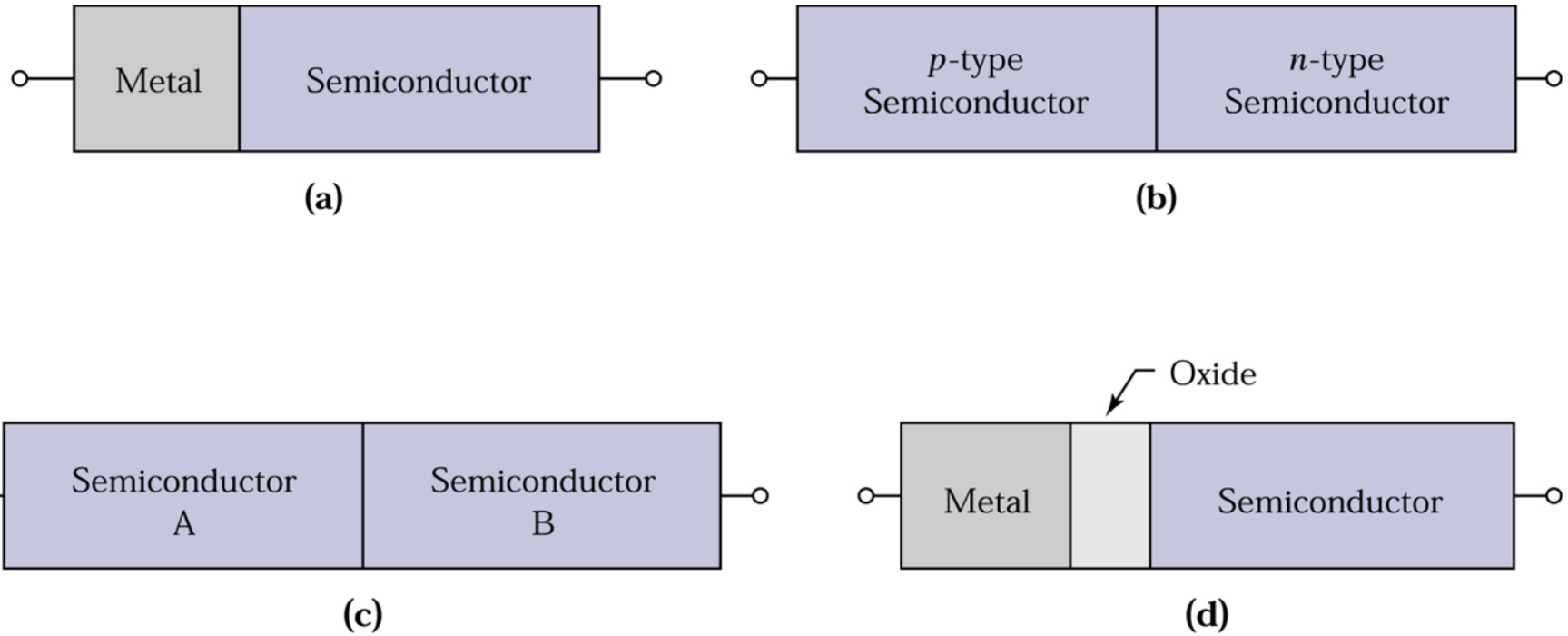
QY2. Quantum Devices

Semiconducting devices:

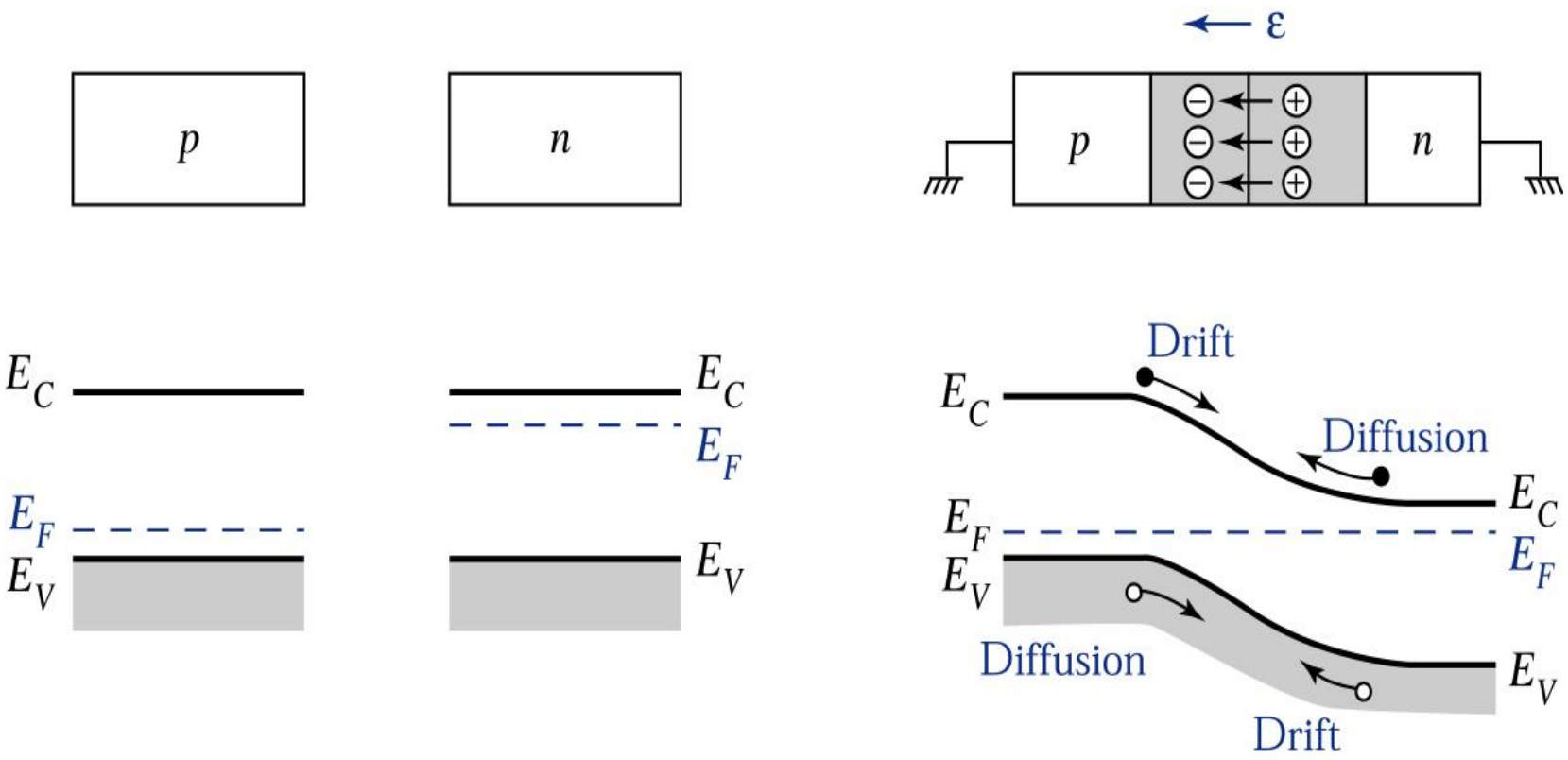
- Esaki-Diode
- Resonant Tunneling diode
- NonVolatile Memory
- HBT
- QW/HEMT

Dr Panagiotis Dimitrakis

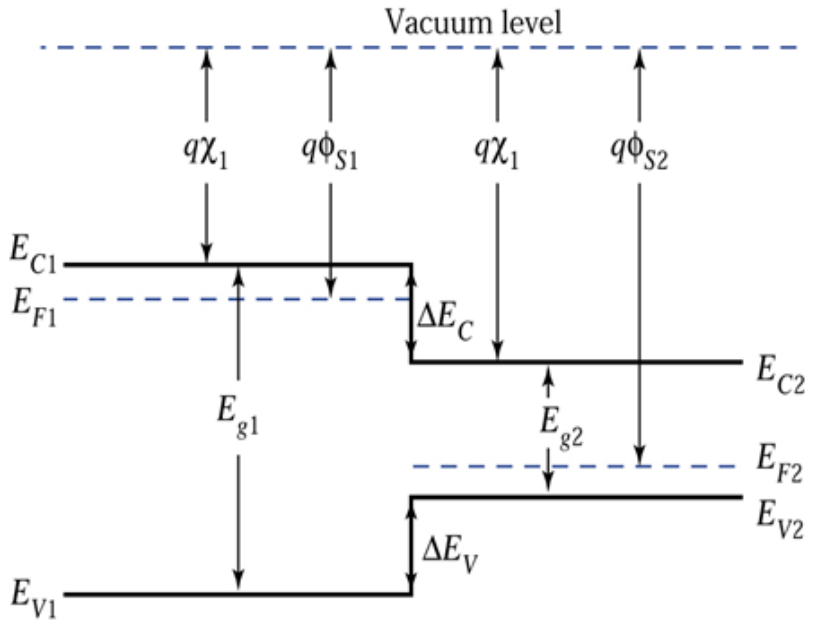
Semiconductor Device Structures



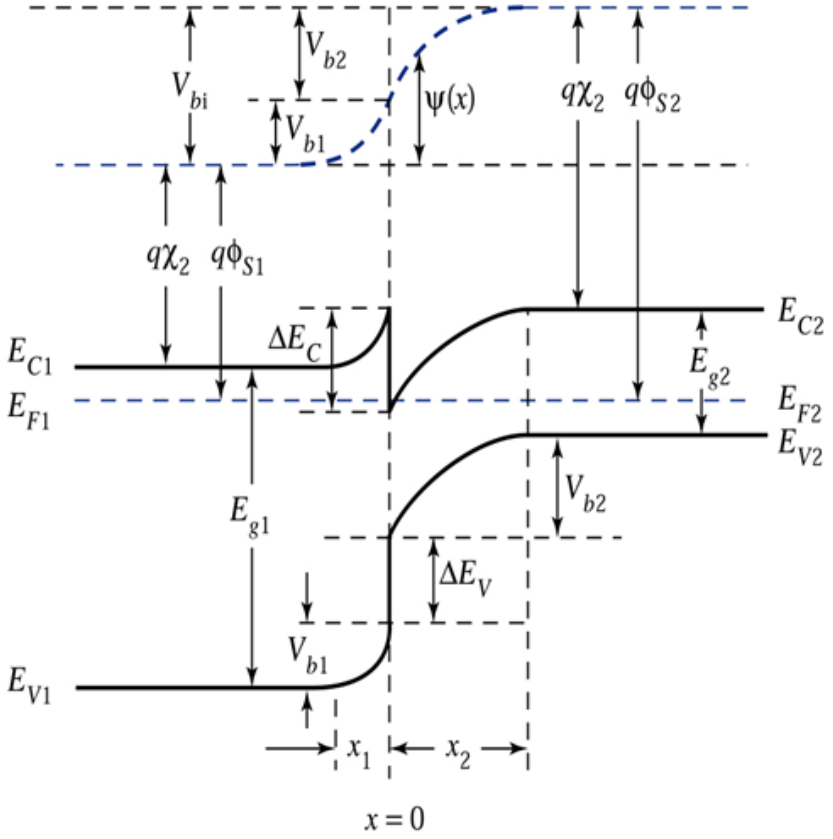
Semiconductor Homojunction (*p-n* diode)



Semiconductor Heterojunction

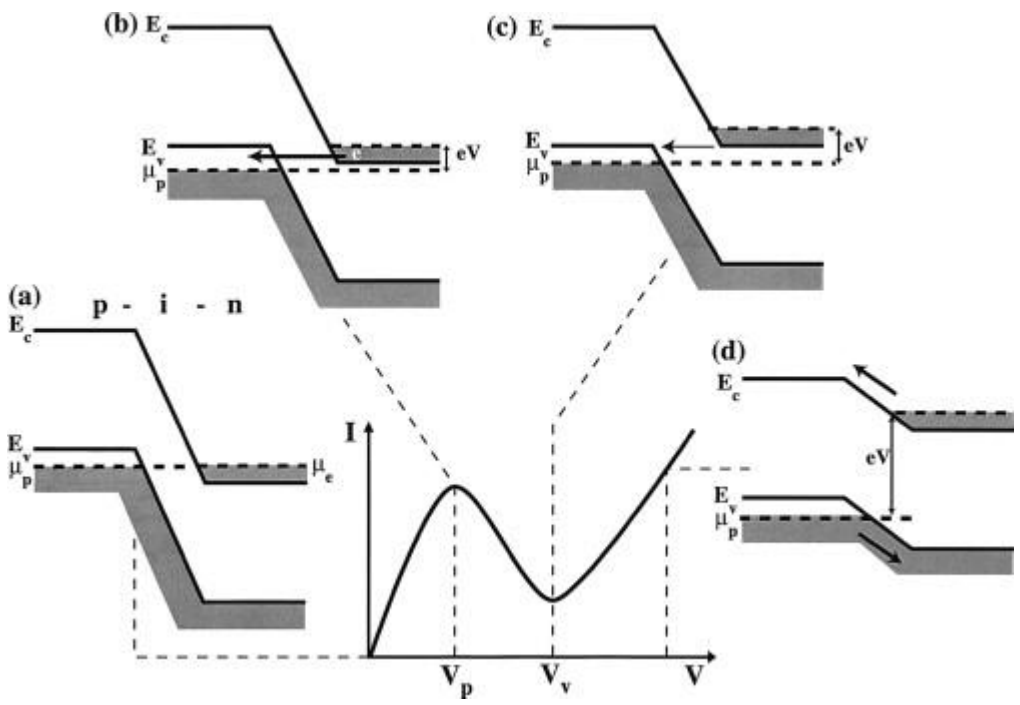


n-p isolated semiconductors



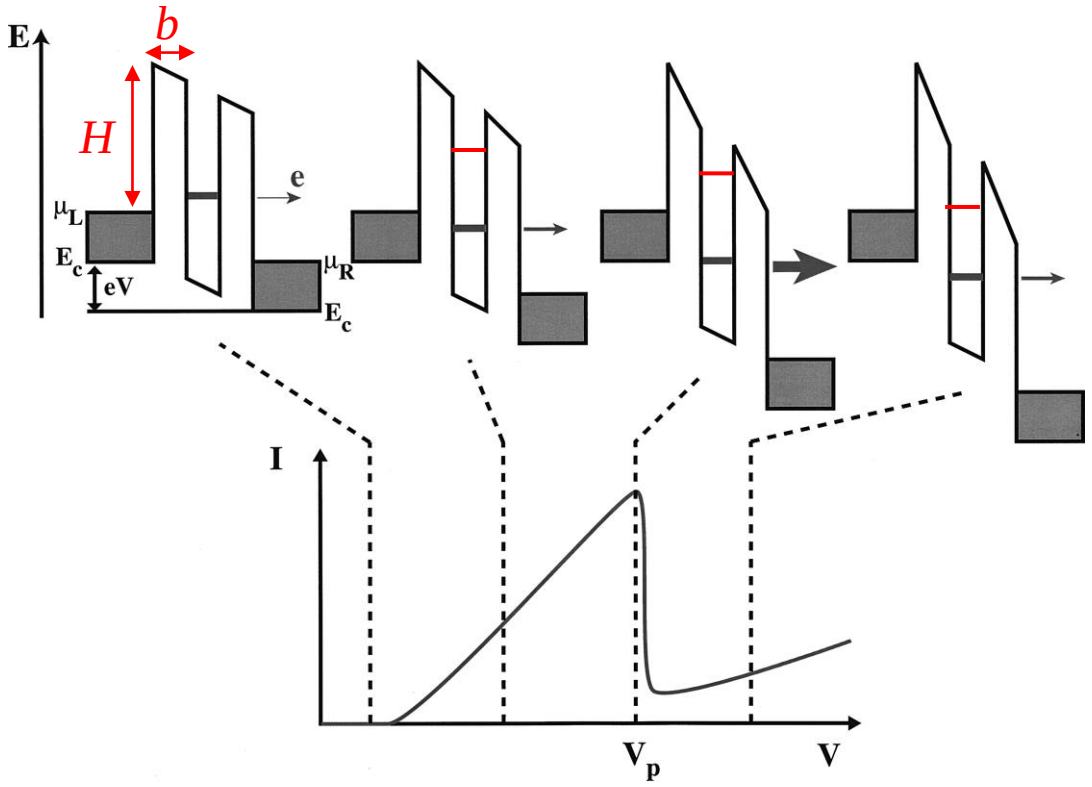
n-p in contact semiconductors

Esaki diode – Interband tunneling diode



The μ_p and μ_e are the chemical potentials in the p and n-regions respectively. Grey areas correspond to states filled with electrons. Bias voltage V increases to positive values.
(a) At zero bias electrons from the conduction band of the n-region cannot tunnel to the valence band because there are no hole (empty) states at the same energy. (b) A peak in the I-V occurs when the reservoir of electrons in the conduction band of the n-region has the maximum overlap in energy with the reservoir of holes in the valence band. (c) The valley in the I-V occurs when the electron reservoir in the n-region becomes higher in energy than all the hole states in the valence band of the p-region. (d) Once the n- and p-states are misaligned, current can only flow due to second-order processes by scattering and tunneling through defect states and deep levels in the bandgap and thermally excited processes.

Resonant tunneling Diode (RTD)

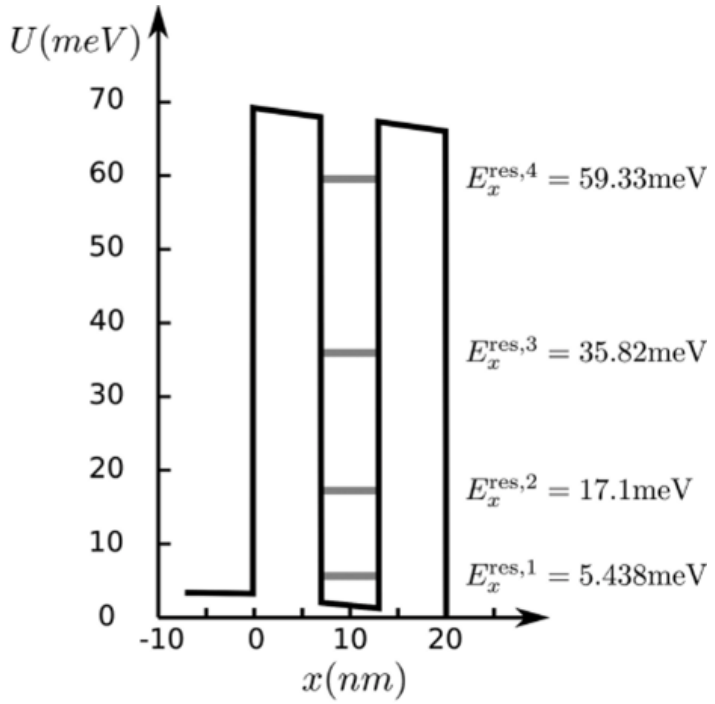


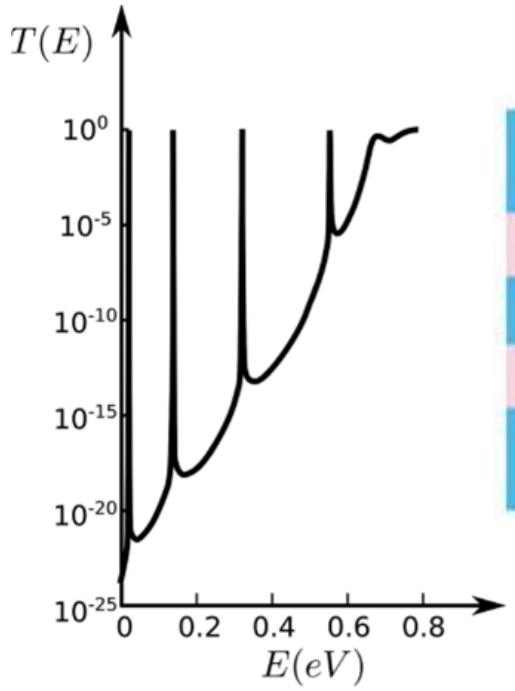
The μ_R is the chemical potential for the right electrode and μ_L, for the left—electron fills states from the top of the conduction band E_c, to the chemical potential. The grey areas are filled electrons states in the heavily doped electrodes that provide reservoirs of electrons for tunneling. Only when the subband in the central quantum well has the same energy as an electron in one of the electrodes can electrons tunnel through the system to the other electrode.

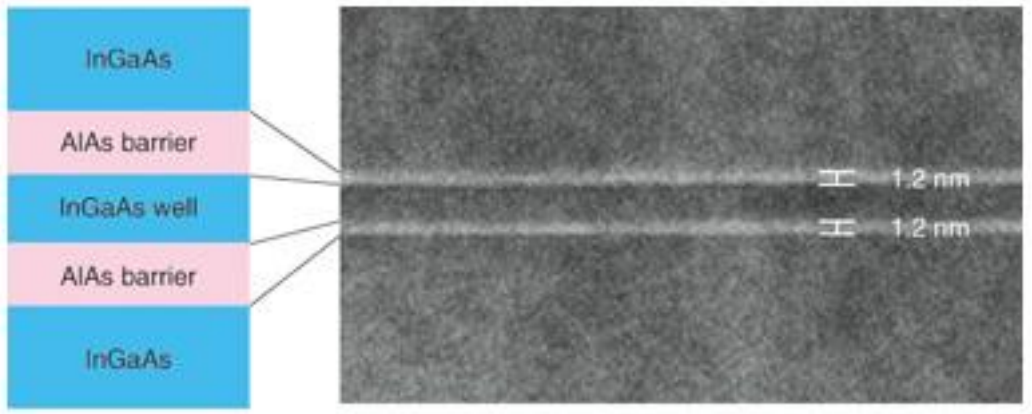
$$T \approx \frac{16E}{H} e^{-2\alpha b}$$

Tunneling or Transmission coefficient

Resonant tunneling Diode (RTN diode)







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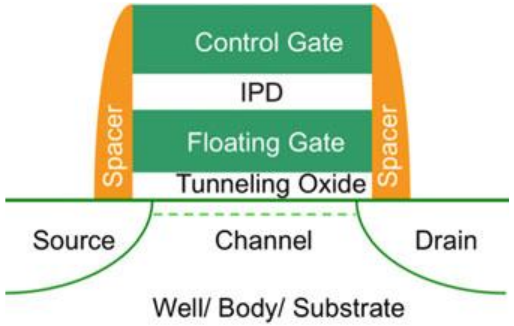
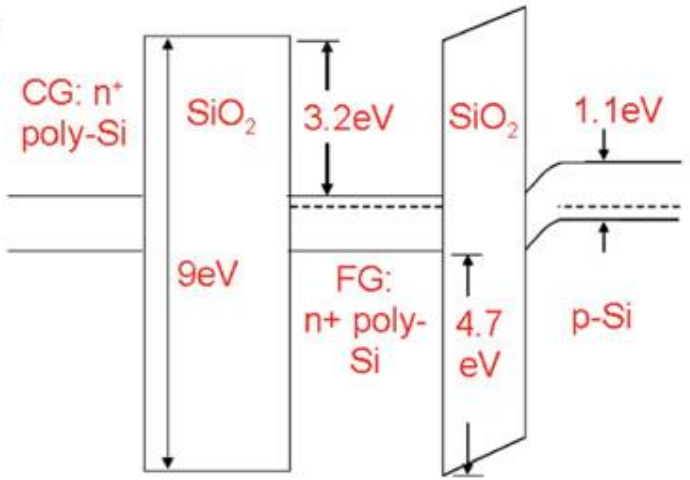
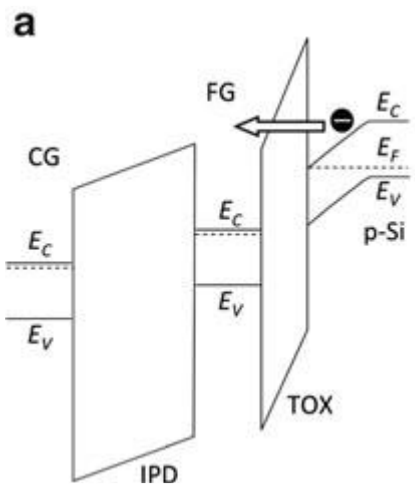
Resonant Tunneling Diode Simulator
Resonant Tunneling Diode Simulator with NEGF
Piece-Wise Constant Potential Barriers Tool
Piece-Wise Constant Potential Barrier Sim2L

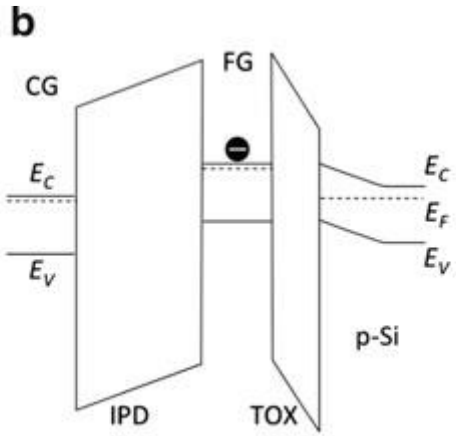
Non-volatile Memories – Flash (Floating Gate)



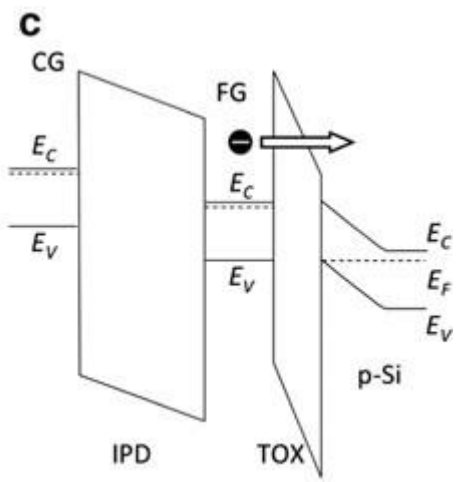




(a) PGM

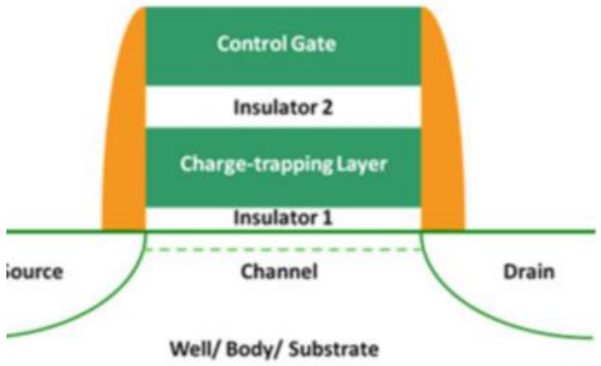


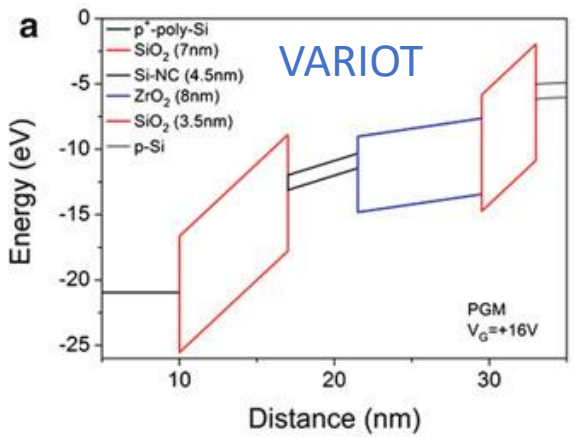
(b) READ



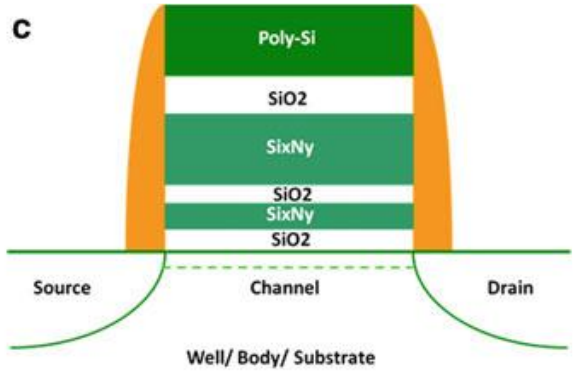
(c) ERS operations

Non-volatile Memories – Flash (Charge Trap)

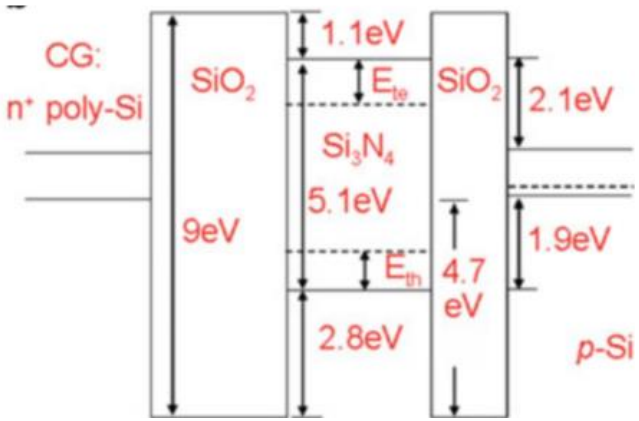


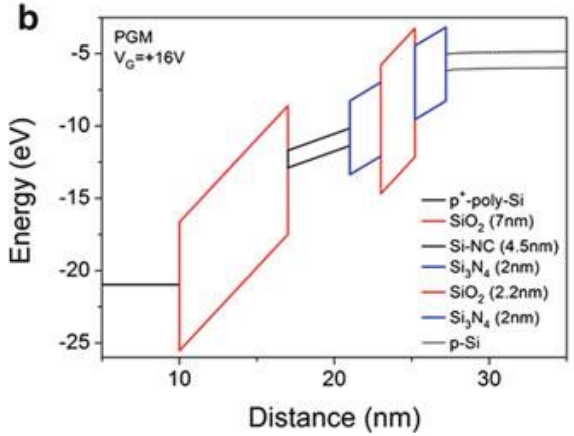


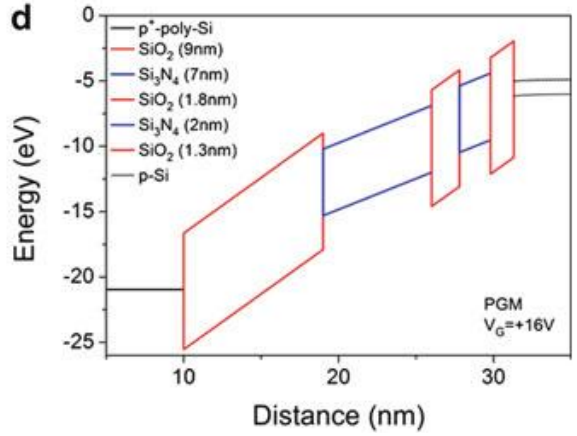
VARIOT



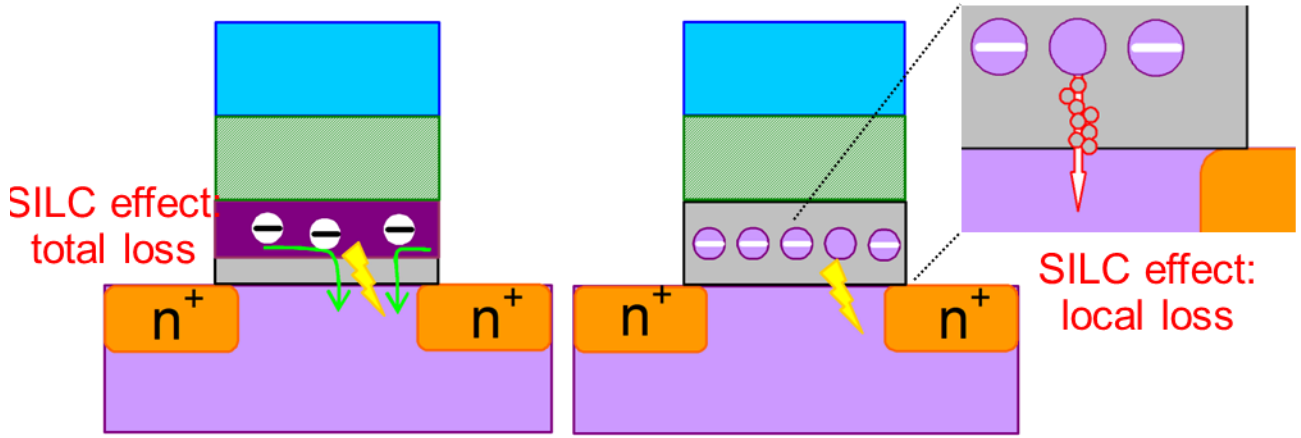
BE-SONOS



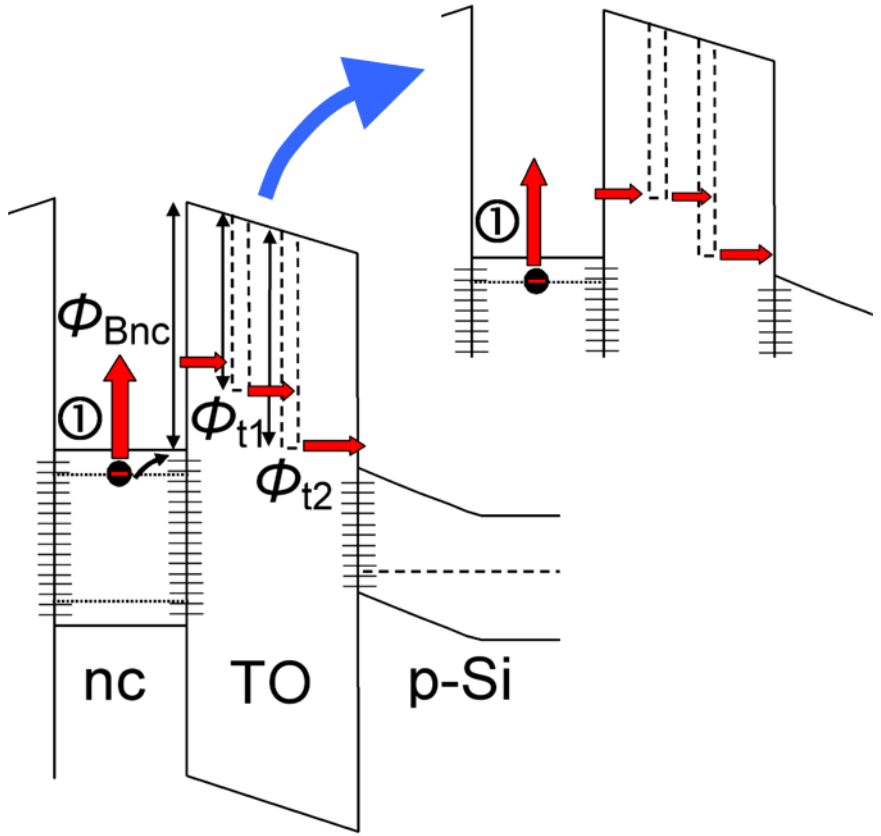




Non-volatile Memories – Flash (QDs memory)

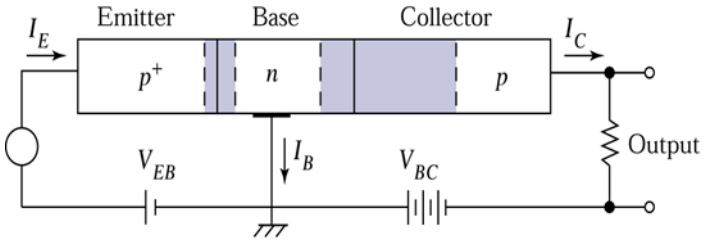


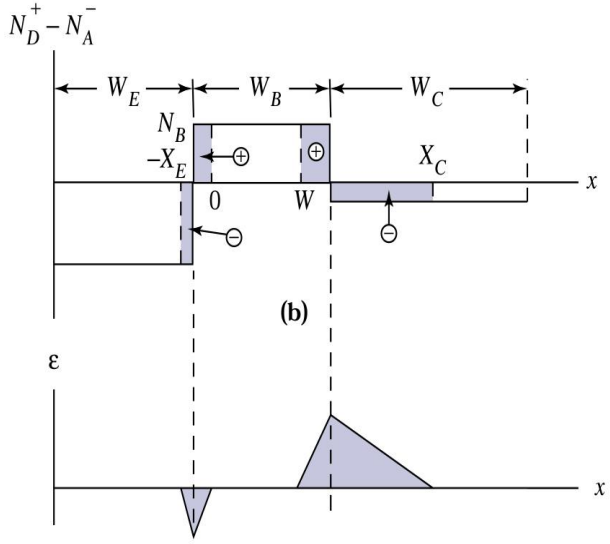
CT-NVM NC(QD)-NVM



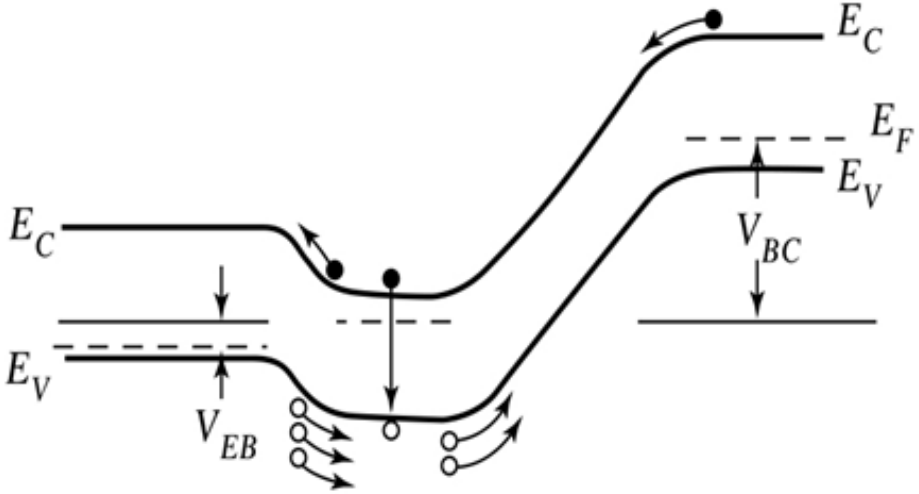
Homojunction Bipolar (Junction) Transistor BJT

Doping profiles, depletion regions and electric-field

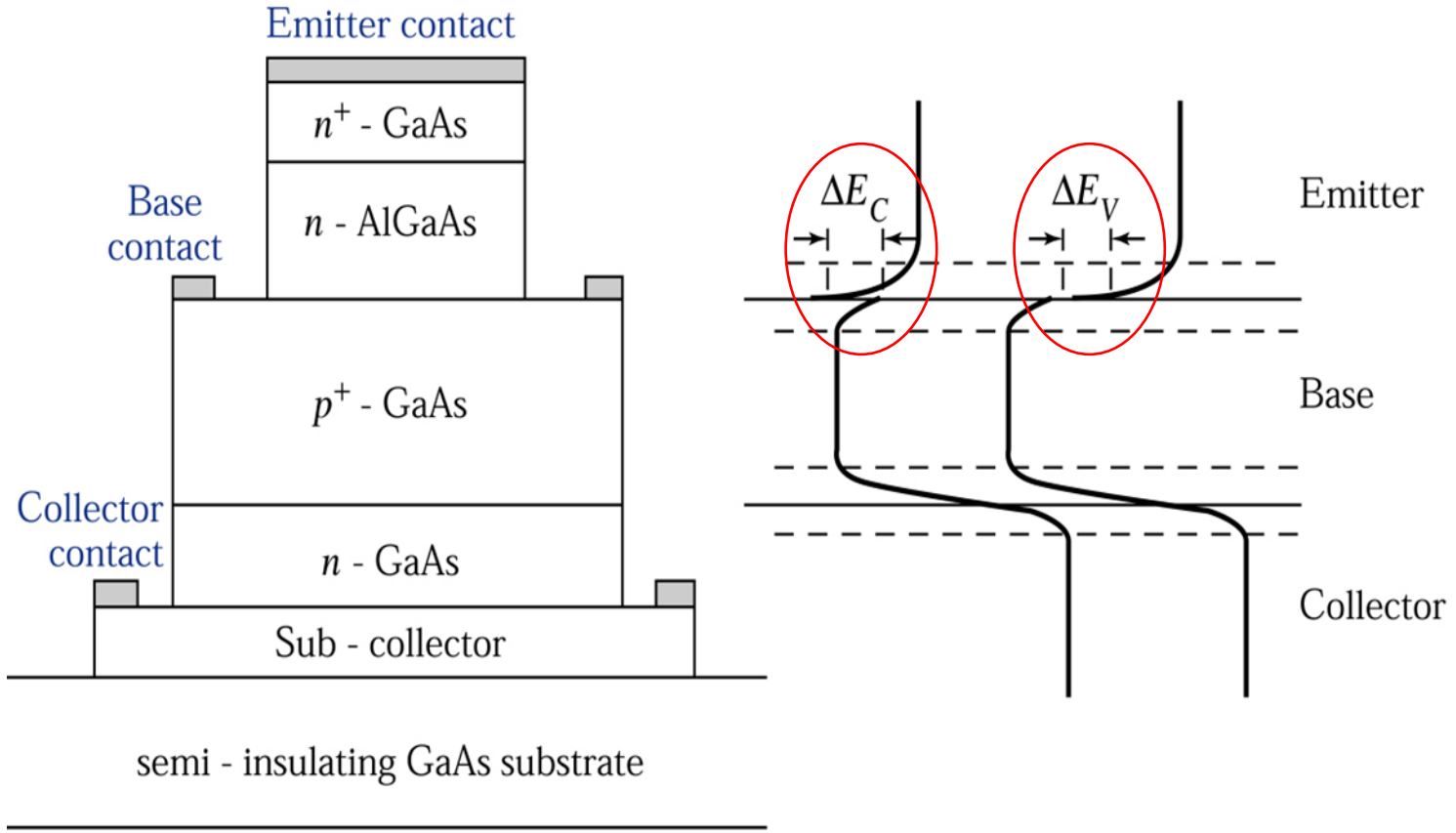




Energy band diagram under bias V_{BC}

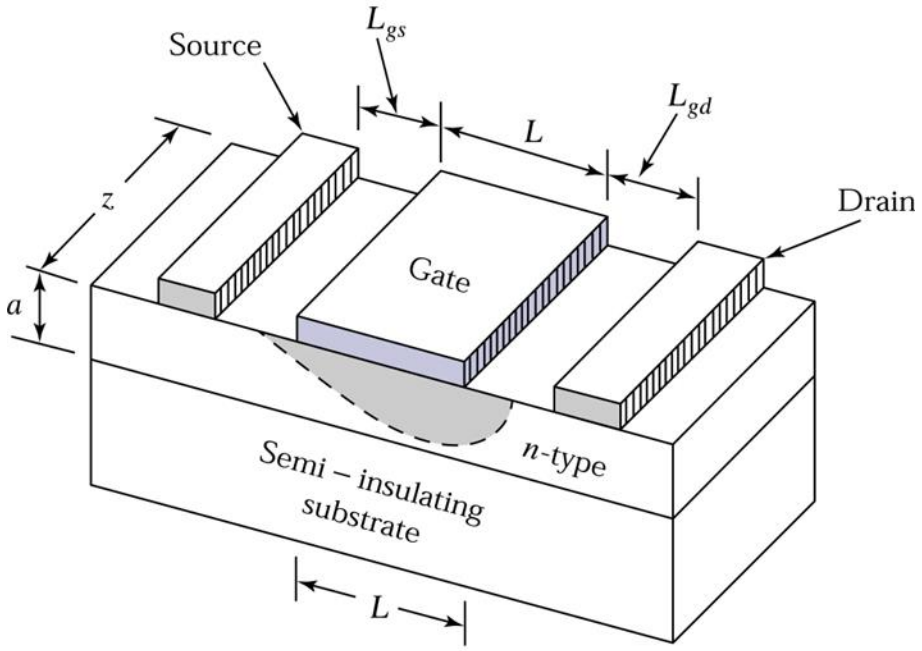


Heterojunction Bipolar Transistor

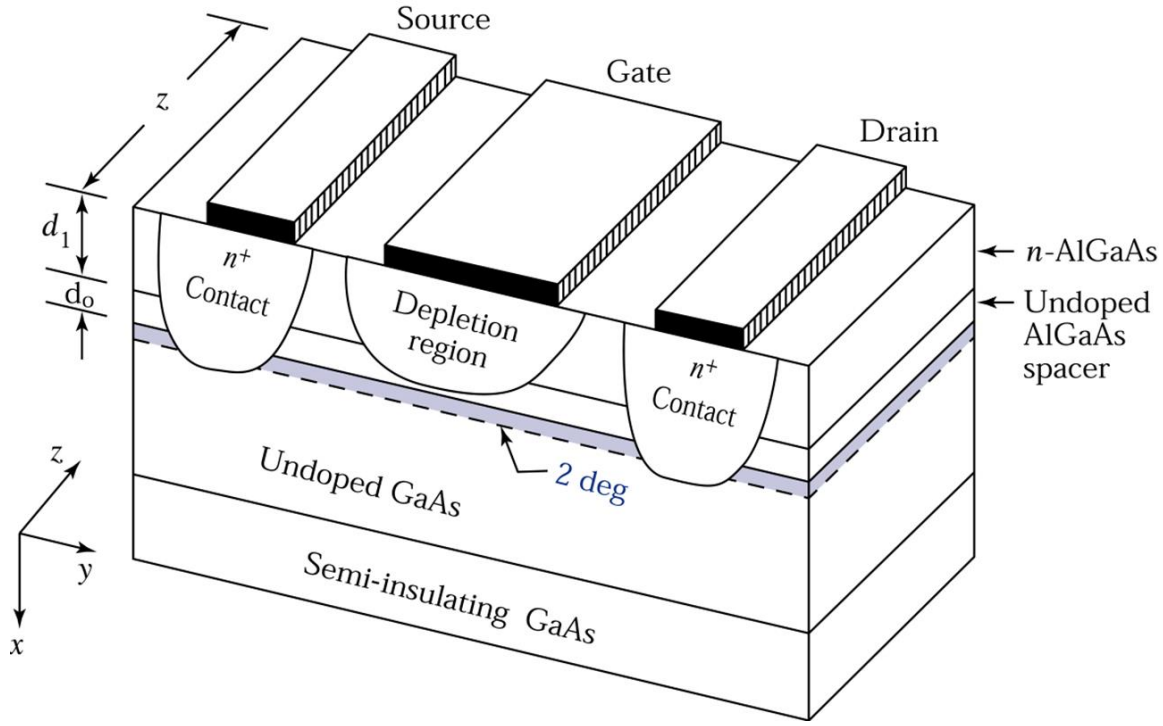


Schematic cross section of an *n-p-n* heterojunction bipolar transistor (HBT) structure and energy band diagram

MESFET – MODFET

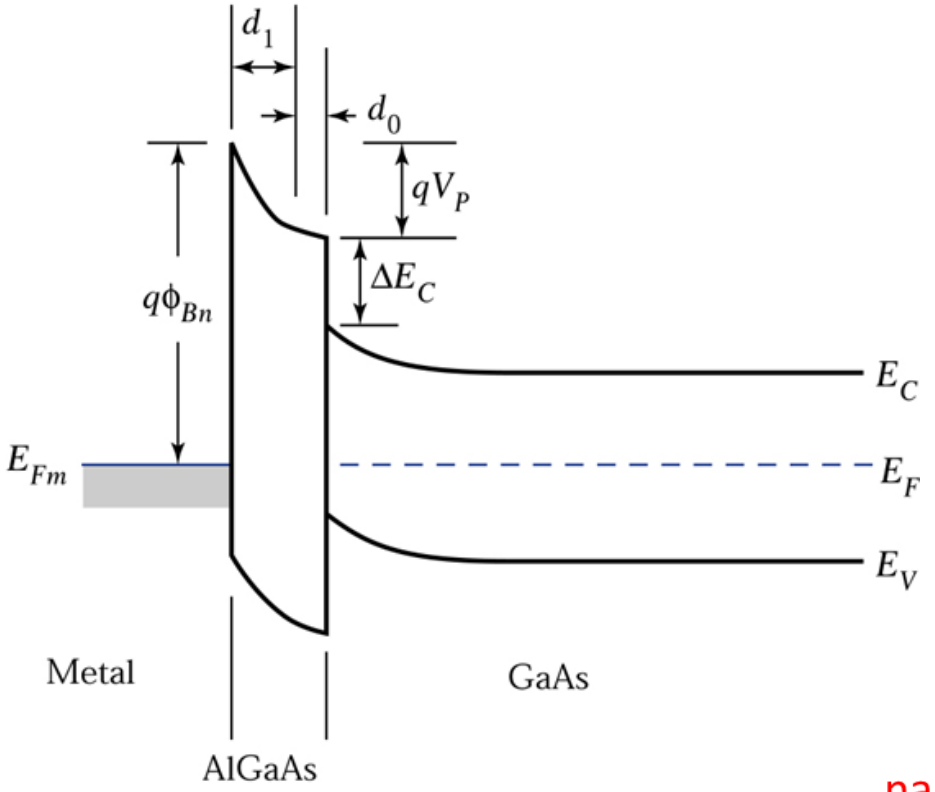


Metal Semiconductor Field Effect Transistor
(MESFET)

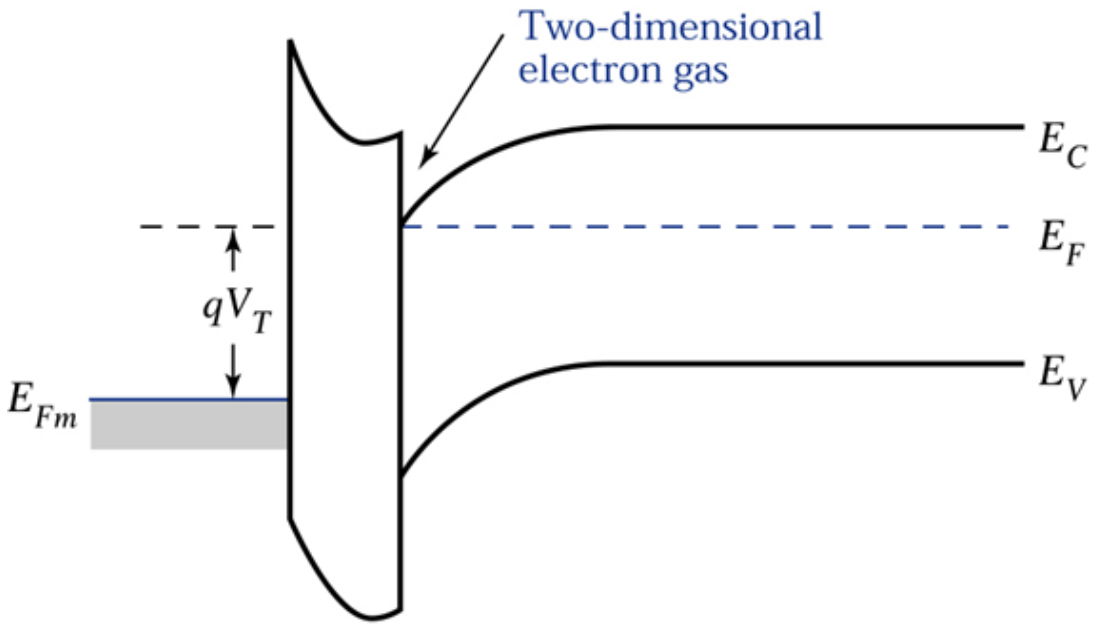


Modulation-doped Field Effect Transistor
(MODFET)

MODFET QW



Equilibrium



Under bias

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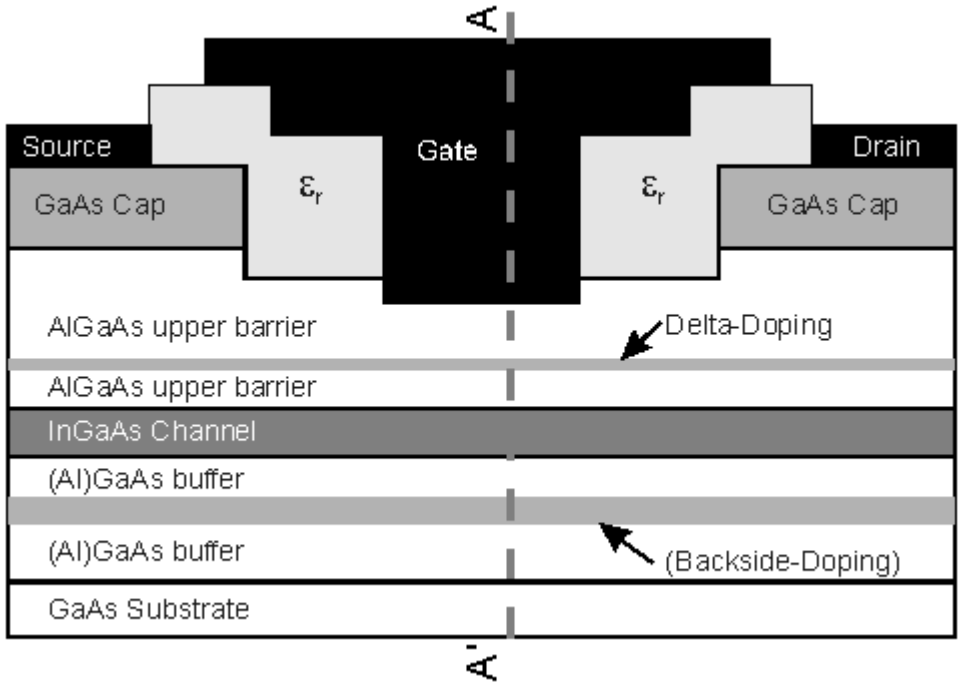
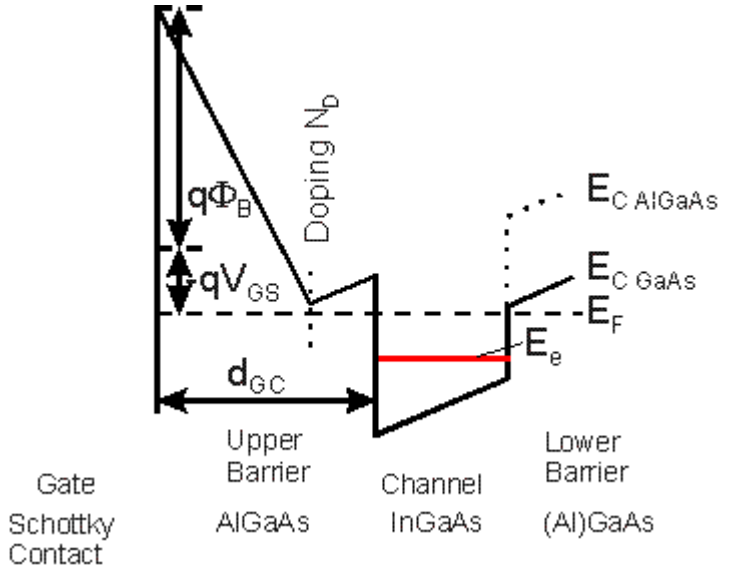
1D Heterostructure Tool

High Electron Mobility Transistor (HEMT)





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1D Heterostructure Tool

…to be continued

Thank you!

E-class Support

Lesson	Kassap	Fu
1	3.2	1.1, 1.3, 1.9, B4, B5
2	3.5	B8
3		4.1, 4.2, 4.3.1, 4.4, 4.5.1