1 Formula

De Broglie Hypothesis

$$p = mv = \frac{h}{\lambda} = k\frac{h}{2\pi}$$

$$k = \frac{2\pi}{\lambda}$$

$$L = n\frac{\lambda}{2}$$

$$p = \frac{hn}{2L}$$

Bragg

$$2dsin\theta = n\lambda$$

Mass Action Law

$$n_i^2 = np$$

Conductivity

$$\sigma = q(\mu_h p + \mu_e n)$$

For intrinsic, ρ is several Ω. For extrinsic, smaller than 1 Ω

Depletion Region Width

$$\epsilon E = qN_D x_p$$

$$\epsilon E = qN_A x_n$$

$$W = x_n + x_p = \frac{\epsilon E_{max}}{q}(\frac{1}{N_D} + \frac{1}{N_A})$$

$$V_{bi} = \frac{1}{2}WE$$

$$V_{bi} = \phi_{Bn} + \phi Bp$$

Speed of CMOS

$$\tau \propto \frac{L^2}{\mu}$$

Band Gap

$$n_i^2 = N_v N_c exp(-\frac{E_g}{k_B T})$$

2 Definition

- **Enhancement Type**:Gate voltage is needed for a channel.
- **Depletion Type**:Need a gate voltage to turn it off.

3 Tao Lu

3.1 Derive I_D

1. Mos capacitor: $Q = CV = -C_0(V_G - V_T - V_x) = qndz$
2. Current definition $I = qnvA$, where v is given by $v = \mu E$, $A = Wdz$
3. Substitute, $I = -C_0(V_G - V_T - V_x)\mu EW$
4. $E = -\frac{dV_x}{dx}$
5. $I = C_0(V_G - V_T - V_x)\mu \frac{dV_x}{dx} W$
6. Multiplied by dx, integration, find I_D

3.2 Derive Threshold Voltage

1. $V_{ox} = \frac{V_G - V_S}{t_{ox}}$, $V_G = V_{ox}t_{ox} + \phi_s$
2. Apply Gauss's Law, get $E_s = \sqrt{\frac{N_A t_s q}{\epsilon_0 \epsilon_s}}$
3. V is the area below E $t_s = \frac{2\phi_s}{E_s}$
4. $E_s = \sqrt{2\frac{N_A q \phi_s}{\epsilon_0 \epsilon_s}}$
5. $\epsilon_{ox}E_{ox} = \epsilon_s E_s$
6. Find V_G

3.3 Find Depletion Region Width

1. Find the point where $E = E_{max}$
2. Apply Gauss's Law $\int DdA = Q = x_p q A N_A = x_n q A N_D$
3. $D = \epsilon E_{max}$
4. $V_{bi} = \frac{1}{2}(x_n + x_p)E_{max}$