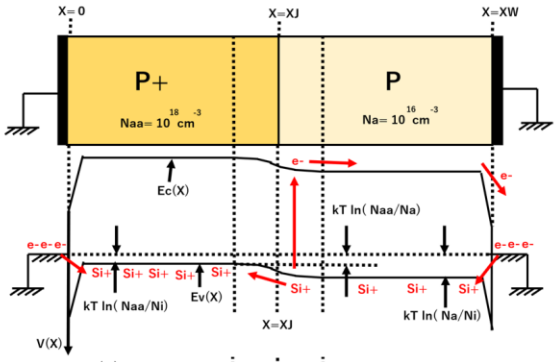
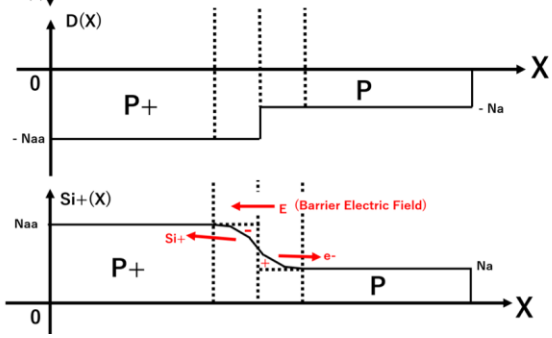
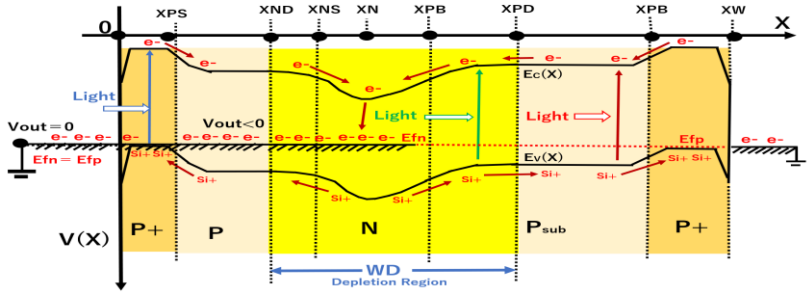
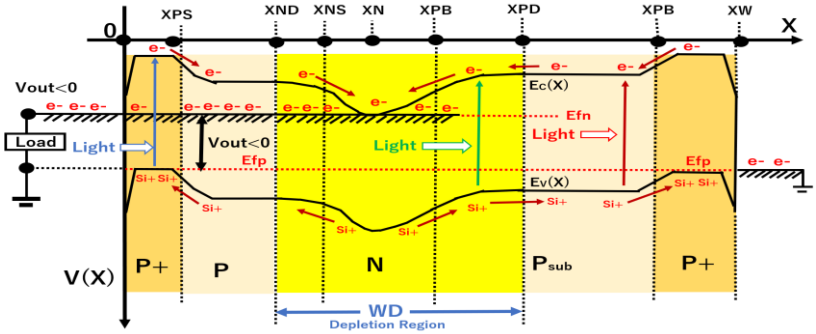
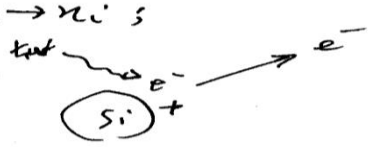








$$\begin{cases} V_o = (kT)\ln\left(\frac{n_i}{N_{aa}}\right) \to 0 \text{ as } N_{aa} \to n_i ; \\ V_w = (kT)\ln\left(\frac{n_i}{N_a}\right) \end{cases}$$



$$Si + h\nu \longrightarrow Si^+ + e^-$$

$$\epsilon_{Si} \frac{d^2V(x)}{dx^2} = -\rho(x) = -\mathcal{D}(x) - Si^+(x)$$

For $0 < x < x_J$, $\mathcal{D}(x) = -N_{aa}$, $Si^+(x) = N_{aa}\exp\left(\frac{V_o - V}{kT}\right)$

$$\frac{1}{2}\epsilon_{Si}\left(\frac{dV}{dx}\right)^2 = (N_{aa})(V - V_o) + (N_{aa})(kT)\left\{\exp\left(\frac{V_o - V}{kT}\right) - 1\right\}$$

For $x_J < x < x_W$, $\mathcal{D}(x) = -N_a$, $Si^+(x) = N_a\exp\left(\frac{V_w - V}{kT}\right)$

$$\frac{1}{2}\epsilon_{Si}\left(\frac{dV}{dx}\right)^2 = (N_a)(V - V_w) + (N_a)(kT)\left\{\exp\left(\frac{V_w - V}{kT}\right) - 1\right\}$$

At $x = x_J$,

$$(N_{aa})(V_J - V_o) + (N_{aa})(kT)\left[\left(\frac{n_i}{N_{aa}}\right)\exp\left(-\frac{V_J}{kT}\right) - 1\right]$$

$$= (N_a)(V_J - V_w) + (N_a)(kT)\left[\left(\frac{n_i}{N_a}\right)\exp\left(-\frac{V_J}{kT}\right) - 1\right]$$

$$(N_{aa})(V_J - V_o) - (N_{aa})(kT) = (N_a)(V_J - V_w) - (N_a)(kT)$$

$$(N_{aa} - N_a)(V_J) = (N_{aa} - N_a)(kT) - \{(N_a)(V_w) - (N_{aa})(V_o)\}$$

$$V_J = kT - \frac{(N_a)(V_w) - (N_{aa})(V_o)}{(N_{aa} - N_a)}$$

$$\left(\frac{V_J}{kT}\right) = 1 - \frac{\ln\left(\frac{n_i}{N_a}\right) - \frac{N_{aa}}{N_a}\ln\left(\frac{n_i}{N_{aa}}\right)}{\left(\frac{N_{aa}}{N_a}\right) - 1}$$

As $N_{aa} \to n_i$,

$$\left(\frac{V_J}{kT}\right) = 1 - \frac{\ln\left(\frac{N_{aa}}{N_a}\right)}{\left(\frac{N_{aa}}{N_a}\right) - 1}$$

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[EDTM2020_Paper_on_the P+PN+P Junction Pinned Photodiode and Schottky Barrier Photodiode.html]

[P2019_3DIC2019_Paper_on_3D_Pinned_Photodiode_6_pages.pdf]