520.216
Introduction to VLSI Systems
Lecture 3

Integrated Circuits Fabrication
and
Very Large Scale Integration
## Charges and Their Movement (I)

- Electrons
- Ions

<table>
<thead>
<tr>
<th>Where?</th>
<th>How Well?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids</td>
<td>Superconductors</td>
</tr>
<tr>
<td>Liquids</td>
<td>Conductors</td>
</tr>
<tr>
<td>Gases</td>
<td>Semiconductors</td>
</tr>
</tbody>
</table>

and

**INTERFACES**

- How?

  - Drift / Diffusion (Classical)
  - Tunneling (Quantum Mechanical)
Charges and Their Movement (II)

**FUNCTIONAL**

- Electrical conduits (1D, 2D, 3D)
- Transistors
- switches

**STRUCTURAL**

- Etching
- Film deposition (electroplating)

**REDOX**

We now consider transport in the solid-state and more specifically in the semiconductor Silicon.

The microelectronics world does not use SI units! Distance will be measured in cm and not meters.

For example: conductivity has units of ohm-cm.
Silicon!
Silicon molecule
5 silicon atoms in a unit cell
Diamond lattice
Covalent bonds

Silicon molecules: http://www.eere.energy.gov/pv/simolecule.html

P.D. Neillist, "Incoherent Transmission Electron Microscopy"
Phys. Rev. Lett. 81, 4156 (9 Nov. 1998)
Doped Silicon

N- doped

- bound electrons
- free electrons and
- holes

P- doped

Silicon molecules: http://www.eere.energy.gov/pv/simolecule.html
Equilibrium Carrier Densities

\[ n_n p_o = n_i^2 = 10^{20} \text{ cm}^{-3} \]

where \( n_o \) is electron and \( p_o \) hole carrier concentrations in most cases of interest the donor doping \( N_D \) or acceptor \( N_A \) doping concentration is much larger than the intrinsic concentration \( n_i \) so that

\[
p_o = N_A \quad \text{and} \quad n_o = \frac{n_i^2}{N_A} \quad p - \text{type}
\]

\[
n_o = N_D \quad \text{and} \quad p_o = \frac{n_i^2}{N_D} \quad n - \text{type}
\]

by convention, donor or acceptor concentrations as well as electron and hole concentrations are given as a number per \ cm^3 \]
Integrated Circuit Fabrication

- Mask set
- Wafer
- Film formation
- Lithography
- Etching
- Impurity doping
- Wafer out
Where is it done?

UMC 300mm wafers

Die size: 20x20 mm²
300mm ODPVT: 148
280mm ODPVT: 67 - 2.6
Basic CMOS components

- Conductors
- Switches (MOS transistors)
- Capacitors (MOS capacitors)
- Inductors
- Resistors
Bulk CMOS Technology (I)
Bulk CMOS Technology (II)

- Polysilicon 2
- Contact
- Metal 1
Bulk CMOS Technology (III)

vias

metal 2

metal 3
CMOS Inverter

(a) CMOS Inverter schematic

(b) CMOS Inverter cross-section

(c) CMOS Inverter cross-section detail
Metallization Details

IBM PowerPC 500nm

UMC CMOS 90nm

- FSG (k=3.7)
- Low K (k=2.9)

L90 1P9M Cu/Low-k (k<2.9)