MOS Transistors

Readings: Chapter 1

N-type

P-type

conductor - gate
insulator
source
drain

conductor - gate
insulator
source
drain

substrate

substrate

n

p

n

p

p

n
Transistor Switches

N-type

G=0

= open switch

G=1

= closed switch

however:

0 —— good 0
1 —— poor 1

P-type

G=0

= closed switch

G=1

= open switch

however:

0 —— poor 0
1 —— good 1

TRUE = 1 = 4 to 5 Volts
FALSE = 0 = 0 to 1 Volts
Basic Gates

Inverter

\[ \text{Vdd (source of 1's)} \]

\[ \text{GND (source of 0's)} \]

Nand Gate

\[
\begin{array}{c}
\text{A} \\
\text{B} \\
\text{C}
\end{array}
\]

\[
\begin{array}{c|c|c}
\text{A} & \text{B} & \text{C} \\
0 & 0 & 0 \\
0 & 1 & 1 \\
1 & 0 & 1 \\
1 & 1 & 0
\end{array}
\]

Nor

\[
\begin{array}{c}
\text{A} \\
\text{B} \\
\text{C}
\end{array}
\]

\[
\begin{array}{c|c|c}
\text{A} & \text{B} & \text{C} \\
0 & 0 & 0 \\
0 & 1 & 0 \\
1 & 0 & 1 \\
1 & 1 & 0
\end{array}
\]
Basic CMOS

CMOS is multiple layers of conducting material, separated by insulation.

Contacts/vias are cuts in the insulation to connect layers
The interaction of Polysilicon & Diffusion creates transistors
Basic Patterning

Add material (e.g., silicon dioxide (SiO2))
Apply photoresist
Expose through a mask
Develop and etch resist
Etch material
Remove resist
Adding Material: Growing SiO2

Expose wafer to oxidizing atmosphere at high temperature
   Wet process: atmosphere with H2O @ 900-1000 degrees C
   Dry process: pure O2 @ 1200 degrees C
Oxide grows both ways
   SiO2 has roughly twice the volume of Si
   Half above, Half below
Adding Material: Other Techniques

Diffusion and Ion Implantation
  Adds dopants to silicon
CVD: Chemical Vapor Deposition
  Silicon, silicon oxide, silicon nitride, etc.
Sputtering and thin-film deposition
  Aluminum and polysilicon
Photoresist

UV light sensitive organic material

Two types of resist
  Positive resist: UV light breaks it down
  Negative resist: UV light hardens it

Selectively expose through a mask

Masks are glass plates
  patterned areas stop UV light

Develop (harden) desired areas by heating

Remove unwanted resist
  Use weak organic solvent
Etch Material

Etch using selective solvent
   Buffered HF dissolves SiO2 but not Si
   Photoresist protects areas from etching
Plasmas, sputtering, etc.
   Excited ions blast away material
Remove resist with strong organic solvent
Mask Making

Traditionally a lithographic process
   Rectangles are 'flashed' onto photographic plate
   Mechanical alignment limits precision
Electron beam techniques are now widely used
   Write each pixel sequentially
Both techniques generate a reticle
   Typically 10X larger than final size
10X reticle is used to produce final mask
   Step-and repeat process