30nm AlGaAs
GaAs
25-30 is ideal

10nm ct, nt

III-IV TRANSISTOR (HIGH ELECTRON MOBILITY TRANSISTOR)

- n-MOS S/D : n-type (P) Substrate : p-type (B)

$\mu = 300-400 cm^2/V\cdot s$

Bulk Mobility of Si = $1300-1500 cm^2/V\cdot s$

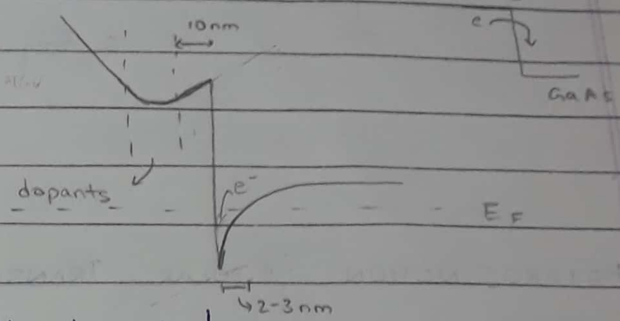
- Lattice vibration → Phonon Scattering
- Doping → ~~Interpha~~ Impurity Scattering
  → Surface Scattering*

* Gradual Channel Approx : E are ⊥ and are non-interfering

→ carrier - Carrier Scattering ($n^{1/3}$)

III-V Transistor ~~i~~ has no impurity ~~scattering~~ scattering

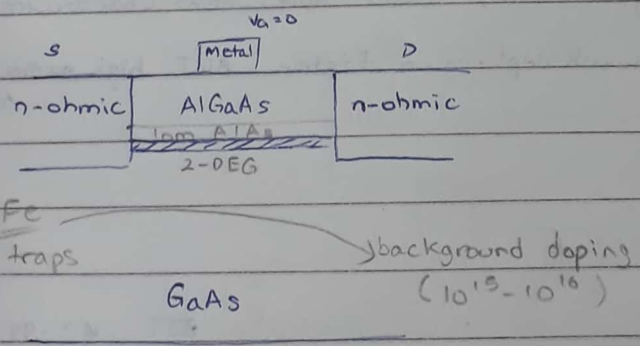
30% 10nm AlGaAs (undoped)
30% 10nm AlGaAs (n^+) Si
30% 10nm AlGaAs (undoped)
5nm GaAs (undoped)



* carriers are separated from the dopants!

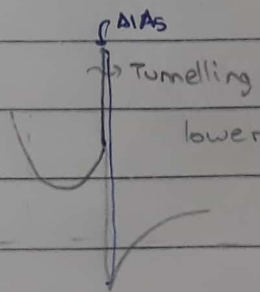
* 2-dimensional e^- gas (e^- are confined on the left by band offset + right by electrostatic poten

↳ $E \sim kT$ $(2 \times \frac{1}{2} k_B T)$



$V_T = -ve$: depletion mode

$V_T = +ve$: enhancement mode



$V_T \approx -(2-3)V$ Depletion Mode

* $V_T < 0$

* μ is high ($2500 cm^2/V\cdot s$) AlGaAs

⇓

f ↑ 300 GHz InP → f ~ 600GHz but high gate leak

due to larger μ

* better gate control (Much higher Transconductance g_m) ↳ $= \frac{\partial I_{DS}}{\partial V_{GS}}$

* Static Power Consumption ≠ 0!

* Top undoped layer ~~has~~ ensures gate current is minimal

* useful for RF (...) 3×10^10

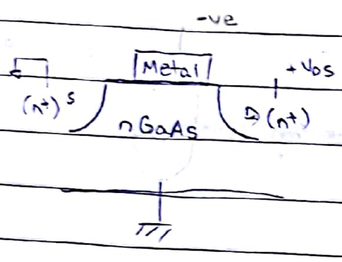
* Si - MOSFET is successful due to native SiO_2

Traps like Capacitor (slows down diode)

$$I_{DS} = \begin{cases} \frac{\mu C W}{L}\left[(V_{GS}-V_T)V_{DS} - \frac{V_{DS}^2}{2}\right] & V_{DS} < V_{GS} - V_T \\ \frac{\mu C W}{2L}(V_{GS}-V_T)^2 & V_{DS} > V_{GS} - V_T \end{cases}$$

HHMT → used for power transistor

MESFET (Metal Semiconductor FET)

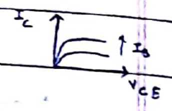


* subthreshold current is significant
* high gate leakage
  ∴ $\mu \downarrow$ (impurity scattering)
* GaAs ~~inher~~ inherently better than Si

so freq/speed : MOSFET < MESFET < HEMT

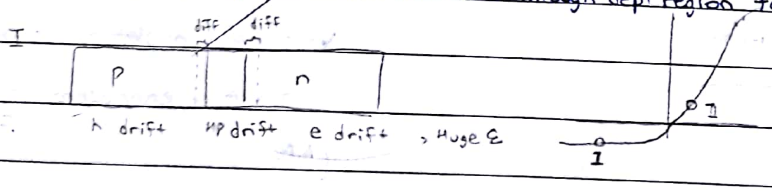
* used as transreceiver

HETEROJUNCTION BIPOLAR TRANSISTOR

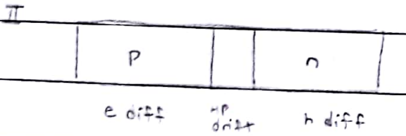


* BJT ⇒ current controlled   MOS ⇒ voltage controlled
  ↳ width of base : narrow (Transfer efficiency), lesser doped B
  CB gain ↳ Heavily doped E (- more e^- injection $E \to B$, lesser hole current (back-current)) lower series R_E)
  ↳ Lightly doped C (e^- will move through depl region faster BUT high series R_C)
  ↑ fix by subcollector

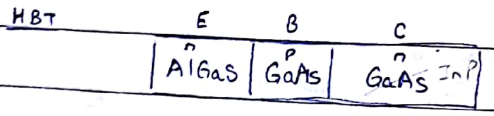
I

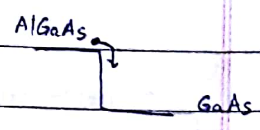


II



10^3-10^4 A/cm^2 ← BJT : $\alpha \sim .99 \to \beta = 100$
HBT : $\alpha \sim .999 \to \beta = 1000$
↳ 200GHz , 10^5 A/cm^2





I_{DS}

(-) series resistance ~~to~~ of AlGaAs ↑ (as high barrier contact is poor)

(+) Base doping can be slightly increased (• back current blocked by barrier • more mobility so lesser time for recombination) ⇒ Even lesser resistance
↳ E doping can be slightly reduced ⇒ lesser C ⟶ faster device

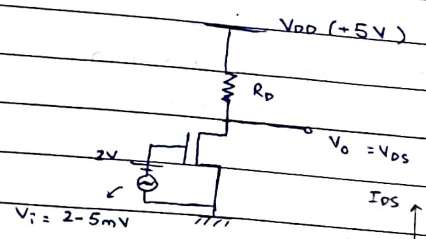
Scanned by CamScanner

* Prefer to use high E_g material (to minimize minority carriers)

E_c
E_d — — — $\geq 2eV$ ✓

insulators are high E_g materials where right dopant has'n't been found

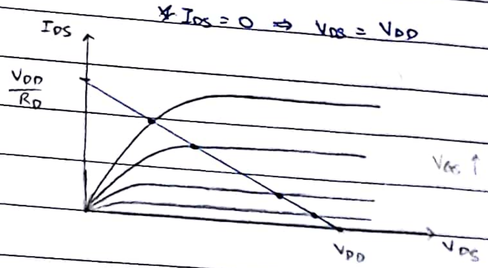
ANALOG MICROELECTRONICS



$V_{DD} = V_{DS} + I_{DS} * R_D$

$V_{DS} = 0 \Rightarrow I_{DS} = V_{DD}/R_D$

$I_{DS} = 0 \Rightarrow V_{DS} = V_{DD}$



$V_{in} \uparrow \rightarrow I_{DS} \uparrow \Rightarrow V_o (= V_{DD} - I_{DS} R_D) \downarrow$

$\frac{\partial V_o}{\partial V_{in}}$ = Gain (A)

$$I_{DS} = \frac{K'}{2}(V_{in} - V_T)^2$$ [Assuming MOS is in SAT.]

$$V_o = V_{DD} - I_{DS} * R_D$$

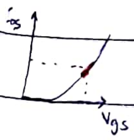
$$V_o = V_{DD} - \frac{K'}{2}(V_{in} - V_T)^2 * R_D \Rightarrow A = \frac{\partial V_o}{\partial V_{in}} = -K'(V_{in} - V_T) R_D$$

↳ circuit is not linear, all signals are not equally magnified

* Linearize the Gain $\Rightarrow V_{in} = V_{DC} + \cancel{V_{DC}} v_{in} \sin\omega t$, $|v_{ac}| << |V_{DC}|$

$$V_o = V_{DC}' + v_{out} \sin\omega t$$

$$A = \frac{\partial V_o}{\partial V_{in}} = \frac{\partial v_{out}}{\partial v_{in}} = \frac{v_{out}}{v_{in}}$$



Transconductance, $g_m = \frac{\partial I_{DS}}{\partial V_{gs}}$ $\longrightarrow$ $\cancel{I_{DS}}$ $V_o = V_{DD} - I_{DS} R_D$

$$\Rightarrow \boxed{\frac{\partial V_o}{\partial V_{in}} = -\frac{\partial V_{DS}}{\partial V_{in}} \cdot R_D = -g_m R_D}$$

NOTE: to maintain linearisation, v_{ac} should be small (small signal)

$V_o = V_{DD} - I_{DS} R_D$

[Assuming MOS is in LIN] $I_{DS} = k'\left[(V_{in} - V_T) V_o - \frac{V_o^2}{2}\right]$ $\frac{\partial V_o}{\partial V_{in}} = -\frac{\partial I_{DS}}{\partial V_{in}} R_D$

$$-\frac{\partial I_D R_D}{\partial V_{in}} = -R_D k'\left[V_o + (V_{in} - V_T)\frac{\partial V_o}{\partial V_{in}} - V_o \frac{\partial V_o}{\partial V_{in}}\right] = \frac{\partial V}{\partial}$$

Page No.:
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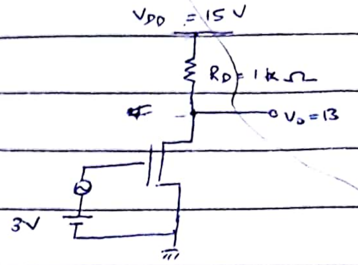
$\beta < \frac{2(16-V_{GG})}{V_{GG}}$

Design an amplifier with $\frac{\partial V_o}{\partial V_{in}} = -2$ $k' = 1\,mS/V$, $V_{DD} = +15$, $V_{Tn} = 1$

~~g_m~~ Chose $R_D = 1k\Omega \Rightarrow g_m = 2\,mS$

$g_m = k'(V_{GS} - V_T) \Rightarrow V_{GS} = 3V$

CHECK $I_{DS} = \frac{10^{-3}}{2}(3-1)^2 = 2mA$



$V_o > V_{in} - V_T$ ✓ (SAT)

~~$\frac{\partial V_o}{\partial V_{in}} = -3$~~, $k' = 1\,mS/V$ $V_T = 1V$, $V_{DD} = 15V$. What is max gain. R_D, V_{GG}

$V_{DS} > V_{GS} - V_T \Rightarrow V_{DD} - I_{DS}R_D > V_{GG} - V_T \Rightarrow R_D < \frac{16 - V_{GG}}{\frac{k'}{2}(V_{GG}-1)^2}$ —(1)

$V_{GG} > 1$ —(2)

$R_D = \theta \frac{2(16 - V_{GG})}{k'(V_{GG}-1)^2}$ $0 \le \theta \le 1$

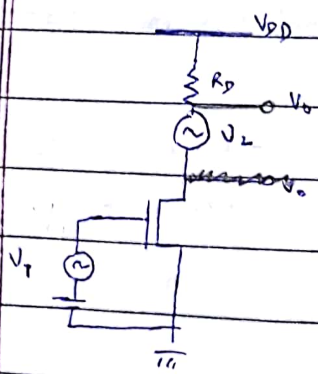
$A = -g_m R_D = -k'(V_{GG}-1)R_D$

$= -\theta\, 2\left[\frac{(16 - V_{GG})}{V_{GG}-1}\right]$

To ensure $|A v_{in}| \ll |V_o|$ → we need extremely small v_{in}

MIXER

$v_1 = A_1 \sin\omega_1 t$ $v_2 = A_2 \sin\omega t$ $\Rightarrow (\omega_1 - \omega_2)$, $(\omega_1 + \omega_2)$



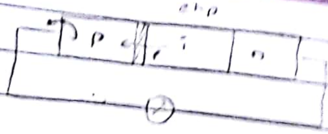
$I_D = k'\left[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}\right]$

$V_o = V_{DD} - I_{DS}R_D$

$\cancel{I_{DS} = k'\left[(V_{GG} - V_T + v_1)v_o - \frac{v_o^2}{2}\right]}$

I

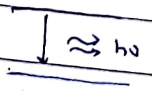
Design a potential well



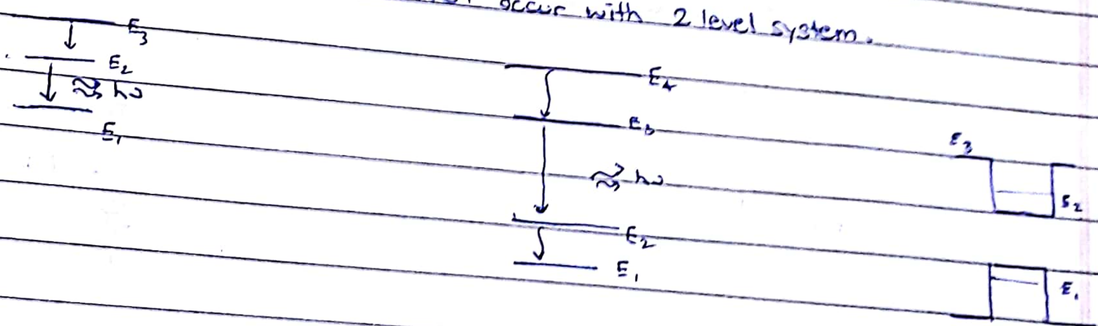
POPULATION INVERSION (Gas Laser)

HeNe, KrF, HeAg, HeCd

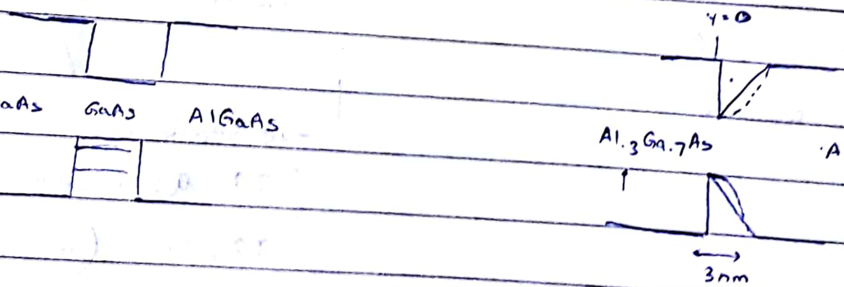
* A LASER can only 'lase' if there are more e^- at higher energy level than the lower energy level



stimulation emission CANNOT occur with 2 level system.



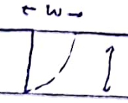
Modulation BW



$AlAs \to 5eV$
$GaAs \to 1.4eV$
$\Delta E_c = .6\Delta E_g$

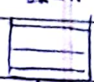
$Al_xGa_{1-x}As$ $x = y/10$

:)

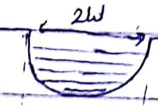


$x = my^2 \to m = \frac{2.16}{w^2}$

$E_n \propto n^2$

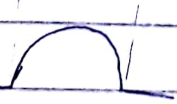


spacing increase

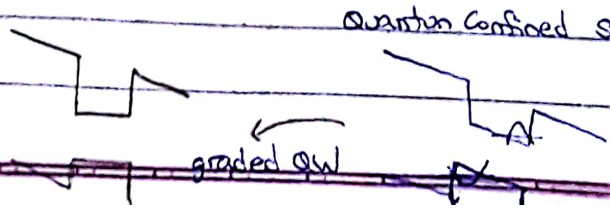


← equally spaced

← compressively spaced



Quantum Confined Stark Effect



graded QW

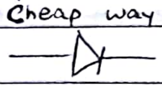
① efficiency ↓

15nm AlGaAs (undoped)

15nm

← δ-doped

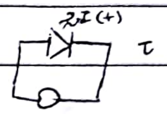
Cheap way to develop harmonics

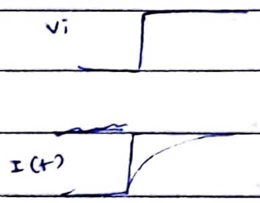


$v_i = V\sin\omega t \longrightarrow v_o = A\sin(3\omega t)$

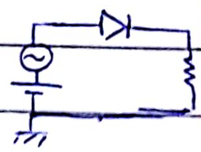
$I = I_0\left(e^{\frac{qV\sin\omega t}{2kT}} - 1\right)$

$= I_0\left(1+\alpha+\frac{\alpha^2}{2!}+\frac{\alpha^3}{3!}+\dots\right)$ keep large V





To measure e

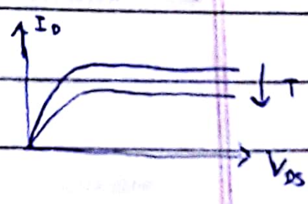


Thermal Run-Away of Diode

$T\uparrow, I\uparrow \longrightarrow I^2R\Uparrow$

+ve feedback

In MOSFET



-ve feedback

$T\uparrow, \mu\downarrow$ (due to decrease in mobility)

$T\uparrow, V_T\downarrow$ (minority carrier conc. ↑ with T)

in linear $I\uparrow$

in sat $I\downarrow$