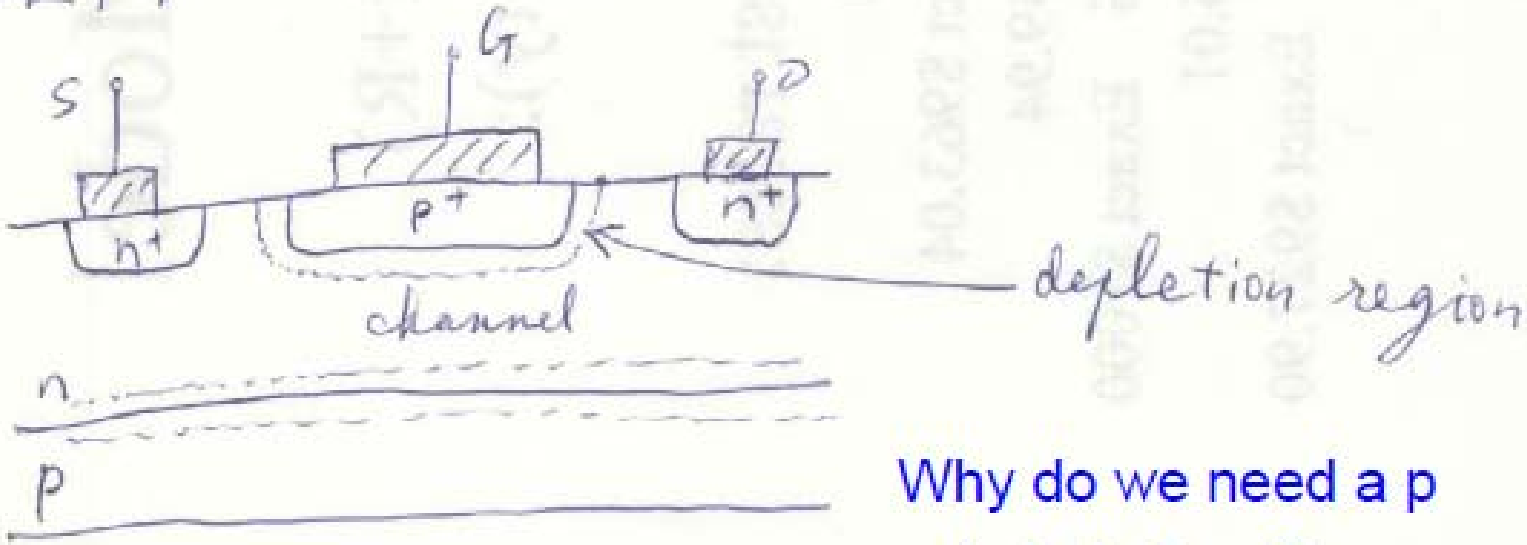
Other types of FETs

- Si is the dominant semiconductor just because of the excellent Si/SiO_2 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, v_{sat}.
- RF, microwave, millimeter wave applications need faster transistors.
- But MOSFETs are not that good w/ those materials due to the lack of a good semiconductor/dielectric interface.

JEFT

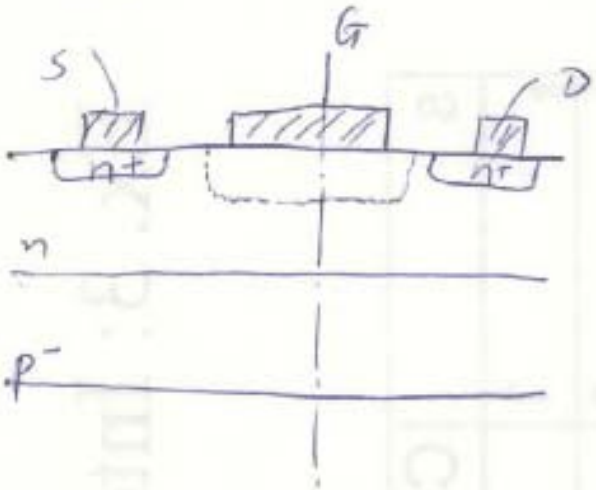


Why do we need a p substrate here?

$V_{GS} < 0 \Rightarrow$ depletion region widens.

At some point, the channel is off!

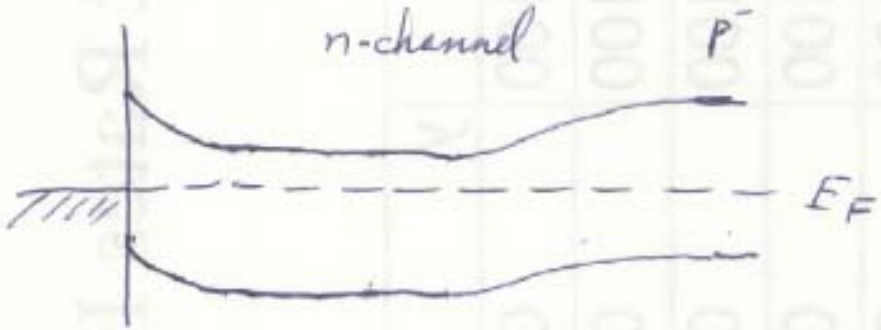
MESFET



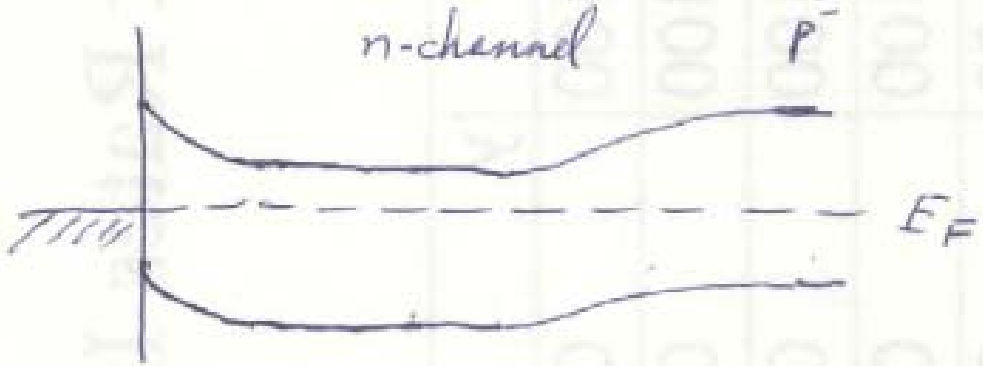
compare to MOSFET.

no self alignment

↓ band diagram



$V_G = 0$



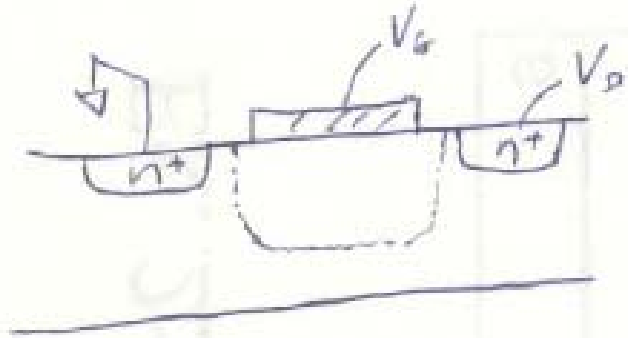
$V_G = 0$

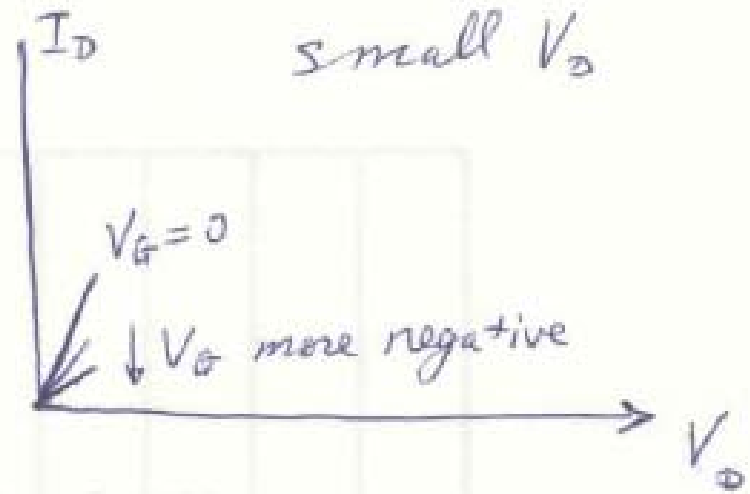
↓

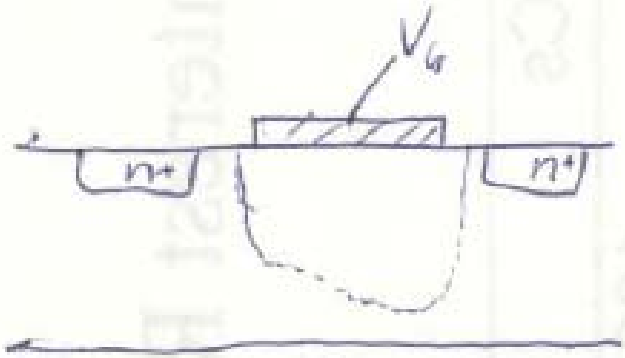
$V_G < 0$

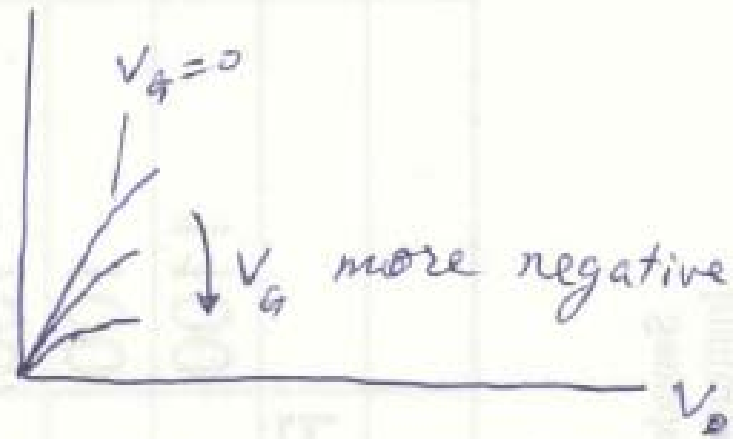
Will you have an inversion layer here?

I-V Characteristics

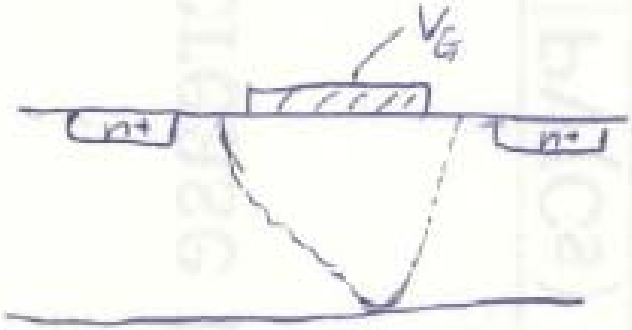




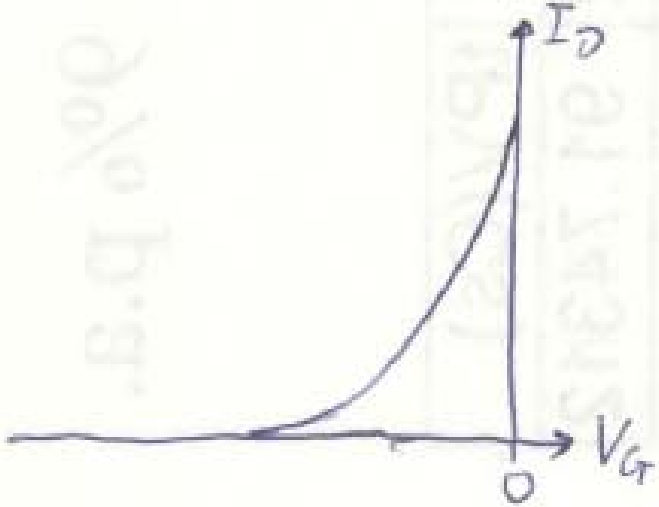


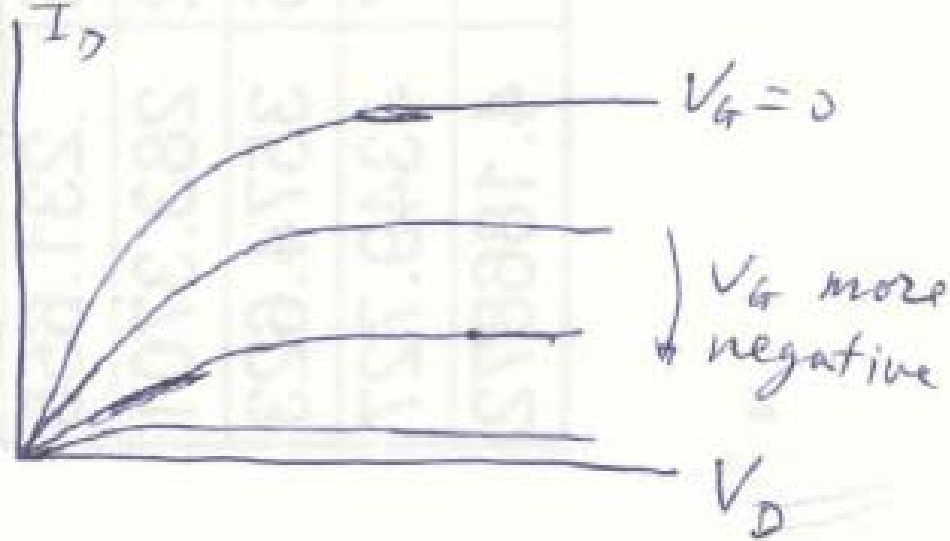


For larger (more positive) V_D, V_{GD} more negative than V_{GS} $\Rightarrow$ depletion region wider on the D side.



High V_D, pinch-off.
saturation





"Normally on"

JFETs & MESFETs are "normally on".

Channels are doped.

Turn them off by depleting them.

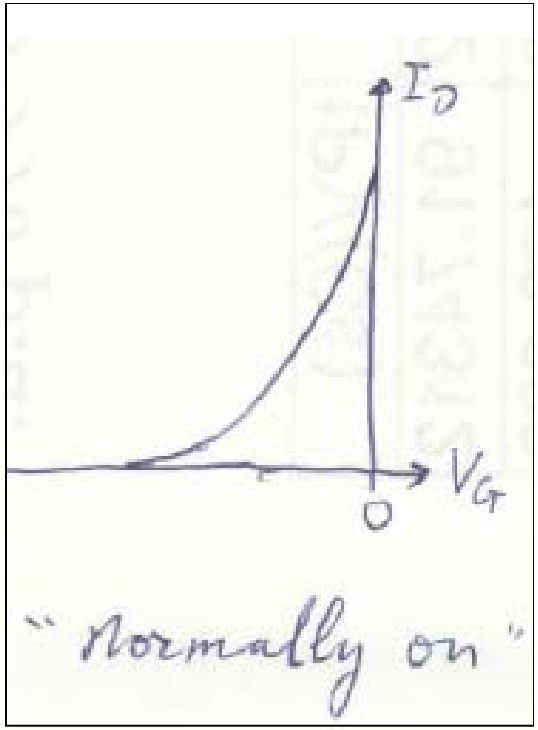
Dopants scatter carriers.

We want μ & V_{sat} as high as possible.

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

Solution: MODFET

many names. HEMT, HFET

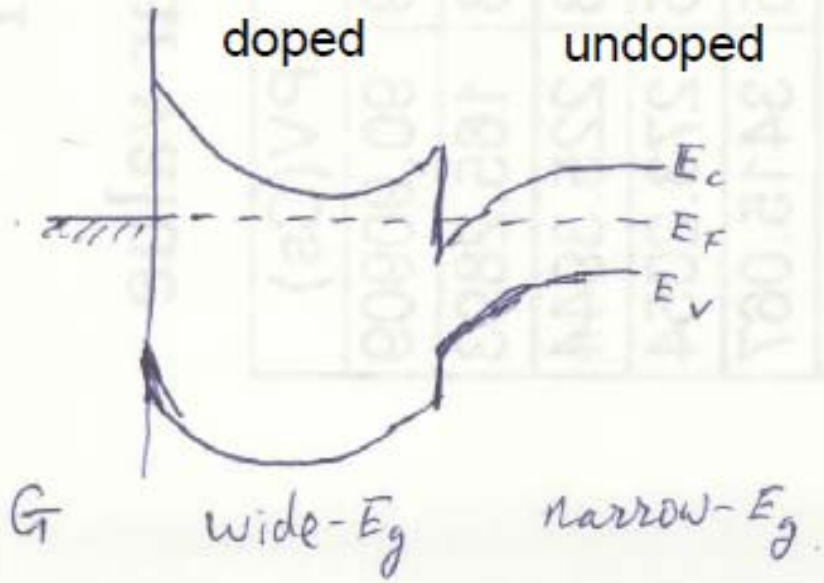


Solution: MODFET

many names: HEMT, HFET

Want electrons (n), but not dopants (N_D).

The idea: have N_D in one layer, but get n in another.



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
MOCVD chemical

Need abrupt interface

→ layer-by-layer growth

2D atomically flat surfaces

Epitaxy < MBE Physical
MOCVD chemical

Need abrupt interface
→ layer-by-layer growth
2D atomically flat surfaces

The impinging atoms must have enough energy to find their right sites,
but not too much energy that would cause bulk diffusion.

A clean starting surface is critical

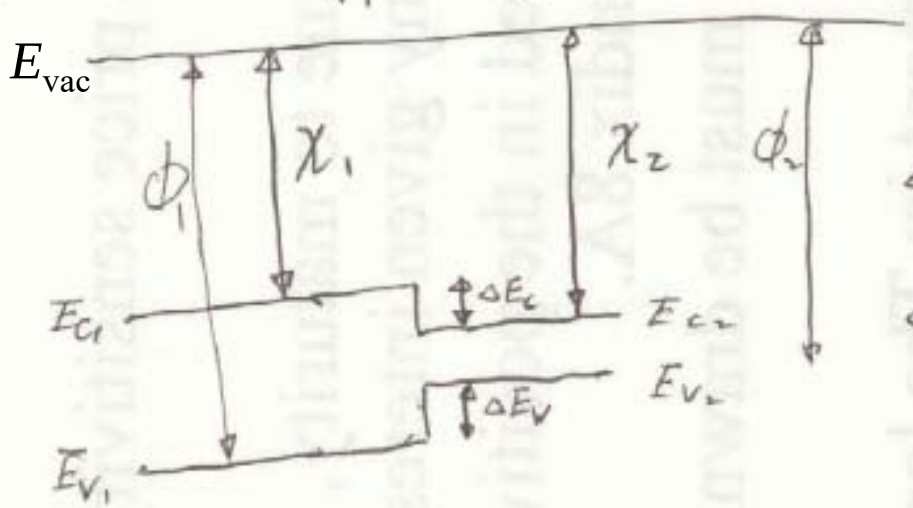
- How do energy levels line up?

  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 <u>not</u> obeyed

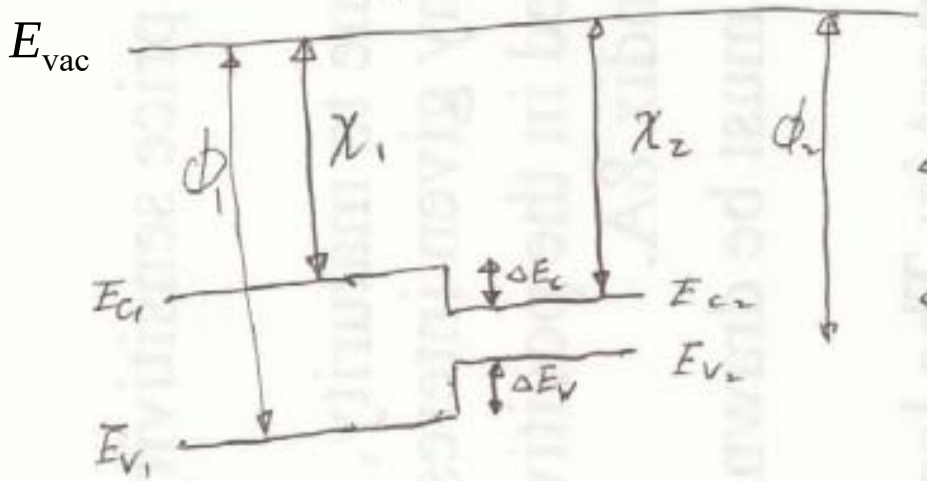
  ① Electron affinity Rule



$$\Delta E_c = \chi_1 - \chi_2$$

$$\Delta E_v = \phi_1 - \phi_2$$

① Electron affinity Rule

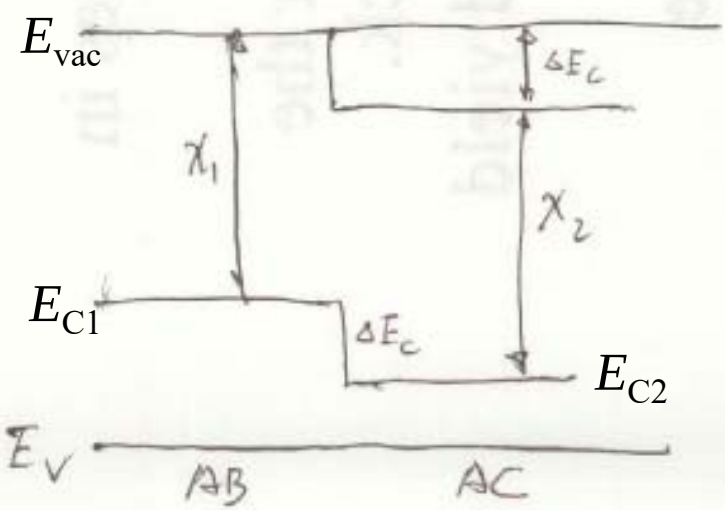


$\Delta E_c = \chi_1 - \chi_2$

$\Delta E_v = \phi_1 - \phi_2$

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

② . Common Anion Rule



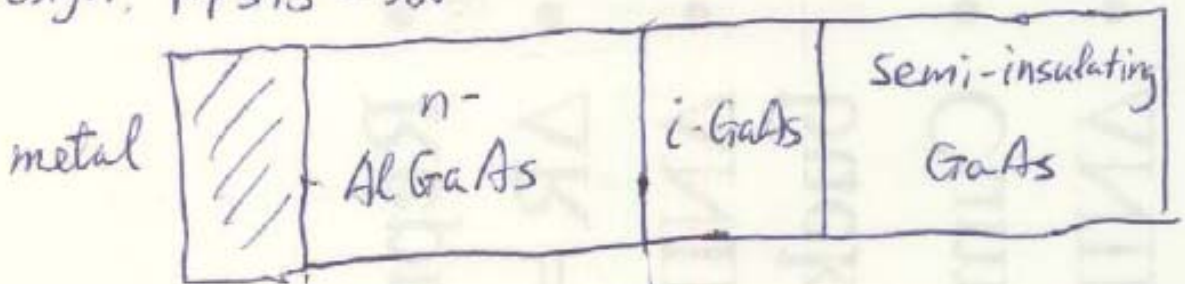
AB & AC.

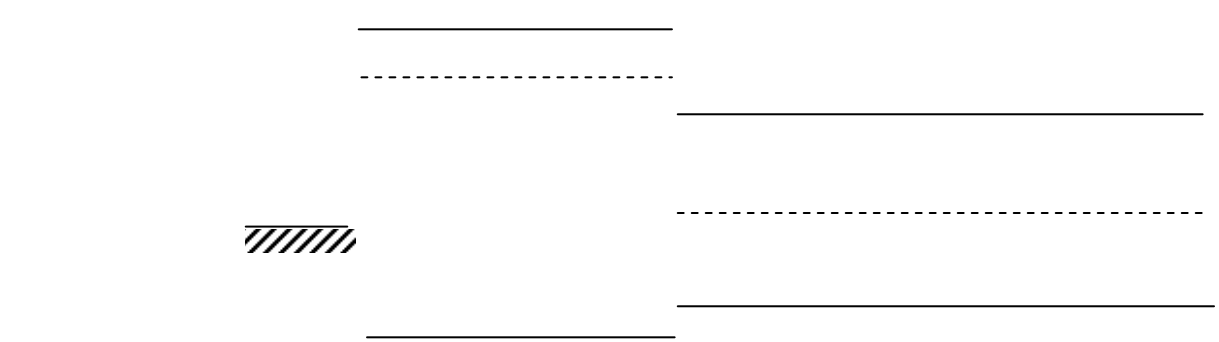
$\Delta E_v \approx 0$

$\Delta E_c \approx \Delta E_g$

Now, back to the MODFET

(Recommended reading: Umesh & Singh, Semiconductor Dev. Phys. & Design, p.p 375 – 388





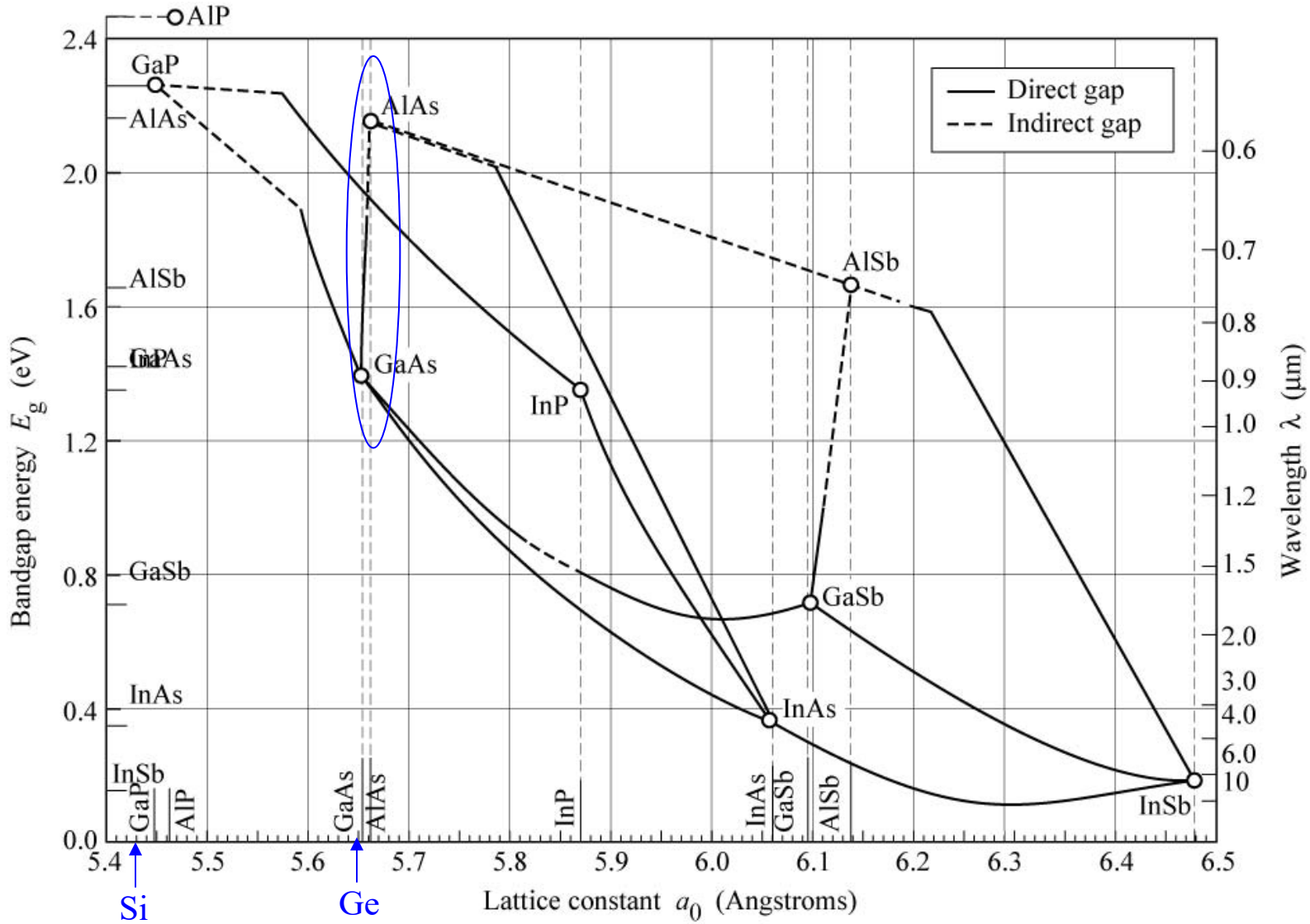
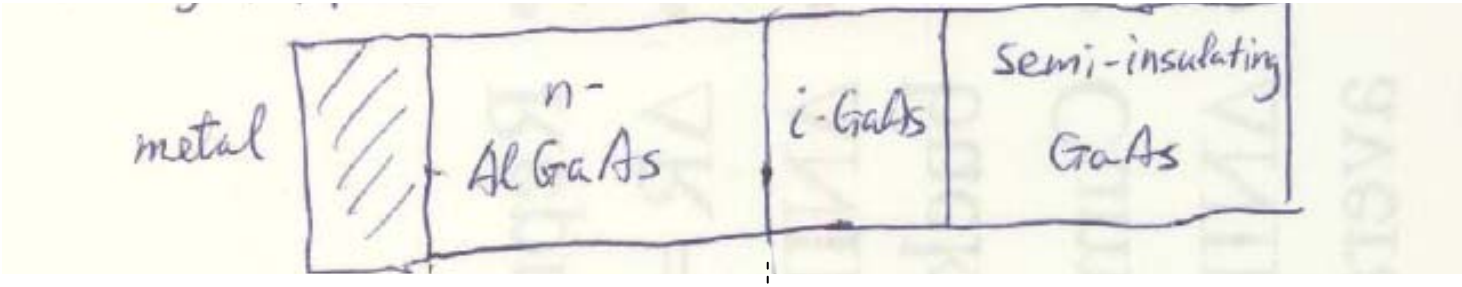
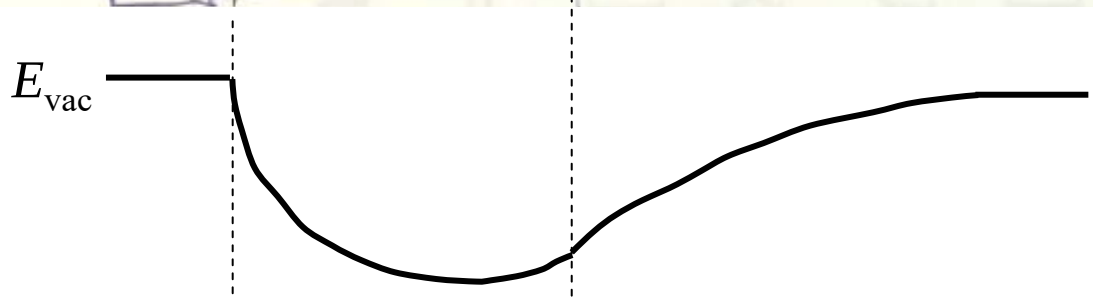
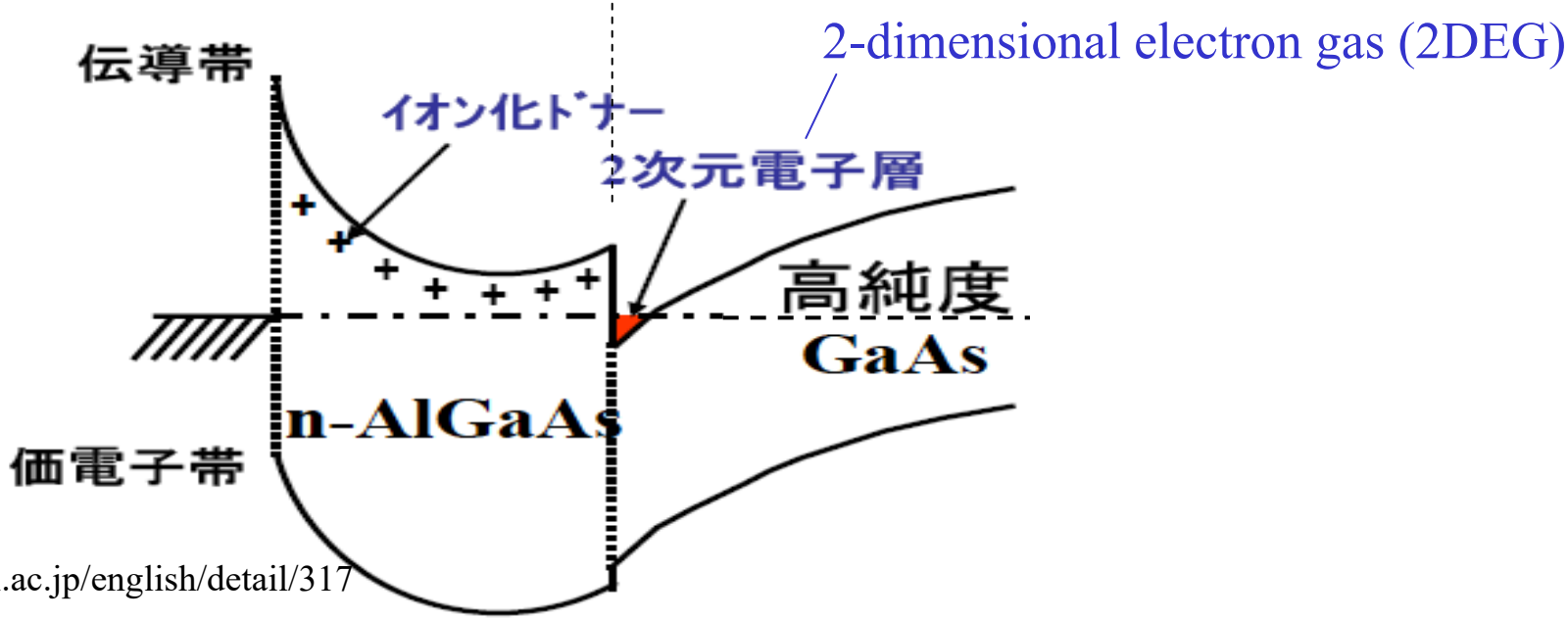


Fig. 12.6. Bandgap energy and lattice constant of various III–V semiconductors at room temperature (adopted from Tien, 1988).

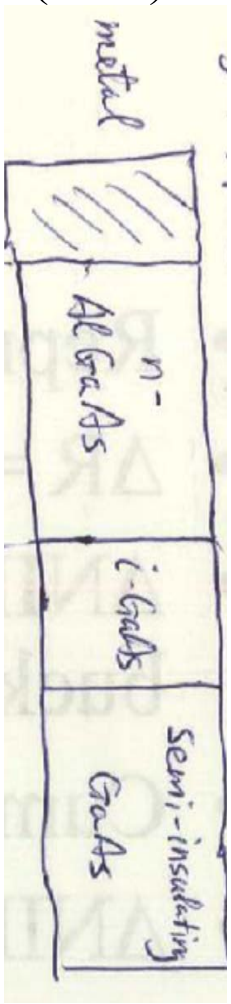


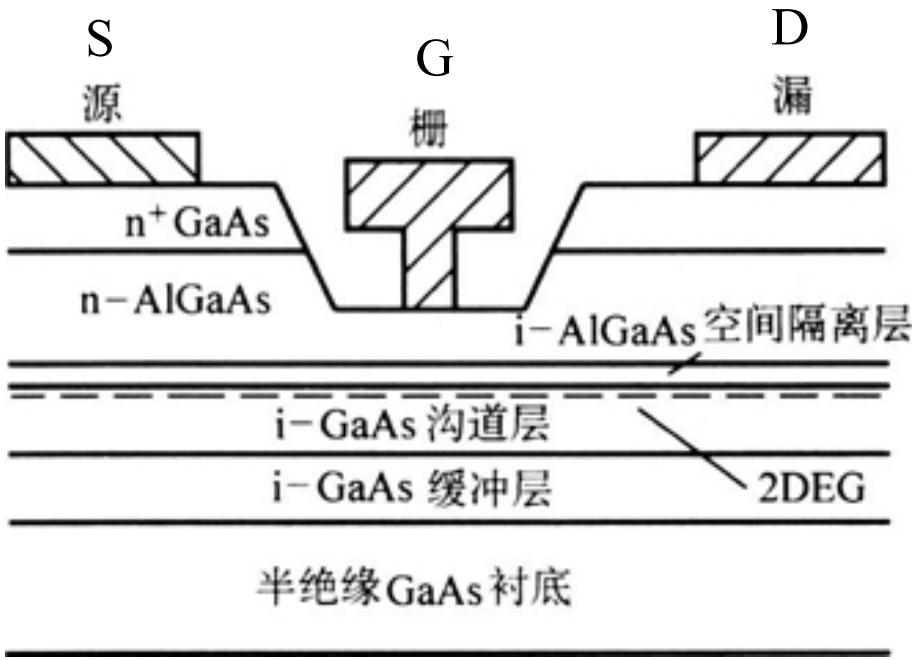




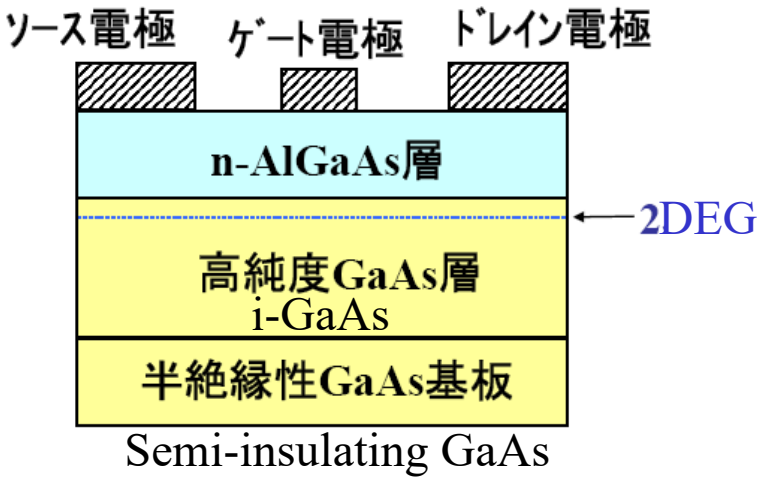
https://dbnst.nii.ac.jp/english/detail/317

(Gate)

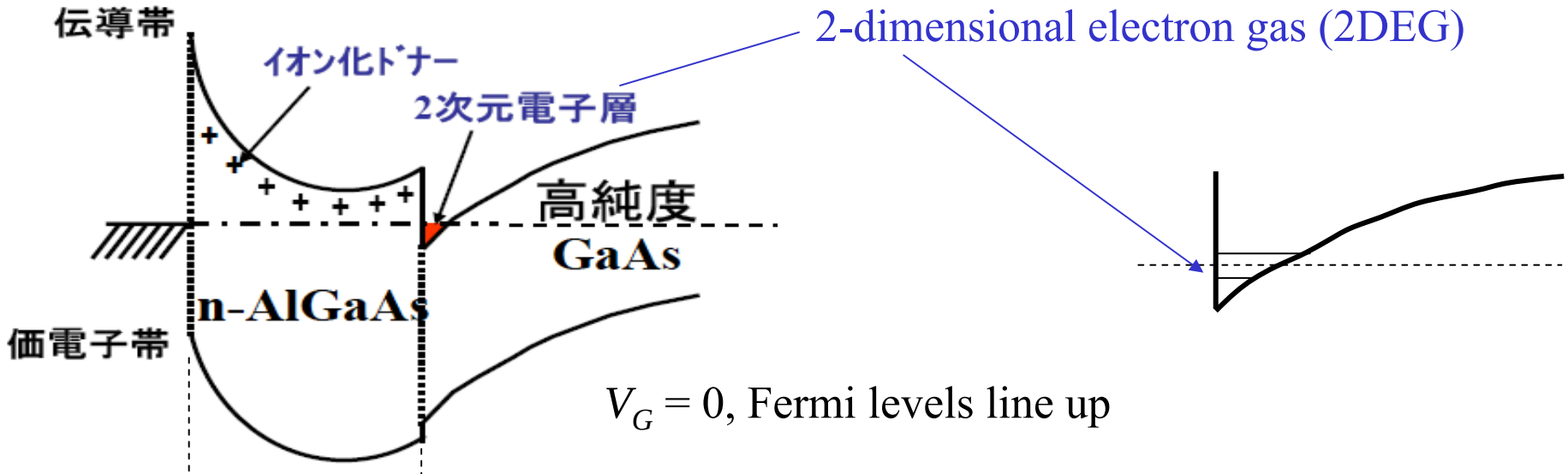




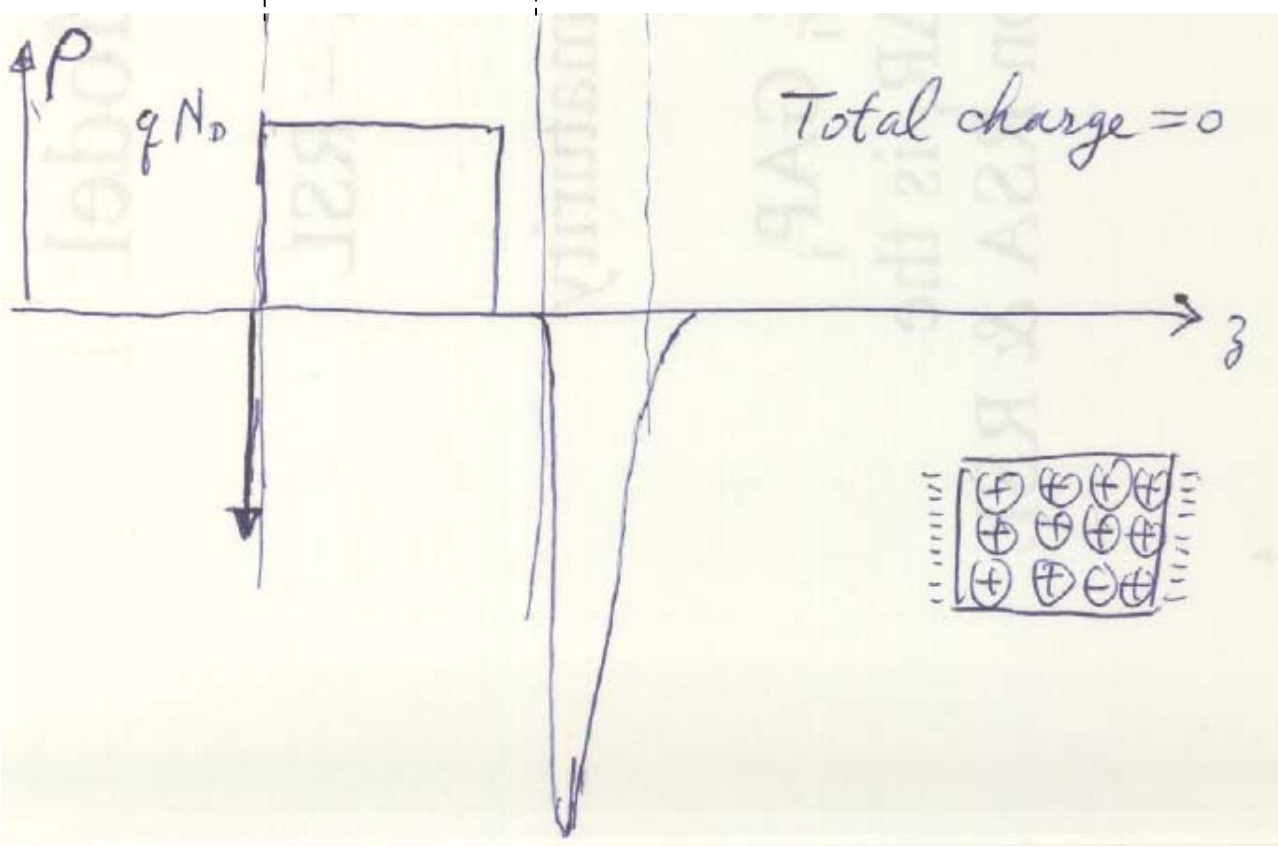
http://wiki.emat.com.cn/index.php?doc-view-106187



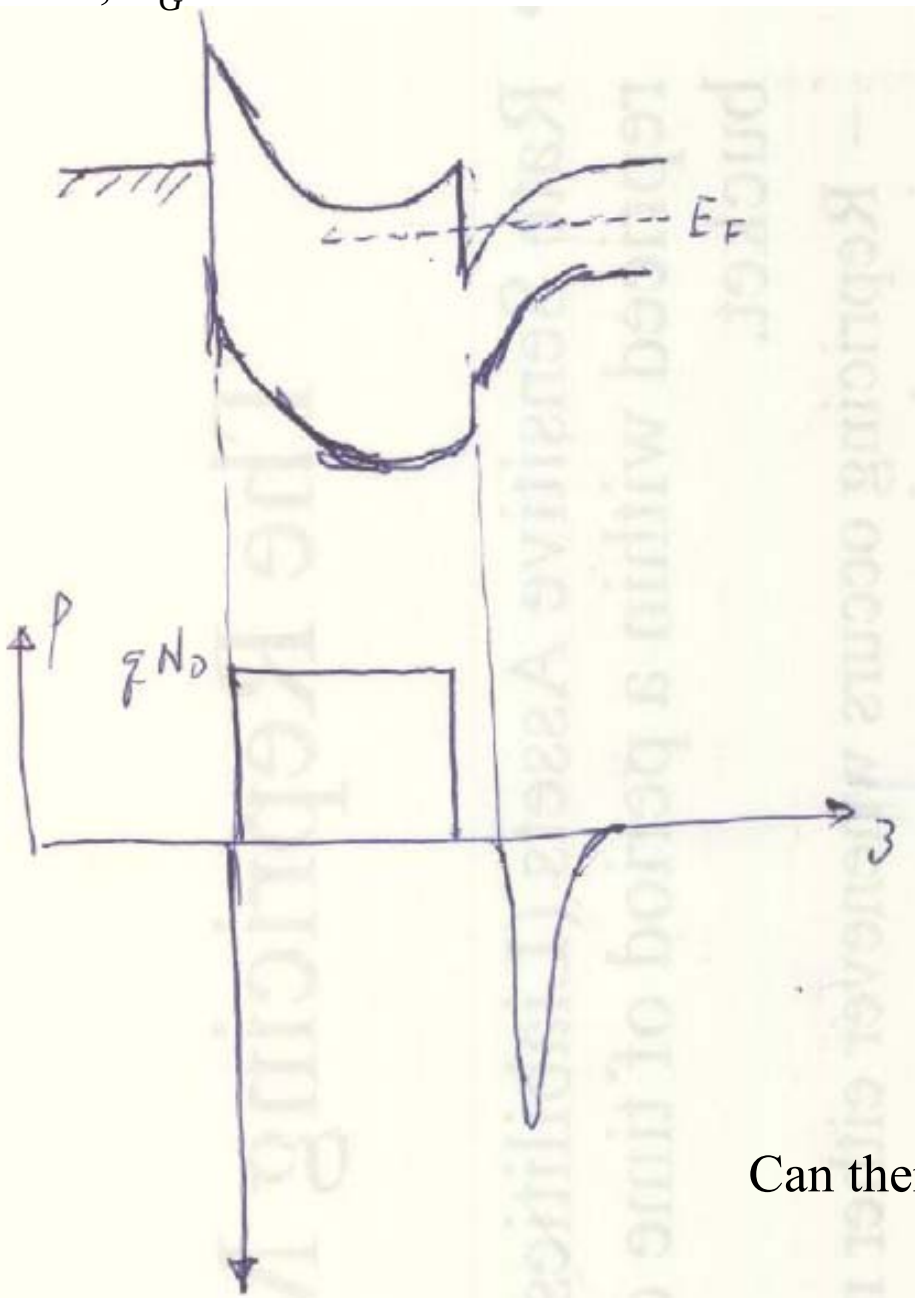
https://dbnst.nii.ac.jp/english/detail/317

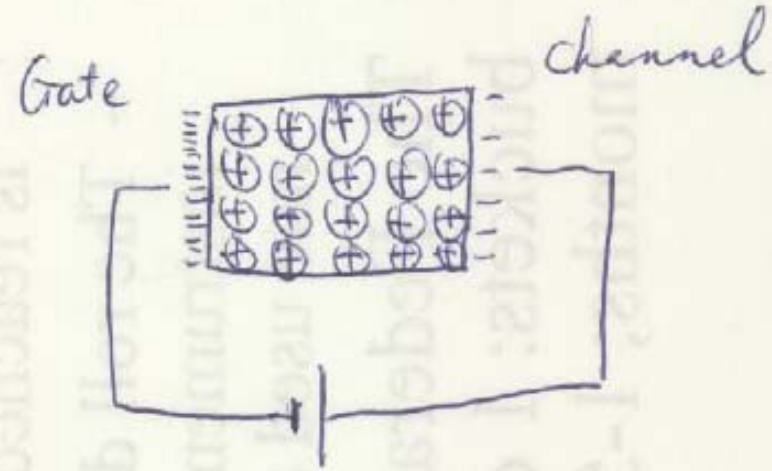


$V_G = 0$, Fermi levels line up



Now, $V_G < 0$

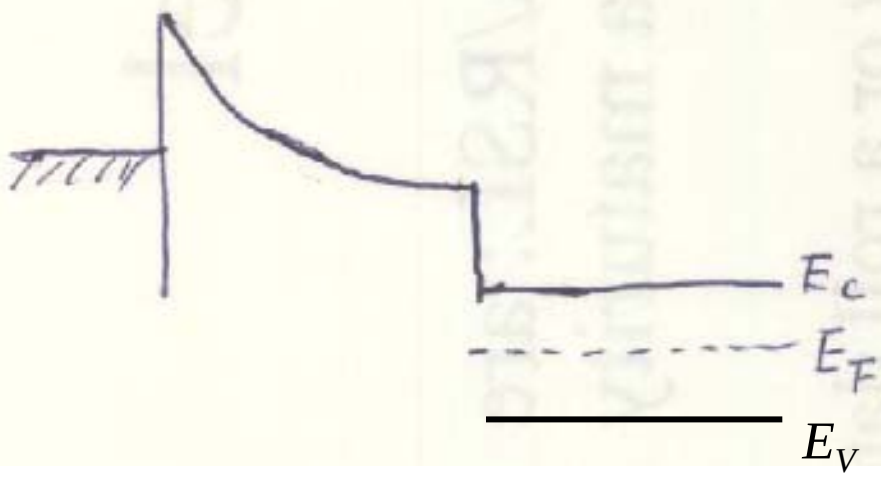




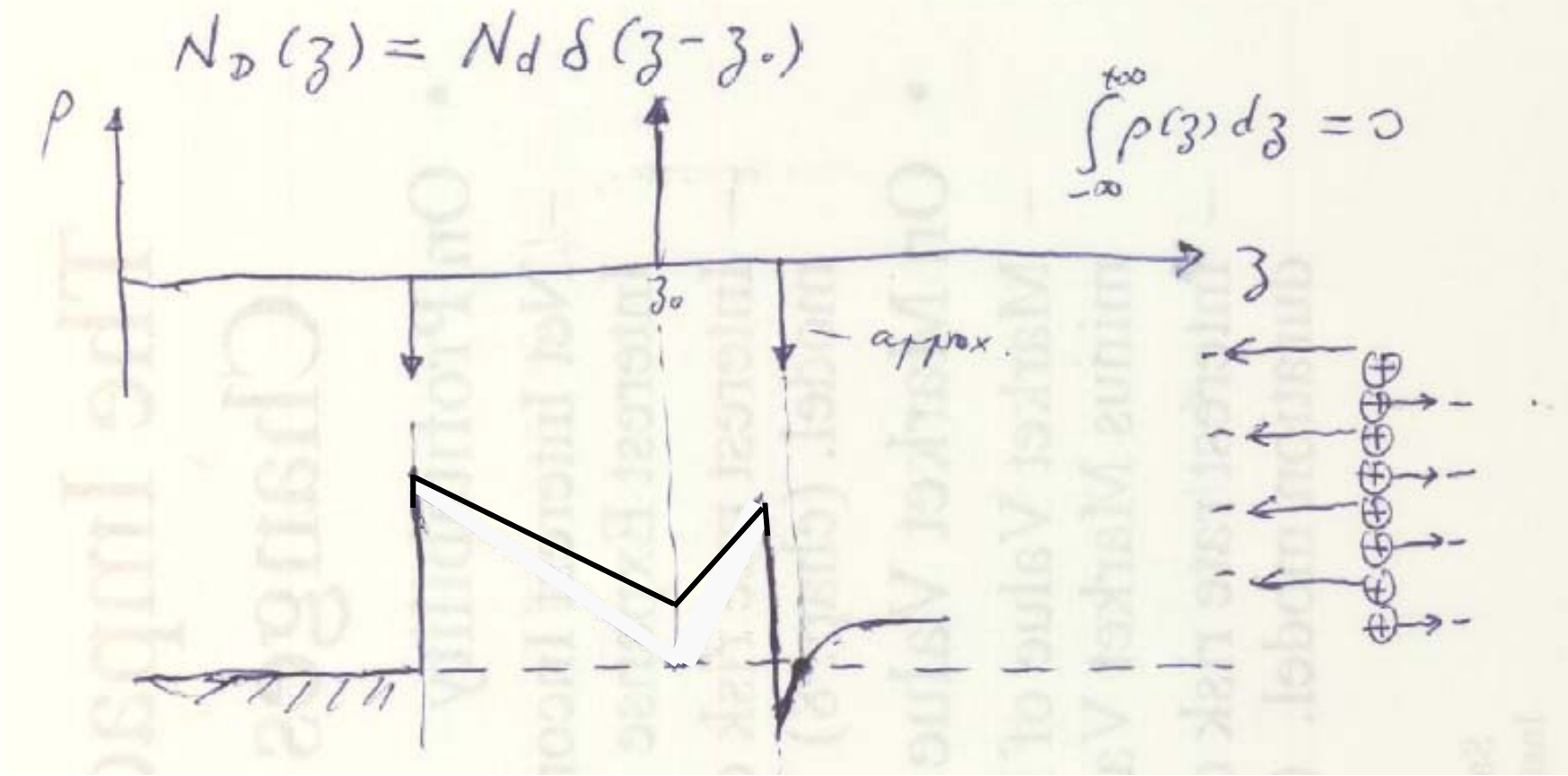
The battery pumps e's to the gate. Total charge conserves.

Can there be an inverted channel in AlGaAs?

Now. more negative V_G, channel depleted.



To avoid “parasitic channel” in AlGaAs, can do “delta doping”



When the channal is totally depleted