SEMICONDUCTOR PHYCICS AND DEVICES

Paper-IV

(M.Sc. Physics III SEM)

Syllabus.....

Unit-I

- Semiconductor Concepts and Energy Bands
- Carrier Transport Phenomena
- Graded impurity distribution

Unit-II

- Non-equilibrium excess carriers in semiconductors
- Shockley-Read-Hall theory of recombination
- Surface effect
- PN Junction Principles
- Metal-semiconductor junctions
- Semiconductor- semiconductor junctions

Unit-III

- Bipolar Transistors
- Field Effect Transistors: JFET
- MOSFET
- Light-Emitting Diodes

Syllabus (Cont.…)

- **Unit-VI**

- Principle of the Laser diode
- Quantum well devices
- Photodetectors
- Ramo's theorem
- Quantum efficiency and responsivity
- Photodiode
- Phototransistors
- Photoconductive detectors and Photoconductive gain

- **Unit-V**

- Solar energy spectrum,
- Photovoltaic Devices
- Effect on p-n junction characteristics
- Depletion approximation
- Calculation of carrier and carrier densities
- General solution for J (V) and p-n junction in dark and under illumination

Reference books:

- **Donald A. Neamen and Dhrubes Biswas; Semiconductor Physics and Devices, 4th edition, McGraw Hill, 2003.**
- **S. O. Kasap; Optoelectronics and Photonics: Principles and Practices, Pearson 2009**
- **Jenny Nelson; The Physics of Solar Cells, 1st edition, Imperial College press, 2003.**
- S.M. Sze; Semiconductor Device, Physics and Technology, John Wiley and Sons, 2002.
- Ben. G. Streetman and Sanjay K. Banerjee, Solid Sate Electronics Devices, 7th edition, PHI, 2014.
- T. Markvart and L. Castaner; Solar Cells: Materials, Manufacture and Operations, Elsevier, 2005.

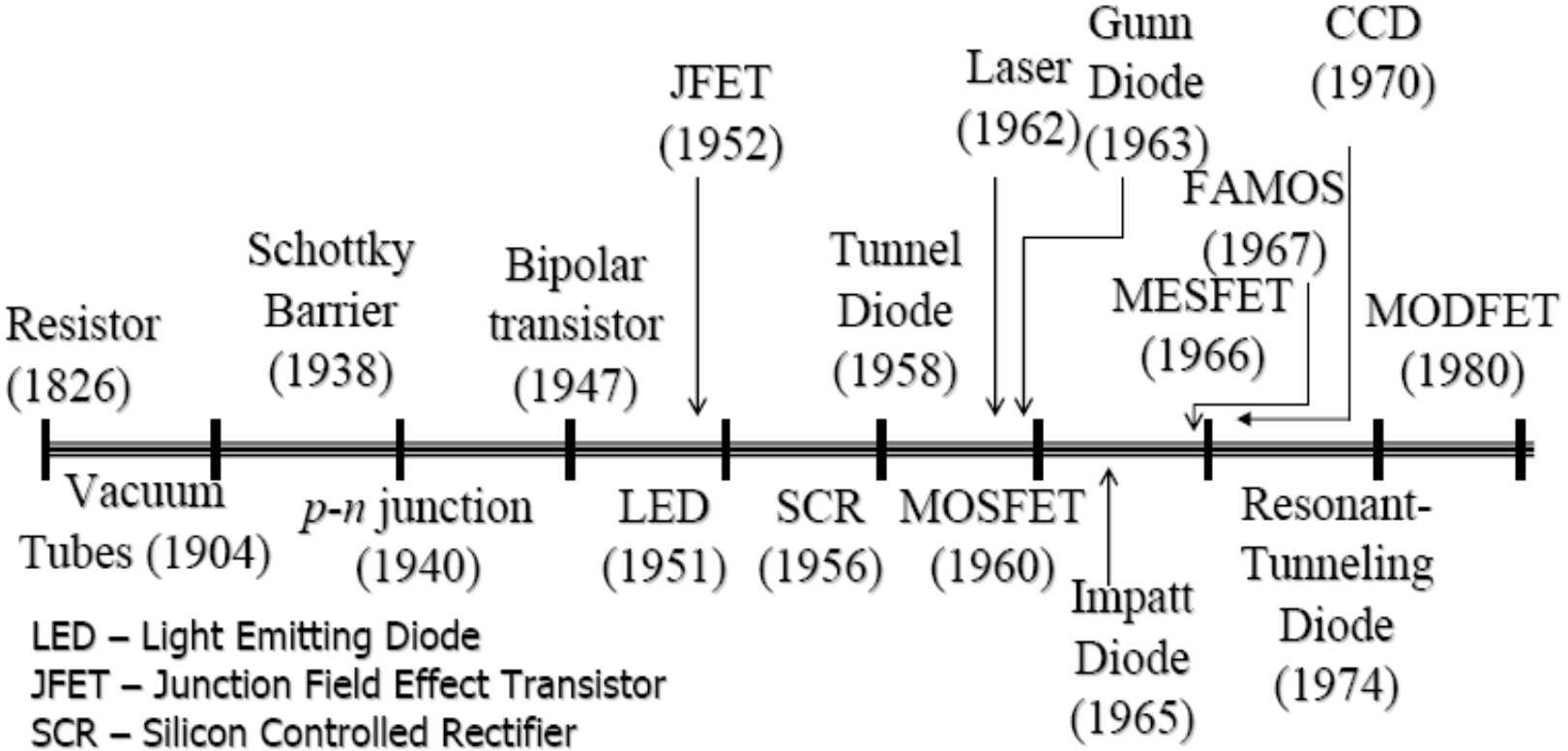
Why semiconductors?

SEMICONDUCTORS: They are here, there, and everywhere

▪ **Computers, palm pilots, laptops, anything "intelligent"**	Silicon (Si) MOSFETs, ICs, CMOS
▪ **Cell phones, pagers**	Si ICs, GaAs FETs, BJTs
▪ **CD players**	AlGaAs and InGaP laser diodes, Si photodiodes
▪ **TV remotes, mobile terminals**	Light emitting diodes (LEDs)
▪ **Satellite dishes**	InGaAs MMICs (Monolithic Microwave ICs)
▪ **Fiber networks**	InGaAsP laser diodes, pin photodiodes
▪ **Traffic signals, car taillights**	GaN LEDs (**green**, **blue**) InGaAsP LEDs (**red**, **amber**)
▪ **Air bags**	Si MEMs, Si ICs

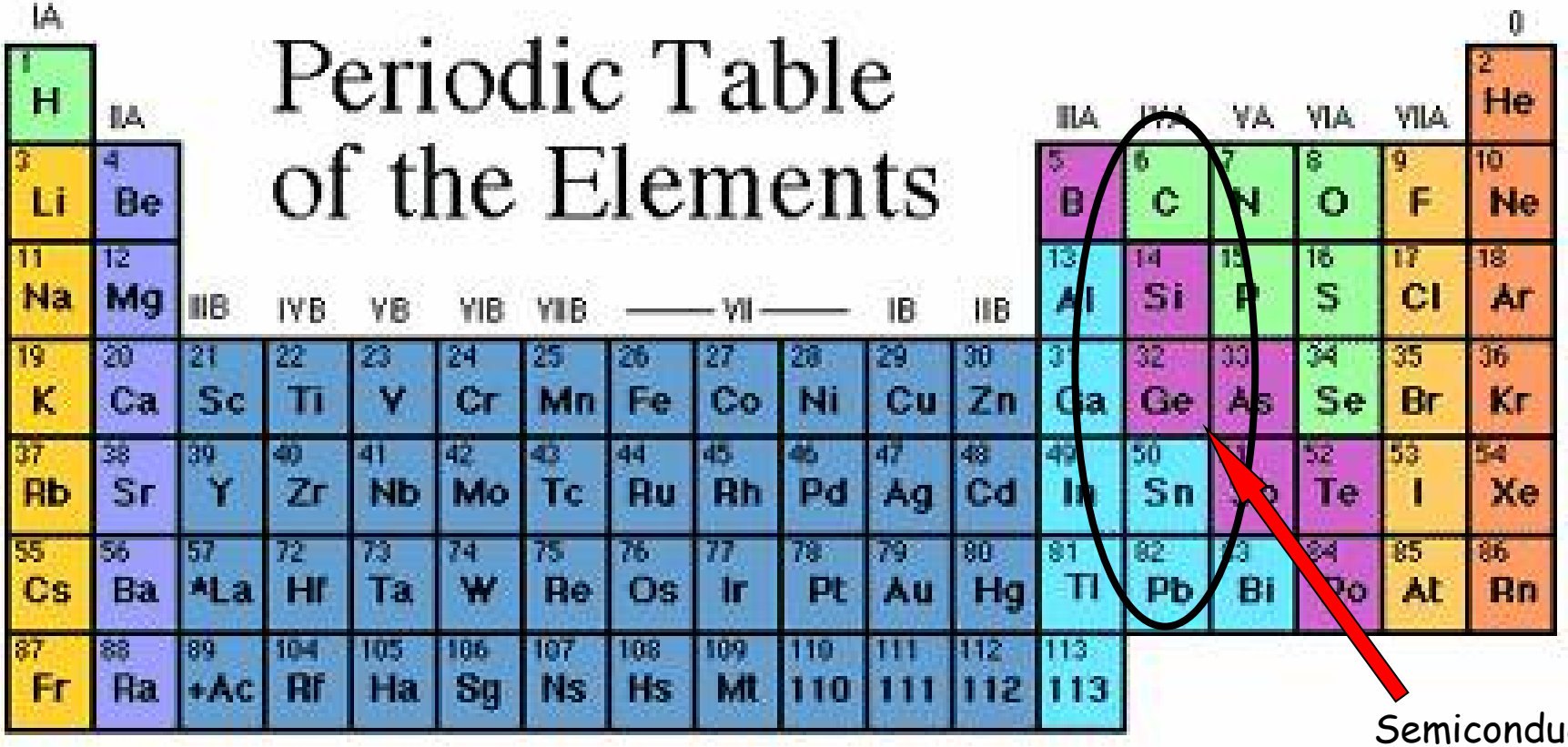
- **and, they are important, especially to Electronics, Engineering & Computer Sciences**

History of Semiconductor



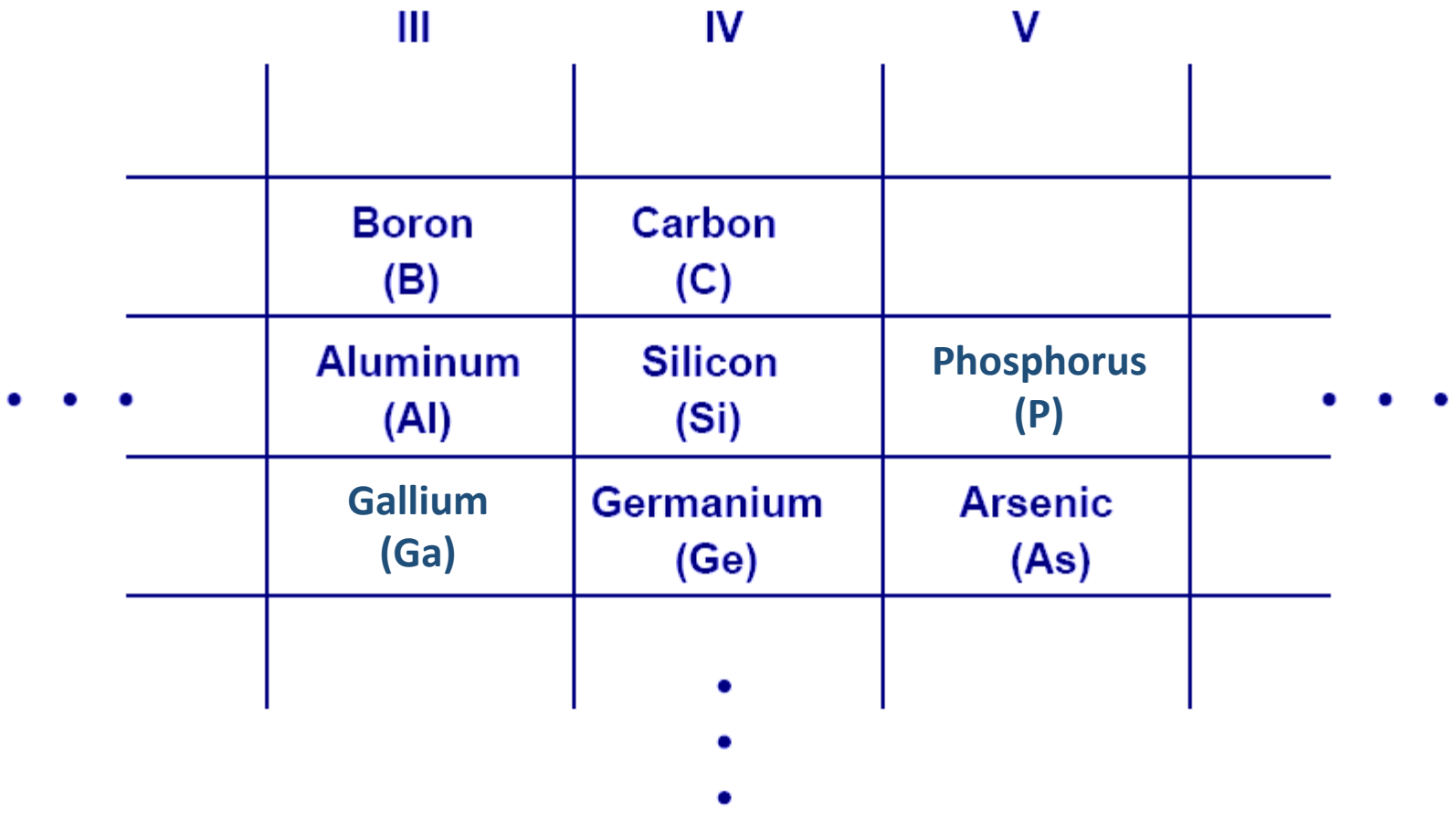
LED – Light Emitting Diode
JFET – Junction Field Effect Transistor
SCR – Silicon Controlled Rectifier
MOSFET – Metal-Oxide Semiconductor Field Effect Transistor
MESFET – Metal-Semiconductor Field Effect Transistor
FAMOS – Floating Gate Avalanche MOS
CCD – Charge-Couple Devices
MODFET – Modulation Doping Field-Effect Transistor

Periodic Table of the Elements



* Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+ Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Semiconductor Materials



Semiconductor Materials…….

- **Elemental semiconductors** – Si and Ge (column IV of periodic table) – compose of single species of atoms
- **Compound semiconductors** – combinations of atoms of column III and column V and some atoms from column II and VI. (combination of two atoms results in binary compounds)
- There are also three-element (ternary) compounds (GaAsP) and four-elements (quaternary) compounds such as InGaAsP.

(a)	II	III	IV	V	VI
		B	C		
		Al	Si	P	S
	Zn	Ga	Ge	As	Se
	Cd	In		Sb	Te

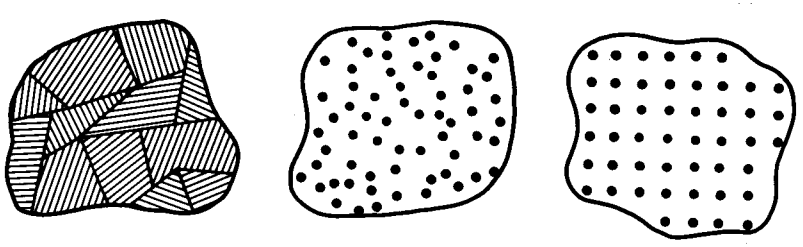
(b)	Elemental	IV compounds	Binary III-V compounds	Binary II-VI compounds
	Si	SiC	AlP	ZnS
	Ge	SiGe	AlAs	ZnSe
			AlSb	ZnTe
			GaP	CdS
			GaAs	CdSe
			GaSb	CdTe
			InP	
			InAS	
			InSb	

Semiconductor Materials……

- The wide variety of electronic and optical properties of these semiconductors provides the device engineer with great flexibility in the design of electronic and opto-electronic functions.
- **Ge** was widely used in the early days of semiconductor development for transistors and diodes.
- **Si** is now used for the majority of rectifiers, transistors and integrated circuits.
- **Compounds** are widely used in high-speed devices and devices requiring the emission or absorption of light.
- The electronic and optical properties of semiconductors are strongly affected by impurities, which may be added in precisely controlled amounts (e.g. an impurity concentration of one part per million can change a sample of Si from a poor conductor to a good conductor of electric current). This process called doping.

What is a Semiconductor?

- Low resistivity => “conductor”
- High resistivity => “insulator”
- Intermediate resistivity => “semiconductor”
  - conductivity lies between that of conductors and insulators
  - generally crystalline in structure for IC devices
    - In recent years, however, non-crystalline semiconductors have become commercially very important



polycrystalline amorphous crystalline