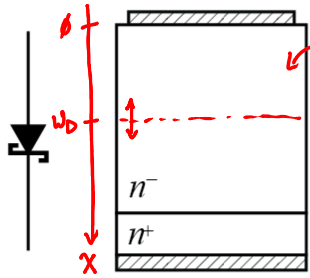
Junction Capacitance



$W_D = f(V_r) = \sqrt{\frac{2\varepsilon|V_r|}{q n_D}}$

$Q_{tot} = q n_D W_D$

$Q_{tot} = q n_D \sqrt{\frac{2\varepsilon|V_r|}{q n_D}} = \sqrt{2\varepsilon|V_r| q n_D}$

'fixed capacitance : $C = \frac{Q}{V}$

small-signal capacitance : $C\big|_{V_r} = \frac{\partial Q}{\partial V}\Big|_{V_r}$

$C\big|_{V_r} = \frac{\partial Q}{\partial V} = \frac{\partial}{\partial V_r}\sqrt{2\varepsilon|V_r| q n_D} = \sqrt{2\varepsilon q n_D}\,\frac{1}{2}|V_r|^{-1/2}$, $V_r < 0$

$C\big|_{V_r} = \sqrt{\frac{\varepsilon q n_D}{2|V_r|}}$ $\left(\frac{F}{cm^2}\right)$

"optimal doping"

$E_{max} = E_{crit} \rightarrow q n_D = \frac{\varepsilon E_{crit}^2}{2 V_{BV}}$

$C\big|_{V_r} = \sqrt{\frac{\varepsilon}{2|V_r|}}\sqrt{\frac{\varepsilon E_{crit}^2}{2V_{BV}}} = \sqrt{\frac{\varepsilon^2 E_{crit}^2}{4|V_r||V_{BV}|}}$ valid for $|V_r| \gg 0$

In reality: $V_{depl} = V_p - V_r$

if $|V_r| \gg |V_F|$, $V_{depl} \approx |V_r|$

More accurate:

$C\big|_{V_r} = \sqrt{\frac{\varepsilon n_D q}{2(V_p - V_r)}}$, $V_r < 0$

$C_{j0} = C\big|_0 = \sqrt{\frac{\varepsilon n_D q}{2V_F}}$

$C\big|_{V_r} = C_{j0}\sqrt{\frac{V_F}{V_p - V_r}} = \boxed{C_{j0}\sqrt{\frac{1}{1-\frac{V_r}{V_F}}}}$ $\left(\frac{F}{cm^2}\right)$

Schottky Capacitance Comparison

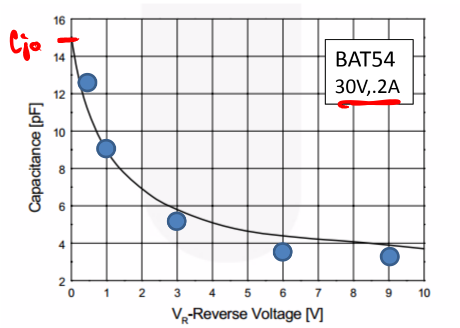
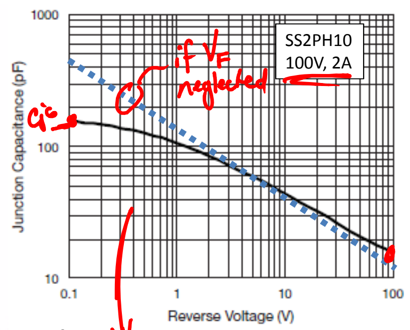
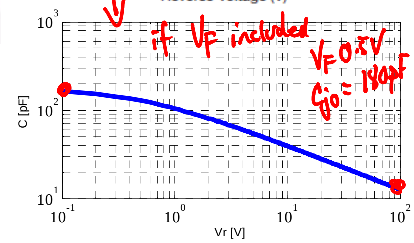
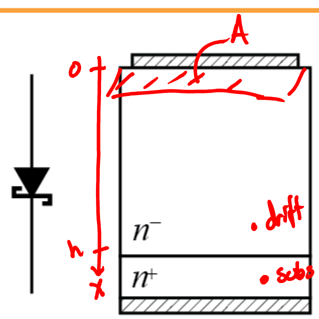


Figure 3. Total Capacitance vs. Reverse Voltage





Drift Region Resistance



$R \simeq R_{metals} + R_{contacts} + R_{subs} + R_{drift}$

$R \simeq R_{drift}$ valid for large V_{BV}

Resistivity: $\rho = \frac{1}{\mu_n n_D q}$ $(\Omega \cdot cm)$

$R = \rho \frac{h}{A} \rightarrow R_{on,sp} = RA = \rho h$ $(\Omega\, cm^2)$

$R_{on,sp} = \frac{1}{\mu_n n_D q} h \rightarrow$ select $h = W_D \, (E_{max} = E_{crit})$

$h = \sqrt{\frac{2 \varepsilon V_{BV}}{q n_D}}$

$$R_{on,sp} = \frac{1}{\mu_n n_D q} \sqrt{\frac{2\varepsilon V_{BV}}{q n_D}} = \sqrt{\frac{2\varepsilon V_{BV}}{(q n_D)^3 \mu_n^2}} \quad (\Omega \cdot cm^2)$$

Baliga's FOM

Baliga, B J, "Advanced Power MOSFET Concepts"

$$qn_D = \frac{\varepsilon E_{crit}^2}{2V_{BV}} \quad (\text{max doping density to have } E_{max} \leq E_{crit})$$

$$R_{on,sp} = \sqrt{\frac{2\varepsilon V_{BV}}{\mu_n^2}} \sqrt{\frac{1}{\left(\frac{\varepsilon E_{crit}^2}{2V_{BV}}\right)^3}} = \sqrt{\frac{2^4 V_{BV}^4}{\mu_n^2 \varepsilon^2 E_{crit}^6}} = \boxed{\frac{4V_{BV}^2}{\mu_n \varepsilon E_{crit}^3}}$$

Baliga's Figure of Merit