$$\Gamma(r) = \sum \Gamma(K_n) e^{iK_n \cdot r}$$

$$b_1=rac{2\pi\overline{[a_2 imes a_3]}}{\Omega}$$
 $b_2=rac{2\pi\overline{[a_1 imes a_3]}}{\Omega}$ $b_3=rac{2\pi\overline{[a_1 imes a_2]}}{\Omega}$

单电子近似电子的势函数是只关于r的函数

量子牛顿方程: $f = \hbar \frac{dk}{dt} = \frac{dp}{dt}$

E 到 $E+\mathrm{d}E$ 之间被电子占据的量子态 $f(E)\mathrm{g}(E)\mathrm{d}E$

$$p = N_
u exp(rac{E_v - E_F}{k_0 T})$$
 $n = N_c exp(-rac{E_c - E_F}{k_0 T})$

质量作用定律:
$$np=N_cN_
u\exp(-rac{E_c-E_
u}{k_0T})=N_cN_
u\exp(-rac{E_g}{k_0T})=n_i^2$$

本征半导体:
$$E_i=E_F=rac{E_c+E_
u}{2}+rac{k_0T}{2}\lnrac{N_
u}{N_c}=rac{E_c+E_
u}{2}+rac{3k_0T}{4}\lnrac{m_p^*}{m_s^*}$$

可借助质量作用定律推得:

$$n=n_i \exp(rac{E_F-E_i}{k_0 T})$$
 $p=n_i \exp(rac{E_i-E_F}{k_0 T})$

杂志饱和电离:
$$E_F=E_c+k_0T\ln(\frac{N_D}{N_C})$$
 $E_F=E_{
m i}+k_0T\ln(\frac{N_D}{n_s})$

简并半导体判断条件:

$$\left\{egin{aligned} E_c-E_F > 3k_0T, 非简并\ 0 < E_c-E_F < 3k_0T, 弱简并\ E_c-E_F < 0, 简并 \end{aligned}
ight.$$

简并半导体: $N_D=0.68N_c[1+2\exp(\frac{\triangle E_D}{k_cT})]$

电离杂质散射: $P_i \propto N_i T$

长纵声学波: $P_s \propto T^{\frac{3}{2}}$

均匀导体的电流密度: $J=rac{I}{s}=rac{V}{Rs}=rac{l|E|}{Rs}=\sigma |E|$

 $\sigma = nq\mu_{\rm n} + pq\mu_{\rm p}$

迁移率: $\mu = \frac{q}{m^*} \frac{1}{4T^{\frac{3}{2}} + RNT^{-\frac{3}{2}}}$

直接复合: $\tau = \frac{\Delta p}{U_d} = \frac{1}{r[(n_0+p_0)+\Delta p]}$

俘获和发射电子能力联系:
$$s_n=r_nn_1$$
 $n_1=N_c\exp(-\frac{E_c-E_t}{k_0T})$ 通过复合中心复合: $U=\frac{N_tr_nr_p(np-n_i^2)}{r_n(n+n_1)+r_p(p+p_1)}=\frac{(np-n_i^2)}{\tau_p(n+n_1)+\tau_n(p+p_1)}$ $\tau=\frac{\Delta p}{U}=\frac{r_n(n_0+n_1+\Delta p)+r_p(p_0+p_1+\Delta p)}{N_tr_nr_p(n_0+p_0+\Delta p)}$ 肖克利-瑞德公式: $\tau=\frac{\Delta p}{U}=\tau_p\frac{n_0+n_1}{n_0+p_0}+\tau_n\frac{p_0+p_1}{n_0+p_0}$ $\tau=\tau_p=\frac{1}{N_tr_p}$ $\tau=\tau_n=\frac{1}{N_tr_n}$

一维扩散方程: $\frac{\partial \Delta p(x)}{\partial t} = D_p \frac{d^2 \Delta p(x)}{dx^2} - \frac{\Delta p(x)}{\tau}$ 一维稳态扩散方程: $-\frac{dS_p(x)}{dx} = D_p \frac{d^2 \Delta p(x)}{dx^2} = \frac{\Delta p(x)}{\tau_p}$

表明非平衡载流子浓度从光照表面向内部按指数衰减: $\Delta p(x) = (\Delta p)_0 e^{-x/L_p}$

爱因斯坦关系式: $\frac{D}{\mu} = \frac{kT}{a}$

连续性方程: $\frac{\partial p}{\partial t} = D_p \frac{\partial^2 p}{\partial x^2} - \mu_p |E| \frac{\partial p}{\partial x} - \mu_p p \frac{\partial |E|}{\partial x} + g_p - \frac{\Delta p}{\tau}$

线性缓变结: $N_D - N_A = \alpha_i(x - x_i)$

突变结接触电势差: $qV_D=E_{Fn}-E_{Fp}$ $V_D=rac{kT}{q}\ln(rac{N_AN_D}{n^2})$

$$\mathbf{P}^{+}\mathbf{N}\left(N_{A}\gg\ N_{D}
ight) \quad X_{D}=\sqrt{rac{2arepsilon_{r}arepsilon_{0}V_{D}}{qN_{D}}}\longrightarrow X_{D}pprox x_{n} \qquad \mathbf{N}_{+}\mathbf{P}$$
结 $\left(N_{A}\gg N_{D}
ight) \quad X_{D}=\sqrt{rac{2arepsilon_{r}arepsilon_{0}V_{D}}{qN_{A}}}\longrightarrow X_{D}pprox x_{n}$

正偏压P-N结: $\Delta n(x) = \Delta n(-x_p) \exp\left(rac{x+x_p}{L_n}
ight) \quad \Delta p(x) = \Delta p(x_n) \exp\left(-rac{x-x_n}{L_p}
ight)$

反偏压P-N结: $\Delta n(x) = -n_{p0} \exp\left(rac{x+x_p}{L_n}
ight)$ $\Delta p\left(x
ight) = -p_{n0} \exp\left(-rac{x-x_n}{L_p}
ight)$

理想P-N结I-V特性: $J=J_s\left[\exp\left(rac{qV}{kT}
ight)-1
ight]$ $J_s=\left(rac{qD_pn_i^2}{L_pN_D}+rac{qD_nn_i^2}{L_nN_A}
ight)$

理想P-N结I-V特件修正:

正向偏压: $\frac{J_{fd}}{J_r} \propto \frac{2n_i L_p}{N_D X_D} \exp(qV/2kT)$

反向偏压:

$$\mathcal{J}_G = qGX_D = qrac{n_i}{2 au}X_D$$

$$rac{J_{rd}}{J_G}=2rac{n_i}{N_D}rac{L_p}{X_D}$$

平行板电容: $C_T = \frac{A\varepsilon_0\varepsilon_r}{X_D}$

P-N结载流子分布:
$$p_{(x)} = n_i e^{\frac{E_i(x) - E_F}{kT}} = p_{P0} e^{\frac{E_F - E_i(x_p)}{kT}} e^{\frac{E_i(x) - E_F}{kT}} = p_{P0} e^{\frac{-qV(x)}{kT}} = p_{N0} e^{\frac{qV_D - qV(x)}{kT}}$$

$$n_{(x)} = n_i e^{\frac{E_F - E_i(x)}{kT}} = n_{N0} e^{\frac{E_i(x_n) - E_F}{kT}} e^{\frac{E_F - E_i(x)}{kT}} = n_{N0} e^{\frac{qV(x) - qV_D}{kT}} = n_{P0} e^{\frac{qV(x)}{kT}}$$

泊松方程: $\frac{d^2V}{dx^2} = -\frac{\rho(x)}{\varepsilon_x \varepsilon_0}$

肖特基二极管空间电荷区宽:
$$d = \left[\frac{2\varepsilon_0\varepsilon_r}{qN_D}(\phi_{ns} - \phi_n)\right]^{1/2} = \left(\frac{2\varepsilon_0\varepsilon_r}{qN_D}V_D\right)^{1/2}$$

适用于势垒宽度>>电子平均自由程:

$$J = J_{_{SD}}[\exp(qV/kT) - 1] \quad J_{_{SD}} = rac{q^2D_nn_0}{kT} [rac{2qN_D}{arepsilon_D}(V_D - V)]^{rac{1}{2}} \exp(rac{-qV_D}{kT})$$

表面空间电荷层的电场:

$$E^2(x) = \left(rac{2kT}{q}
ight)^2 \left(rac{q^2p_{p0}}{2arepsilon_s kT}
ight) \left\{ \left[\exp\left(-rac{qV}{kT}
ight) + rac{qV}{kT} - 1
ight] + rac{n}{p_{p0}} \left[\exp\left(rac{qV}{kT}
ight) - rac{qV}{kT} - 1
ight]
ight\} \ E(x) = \pm rac{2kT}{qL_D} F\left(rac{qV(x)}{kT}, rac{n_{p0}}{p_{p0}}
ight) \quad L_D = \left(rac{arepsilon_S kT}{q^2p_0}
ight)^{1/2}$$

耗尽层宽度最大值: $d_{\max} = \left(\frac{2\varepsilon_s}{q} \frac{2V_B}{N_A}\right)^{1/2}$ 外加电场被反型层屏蔽,耗尽层宽度达到最大

$$\left|C_{s}=\left|rac{dQ_{s}}{dV_{s}}
ight|=rac{arepsilon_{s}}{L_{D}}igg\{\left[-\exp\left(-rac{qV_{s}}{kT}
ight)+1
ight]+rac{n_{p0}}{p_{p0}}\left[\exp\left(rac{qV_{s}}{kT}
ight)-1
ight]igg\}/F\left(rac{qV_{s}}{kT},rac{n_{p0}}{p_{p0}}
ight)$$

绝缘层单位面积电容: $C_{ox} = rac{\mathcal{E}_{ox}}{d_{ox}}$

平带电容:

$$C_{FBS} = \lim_{V_s o 0} rac{dQ_s}{dV_s} = rac{\sqrt{2}arepsilon_s}{L_D} \Biggl(1 + rac{n_{p0}}{p_{p0}}\Biggr)^{1/2} pprox rac{\sqrt{2}arepsilon_s}{L_D} \quad C_{FB} = C_{_{FB}} = C_{_{ox}}/1 + rac{arepsilon_{ox}}{d_{ox}} \Biggl(rac{kT}{q^2N_A oldsymbol{arepsilon}_s}\Biggr)^{rac{1}{2}}$$

高频情况反型层电子产生复合更不上高频信号的变化: $\frac{C'_{\min}}{C_{\mathrm{ox}}} = \frac{1}{1+\frac{4e_skT}{c_s}\ln\left(\frac{N_A}{n_i}\right)]^{1/2}}$

阈值电压: $V_T = \phi_{ms} - rac{Q_{ox}}{C_{ox}} - rac{Q_B}{C_{ox}} + 2\phi_F$

反型层电荷: $Q_n(y) = -C_{oX}[V_{cs} - V(y) - V_T]$

萨支唐方程: $I_{DS}=eta\left[(V_{GS}-V_T)V_{DS}-rac{1}{2}V_{DS}^2
ight]$ $eta\equivrac{\mu_nWC_{ox}}{L}$

沟道夹断: $I_{DSat}=rac{eta}{2}(V_{GS}-V_T)^2$ $V_{DSat}\equiv V_{GS}-V_T$