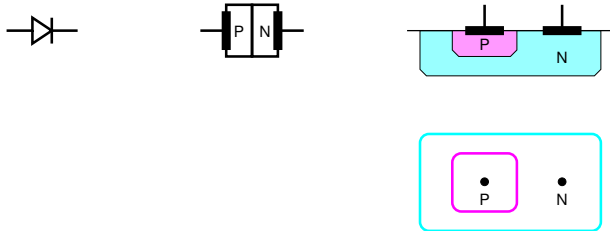


Diodes and Bipolar Transistors

Diode

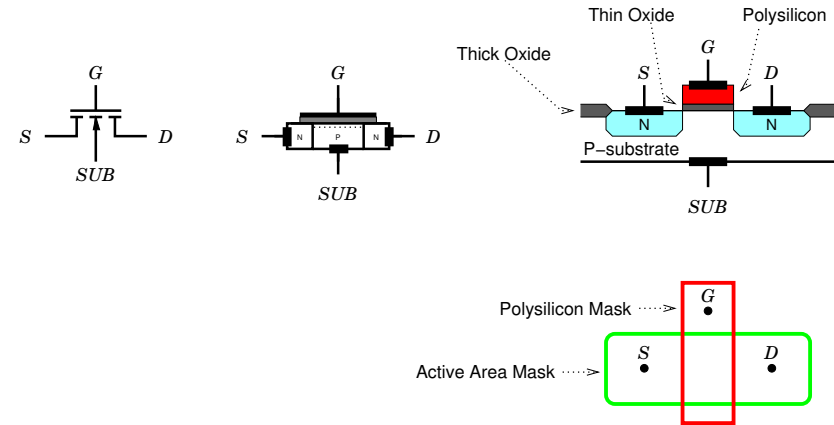


- Ideal structure - 1D
- Real structure - 3D
- Depth controlled implants.

3001

MOS Transistors

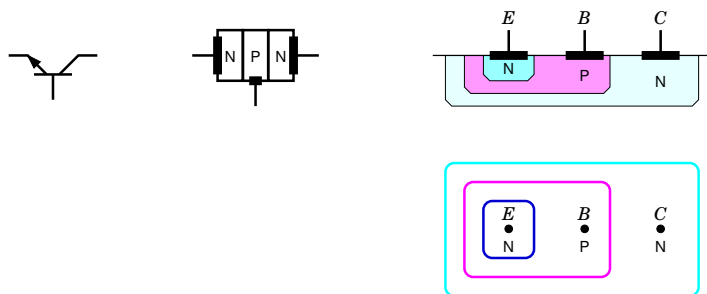
Simple NMOS Transistor



3003

Diodes and Bipolar Transistors

NPN Transistor



- Two n-type implants.

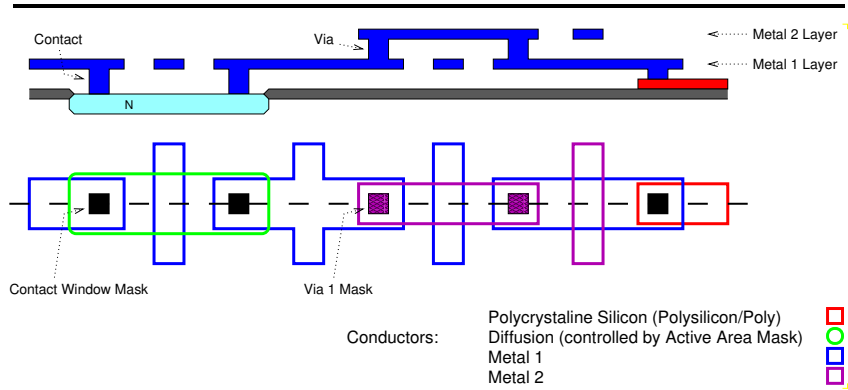
3002

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



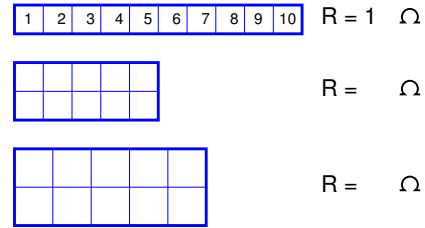
- Crossing conductors on different masks do not interact<sup>1</sup>.  
 - Explicit contact/via is required for connection.
- Crossing conductors on the same mask are always connected.

<sup>1</sup>the exception to this rule is that polysilicon crossing diffusion gives us a transistor

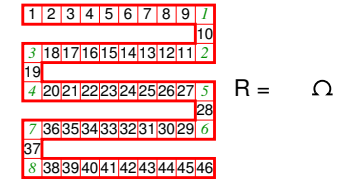
# Components for IC Design

## Resistors

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



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

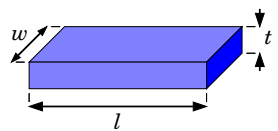


- for larger resistances we need minimum width poly (often combined with a serpentine shape) to save on area
- corner squares count as half<sup>2</sup> squares
- for predicatability and matching we may need wider tracks without corners

<sup>2</sup>effective resistance  $\approx 0.56 R_s$

# Interconnect

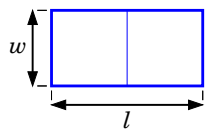
## Resistance



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

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



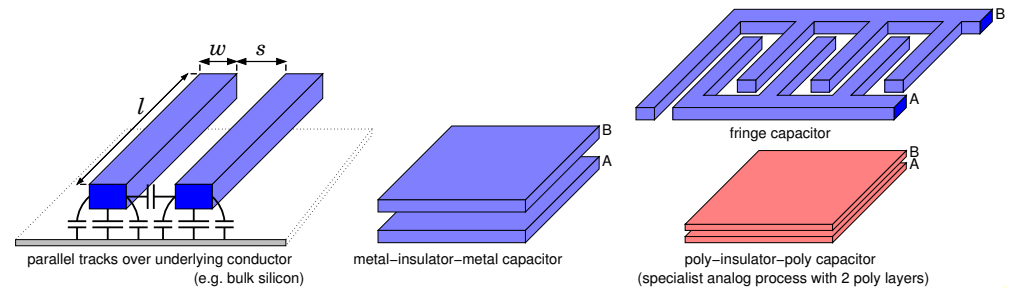
$$R = R_s \left(\frac{l}{w}\right)$$

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  $\Omega/\square$  (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