Unit I

Crystal growth phenomena: Significance of single crystals – crystal growth techniques, Recent developments. Ideal growth laws – crystal-ambient phase equilibrium – criteria for equillibria in crystal growth – phase diagrams. Classification of growth processes.

Theories of nucleation- energy of formation - homogeneous nucleation – Gibb's Thompson equation for vapour, melt and solution, equilibrium shape of crystals. Heterogeneous nucleation – cap and disc shaped nuclei –constitutional supercooling - velocity of growth. Atomistic, thermodynamical models of crystal growth - Kossel and BCF theory. Problems and related experiments. 14 hours

Unit II

Crystal growth techniques: Bulk crystal growth – solution growth methods - supersaturation - aqueous solution, flux, hydrothermal methods. Melt growth – Kryopoulos, Bridgman – Stockbarger, Czochkralski, float zone and zone refining techniques. Impurity levelling factor – segregation coefficient. Verneuil method.

Low and high temperature solution growth – methods of crystallization – temperature gradient methods - growth of KDP and KTP crystals. Recent developments. Areas of applications. 14 hours

Unit III

Epitaxial growth methods – advantages - PVD – chemical vapour deposition – liquid and chemical vapour phase epitaxy – hot wall epitaxy- molecular beam epitaxy – MOCVD. Recent developments. Surface impurity contamination, defects and dislocations, determination of dislocation density.

Application: Si and Ge in semiconductor industry- IC technology: monolithic IC-masking and etching - elements of lithography- resist systems and patterning.

14 hours

References

1. Essentials of Crystallography, 2nd Edition – M A Wahab (Narosa Publishing House Pvt. Ltd, 2011)
2. Statistical Physics of Crystal Growth – Saito Yukio (World Scientific, 1996)
3. Crystal Growth for Beginners: Fundamentals of Crystal Growth, Nucleation and Epitaxy – Ivan V Markov (World Scientific, 1996)
4. Solid State Chemistry – R C Ropp (Elsevier, 2003)
5. Principles of The Solid State – H V Keer (Wiley Eastern, 1993)
6. Crystal Growth 1974, Proc. Of 4th Int. Conf. on Crystal Growth, Tokyo, Japan 24-29 March 1974, Eds. K A Jackson, N Kato and J B Mullin.
7. Current Trends in Crystal Growth and Characterization – Byrappa K (MIT, 1991)
8. Physics of Crystal Growth- Pimpinelli Alberto (Cambridge University, 1998)
9. The Growth of Crystals from Liquids – Brice J C (North Holland Press, 1973)

MSE 509: MATERIALS IN ENERGY PRODUCTION -OPEN ELECTIVE-2

(3 Credits)

Objectives: Objective of the course is to impart a basic knowledge about (i) global energy scenario and energy consumption in various sectors (ii) highlight the necessity

for materials for renewable energy sources and energy production (iii) efficient energy production using solar cells, fuel cells (iv) efficient production and storage of energy using superconducting materials.

Expected course outcomes: The students should gain knowledge on (i) global energy scenario such as production and consumption by various sectors and the need for finding efficient and renewable energy sources (ii) the various sources of energy such as solar power, hydrogen energy (iii) how solar power may be efficiently harnessed using solar cells (iii) the basic working principles of hydrogen and fuel cells (iv) efficient power transmission, energy production and storage by superconductors (v) the use of energy resources effectively and efficiently (vi) companies involved in efficient power production and storage.

Unit I

Global energy scene- energy consumption in various sectors, projected energy consumption for the next century. Definition and units of energy, power. Forms of energy, Conservation of energy, second law of thermodynamics. Solar Cells – photovoltaic effect- light absorption- carrier generation and recombination, p-n junction: homo and heterojunctions. Metal-semiconductor interface. Equivalent circuit of the solar cell, analysis of PV Cells - dark and illumination characteristics. Solar cell- efficiency limits; variation of efficiency with band-gap and temperature. Efficiency measurements-high efficiency cells. Types of solar cells. Solar Cell fabrication technology. Recent developments. 14 hours

Unit II

Hydrogen energy – merits as a fuel – production of hydrogen – fossil fuels, electrolysis, thermal decomposition, photochemical and photocatalytic methods. Hydrogen storage – metal hydrides, metal alloy hydrides, carbon nanotubes, sea as source of deuterium. Fuel cells – introduction – difference between batteries and fuel cells, components of fuel cells, principle of working of fuel cell, performance characteristics of fuel cells, efficiency of fuel cell, fuel cell stack, fuel cell power plant: fuel processor, fuel cell power section, power conditioner, advantages and disadvantages of fuel cell power plant. Types of fuel cells - Solid oxide fuel cells (SOFC), Molten carbonate fuel cells (MCFC), Phosphoric acid fuel cells (PAFC) Polymer electrolyte fuel cells. Application of fuel cells – Recent developments-commercially available fuel cells. 14 hours

Unit III

Superconductors - development in the field of superconductivity – properties of superconductors - perfect diamagnetism, Meissner effect – critical field and current – BCS theory. Types of superconductors - high T_c superconductors – properties - synthesis of high T_c superconductors. Applications of superconductors in energy production and storage. Superconducting wires and their characteristics, high field magnets for production of energy by magnetic fusion, energy generation-magnetohydrodynamics (MHD), energy storage, electric generators and role of superconductors. Large scale applications of superconductors- electric power transmission, applications of superconductor in medicine - Magnetic Resonance Imaging (MRI), areas of applications, superconducting quantum interference devices (SQUID). 14 hours