Lec 01: Electronic Devices



**Table A.4** *Silicon, gallium arsenide, and germanium properties (T = 300 K)*

| *Property* | *Si* | *GaAs* | *Ge* |
|---|---|---|---|
| Atoms ($cm^{-3}$) | $5.0 \times 10^{22}$ | $4.42 \times 10^{22}$ | $4.42 \times 10^{22}$ |
| Atomic weight | 28.09 | 144.63 | 72.60 |
| Crystal structure | Diamond | Zincblende | Diamond |
| Density ($g/cm^{-3}$) | 2.33 | 5.32 | 5.33 |
| Lattice constant (Å) | 5.43 | 5.65 | 5.65 |
| Melting point (°C) | 1415 | 1238 | 937 |
| Dielectric constant | 11.7 | 13.1 | 16.0 |
| Bandgap energy (eV) | 1.12 | 1.42 | 0.66 |
| Electron affinity, $\chi$ (volts) | 4.01 | 4.07 | 4.13 |
| Effective density of states in conduction band, $N_c$ ($cm^{-3}$) | $2.8 \times 10^{19}$ | $4.7 \times 10^{17}$ | $1.04 \times 10^{19}$ |
| Effective density of states in valence band, $N_v$ ($cm^{-3}$) | $1.04 \times 10^{19}$ | $7.0 \times 10^{18}$ | $6.0 \times 10^{18}$ |
| Intrinsic carrier concentration ($cm^{-3}$) $n_i$ | $1.5 \times 10^{10}$ | $1.8 \times 10^{6}$ | $2.4 \times 10^{13}$ |
| Mobility ($cm^2/V\text{-}s$) | | | |
| Electron, $\mu_n$ | 1350 | 8500 | 3900 |
| Hole, $\mu_p$ | 480 | 400 | 1900 |
| Effective mass $\left(\frac{m^*}{m_0}\right)$ | | | |
| Electrons | $m_l^* = 0.98$<br>$m_t^* = 0.19$ | 0.067 | 1.64<br>0.082 |
| Holes | $m_{lh}^* = 0.16$<br>$m_{hh}^* = 0.49$ | 0.082<br>0.45 | 0.044<br>0.28 |
| Effective mass (density of states) | | | |
| Electrons $\left(\frac{m_n^*}{m_0}\right)$ | 1.08 | 0.067 | 0.55 |
| Holes $\left(\frac{m_p^*}{m_0}\right)$ | 0.56 | 0.48 | 0.37 |

**Table A.5** *Other semiconductor parameters*

| *Material* | $E_g$ *(eV)* | *a (Å)* | $\epsilon_r$ | $\chi$ | $\overline{n}$ |
|---|---|---|---|---|---|
| inum arsenide (AlAs) | 2.16 | 5.66 | 12.0 | 3.5 | 2.97 |

lec 01: Electronic Devices 12/7/2015

Pre-requist concepts:

1. Si Vs Ge Vs GaAs
2. Intrinsic and extrinsic semiconductor
3. Energy band diagram of Semiconductor / Metal / Insulator
4. Effect of external bias on band diagram
5. Degenerated / Non-degenerate Semiconductor
6. Compound Semiconductor
7. Narrow band-gap / Wide bandgap semiconductor.
8. Direct / Indirect bandgap semiconductor
9. Electron-hole pair generation.
10. Concept of Thermal equilibrium
11. Mass Action Law
12. Mobility, Scattering phenomenon (Lattice scattering)
13. Fermi-Dirac Statistics / Occupancy

## Devices: (Review)

**PN Junction**

Zener diode

Varactor diode

Tunnel diode

TED

Gunn diode

IMPATT

**BJT**

HBT

**JFET**

**MOSFET**

MESFET

MODFET

Schottky barrier diode

**Heterojunctions**

**Optical devices**

Solar cell

Photoconductor

Photodiode

APD

Photodetector

Optocoupler

**Power devices**

PNPN diode

SCR

DIAC & TRIAC

GTO

PUT

UJT

IGBT

# Semiconductor Fundamentals



- Device classification → h.f & L.f
  → based on power they handle

These devices try to amplify & modify electrical power:

1) Small signal diodes & Transistor.
2) Power Device (IGBT, SCR)
   ↓
   (handle large amount of power)

a) High $freq^n$ devices → HEMT

I] Discrete devices & Integrated ckt devices
↳ no of devices integrated on Single Si substrate.

eg Monolithic Accelerometer
MEMS device (Micro electro-mechanical systems)
↓
involve conversion from mechanical (acceleratn) to electrical energy & vice-verse.

i) Opto-electronic device eg Laser diode.

- Importance of Semiconductor devices:

These devices enhance · Performance, Reliability, Cost-effectiveness of

- Energy systems
  ↓
  generate, distribute & regulate electrical energy

  AIM
  To manage larger & larger amt of energy & power

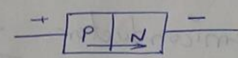
- Information systems
  ↓
  store, process & communicate information

  AIM
  To manage large amt of $informat^n$ using lesser amt of power.

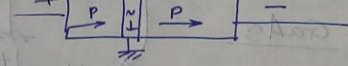
R

# Devices

1. PN Junction

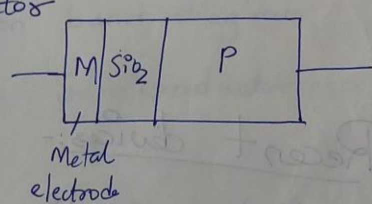



2. BJT

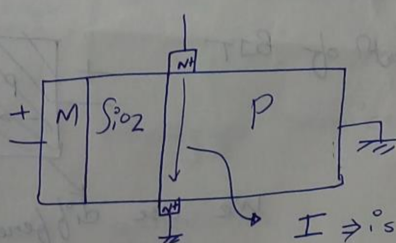



3. Metal oxide semiconductor (MOS) junction

(Becoz of $SiO_2$ (insulator), there is no dc current flow) → $C = f(V)$




4. MOSFET

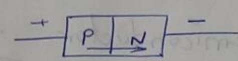



I ⇒ is contoolled by $V_{GS}$

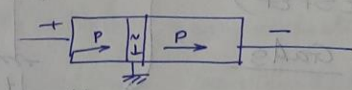
R

# Devices

1. PN Junction

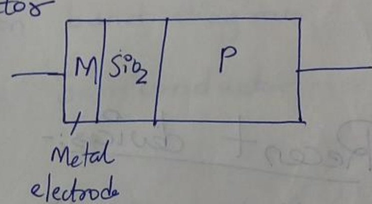



2. BJT

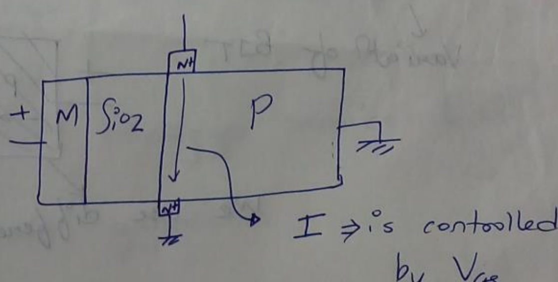



3. Metal oxide semiconductor (MOS) junction

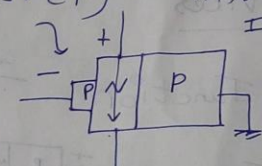
(Becoz of $SiO_2$ (insulator), there is no dc current flow) → $C = f(v)$



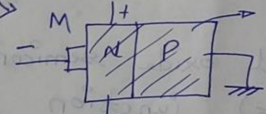

4. MOSFET



5. a) Junction FET (JFET) → Here, I flow in N region, & this I is ctrlled by PN Jn




b) Metal semiconductor FET (MESFET)
↳ made in GaAs

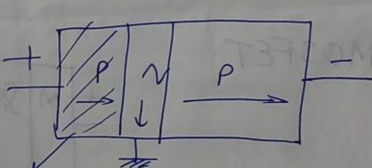



→ material are different

↳ Vtg applied to metal electrode, modulates the current flow in this N region

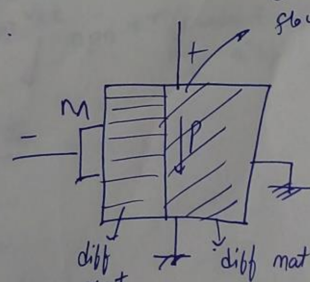
## Recent devices:-

6. Hetero-junction BJT
↳ Variatn of BJT




We use different material

7. Hetero-Junction FET.
↳ similar to MESFET
expect difference is I is shifted from N region to N-P heteroJn.




current flows thr N-P heterojn interface.

↳ I contolled by vtg applied to M.