PHASE DIAGRAMS IN MATERIALS SCIENCE AND ENGINEERING

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PRE-REQUISITES: Metallurgical Thermodynamics and knowledge of using computer softwares

INTENDED AUDIENCE: It is an elective for students of UG/PG

COURSE OUTLINE:

Phase diagrams are important for materials science and engineering applications encompassing from structural materials to functional materials, including electronic, magnetic applications. The course is intended to make the students and research familiarize with binary and ternary phase diagrams and microstructure of different materials. It is to be noted that microstructure plays a vital role in deciding the properties of the materials. Thus, it is important to connect the phase diagram information for microstructural evolution.

ABOUT THE INSTRUCTOR:

Prof. Krishanu Biswas, Ranjit Singh chair professor at the Department of Materials Science and Engineering at IIT Kanpur. He is a prolific teacher, developed courses on Phase Diagrams, Phase Transformation and Nanomaterials under the umbrella of NPTEL. He teaches both UG/PG courses at IIT Kanpur. He also works on application of AI-ML in materials engineering. His research includes multicomponent materials, materials for hydrogen energy, electron microscopy etc.

COURSE PLAN:

Week 1:
Lecture 1: Phase rule, lever rule, Free energy of phase mixture
Lecture 2 : Unary systems, Effect of pressure on phase diagrams
Lecture 3: Binary Isomorophous Systems, Free energy-composition digrams,

Week 2:
Lecture 4 : Equilibrium solidification, Non- Equilibrium solidification of alloys,
Lecture 5: Coring, examples from Cu-Ni alloys, Zone refining
Lecture 6: Phase Diagrams of Binary Eutectic systems

Week 3:
Lecture 7: Solidification of eutectic, hypo-eutectic, and hyper-eutectic alloys and their morphologies with examples from Al-Si, Fe-C, Ag-Cu, Pb-Sn systems
Lecture 8: Phase diagrams of binary peritectic System, evolution of these phase diagrams
Lecture 9 : Solidification of peritectic alloys,

Week 4:
Lecture 10 : hypo and hyper-peritectic alloys; Morphologies
Lecture 11: Concept of Liquid Phase immiscibility Binary Monotectic and Systectic Systems
Lecture 12: Evolution of monotectic and syntactic phase diagrams, free –energy composition diagrams,

Week 5:
Lecture 13: Development of microstructures in systems Cu-Pb, Na-Zn, K-Zn, Effect of gravity on solidification of these alloys
Lecture 14: Concept of solid state immicibility and spinodal decompositions,
Lecture 15: Phase diagrams showing spinodal decomposition, microstrucural evolution

Week 6:
Lecture 16: Thermodynamics of phase equilibria: Regular and irregular solutions
Lecture 17: Models for regular and irregular solutions,
Lecture 18: Quasichemical theory : detailed descriptions

Week 7 :
Lecture 19 : Stability of regular solution and miscibility gap,
Lecture 20- 21: Application of Quaichemical to eutectic, peritectic
Lecture 22 : and Monotectic systems, intrinsic stability of solution and spinodal.

Week 8:
Lecture 23: Theory of alloy Phases: Hume-Rothery rules,
Lecture 24 : Intermediate phases e.g., laves, sigma, electron compounds
Lecture 25: Important systems with intermediate phases: Ni-Al, Ti-Al and Fe-Al systems

Week 9:
Lecture 26 : Iron-carbon phase diagram and microstructures of plain carbon steel and cast iron: non-equilibrium structures
Lecture 27-28::Some binary ceramics systems: SiO_2-Al_2O_3, NiO-MnO, etc and their microstructure.

Week 10:
Lecture 29 : Ternary phase diagrams: Gibbs triangle, isothermal and vertical sections,
Lecture 30-31: Polythermal projections, two-phase equilibrium

Week 11:
Lecture 32: Concept of the lines, rules for construction of tie lines,
Lecture 33-34: three phase equilibrium, concept of tie-triangle, four phase equilibria.

Week 12:
Lecture 35-36: Multi-component alloy systems: Stainless steels, high speed steels, super alloys, light metal alloys, refractory systems (Al_2O_3 - SiO_2 -MgO)