What is the Course All About?

- The course is an "***illustrated***" survey of the underlying principles of silicon-based MOS semiconductor manufacturing and design
- Multiple-step integration of
  - Material Science
  - Electrical Engineering
  - Chemical Engineering

Course Objectives

Introductory subject to theory and technology of integrated circuit fabrication

– Course will discuss on theories and applications of semiconductor devices and focus on Si CMOS.

– Course will discuss theory of basic processing techniques

- **Substrate Modification**:
  Crystal Growth, Diffusion, Oxidation, Ion Implantation, Epitaxy, Molecular Beam Epitaxy (MBE)
- **Thin Film Deposition**:
  Chemical Vapor Deposition (CVD) & Physical Vapor Deposition (PVD)
- **Pattern Definition**
  Lithography(Photo, E-beam & Ion) & Etching and Lift-off

– Course will discuss MOS Transistor and its characteristics

– Course will discuss basic VLSI lay-out design

Introduction

- **Basic Atomic Theory**

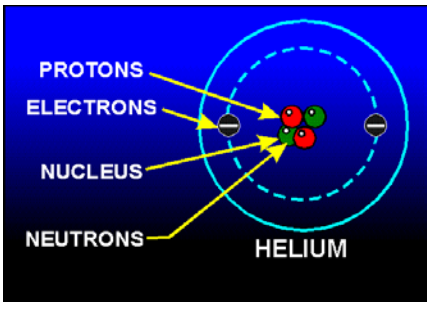
- To study the semiconductor devices we must study the atomic theory. Bohr model of atomic structure is the simplest model

Bohr Atom

- The most fundamental unit of all matters is the atom. Three distinct types of particles

  1- neutrons **2- protons**
  3- electrons

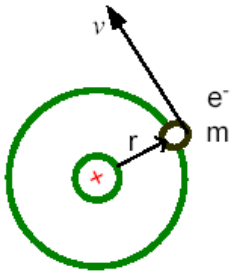
- Neutrons and protons make up the nucleus or core of the atom
- Neutrons have no electrical charges while proton are charged positively.
- Electrons have a weight of about 1/1800 of a neutron or proton.



Bohr's made the ffg postulates:

- That the atom has a massive positively charge nucleus.
- That the electrons revolve round their nucleus orbits, the centrifugal force being balanced by electrostatic pull between the nucleus and electrons.
- That an electron cannot revolve round the nucleus in any arbitrary orbit but in just certain definite discrete orbits (called stationary orbits). Only those orbits are possible (or permitted) for which the orbital angular momentum (i.e moment of momentum) of the electron is equal to an integral multiple of $h/2\pi$.

- Orbital angular momentum = $n\ h/2\pi$



$\omega I = n\ h/2\pi$

$(mr^2)\ \omega = n\ h/2\pi$

And so, the momentum around the nucleus is mvr and is given by $(mr^2)\ v/r = n\ h/2\pi$

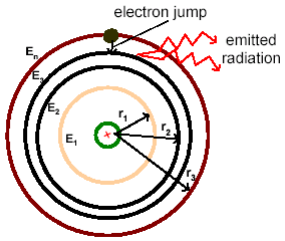
$$mrv = n\ h/2\pi$$

Where , n is an integer representing the orbits and is called the *principle quantum number* and *h* is Plank's constant.

- While revolving in these permitted stationary (or stable) orbits, the electron does not radiate out any electromagnetic energy. In other words, the permissible orbits are non-radiating paths of the electron;
- The atom radiates out energy only when an electron jumps from one orbit to another. If E2 and E1 are the energies corresponding to two orbits before and after the jump, the frequency of the emitted photon is given by the relation

$E2 - E1 = hf$ or $\Delta E = hf$

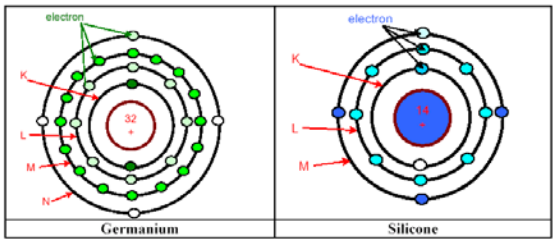
Where, f is the frequency of the emitted radiations



Electron Orbits and Energy

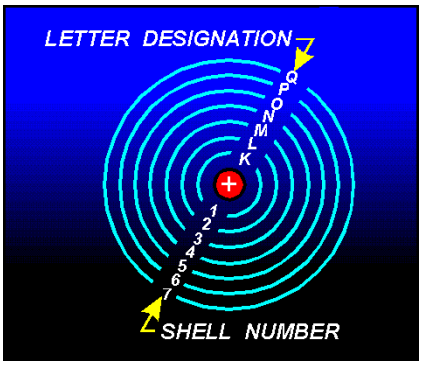
- For each isolated atom there are only a certain number of orbits available that exist at discrete levels. The orbits represent energy levels of the electrons. Each orbit corresponds to certain value of total electron energy. No more than two electrons may exist in one level or orbit. This is known as ***Pauli's Exclusion Principle***.
- The electron volt *ev* is defined as that amount of unit energy gained or lost when an electron moves with or against a potential difference of one volt. In terms of Joules $ev = 1.6 \times 10^{-19}$ J.

- No electron may exist at any energy level or orbit other than one of the permissible levels. At most, two electrons can have exactly the same energy level or occupy the same orbit at the same time.
- A group of permissible levels or orbits are combined into electron "shells". The difference in energy levels within a shell is smaller than the difference in energy between shells. Thus, the shells can be regarded as appropriate groupings of the possible orbits.



- The numbers of electrons existing in the various shells (which are made of sub-shells) determine the chemical properties of the atom. The electron shells in an atom are usually denoted by letters K, L, M, N,…., the K-shell being the closes to the nucleus.
- Atoms are complex than others if it contains more orbiting electrons. The distribution of electron in an atom in its sub-shells around the nucleus follows the following rules:
  1- Maximum number of electrons a shell can have is = $2n^2$.
  2- In the nth shell, there are n sub-shells having different values of l such as 0,1,2,… (n-1), where l azimuthally quantum number.
  3- Each sub-shell can accommodate a maximum of 2(2 l +1) electrons.

Shell Designation



SHELL			
Numerical	Literal	Subshells	Capacity
1	K	s2	2 e-
2	L	s2, p6	8 e-
3	M	s2, p6, d10	18 e-
4	N	s2, p6, d10, f14	32 e-
•	•	•	•
•	•	•	•
•	•	•	•