Electron Multiplication in GaAs/GaN Heterostrucutre

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Outline

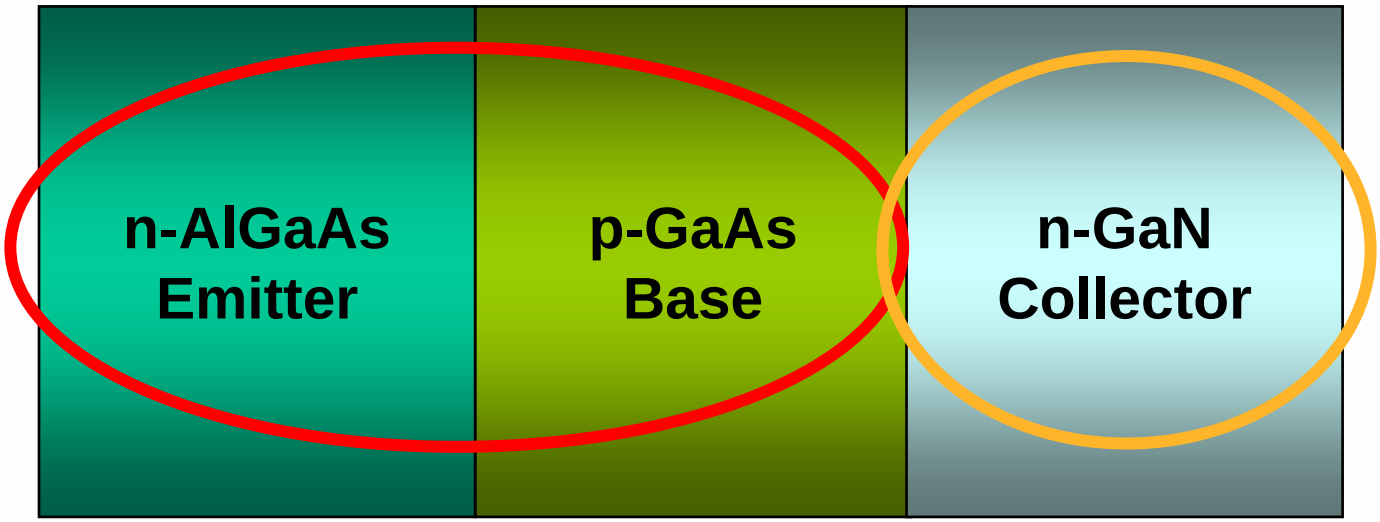
- Motivation
- Impact Ionization
- Non-local model
  - Simplified Energy Balance equation
- Proposed work
  - p-GaAs/n-GaAs homojunction
  - p-GaAs/n-GaN heterojunction
  - p-GaAs/setback/n-GaN

Motivation

Properties	Si	GaAs	4H-SiC	GaN
Band gap (eV)	1.12	1.42	3.26	3.42
Electron mobility ($cm^2/V \cdot s$)	1350	**8500**	700	900
Critical breakdown field (MV/cm)	0.3	0.4	2	**3.3**
Saturated velocity (10^7 cm/s)	1	2	2	2.5
Relative dielectric constant	11.8	12.8	10	9

High emitter injection efficiency & low base transit time

but low critical electrical field



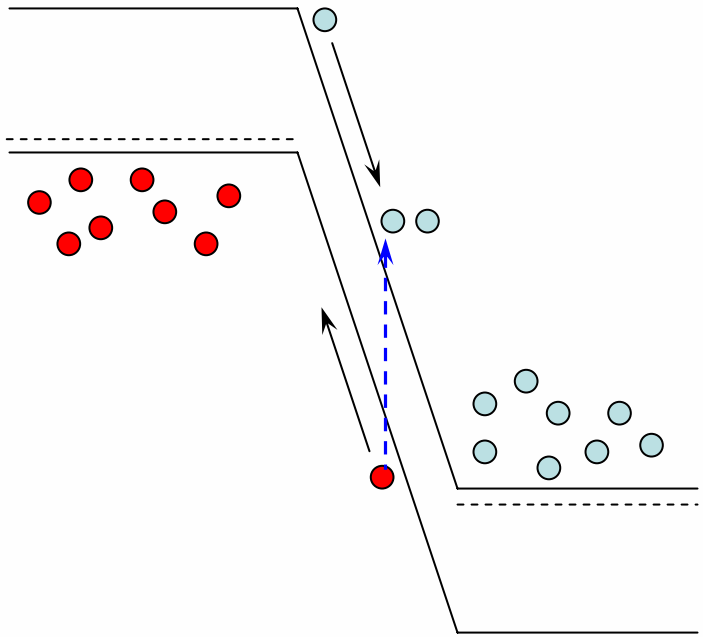
Lattice constant: 5.7 Å

3.2 Å

Large bandgap thus high breakdown voltage

But low minority carrier lifetime

Impact Ionization



Impact Ionization Coefficient

$$\alpha(x) = A_e \exp[-(\frac{B_e}{E})^c]$$

the number of electron-hole pairs produced by an energetic carrier per unit distance traveled

Simplified Energy Balance Equation

$$\frac{\partial W}{\partial t} = -\frac{\partial}{\partial x}[(W + kT_e)v_d - \frac{1}{n}\kappa\frac{\partial T_e}{\partial x}] - qv_d E(x) - \frac{W - W_0}{\tau}$$

$$W = \frac{1}{2}m^* v_d^2 + \frac{3}{2}kT_e; \qquad W_0 = \frac{3}{2}kT_l$$

1. Neglect kinetic energy
2. Neglect heat flow

$$\frac{d(W - W_0)}{dx} + \frac{3(W - W_0)}{5v_s\tau} + \frac{3}{5}qE(x) = 0$$

$$W - W_0 = \frac{3}{5}q\int_0^x E(\xi)\exp[\frac{3(\xi - x)}{5v_s\tau}]d\xi$$

E.F.Crabbe, IEDM 1990, pp. 463

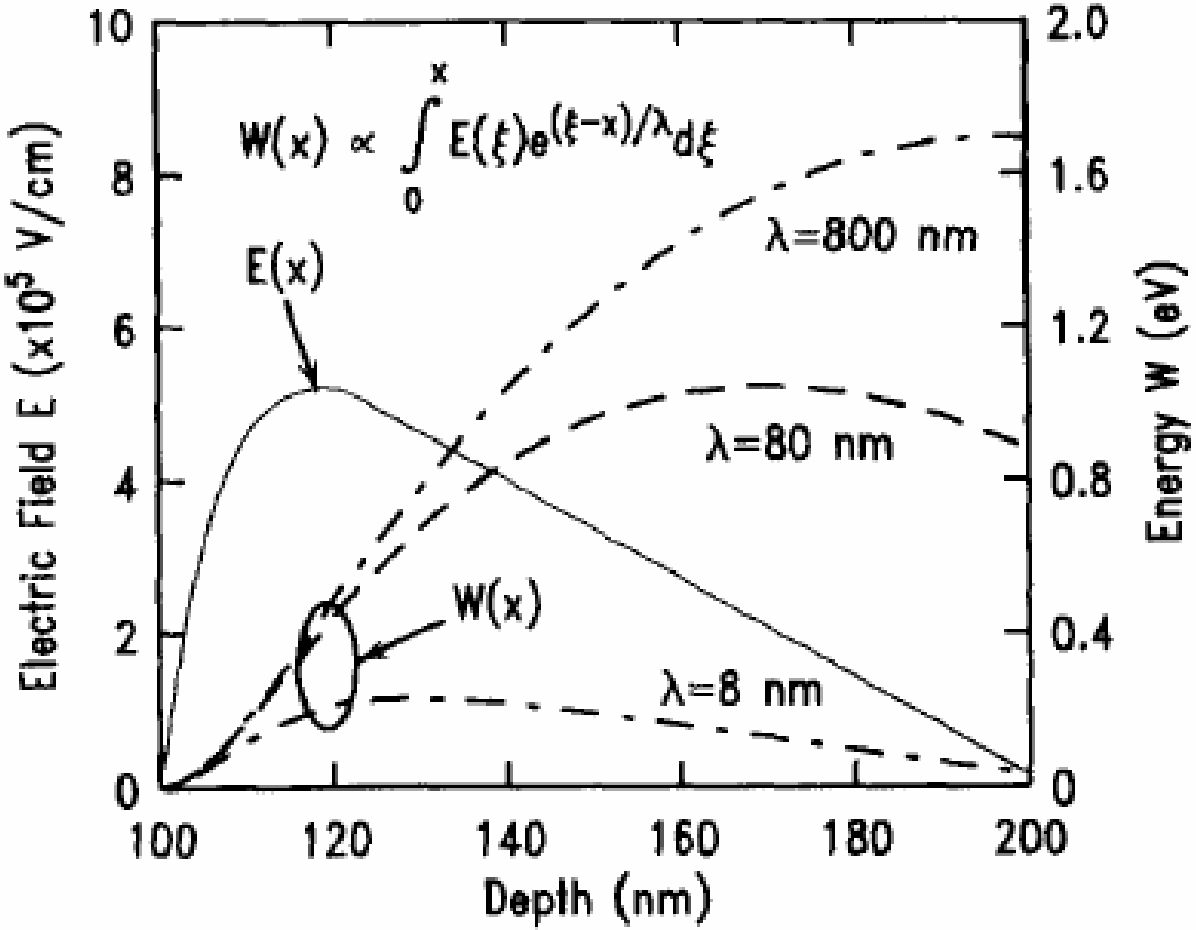


Figure 7.
Energy distributions in the space-charge region for various values of the energy relaxation length λ_w.

E.F.Crabbe, IEDM 1990, pp. 463

Electron Multiplication

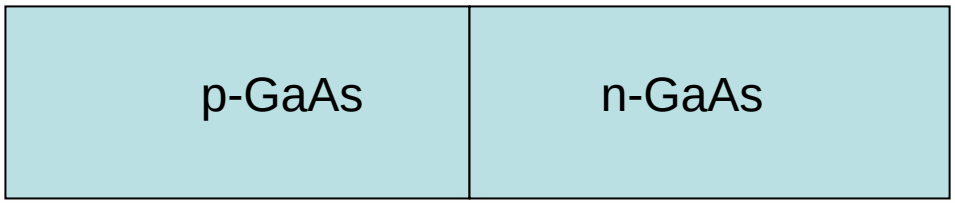
$$E_{eff} = \frac{W - W_0}{q v_s \tau}$$

$$\alpha(x) = A_e \exp[-(\frac{B_e}{E_{eff}})^c]$$

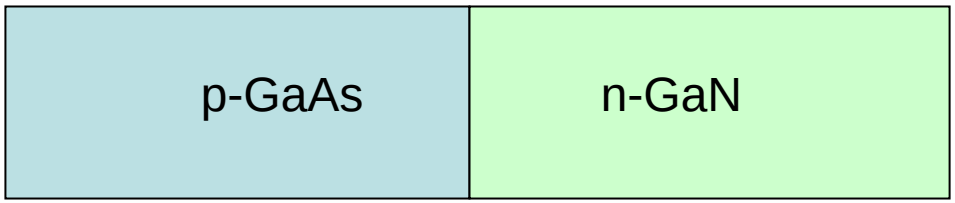
$$M_n - 1 = \frac{n - n_0}{n_0} = \frac{1}{1 - \int_0^w \alpha(x) \exp\{-\int_0^x [\alpha(\xi) - \beta(\xi)] d\xi\} dx} - 1$$

Device structures to be studied

1.



2.



3.