INTRODUCTION TO MATERIALS SCIENCE AND ENGINEERING

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PREREQUISITES: Science at school level equivalent to 10+2 of Central Board of Secondary Education (CBSE), India.

INTENDED AUDIENCE : Undergraduate students from all disciplines in engineering. Could be useful for students of solid state physics and solid state chemistry as well as engineers in industry looking for fundamentals of materials science

INDUSTRY SUPPORT: Any industry concerned with materials, in particular automobile and manufacturing industries. Condensed versions of this course have been offered at Maruti Udyog Limited, Gurugram, and Terminal Ballistic Research Lab of DRDO, Chandigarh, India.

ABOUT THE COURSE :

This course is designed as a first introduction to microstructure and mechanical properties of engineering materials for undergraduate engineering students. The focus will be on clear presentation of basic fundamentals of structure and defects of crystalline materials. This will then be used to understand the transformations, heat treatments and mechanical behavior of structural materials. The course will also include several classroom and laboratory demonstrations. The course will also be useful as an introduction to materials science for engineers and scientists in industry, research labs and academic institutions.

COURSE PLAN:

Week 1: Lattice and crystal, 7 crystal systems, 14 Bravais lattices, Symmetry.

Week 2: Miller indices of directions and planes, Weiss Zone Law, Bragg's Law, Close-Packed structures: CCP, HCP.

Week 3: Voids in close-packed structures, Solid solutions: interstitial, substitutional, ordered, disordered. Hume-Rothery rules. Graphene, graphite and diamond.

Week 4: Carbon nanotubes, Buckminsterfullerene.Ionic Solids: NaCl, CsCl, ZnS, BCC vs CsCl. Amorphous solids. Polymers: thermoplastic, thermosets, tacticity, copolymers, crystallinity.

Week 5 : Defects: zero-, one- and two-dimensional. Vacancies. Dislocations: edge, screw and mixed. Burgers vectors and burgers circuit. Constancy of Burgers vector. Elastic energy of a dislocation.

Week 6 : Dislocation cannot end abruptly inside a crystal, dislocation loop, dislocation node, dislocation motion: glide, climb and cross slip. 2D defects: free surfaces, grain boundaries, twin boundary, stacking faults, tilt and twist boundaries, ball bearing model.

Week 7 : Phase diagrams. Phases and components. Phases present in the system. Composition of phases: Tie-Line rule. Proportion of Phases: Lever Rule. Microstructure Evolution. Invariant reactions: eutectic, eutectoid, peritectic, peritectoid. Gibbs phase rule. Fe-C diagram.

Week 8 : Fe-C diagram (Continued). Eutectoid, hypoeutectoid and hypereutectoid steels. Diffusion: Fick's First and Second Laws. Error function solution of Fick's second law. Atomistic mechanisms of diffusion: interstitial and substitutional diffusion. Diffusion paths: lattice, grain boundary, dislocation and surface. Steady vs. unsteady state diffusion.

Week 9 : Phase transformation. Nucleation: Homogeneous and heterogeneous. Nucleation and capillary rise. Growth and overall transformation. TTT diagrams. Heat treatment of steels. TTT diagrams of eutectoid steels.

Week 10 : Quenching and martensite, Austempering and Bainite. Tempering and tempered martensite. Residual stresses and quench cracks. Marquenching and Martempering. TTT diagram of hypoeutectoid, hypereutectoid and alloy steels. Hardenability of steels. Glass ceramics. Mechanical behaviour of materials. Tensile test. Plastic deformation and crystal structure. Slip. Resolved shear stress and critical resolved shear stress. Schmid's law.

Week 11 : CRSS: theory vs. experiment. Strengthening mechanisms: strain hardening, grain size hardening, solid solution hardening and age hardening. Dislocation density. Frank-Read source. Annealing of cold-worked materials: Recovery, Recrystallisation, Grain Growth.

Week 12: True stress and true strain.Creep. Effect of stress and temperature. Creep mechanisms. Composites: isostrain and isostress modulus. Fracture. Ductile and brittle fracture. Role of crack size: Griffith's criterion. Stress concentration. Ductile-to-brittle transition. Enhancing fracture resistance. Toughening of glass:tempering and ion-exchange.Fatigue.Sub-critical crack growth.