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

倒格矢：$b_1=\frac{2\pi[a_2\times a_3]}{\Omega}\quad b_2=\frac{2\pi[a_1\times a_3]}{\Omega}\quad b_3=\frac{2\pi[a_1\times a_2]}{\Omega}$

单电子近似电子的势函数是只关于r的函数

德布罗意：$P=\frac{h}{\lambda}$

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

有效质量:$\frac{1}{\hbar^2}\left(\frac{\mathbf{d}^2E}{\mathbf{d}k^2}\right)_{k=0}=\frac{1}{m_{\mathrm{n}}^*}$

电子速度:$v=\frac{\hbar k}{m_n*}$

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

导带有效能态密度：$N_c=2(\frac{m_n^*k_0T}{2\pi\hbar^2})^{\frac{3}{2}}$

$p=N_\nu exp(\frac{E_v-E_F}{k_0T})\quad n=N_cexp(-\frac{E_c-E_F}{k_0T})$

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

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

可借助质量作用定律推得:

$n=n_i\exp(\frac{E_F-E_i}{k_0T})\quad p=n_i\exp(\frac{E_i-E_F}{k_0T})$

电中性方程：$\rho=q\left(N_D+p-n-N_A-n_D+p_A\right)$

由电中性方程与质量作用定理$\rightarrow n=\frac{N_D}{2}\left[1+\sqrt{1+\left(4n_i^2/N_D^2\right)}\right]$

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

简并半导体判断条件：

$$\begin{cases}E_c-E_F>3k_0T,\text{非简并}\\0<E_c-E_F<3k_0T,\text{弱简并}\\E_c-E_F<0,\text{简并}\end{cases}$$

简并半导体：$N_D=0.68N_c[1+2\exp(\frac{\triangle E_D}{k_0T})]$

电离杂质散射: $P_i\propto N_iT^{-\frac{3}{2}}$

长纵声学波：$P_s\propto T^{\frac{3}{2}}$

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

平均迁移率：$\mu=\frac{q\tau}{m_n^*}$

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

迁移率：$\mu=\frac{q}{m^*}\frac{1}{AT^{\frac{3}{2}}+BN_iT^{-\frac{3}{2}}}$

霍尔效应:

对于n型半导体温度不太高时$R_H\approx-\frac{1}{nq}$

对于p型半导体温度不太高时$R_H\approx\frac{1}{pq}$

本征情况$R_H\approx\frac{1-b^2}{n_iq(1+b)^2}$

非子复合：$U=R-G\quad R=rnp\quad G=R_0=rn_0p_0$

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：$s_n=r_{\mathrm{n}}n_1\quad n_1=N_c\exp(-\frac{E_c-E_t}{k_0T})$

通过复合中心复合:

$U=\frac{N_tr_nr_p(np-n_i^2)}{r_n(n+n_1)+r_p(p+p_1)}=\frac{(np-n_i^2)}{\tau_p(n+n_1)+\tau_n(p+p_1)}\quad\tau=\frac{\Delta p}{U}=\frac{r_n(n_0+n_1+\Delta p)+r_p(p_0+p_1+\Delta p)}{N_tr_nr_p(n_0+p_0+\Delta p)}$

ps:$n_t=$ 可以通过$\frac{N_t(r_nn+r_pp_1)}{r_n(n+n_1)+r_p(p+p_1)}$推得另外书上和ppt中的公式是错的

肖克利-瑞德公式：$\tau=\frac{\Delta p}{U}=\tau_p\frac{n_0+n_1}{n_0+p_0}+\tau_n\frac{p_0+p_1}{n_0+p_0}\quad\tau=\tau_p=\frac{1}{N_tr_p}\quad\tau=\tau_n=\frac{1}{N_tr_n}$

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：$\Delta p(x)=(\Delta p)_0e^{-x/L_p}$

爱因斯坦关系式：$\frac{D}{\mu}=\frac{kT}{q}$

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

线性缓变结：$N_D-N_A=\alpha_j(x-x_j)$

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

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

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

$\mathbf{P^+N}\,(N_A\gg\ N_D)\quad X_D=\sqrt{\frac{2\varepsilon_r\varepsilon_0V_D}{qN_D}}\longrightarrow X_D\approx x_n\qquad\mathbf{N^+P}$结$(N_D\gg N_A)\quad X_D=\sqrt{\frac{2\varepsilon_r\varepsilon_0V_D}{qN_A}}\longrightarrow$

线性缓变结：$X_D=\left(\frac{12\varepsilon_r\varepsilon0V_D}{q\alpha}\right)1/3$

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

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

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

理想P-N结I-V特性修正：

正向偏压：$\frac{J_{fd}}{J_r}\propto\frac{2n_iL_p}{N_DX_D}\exp(qV/2kT)$

反向偏压：

$J_G=qGX_D=q\frac{n_i}{2\tau}X_D$

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

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

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

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：

$J=J_{SD}[\exp(qV/kT)-1]\quad J_{SD}=\frac{q^2D_nn_0}{kT}[\frac{2qN_D}{\varepsilon_0\varepsilon_r}(V_D-V)]^{\frac{1}{2}}\exp(\frac{-qV_D}{kT})$

表面空间电荷层的电场：

$E^2(x)=\left(\frac{2kT}{q}\right)^2\left(\frac{q^2p_{p0}}{2\varepsilon_skT}\right)\left\{\left[\exp\left(-\frac{qV}{kT}\right)+\frac{qV}{kT}-1\right]+\frac{n_{p0}}{p_{p0}}\left[\exp\left(\frac{qV}{kT}\right)-\frac{qV}{kT}-1\right]\right\}$

$E(x)=\pm\frac{2kT}{qL_D}F\left(\frac{qV(x)}{kT},\frac{n_{p0}}{p_{p0}}\right)\quad L_D=\left(\frac{2\varepsilon_sKT}{q^2p_{p0}}\right)^{1/2}$

高斯原理：$Q_s=-\varepsilon_s E_s$

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

$C_s=\left|\frac{dQ_s}{dV_s}\right|=\frac{\varepsilon_s}{L_D}\left\{\left[-\exp\left(-\frac{qV_s}{kT}\right)+1\right]+\frac{n_{p0}}{p_{p0}}\left[\exp\left(\frac{qV_s}{kT}\right)-1\right]\right\}/F\left(\frac{qV_s}{kT},\frac{n_{p0}}{p_{p0}}\right)$

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

平带电容：

$C_{FBS}=\lim_{V_s\to 0}\frac{dQ_s}{dV_s}=\frac{\sqrt{2}\varepsilon_s}{L_D}\left(1+\frac{n_{p0}}{p_{p0}}\right)^{1/2}\approx\frac{\sqrt{2}\varepsilon_s}{L_D}\quad C_{_{FB}}=C_{_{ox}}/1+\frac{\varepsilon_{ox}}{d_{ox}}\left(\frac{kT}{q^2N_A\boldsymbol{\varepsilon}_s}\right)^{\frac{1}{2}}$

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

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

$V_n=-V_{ms}-\frac{Q_{\alpha x}}{C_{\alpha x}}+\frac{qN_d x_{\mathrm{dmax}}}{C_{\alpha x}}+\frac{2kT}{q}\ln\frac{N_A}{n_i}$

$V_p=-V_{ms}-\frac{Q_{\alpha x}}{C_{\alpha x}}-\frac{qN_D x_{\mathrm{dmax}}}{C_{\alpha x}}-\frac{2kT}{q}\ln\frac{N_D}{n_i}$

反型层电荷：$Q_n\left(y\right)=-C_{oX}\left[V_{_{GS}}-V\left(y\right)-V_{_T}\right]$

萨支唐方程：$I_{DS}=\beta\left[(V_{GS}-V_T)V_{DS}-\frac{1}{2}V_{DS}^2\right]\quad\beta\equiv\frac{\mu_n WC_{ox}}{L}$

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