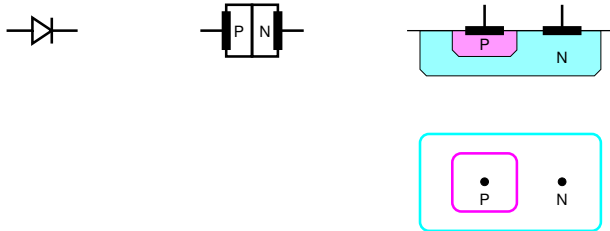


Diodes and Bipolar Transistors

Diode

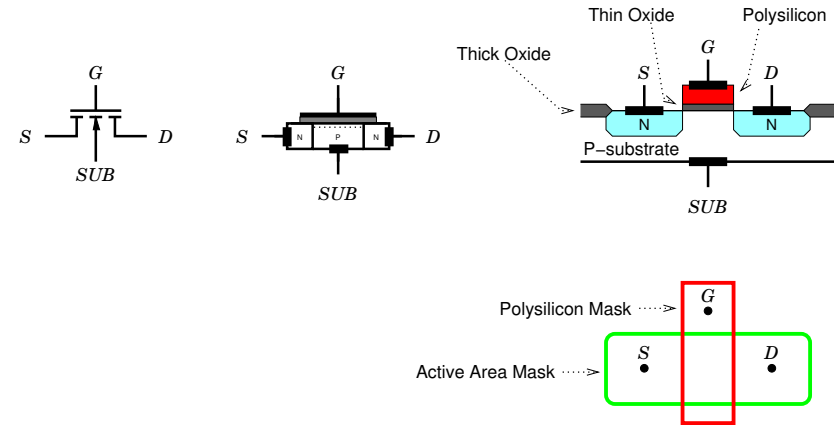


- Ideal structure - 1D
- Real structure - 3D
- Depth controlled implants.

3001

MOS Transistors

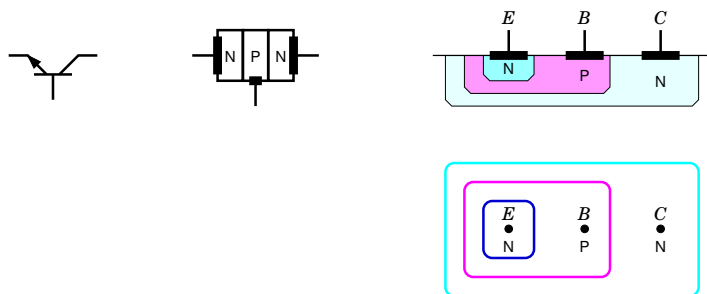
Simple NMOS Transistor



3003

Diodes and Bipolar Transistors

NPN Transistor



- Two n-type implants.

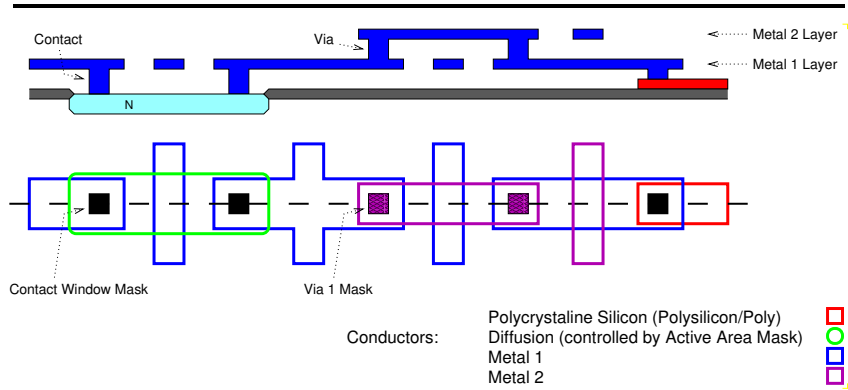
3002

Simple NMOS Transistor

- Active Area mask defines extent of *Thick Oxide*.
- Polysilicon mask also controls extent of *Thin Oxide* (alias *Gate Oxide*).
- N-type implant has no extra mask.
 - It is blocked by thick oxide and by polysilicon.
 - The implant is *Self Aligned*.
- Substrate connection is to bottom of wafer.
 - All substrates to ground.
- Gate connection not above transistor area.
 - Design Rule.

3004

Interconnect



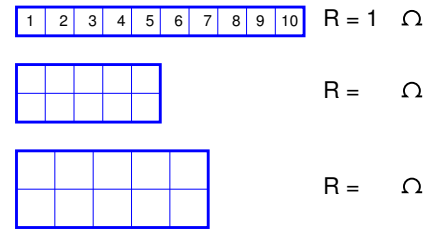
- Crossing conductors on different masks do not interact¹.
 - Explicit contact/via is required for connection.
- Crossing conductors on the same mask are always connected.

¹the exception to this rule is that polysilicon crossing diffusion gives us a transistor

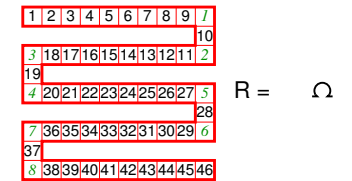
Components for IC Design

Resistors

Examples for Metal
 assuming $R_s = 0.1$ ohms per square



Example for Polysilicon
 assuming $R_s = 200$ ohms per square

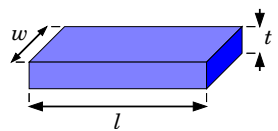


- for larger resistances we need minimum width poly (often combined with a serpentine shape) to save on area
- corner squares count as half² squares
- for predicatability and matching we may need wider tracks without corners

²effective resistance $\approx 0.56 R_s$

Interconnect

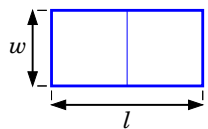
Resistance



$$R = \left(\frac{\rho}{t}\right) \left(\frac{l}{w}\right)$$

where ρ is the resistivity constant
 $3.2 \times 10^{-8} \Omega m$ for aluminium
 $1.7 \times 10^{-8} \Omega m$ for copper

Since t and ρ are fixed for a particular mask layer, the value that is normally used is the sheet resistance: $R_s = \left(\frac{\rho}{t}\right)$.



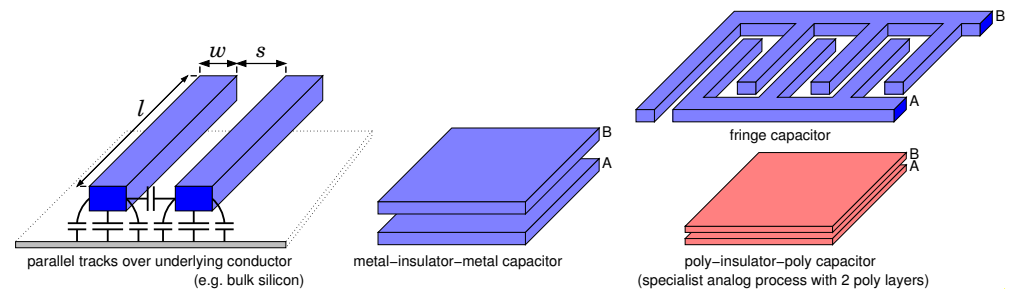
$$R = R_s \left(\frac{l}{w}\right)$$

where R_s is sheet resistance
 $0.1 \Omega/\square$ for 170nm thick copper

$R_s =$ resistance of a square (i.e. $w = l$) so the units for R_s are Ω/\square (ohms per square).

Components for IC Design

Capacitors



- Capacitance to underlying conductor $C = C_a w l + 2 C_f l$
- Coupling capacitance to adjacent track $C = C_c l/s$
 where C_a, C_f, C_c are constants for a given layer and process
 in digital designs our only aim is to minimise parasitic capacitance