JUNCTION BREAKDOWN

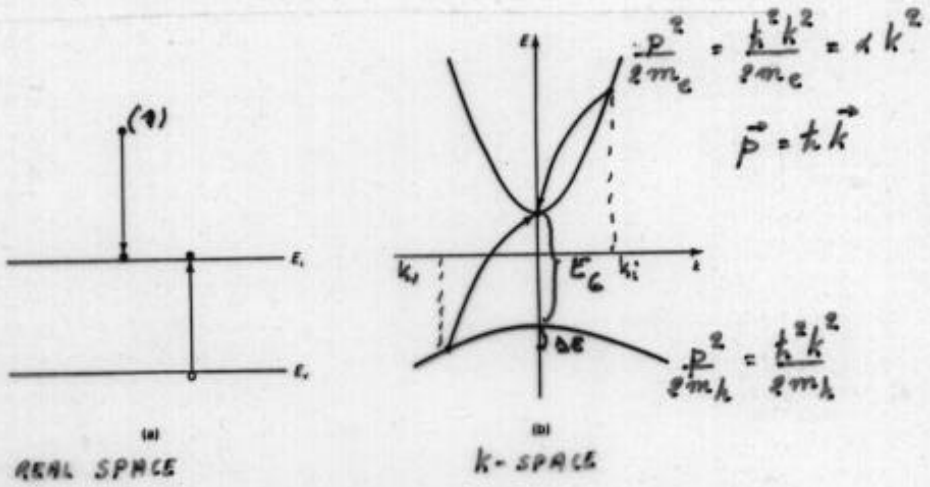
- NON-DESTRUCTIVE, REVERSIBLE HIGH VOLTAGE PROCESSES.

- TWO MECHANISMS:

  - AVALANCHE BREAKDOWN ← IMPACT IONIZATION

  - ZENER TUNNELING ← QUANTUM MECHANICAL TUNNELING

IMPACT IONIZATION : K. HESS RTSD : 13.3.2.-3 pp 188-199



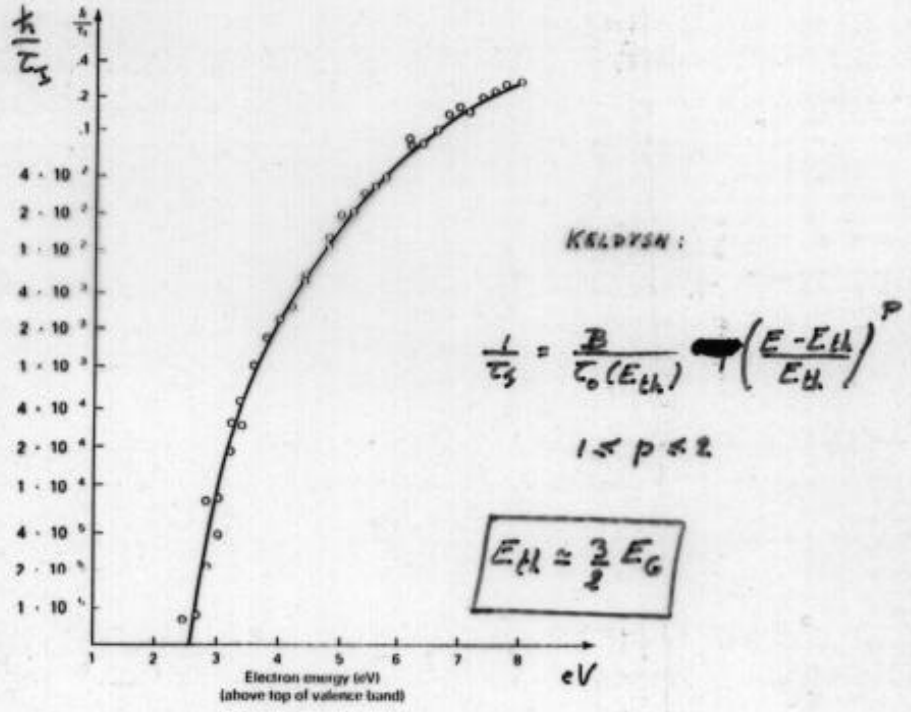
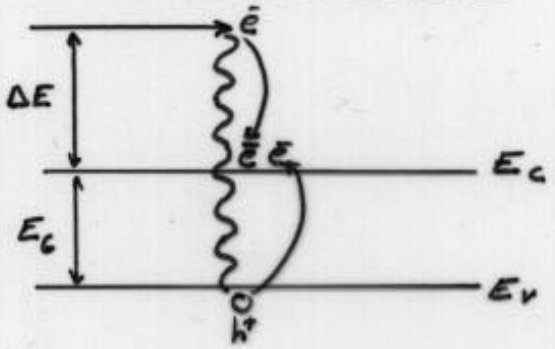


Figure 13.17 Impact ionization rate for electrons in silicon as a function of energy. (After Kane)

- AVALANCHE BREAKDOWN

- IMPACT IONIZATION

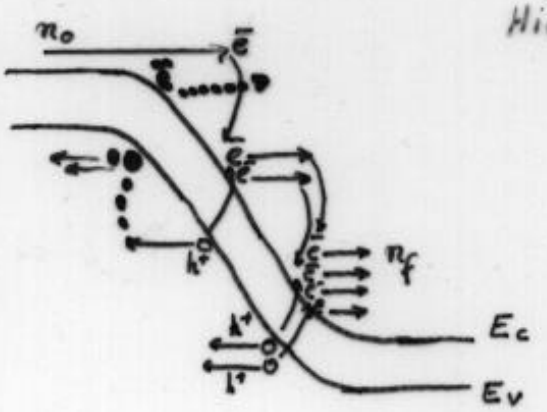


CONDITION: $\Delta E > E_G$

$\Rightarrow \Delta E_{TH}$: THRESHOLD ENERGY

$\Rightarrow$ 1 INCIDENT PARTICLE
$\Downarrow$
3 SECONDARY PARTICLES

- AVALANCHE MULTIPLICATION



HIGH FIELD: $\Delta E = q\int_0^x \mathcal{E}\,dx$

- MULTIPLICATION FACTOR

$$M \equiv \frac{n_f}{n_0} = \frac{1}{1 - \int_{x_a}^{x_c} \alpha\,dx} \longrightarrow \infty \quad \text{FOR} \quad \int_{x_a}^{x_c} \alpha\,dx \to 1$$

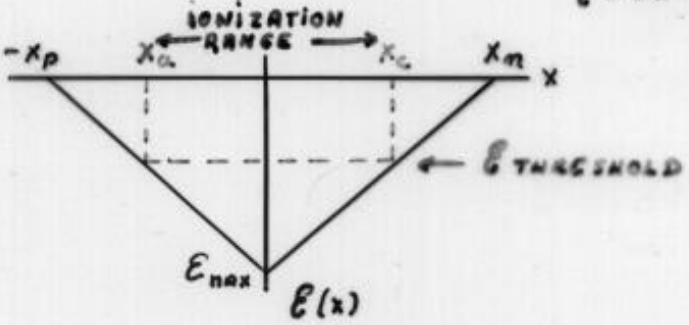
(AVALANCHE)

α : IONIZATION ~~FACTOR~~ COEFFICIENT : NUMBER OF $\bar{e}$-h^+ PAIRS / UNIT DISTANCE

MULTIPLICATION FACTOR

$$M = \frac{1}{1 - \int_{X_a}^{X_c} \alpha_{AV}[\mathcal{E}(x)]\,dx}$$

- α_{AV} : AVERAGE ON α_n, α_p
- ELECTRIC FIELD DEPENDENCE
- DETERMINATION X_c, X_a



EMPIRICAL FORMULA

$$M = \frac{1}{1 - (|V_R|/BV)^n}$$

- BV: BREAKDOWN VOLTAGE
- $2 < n < 6$
- $V_R < 0$: APPLIED (REVERSE) BIAS

$$\phi_c + BV = \frac{1}{2}\,\mathcal{E}_{THRESHOLD}\,(X_n + X_p) \text{ WITH } |X_n + X_p| = \sqrt{\frac{2\epsilon_0\epsilon_s}{q}\,\frac{1}{N}\,(\phi_c + BV)}$$

(ϕ_c: NEGLIGIBLE; the second ϕ_c: NEGLIGIBLE)

$$\mathcal{E}_{TH} = \frac{2\,BV}{|X_n + X_p|} = \sqrt{\frac{2qN\,BV}{\epsilon_0\epsilon_s}}$$

$$BV = \frac{\epsilon_0\epsilon_s\,\mathcal{E}_{TH}^2}{2qN}$$

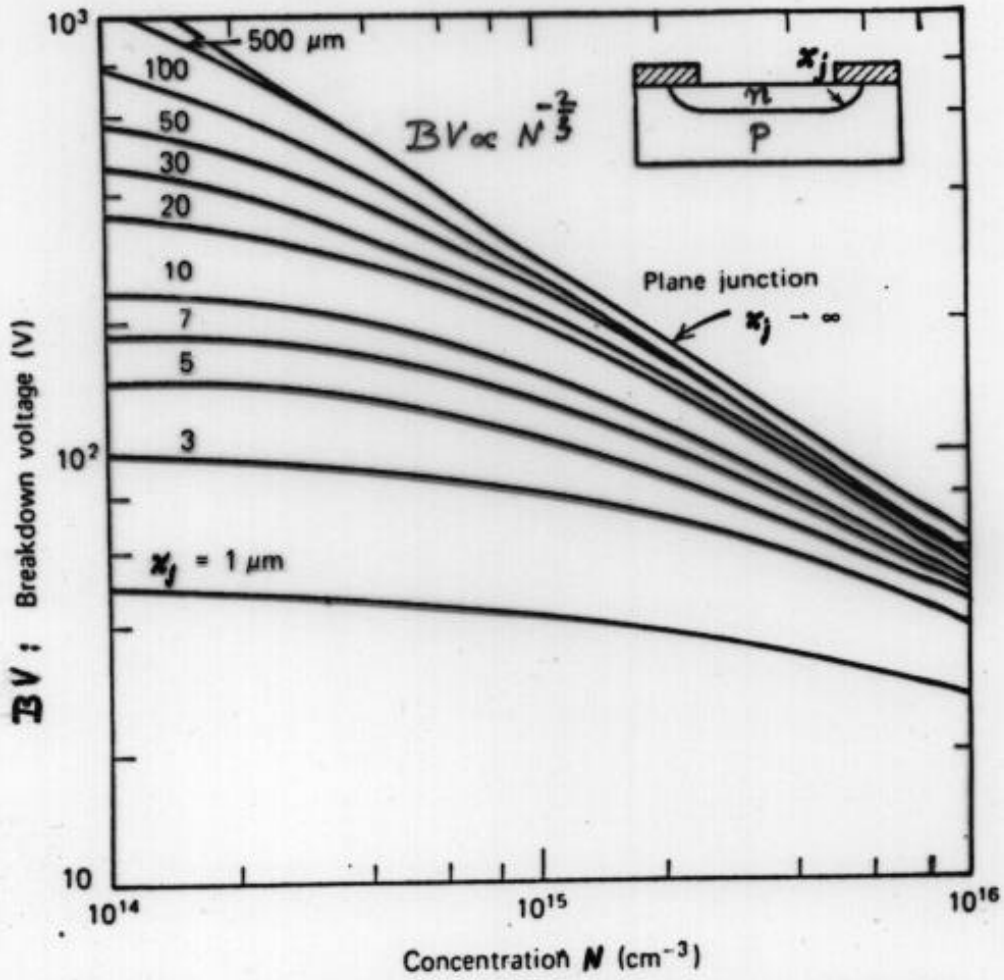


Figure 4.13 Breakdown voltage of one-sided, plane, silicon step junction showing the effect of junction curvature.[4.5]

$$BV = \frac{\epsilon_0 \epsilon_s \mathcal{E}_{TH}^2}{2qN}$$

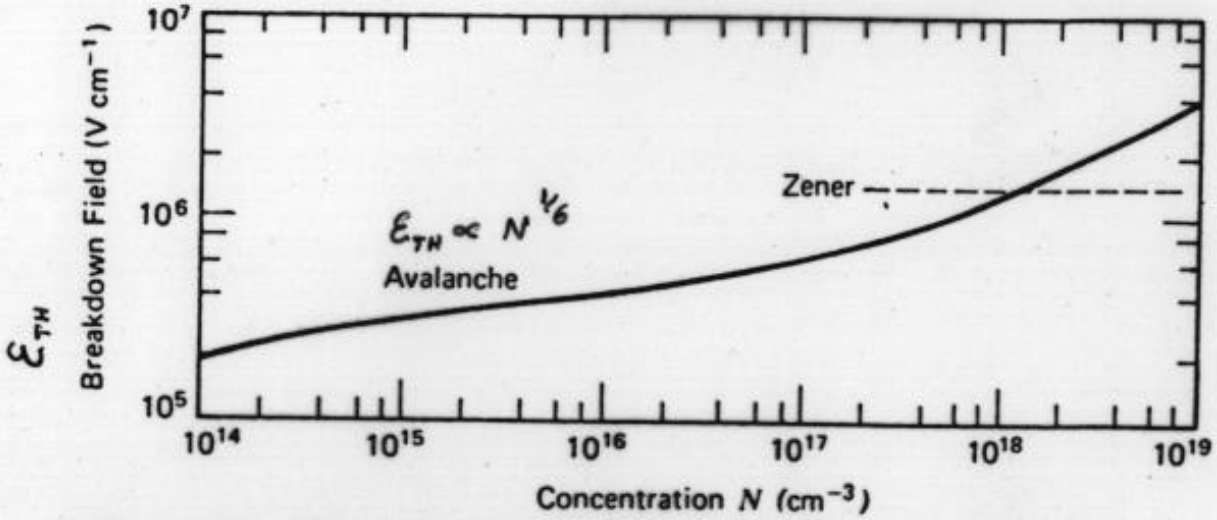
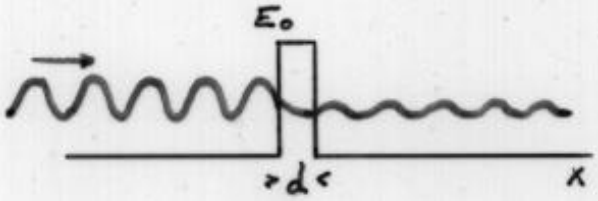


Figure 4.12 The critical electric fields for avalanche and Zener breakdown in silicon as functions of dopant concentration.[1.2.3]

- ZENER BREAKDOWN : QUANTUM MECHANICAL

- TUNNELING

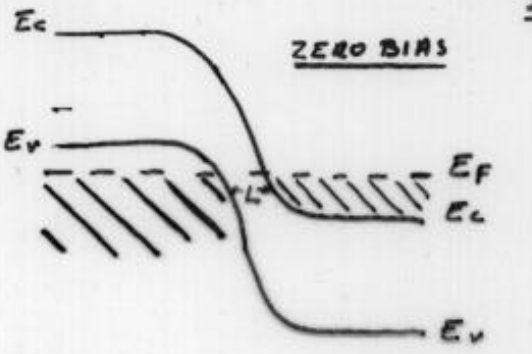


CONDITION : $\lambda_{BARRIER} \geq d$.

$d < 100\,\text{Å}$

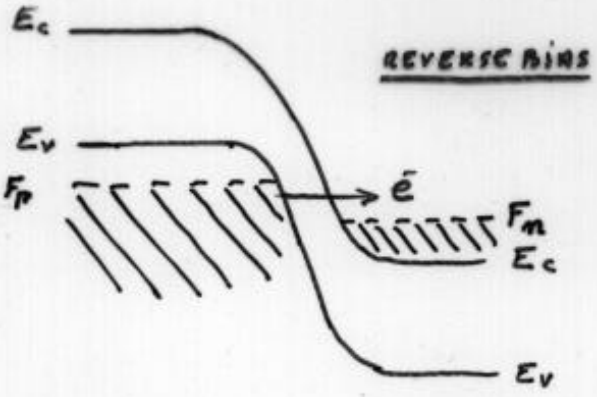
- INTERBAND TUNNELING (HEAVY DOPING)

DEGENERATE SEMICONDUCTORS



TUNNELING PROBABILITY

$$\ominus = \exp\left[-\frac{4\sqrt{2m}\,E_g^{3/2}\,L}{3\hbar}\right]$$



CURRENT:

$$I = qAN_v v \ominus$$

N_v = VALENCE BAND ELECTRON DENSITY

- TEMPERATURE SENSITIVITY

- ZENER BV : DECREASES WITH T INCREASING
- AVALANCHING BV: INCREASES WITH T INCREASING