Other types of FETs

- Si is the dominant semiconductor just because of the excellent Si/SiO₂ interface. So far, this is the best semiconductor/dielectric interface.
- But Si is inferior to many other semiconductors (e.g., GaAs, InSb, etc) in terms of μ, v₂τ.
- RF, microwave, millimeter wave applications need faster transistors.
- But MOSFETs are not that good with those materials due to the lack of a good semiconductor/dielectric interface.
JFET

Why do we need a p substrate here?

$V_{GS} < 0 \Rightarrow$ depletion region widens.
At some point, the channel is off?
MESFET

Compare to MOSFET.
No self alignment.

Band diagram

n-channel

$V_G = 0$
Will you have an inversion layer here?
I - V Characteristics

For larger (more positive) $V_D$, $V_{GD}$ more negative than $V_{GS} \Rightarrow$ depletion region wider on the D side.
High $V_D$, pinch-off.

Saturation

"Normally on"
JFETs & MESFETs are "normally on". Channels are doped. Turn them off by depleting them. Dopants scatter carriers.

We want $\mu$ & $V_{th}$ as high as possible.

(what's the mobility of a typical Si MOSFET?)

Solution: MODFET.

Many names: HEMT, HFET.
Solution: MODFET

many names: HEMT, HFET

Want electrons ($n$) but not dopants ($N_o$).

The idea: have $N_o$ in one layer but get $n$ in another.

doped undoped

$E_C$ $E_F$ $E_V$

$E_g$ wide $E_g$ narrow $E_g$
To really understand MODFETs, we need to understand heterojunctions.

(Recommended reading: Singh, Physics of Semicond. & Their Heterostructures, p.p. 190-250)

- Fabrication of heterostructures
- Epitaxy
- MBE
- Physical

Epitaxy \( \lessdot \) MOCVD
- Chemical

Need abrupt interface
- \( \rightarrow \) layer-by-layer growth
- 2D atomically flat surfaces
A clean starting surface is critical
How do energy levels line up?

Simply, there's no simple theory.

Pretty much every interface (even the same pair but different growth order) needs to be experimentally determined.

Two "Rules" that are not obeyed

1. Electron affinity rule

\[ \Delta E_c = \chi_1 - \chi_2 \]

\[ \Delta E_V = \phi_1 - \phi_2 \]
1. Electron affinity rule

\[ \Delta E_c = \chi_1 - \chi_2 \]

\[ \Delta E_V = \phi_1 - \phi_2 \]

But there's charge transfer.
There are interface dipoles.

2. Common Anion Rule

\[ \Delta E_V \approx 0 \]

\[ \Delta E_c \approx \Delta E_g \]