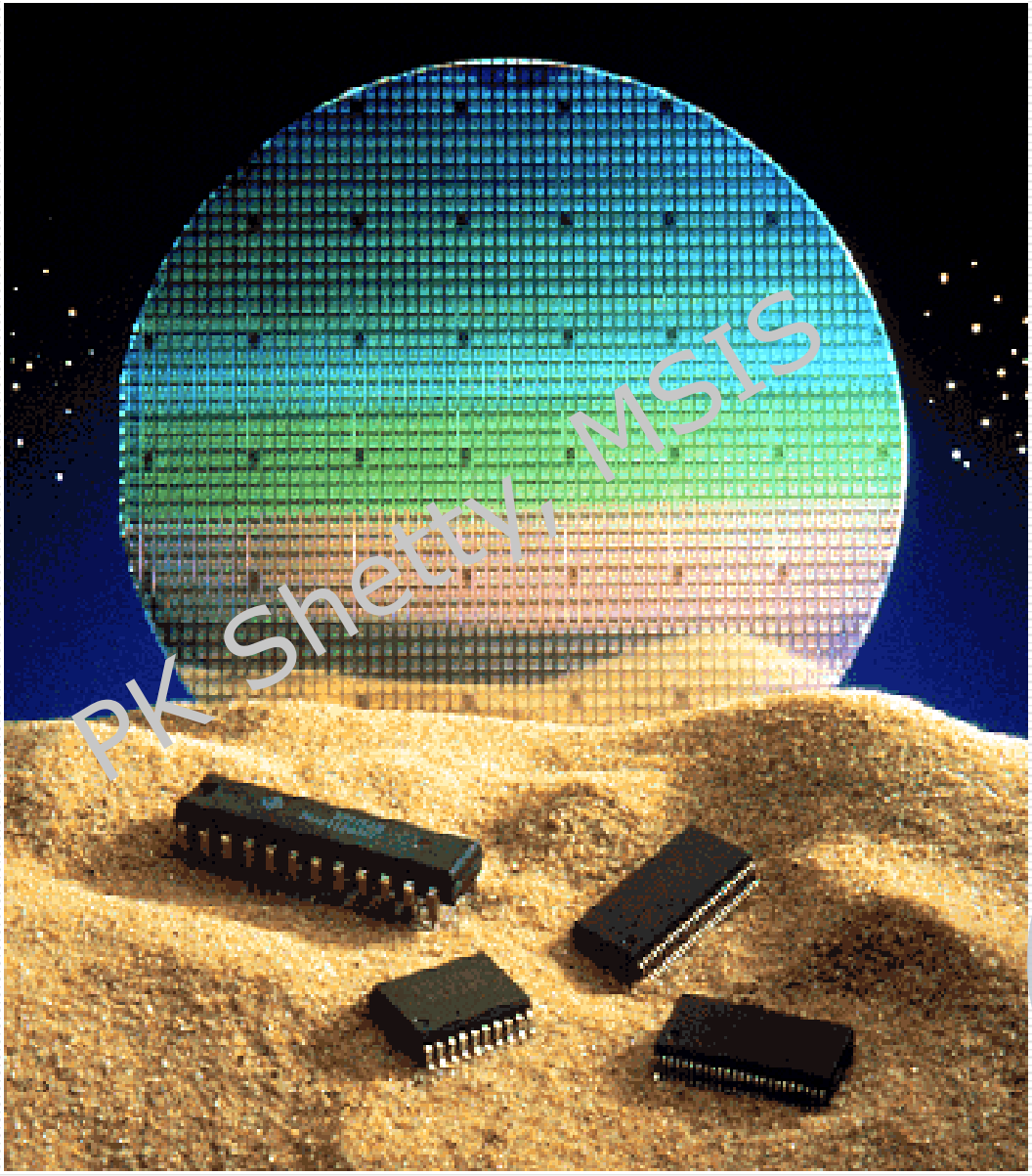
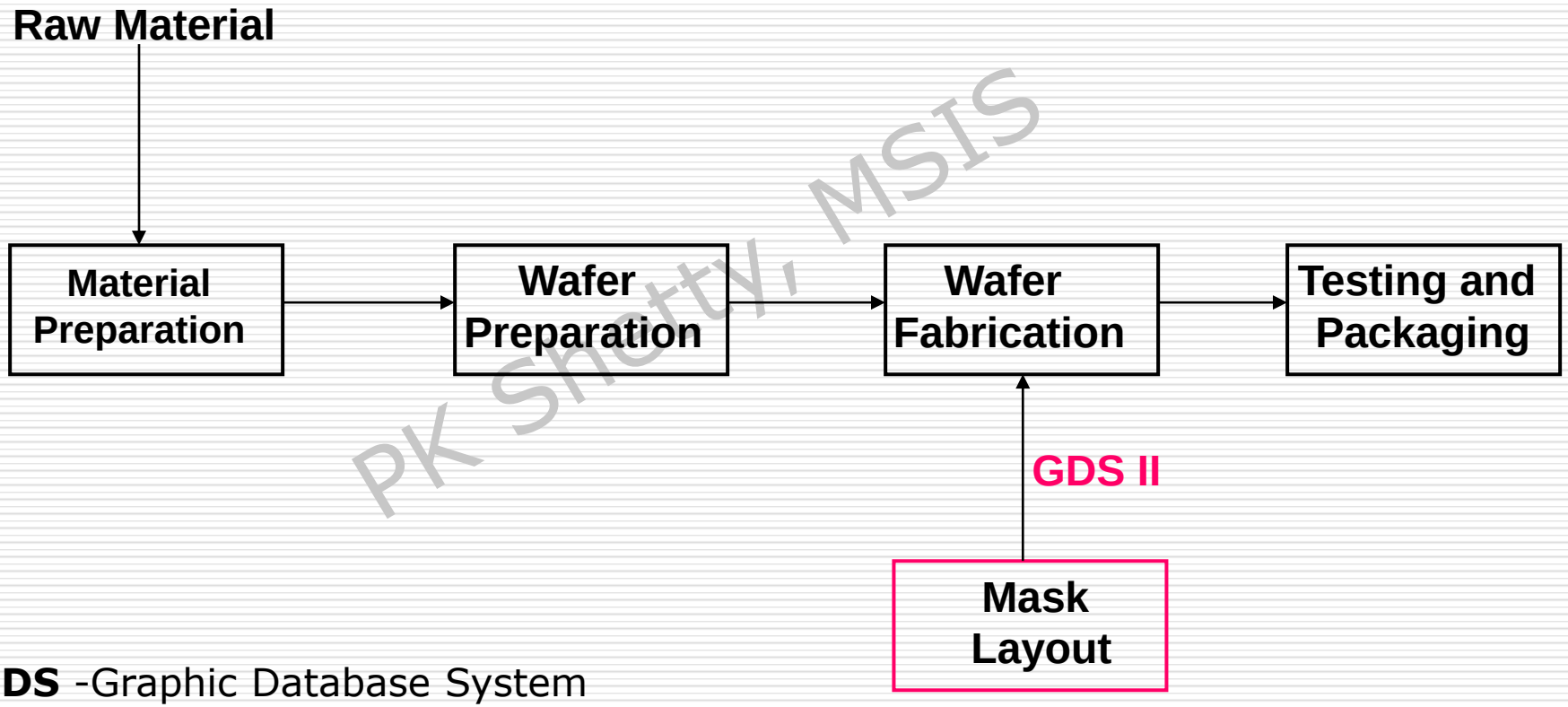
Semiconductor Materials



Stages of IC Manufacturing

1. Material Preparation – raw material mined and purified.
2. Wafer Preparation – Done in a separate dept. or supplied by vendors.
3. Wafer Fabrication – Devices or ICs are actually formed on wafers (merchant / Captive producers)
4. Testing and Packaging

Stages of Manufacturing



GDS -Graphic Database System
Geometric Data Stream

Atomic Structure

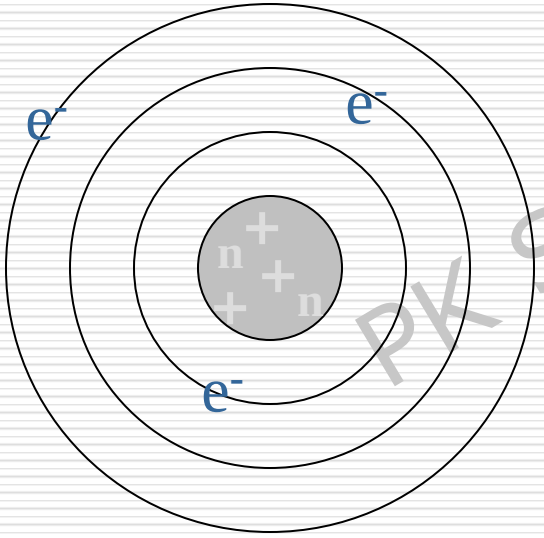
- There are 118 ***elements***, and the entire universe is made from these elements
- The smallest piece of any element that still retains its properties is called an ***atom***
- Atoms are the building block of the physical universe

Atomic Structure

- Further subdivision of the atom will result in 3 subatomic particles: **Protons**, **Electrons** and **Neutrons**
- They are arranged in a particular order which gives physical, chemical and electrical properties to the material

Bohr Atomic Model

- The structure / organization of protons, electrons, neutrons are best explained by a model first proposed by a famous physicist, Niels Bohr in 1915



Bohr Atomic Model

Each orbit/shell has a max. number of positions available for electrons.

Shells: K, L, M, N, …

Capacity: 2, 8, 18, 32, … $2n^2$

Subshells: s, p, d, f

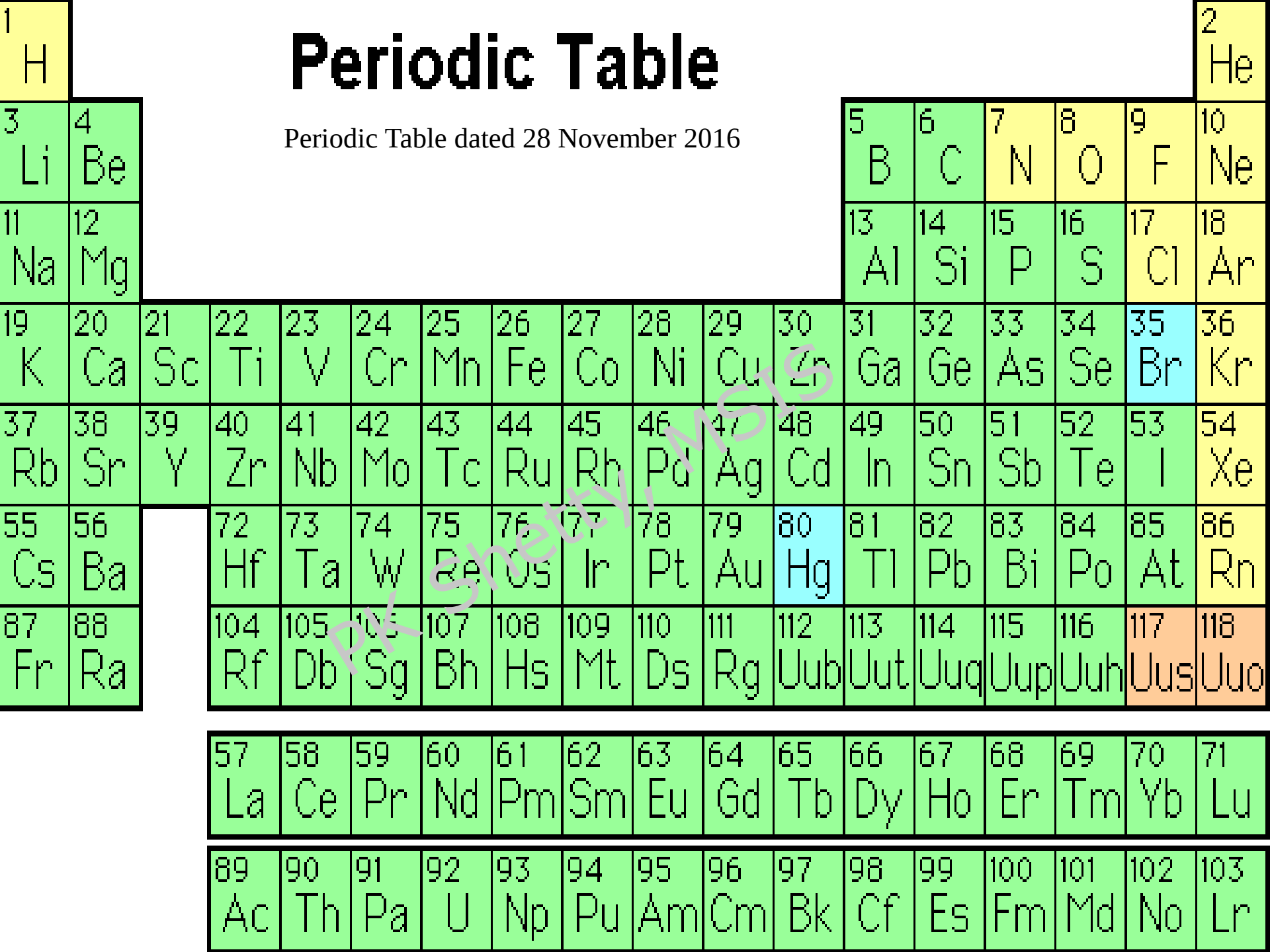
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$…

Periodic Table

- It is the basic reference to the elements.
- Elements range from the simplest, hydrogen, to the most complicated one, lawrencium.
- In each atom of an element, the number of protons is equal to number of electrons.
- ***Atomic number*** – no. of protons or electrons.
- Each orbit **n** can hold **$2n^2$** electrons.
- Elements with the same no. of outer-orbit (valence) electrons have similar properties and are grouped in the same column in the table.

Periodic Table

Periodic Table dated 28 November 2016



Periodic Table

- Elements are stable with a filled or with 8 electrons in the outer ring.
- Atoms seek to combine with other atoms to create the stable condition of full orbits or 8 electrons in their outer ring through sharing.

Electrical Conduction

- Conductors
- Insulators (Dielectrics)
- Semiconductors

Conductors

- Conduct electricity
- The attractive hold of the protons in the nucleus of the atom on the electrons is relatively week

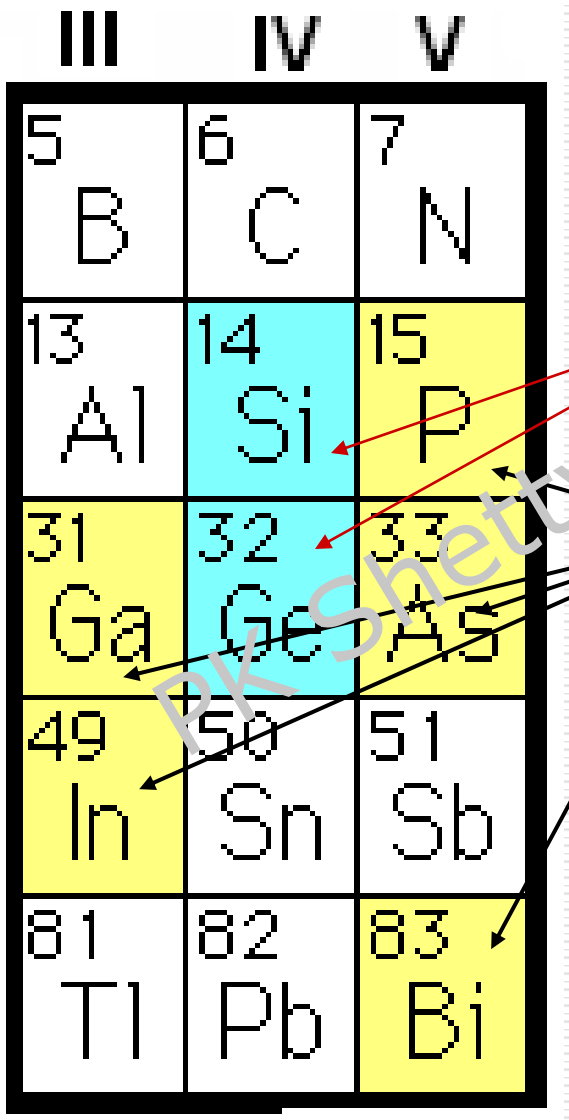
Example:

^{29}**Cu** Copper
^{47}**Ag** Silver
^{79}**Au** Gold

Insulators (Dielectrics)

- Exhibit a large force of attraction between the nucleus and the orbiting electrons.

Semiconductors



Elemental S.C.

III-V compound S.C.

Eg: GaAs, GaP etc

Semiconductors

- **Intrinsic Semiconductors - pure**

  Eg: Ge, Si

- **Extrinsic Semiconductors - doped**

  Dopants that create **p**-type – acce**p**tors

  Dopants that create **n**-type - do**n**ors

Germanium and Silicon

- First transistor was made with Germanium.
- Disadvantages of Germanium:

  * Its 937°C melting point limits high temperature processing.
  * It lacks naturally occurring oxide which leaves the surface prone to electrical leakage.

But Silicon allows higher temperature processing (melting point: 1415°C) and represents 90% of the wafers processed worldwide.

Compound Semiconducting materials

- Most used in commercial compound semiconductor devices are:
  - Gallium Arsenide (GaAs)
  - Gallium Arsenide Phosphide (GaAsP)
- Diodes made from GaAs and GaAsP gives off visible and laser light. Hence they make the LEDs.
- GaAs has high carrier mobility, hence can be used for high speed circuits. Devices of GaAs operate 2 to 3 times faster than their silicon counterparts.
- GaAs is naturally *radiation hardened* - space application
- GaAs is semi-insulating – minimizes leakage between adjacent devices, allowing higher packing density – faster circuit.

Drawbacks:

- Trade-offs between performance & processing difficulty.
- Majority of electronic products do not require their level of speed.
- Do not possess a natural oxide. Layers of dielectrics must be deposited on the GaAs – longer processing and low yield.
- Half of the atoms in GaAs are Arsenic, an element very dangerous to human beings which evaporates from the compound at normal process temperatures.
- The same problem occurs during the crystal growing stage resulting in nonuniform crystals and wafers.