The Two-Dimensional Electron Gas (2DEG)

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

MODFET

GaAlAs

GaAs

MOSFET

SiO₂

Si

2DEG

$E_F$

$U_{\text{electrostatic}}$

$V_{\text{Gate}}$
Triangular Potential at the Interface

- Quantized energy levels $E_1, E_2, \ldots$ in the triangular potential

- The shaded region represents 2D electrons with extra kinetic energy (for movement $\perp$ to the drawing, $\parallel$ 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 \(10^{10} \text{ e}^-/\text{cm}^2\), 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: \(2k_B T \ll (E_2 - E_1)\) 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.