Principles of Physical Metallurgy - Video course

COURSE OUTLINE

The aim of this course is to provide a basic understanding of the underlying principles that determine the evolution of microstructures in metals and alloys during their processing and its relation with its properties & performance in service. Attempts will be made to introduce the concept of thermodynamics & kinetics of phase transformation, micro-structural engineering, alloy design, processing (casing, forming & heat treatment) techniques, and structure property relationship.

The course would also include a brief introduction to the tools & techniques of examination of microstructure & evaluation of its properties. This would also include a brief outline of crystal structure & crystal defects. In short an attempt will be made to take the students from the fundamentals to the frontiers of physical metallurgy. Although the main focus in this courses will be on metals and alloys students of allied discipline may find this course to be useful.

Course content:
Atomic bonding & crystal structure, Experimental tools & techniques, Solidification & plastic deformation of pure metal, Crystal defects, Diffusion, Solidification of binary alloys, Three phase equilibrium (Eutectic, Peritectic system), Phase diagrams of common binary alloys, Iron carbon (cementite) diagram, Cold working & annealing, Precipitation hardening, Pearlitic, Bainitic & Martensitic transformation, Heat treatment of steel, TTT diagram, Effect of alloying elements, Hardenability, Application of physical metallurgy.

COURSE DETAIL

Sl. No	Topic	Hours
1.	**Atomic Bonding & Crystal Structure:** Metallic bond, unit cell, atomic packing, interstitial sites, Miller indices, crystal orientation, stereographic projection.	3
2.	**Experimental tools & techniques:** Metallography (Optical TEM, SEM), X Ray Diffraction, Mechanical Properties, Thermal analysis.	2
3.	**Solidification of pure metal:** Phase rule, Concept of Free Energy, Entropy, Surface Energy (grain boundary)& under cooling, Nucleation& Growth, homogeneous& heterogeneous nucleation, directional solidification.	2
4.	**Plastic deformation of pure metal:** Mechanisms(slip& twin), critical resolved shear stress, single crystal tensile test (fcc), theoretical strength of ideal crystal.	2
5.	**Crystal defects in metals:** Vacancy, interstitial, substitutional, free energy of mixing, dislocation (elementary concepts only), edge / screw dislocation,	5

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Metallurgy and Material Science

Pre-requisites:

Elementary knowledge of Metallurgical Thermodynamics, X-Ray diffraction & crystallography will be helpful but not essential.

Additional Reading:

Handbooks for Material Property Data

- ASM Metals Handbook - ASM International Metals Park, Columbus, Ohio, USA
- Smithells Metals Reference Book - Butterworth, Heinemann, London

Coordinators:

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	partial dislocation, stacking fault, dislocation lock, dislocation pile up, Hall Petch relation, grain boundary structure.	
6.	**Diffusion:** Elementary concepts of phenomenological& atomistic approaches.	3
7.	**Solidification of binary alloys:** Limits of solubility, isomorphous system, lever rule, constitutional super cooling, effect of non equilibrium cooling, eutectic, peritectic, eutectoid& peritectoid system, complex phase diagram, ternary diagram, composition triangle, ternary eutectic, vertical& horizontal sections, structure of cast metal, segregation& porosity, iron-carbon diagram, steel& cast iron.	8
8.	**Binary phase diagrams of common commercial alloys:** Cu-Ni, Au-Cu, Ni-Cr, Al-Si, Al-Zn, Al-Ag, Pb-Sn, Cu-Zn, Cu-Sn, Cu-Al, Ti-Al, Ti-V: interpretation of microstructure& properties.	3
9.	**Cold working & Annealing:** Recovery, recrystallization& grain growth, phenomenological& mechanistic approaches.	2
10.	**Precipitation from super-saturated terminal solid solution:** Thermodynamics& kinetics of precipitation, precipitation hardening.	2
11.	**Heat treatment of steel:** T-T-T diagram, Pearlitic, Martensitic& Bainitic transformation, effect of alloy elements on phase diagram& TTT diagram, CCT diagram, Annealing, normalizing, hardening& tempering, hardenability.	8
12.	**Application of physical metallurgy:** Strengthening mechanism, strength vs. toughness (ductility), thermo mechanical processing, micro alloyed steel, ultra high strength steel, superalloy, control of texture.	4

References:

1. Physical Metallurgy Principles - Robert E Reed-Hill and Reza Abbaschian
2. Phase Transformation in Metals & Alloys - D A Porter & K Easterling
3. Fundamentals of Physical Metallurgy - John D Verhoeven
4. Physical Metallurgy - Peter Haasen
5. Structure and Properties of Alloys - R M Brick, R B Gordon, A. Phillips
6. Physical Foundations of Materials Science - G. Gottstein