JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY
HYDERABAD

I Year B.Tech.

L T/P/D C

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ENGINEERING PHYSICS

UNIT-I

1. Bonding in Solids: Ionic Bond, Covalent Bond, Metallic Bond, Hydrogen Bond, Vander-Waal's Bond,
Calculation of Cohesive Energy.

2. Crystallography and Crystal Structures: Space Lattice**,** Unit Cell, Lattice Parameters, Crystal Systems,Bravais Lattices, Miller Indices, Crystal Planes and Directions, Inter Planar Spacing of Orthogonal CrystalSystems, Atomic Radius, Co-ordination Number and Packing Factor of SC, BCC, FCC, Diamond and hcp Structures, Structures of NaCl, ZnS, CsCl.

UNIT-II

3. X-ray Diffraction: Basic Principles, Bragg's Law, Laue Method, Powder Method, Applications of X- ray
Diffraction.

4. Defects in Crystals: Point Defects: Vacancies, Substitutional, Interstitial, Frenkel and Schottky Defects;Qualitative treatment of line (Edge and Screw Dislocations) Defects, Burger's Vector, Surface Defects andVolume Defects.

UNIT-III

5. Elements of Statistical Mechanics: Maxwell-Boltzman, Bose-Einstein and Fermi-Dirac Statistics(Qualitative Treatment), Photon gas , Wein's Law, Rayleigh-Jeans law,, Planck's Law of Black BodyRadiation, Concept of Electron Gas, Fermi Energy, Density of States.

6. Principles of Quantum Mechanics: Waves and Particles, de Broglie Hypothesis , Matter Waves,Davisson and Germer's Experiment, G. P. Thomson Experiment, Heisenberg's Uncertainty Principle,Schrödinger's Time Independent Wave Equation - Physical Significance of the Wave Function - Particle in
One Dimensional Potential Box.

UNIT-IV

7. Band Theory of Solids: Electron in a periodic Potential, Bloch Theorem, Kronig-Penny Model (Qualitative Treatment), Origin of Energy Band Formation in Solids, Classification of Materials into Conductors, Semi Conductors & Insulators, Concept of Effective Mass of an Electron and Hole.

UNIT-V

8. Semiconductor Physics: Fermi Level in Intrinsic and Extrinsic Semiconductors, Intrinsic Semiconductors
and Carrier Concentration, Extrinsic Semiconductors and Carrier Concentration, Equation of Continuity,Direct & Indirect Band Gap Semiconductors, Hall Effect.

9. Physics of Semiconductor Devices: Formation of PN Junction, Open Circuit PN Junction, EnergyDiagram of PN Diode, I-V Characteristics of PN Junction, PN Diode as a Rectifier (Forward and ReverseBias), Diode Equation, LED, LCD and Photo Diodes.

UNIT-VI

10. Dielectric Properties: Electric Dipole, Dipole Moment, Dielectric Constant, Polarizability, ElectricSusceptibility, Displacement Vector, Electronic, Ionic and Orientation Polarizations and Calculation ofPolarizabilities - Internal Fields in Solids, Clausius - Mossotti Equation, Piezo-electricity, Pyro-electricity and
Ferro- electricity.

11. Magnetic Properties: Permeability, Field Intensity, Magnetic Field Induction, Magnetization, MagneticSusceptibility, Origin of Magnetic Moment, Bohr Magneton, Classification of Dia, Para and Ferro MagneticMaterials on the basis of Magnetic Moment, Domain Theory of Ferro Magnetism on the basis of HysteresisCurve, Soft and Hard Magnetic Materials, Properties of Anti-Ferro and Ferri Magnetic Materials, Ferrites andtheir Applications, Concept of Perfect Diamagnetism, Meissner Effect, Magnetic Levitation, Applications of Superconductors.

UNIT-VII`

12. Lasers: Characteristics of Lasers, Spontaneous and Stimulated Emission of Radiation, Meta-stableState, Population Inversion, Lasing Action, Einstein’s Coefficients and Relation between them, Ruby Laser,Helium-Neon Laser, Carbon Dioxide Laser, Semiconductor Diode Laser, Applications of Lasers.

13. Fiber Optics: Principle of Optical Fiber, Acceptance Angle and Acceptance Cone, Numerical Aperture,Types of Optical Fibers and Refractive Index Profiles, Attenuation in Optical Fibers, Application of OpticalFibers.

UNIT-VIII

14. Acoustics of Buildings & Acoustic Quieting: Basic Requirement of Acoustically Good Hall,Reverberation and Time of Reverberation, Sabine’s Formula for Reverberation Time(Qualitative Treatment),Measurement of Absorption Coefficient of a Material, Factors Affecting The Architectural Acoustics and theirRemedies. Acoustic Quieting: Aspects of Acoustic Quieting, Methods of Quieting, Quieting for SpecificObserver**s,** Mufflers, Sound-proofing.

15. Nanotechnology: Origin of Nanotechnology, Nano Scale, Surface to Volume Ratio, QuantumConfinement, Bottom-up Fabrication: Sol-gel, Precipitation, Combustion Methods; Top-down Fabrication:Chemical Vapour Deposition, Physical Vapour Deposition, Pulsed Laser Vapour Deposition Methods, Characterization(XRD&TEM) and Applications.

TEXT BOOKS:

1. Applied Physics – P.K.Palanisamy (SciTech Publications (India) Pvt. Ltd., Fifth Print 2008).
2. Applied Physics – S.O. Pillai & Sivakami (New Age International (P) Ltd., Second Edition 2008).
3. Applied Physics – T. Bhima Shankaram & G. Prasad (B.S. Publications, Third Edition 2008).

REFERENCES:

1. Solid State Physics – M. Armugam (Anuradha Publications).
2. Modern Physics – R. Murugeshan & K. Siva Prasath – S. Chand & Co. (for Statistical Mechanics).
3. A Text Book of Engg Physics – M. N. Avadhanulu & P. G. Khsirsagar– S. Chand & Co. (for acoustics).
4. Modern Physics by K. Vijaya Kumar, S. Chandralingam: S. Chand & Co.Ltd
5. Nanotechnology – M.Ratner & D. Ratner (Pearson Ed.).
6. Introduction to Solid State Physics – C. Kittel (Wiley Eastern).
7. Solid State Physics – A.J. Dekker (Macmillan).
8. Applied Physics – Mani Naidu Pearson Education

PHYSICS

LIST OF CONTENTS

APPLIED PHYSICS

UNIT-I

1. BONDING IN SOLIDS

INTRODUCTION

In the gaseous state of matter, individual atoms or molecules can move freely in space with a velocity determined by the temperature. But in solid state, the constituent atoms or molecules that build the solid are confined to a localized region. The principle region between the two states is bonding. In gases, the atoms or molecules are free whereas in solids they are bound in a particular form because of which, they possess certain physical properties such elasticity, electrical and optical properties.

BONDING

Bonding is the physical state of existence of two or more atoms together in a bound form. The supply of external energy is required to get back the bonded atoms to the Free State as energy is needed to break the bonds. This energy is called dissociation (binding) or cohesive energy.

Bonding occurs between similar or dissimilar atoms, when an electrostatic interaction between them produces a resultant state whose energy is lesser than the sum of the energies possessed by individual atoms when they are free.

TYPES OF BONDING IN SOLIDS

Bonds in solids are classified basically into two groups namely primary and secondary bonds. Primary bonds are inter atomic bonds i.e. bonding between the atoms and secondary bonds are intermolecular bonds i.e. between the molecules.

Primary bonds

The primary bonds are interatomic bonds. In this bonding interaction occurs only through the electrons in the outermost orbit, i.e. the valence electrons. These are further classified into three types

Ionic bonding
Covalent bonding
Metallic bonding

1. *Ionic Bonding* :

Ionic bonding results due to transfer of one or more electrons from an electropositive element to an electronegative element. The two types of atoms involved in the bonding are of dissimilar type.

Example:

In NaCl crystal, Na atom has only one electron in outer most shell and a Cl atom needs one more electron to attain inert gas configuration. During the formation of NaCl molecule, one electron from the Na atom is transferred to the Cl atom resulting which, both Na and Cl ions attain filled- shell configuration.

$$Na + Cl \rightarrow Na^+ + Cl^- \rightarrow NaCl$$

A strong electrostatic attraction is set up that bond the Na^+ cation and the Cl^- anion into a very stable molecule NaCl at the equilibrium spacing.
Since Cl exist as molecules, the chemical reaction must be written as

$$2Na + Cl_2 \rightarrow 2Na^+ + 2Cl^- \rightarrow 2NaCl$$

Other examples of ionic crystals are

$$2Mg + O_2 \rightarrow 2Mg^{++} + 2O^{--} \rightarrow 2MgO$$

$$Mg + Cl_2 \rightarrow Mg^{++} + 2Cl^- \rightarrow MgCl_2$$

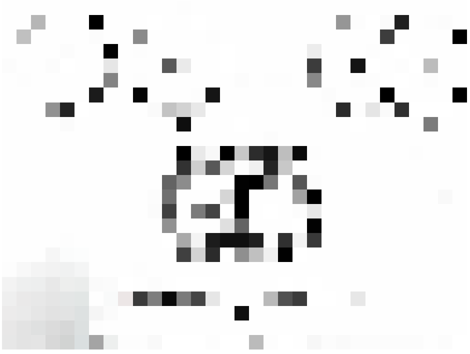
Properties:

1. As the ionic bonds are strong, the materials are hard and possess high melting and boiling points.
2. They are good ionic conductors, but poor conductors of both heat and electricity
3. They are transparent over wide range of electromagnetic spectrum
4. They are brittle. They possess neither ductility (ability to be made into sheets) nor malleability (ability to be made into wires).
5. They are soluble in polar liquids such as water but not in non-polar liquids such as ether.

2. Covalent Bonding

Covalent bond is formed by sharing of electrons between two atoms to form molecule.

Example: Covalent bonding is found in the H_2 molecule. Here the outer shell of each atom possesses 1 electron. Each H atom would like to gain an electron, and thus form a stable configuration. This can be done by sharing 2 electrons between pairs of H atoms, there by producing stable diatomic molecules.



Thus covalent bonding is also known as shared electron pair bonding.

Properties:

1. Covalent crystals are very hard since the bond is strong. The best example is diamond which is the hardest naturally occurring material and possess high melting and boiling points, but generally lower than that for ionic crystals.
2. Their conductivity falls in the range between insulators and semiconductors. For example, Si and Ge are semiconductors, where as diamond as an insulator.
3. They are transparent to electromagnetic waves in infrared region, but opaque at shorter wavelengths.

They are brittle and hard.

They are not soluble in polar liquids, but they dissolve in non-polar liquids such as ether, acetone, benzene etc.

The bonding is highly directional.

3. Metallic Bonding:

The valance electrons from all the atoms belonging to the crystal are free to move throughout the crystal. The crystal may be considered as an array of positive metal ions embedded in a cloud of free electrons. This type of bonding is called metallic bonding.

In a solid even a tiny portion of it comprises of billions of atoms. Thus in a metallic body, the no. of electrons that move freely will be so large that it is considered as though there is an electron gas contained with in the metal. The atoms lay embedded in this gas but having lost the valence electrons, they become positive ions. The electrostatic interaction between these positive ions and the electron gas as a whole, is responsible for the metallic bonding.

Properties:

1. Compared to ionic and covalent bonds, the metallic bonds are weaker. Their melting and boiling points are also lower.
2. Because of the easy movement possible to them, the electrons can transport energy efficiently. Hence all metals are excellent conductors of heat and electricity.
3. They are good reflectors and are opaque to E.M radiation.
4. They are ductile and malleable.

Secondary Bonds

There are two types of secondary bonds. They are Vander Waal’s bonds and Hydrogen bonds.

1. **Vander Waal’s bonding:** Vander Waal’s bonding is due to Vander Waal’s forces. These forces exist over a very short range. The force decreases as the 4^{th} power of the distance of separation between the constituent atoms or molecules when the ambient temperature is low enough. These forces lead to condensation of gaseous to liquid state and even from liquid to solid state though no other bonding mechanism exists.(except He)

Properties:

1. The bonding is weak because of which they have low melting points.
2. They are insulators and transparent for visible and UV light.
3. They are brittle.
4. They are non-directional

2. **Hydrogen bonding:** Covalently bonded atoms often produce an electric dipole configuration. With hydrogen atom as the positive end of the dipole if bonds arise as a result of electrostatic attraction between atoms, it is known as hydrogen bonding.

FIG………………………..

Properties:

1. The bonding is weak because of which they have low melting points.
2. They are insulators and transparent for visible and UV light.
3. They are brittle.
4. The hydrogen bonds are directional.

Forces between atoms:

In solid materials, the forces between the atoms are of two kinds. 1) Attractive force 2) Repulsive force

To keep the atoms together in solids, these forces play an important role. When the atoms are infinitely far apart they do not interact with each other to form a solid and the potential energy will be zero. From this, it can be understood that the potential energy between two atoms is inversely proportional to some power of the distance of separation. In all atoms, moving electric charges will be present, hence either attractive interaction or repulsive interaction takes place as they approach each other.

The attractive forces between the atoms bring them close together until a strong repulsive force arises due to overlap of electron shell. The atoms attract each other when they come close to each other due to inter-atomic attractive force which is responsible for bond formation. Suppose two atoms A and B experiences attractive and repulsive forces on each other, then the interatomic or bonding force 'f(r)' between them may be represented as

$$F(r)=A / r^M - B / r^N \qquad (N > M)\text{--------------}(1)$$

Where 'r ' is the interatomic distance

A, B, M, N are constants.

In eqn-1, the first term represents attractive force and the second the repulsive force.

At larger separation, the attractive force predominates. The two atoms approach until they reach equilibrium spacing. If they continue to approach further, the repulsive force pre dominates, tending to push them back to their equilibrium spacing.

Fig. Variaration of interatomic force with interatomic spacing

To calculate equilibrium spacing r_0 :

The general expression for bonding force between two atoms is

$$F(r)=A / r^M - B / r^N$$

At equilibrium spacing $r = r_0$, F = 0

$$\text{Hence} \qquad \mathbf{A / r_0^M = B / r_0^N}$$

$$\text{i.e.} \quad (r_0)^{N-M} = B / A$$

$$\text{or} \quad r_0 = (B / A)^{1/(N-M)}$$

Cohesive energy:

The energy corresponding to to the equilibrium position $r = r_0$ is called the bonding energy or the energy of cohesion of the molecule. Since this is the energy required to dissociate the atoms, this is also called the energy of dissociation.

The potential energy or stored internal energy of a material is the sum of the individual energies of the atoms plus their interaction energies. Consider the atoms are in the ground state and are infinitely far apart. Hence they do not interact with each other to form a solid. The potential energy, which is inversely proportional to some power of the distance of separation, is nearly zero. The potential energy varies greatly with inter-atomic separation. It is obtained by integrating the eqn –(1)

$$U(r) = \int F(r)dr$$

$$= \int [A/r^M - B/r^N] dr$$

$$= [(A/1-M)x\ r^{1-M} - (B/1-N)x\ r^{1-N}] + c$$

$$= [-(A/M-1)\ r^{-(M-1)} + (B/N-1)\ r^{-(N-1)} + c$$

$= -a / r^m + b / r^n + c$ where $a = A/M-1$, $b = B/N-1$, $m = M-1$, $n = N-1$

At $r = \alpha$, $U(r) = 0$, then $c = 0$

Therefore $U(r) = -a / r^m + b / r^n$

The condition under which the particles form a stable lattice is that the function U(r) exhibits min. for a finite value of r i.e. $r = r_0$ this spacing r_0 is known as equilibrium spacing of the system. This min. energy Umin at $r = r_0$ is negative and hence the energy needed to dissociate the molecule then equals the positive quantity of (- Umin). Umin occurs only if m and n satisfy the condition $n>m$

When the system in equilibrium then $r = r_0$ and $U(r) = U_{min}$

$[dU / dr]_{r = ro} = 0$

$= d / dr [-a / r_o^m + b / r_o^n] = 0$

or $0 = [a\, m\, ro^{-m-1}] - [b\, n\, ro^{-n-1}]$

or $0 = [a\, m / r_o^{m+1}] - [b\, n / r_o^{n+1}]$ -------→ (2)

Solving for r_o

$r_o=[(b / a) (n / m)]^{1/n-m}$

or $r_o^n = r_o^m[(b /a) (n / m)]$

at the same time , $n>m$ to prove this,

$[d^2U / dr^2]_{r = ro} = - [a\, m(m+1) / r_o^{m+2}] + [b\, n(n+1) / r_o^{n+2}] > 0$

$[r_o^{m+2}\ b\, n(n+1)] - [r_o^{n+2} a\, m(m+1)] > 0$

$r_o^m\ b\, n (n+1) > r_o^n\ a\, m (m+1)$

$b\, n (n+1) > a\, m (m+1) r_o^{n-m}$

$b\, n (n+1) > a\, m (m+1) (b / a) (n / m)$

i.e. $n > m$

Calculation of cohesive energy:

The energy corresponding to the equilibrium position $r = r_0$ **,** denoted by $U(r_0)$ is called boning energy or cohesive energy of the molecule.

Substituting 'r_o^n' in expression for U_{min},

We get

$$U_{(min)} = - a / r_o^m + b / r_o^n$$

$$= - a / r_o^m + b (a / b) (m/ n)1 / r_o^m$$

$$= - a / r_o^m + (m/ n) (a / r_o^m)$$

$$= - a / r_o^m[1-m / n]$$

$$U_{min} = - a / r_o^m [1-m / n]$$

Thus the min. value of energy of U_{min} is negative. The positive quantity $|U_{min}|$ is the dissociation energy of the molecule, i.e. the energy required to separate the two atoms.

Calculation of cohesive energy of NaCl Crystal

Let Na and Cl atoms be free at infinite distance of seoarartion. The energy required to remove the outer electron from Na atom (ionization energy of Na atom), leaving it a Na+ ion is 5.1eV.

i.e. $Na + 5.1eV \rightarrow Na^+ + e^-$

The electron affinity of Cl is 3.6eV. Thus when the removed electron from Na atom is added to Cl atom, 3.6eV of energy is released and the Cl atom becomes negatively charged.

Hence $Cl + e^- \rightarrow Cl^- + 3.6eV$

Net energy = 5.1 – 3.6 = 1.5 eV is spent in creating Na^+ and Cl^- ions at infinity.

Thus $Na + Cl + 1.5\ eV \rightarrow Na^+ + Cl^-$

At equilibrium spacing r0= 0.24nm, the potential energy will be min. and the energy released in the formation of NaCl molecule is called bond energy of the molecule and is obtained as follows:

$$V = e^2 / 4\Pi\varepsilon_0 r_0$$

$$= - [(1.602x10^{-19})^2 / 4\Pi(8.85x10^{-12})(2.4x10^{-10})] \text{ joules}$$

$= - [(1.602\times10^{-19})^2 / 4\Pi(8.85\times10^{-22} \times 2.4)(1.602\times10^{-19})]$ eV

$= -6$ eV

Thus the energy released in the formation of NaCl molecule is (5.1 - 3.6 – 6) = - 4.5 eV

To dissociate NaCl molecule into Na^+ and Cl^- ions, it requires energy of 4.5 eV.

Madelung Constant

Let r be the distance of separation between the two ions, z1 and z2 be the atomic numbers of the respective nuclei.

The coulomb's force of attraction F between the positive and negative ions is,
$F = (z_1z_2)e^2 /4\Pi\varepsilon_0 r^2$

The work done while they move under the attractive force towards each other through a distance dr,

$W = Fdr = [(z_1z_2)e^2 / 4\Pi\varepsilon_0 r^2]\, dr$

Therefore the work done while they move from infinite distance of separation to a distance r,

$= {}_{\infty}\int^{r} f dr = [(z_1z_2)e^2 / 4\Pi\varepsilon_0]\ {}_{\infty}\int^{r} dr/ r^2$

$= - (z_1z_2)e^2 / 4\Pi\varepsilon_0 r$

Work done by them becomes the attractive potential energy U_a
Therefore $U = - (z_1z_2)e^2 / 4\Pi\varepsilon_0 r$

$= - \alpha [e^2 / 4\Pi\varepsilon_0 r]$

Where α is constant called Madelung constant which has different values for different crystals.