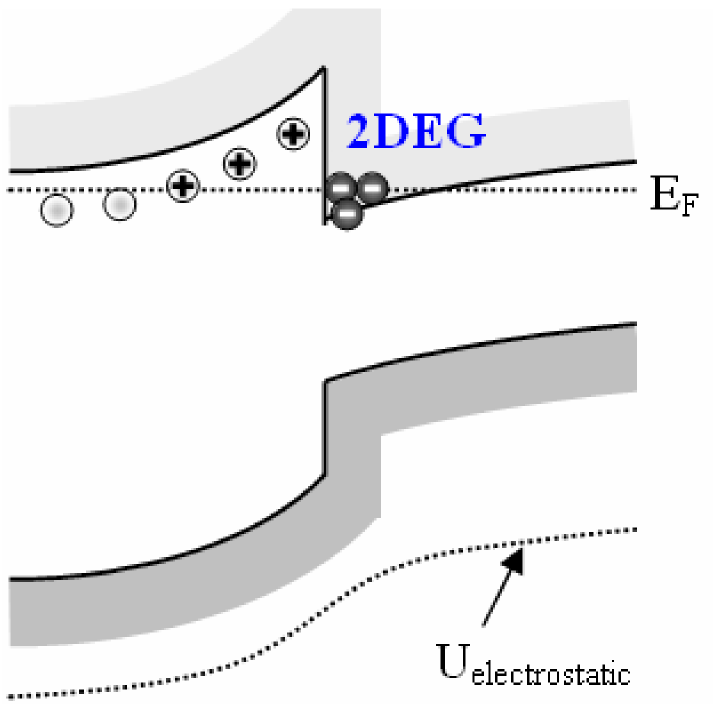
The Two-Dimensional Electron Gas (2DEG)

Producing a 2DEG in a Field Effect Transistor (FET)

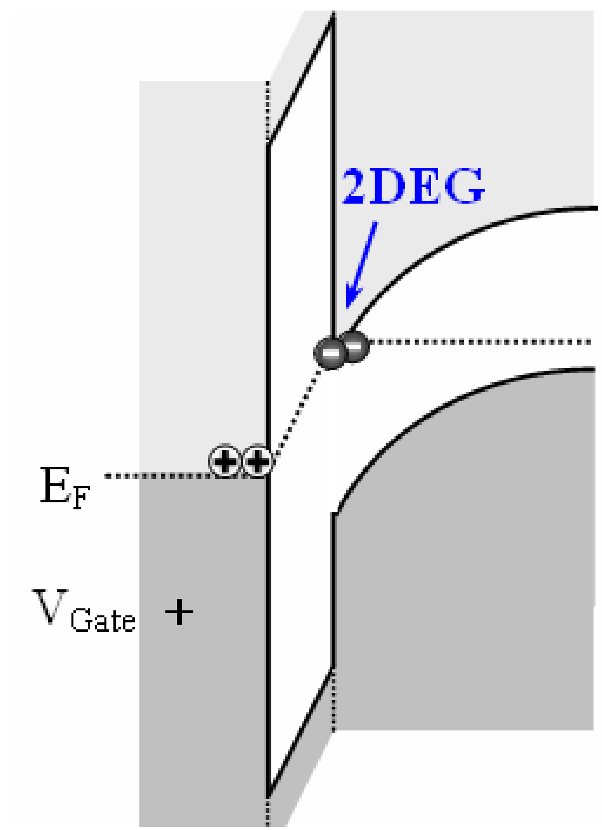
MODFET

GaAlAs GaAs



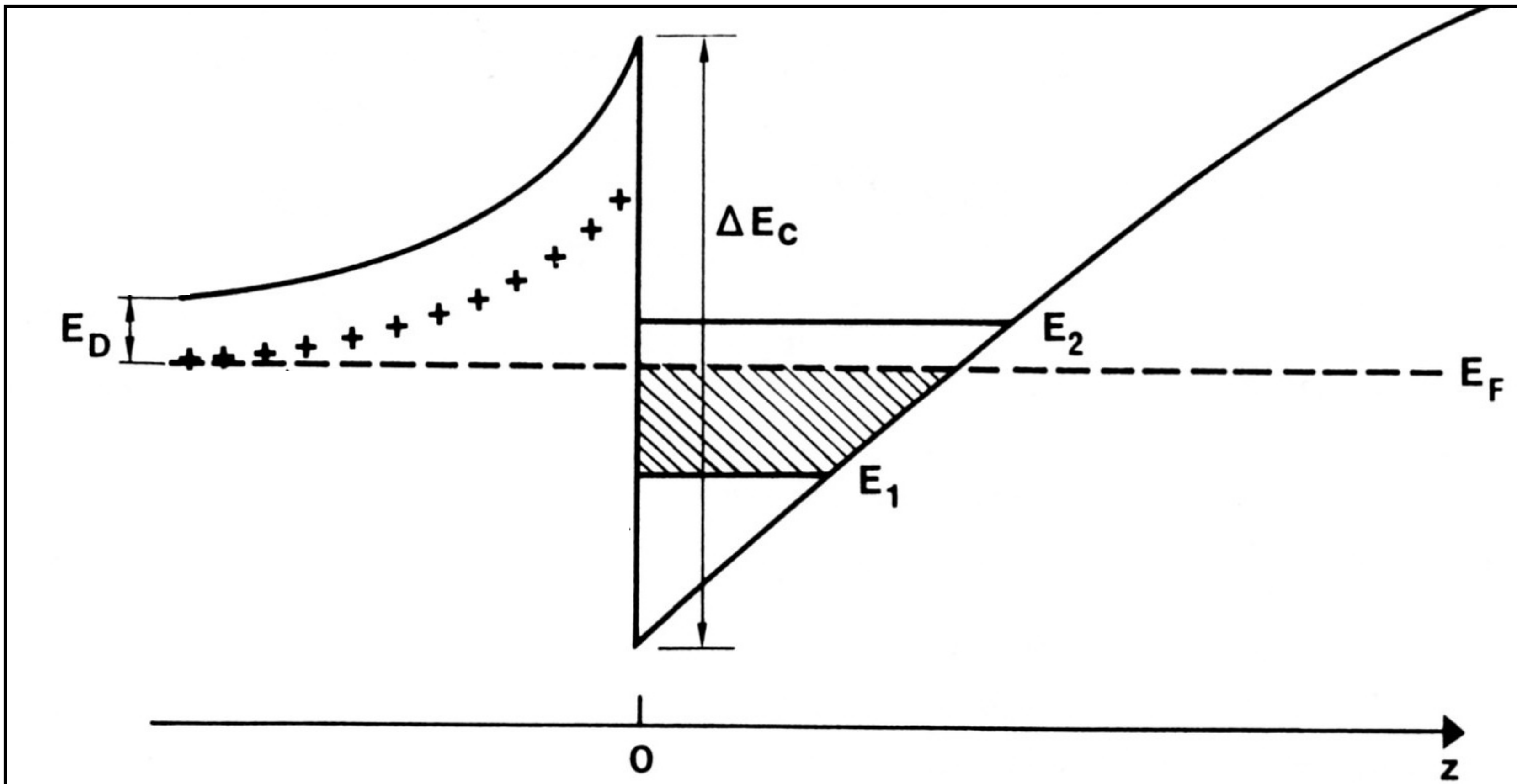
MOSFET

SiO_2 Si



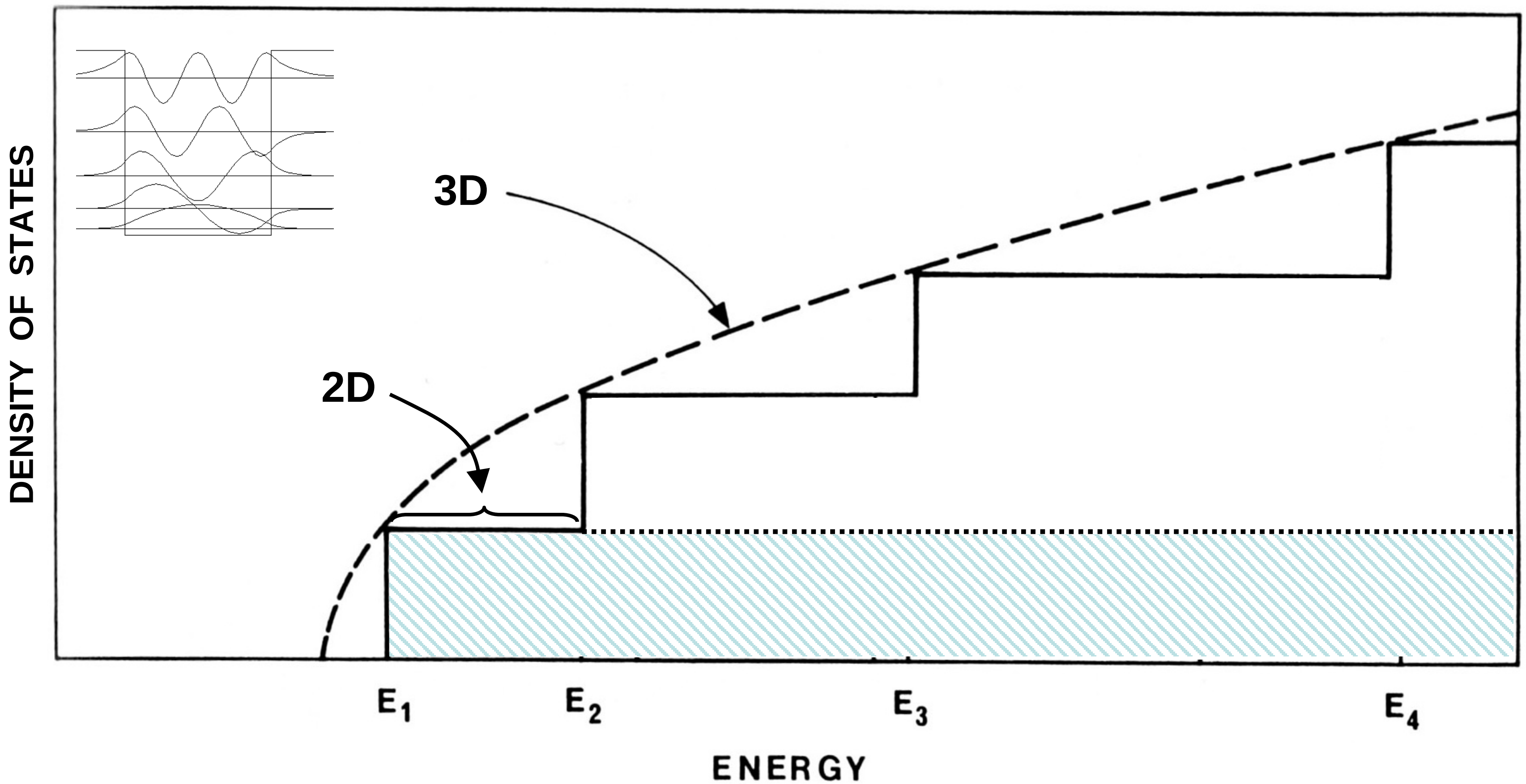
Triangular Potential at the Interface

- Quantized energy levels E_1, E_2, … in the triangular potential
- The shaded region represents 2D electrons with extra kinetic energy (for movement ⊥ to the drawing, ∥ to the 2DEG).

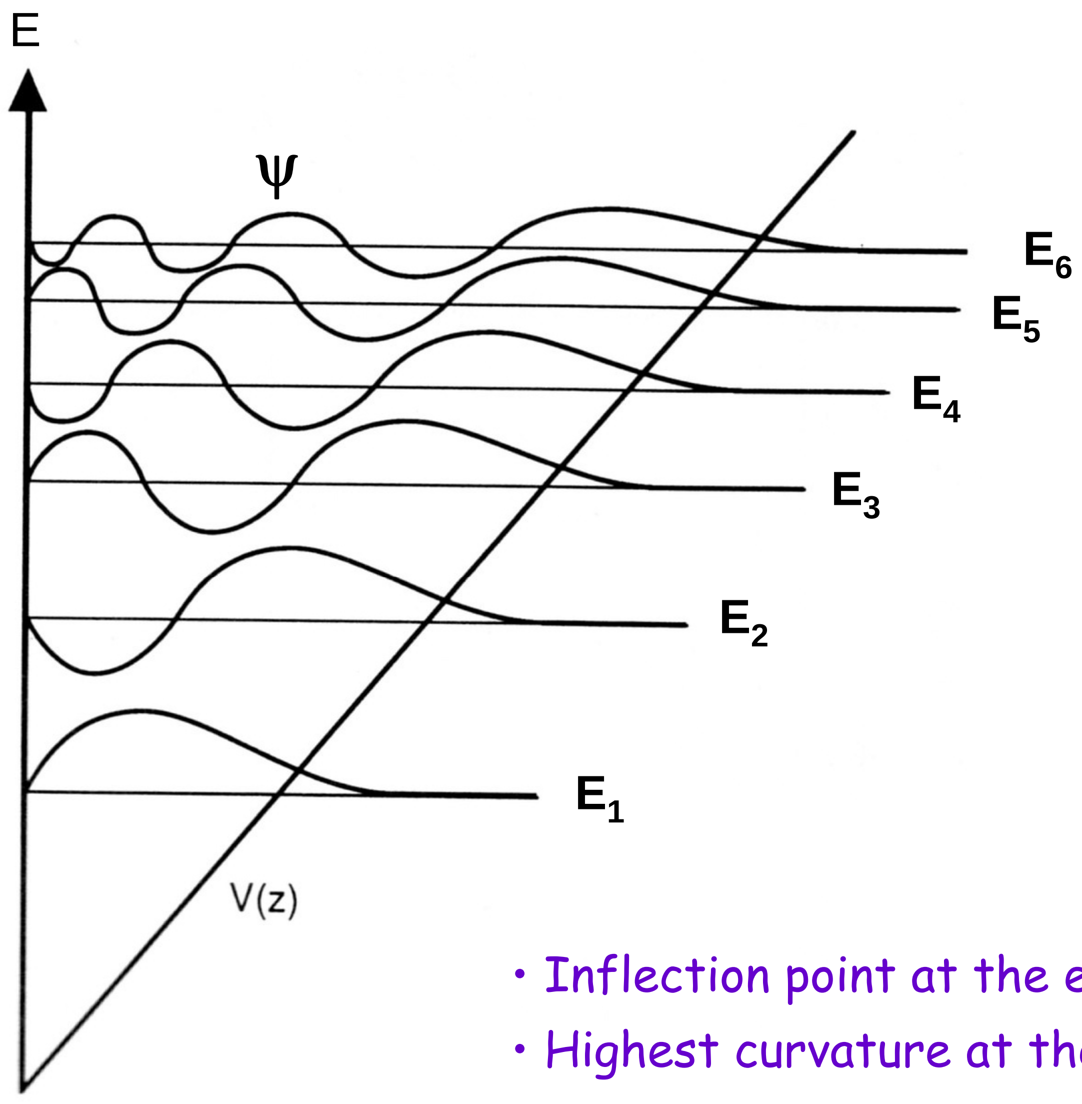


Density of States from 2D to 3D

Approximate the 3D density of states by a sequence of 2D step functions for the quantized states E_n. A true 2D density of state is obtained only when E_F lies between E_1 and E_2, i.e. only the lowest quantum state is occupied.



Wave Functions in a Triangular Potential Well



- Inflection point at the edge of the well.
- Highest curvature at the lowest point of the well.

Practical Aspects for Producing a 2DEG

In order to occupy only the lowest quantum state ($E_F < E_2$) one needs very low electron density (lower than in typical transistor applications). This can be achieved by making the gate less positive. Typical electron densities are 10^{10} e^-/cm^2 , i.e. only $\approx 10^{-5}$ electrons per surface atom ! The interface defect density has to be even lower.

Furthermore, the Fermi-Dirac cutoff needs to be much sharper than the level spacing: $2\, k_B T \ll (E_2 - E_1)$
That requires either low temperature or very narrow quantum wells.
Devices made with standard lithography require liquid He temperature.
With nanometer devices it is possible to work at room temperature.