Components for Digital IC Design
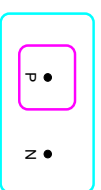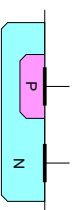
Diodes and Bipolar Transistors
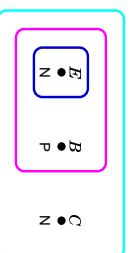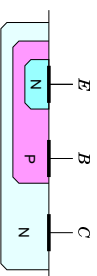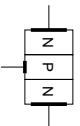
Diode

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

Components for Digital IC Design
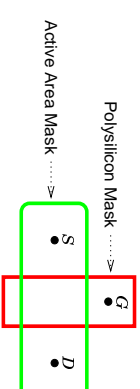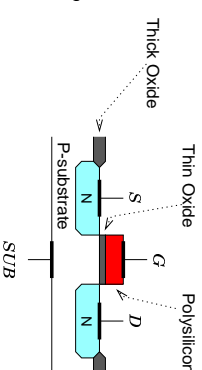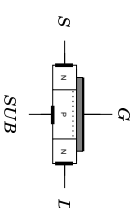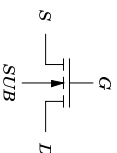
Diodes and Bipolar Transistors

NPN Transistor

E B C

- Two n-type implants.

Components for Digital IC Design

MOS Transistors

Simple NMOS Transistor

S G D

SUB

SUB

Thick Oxide

Thin Oxide

P-substrate

Polysilicon

SUB

Polysilicon Mask

Active Area Mask

Components for Digital IC Design
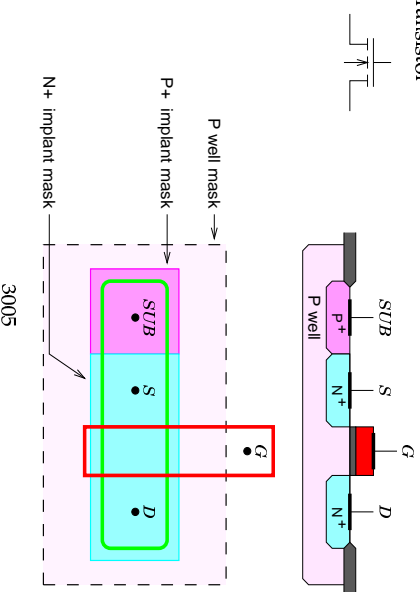
Simple NMOS Transistor

- 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.

Components for Digital IC Design

MOS Transistors

NMOS Transistor

N+ implant mask

P+ implant mask

P well mask

P well

SUB
P+
S
N+
G
D
N+

SUB
S
G
D

# Components for Digital IC Design

NMOS Transistor

Where it is not suitable for substrate connections to be shared, a more complex process is used.

- Five masks must be used to define the transistor:
  - P Well
  - Active Area
  - Polysilicon
  - N+ implant
  - P+ implant
- P Well, for isolation.
- Top *substrate* connection.
- P+/N+ implants produce good *ohmic* contacts.


CMOS Process

CMOS Inverter

N-well
Active Area
N implant
P implant
Polysilicon
Contact Window
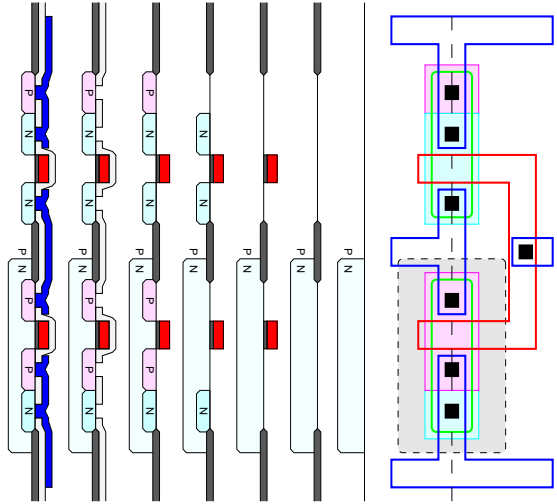Metal

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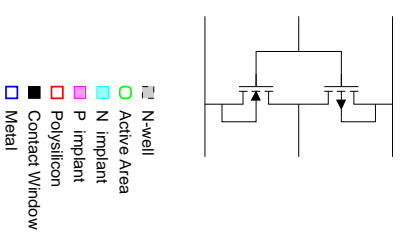
CMOS Process

CMOS Inverter

- The process described here is an *N Well process* since it has only an N Well. P Well and Twin Tub processes also exist.
- Note that the P-N junction between chip substrate and N Well will remain reverse biased.
  Thus the transistors remain isolated.
- N implant defines NMOS source/drain and PMOS substrate contact.
- P implant defines PMOS source/drain and NMOS substrate contact.
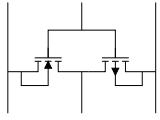
N-well

Active Area
defines Thick Oxide

Polysilicon
defines Thin Oxide

N implant
aligned to AA and Poly

P implant
aligned to AA and Poly

Contact Window

Metal

3009