UNIVERSITY DEPARTMENTS
ANNA UNIVERSITY CHENNAI : : CHENNAI 600 025
REGULATIONS - 2009
CURRICULUM I TO IV SEMESTERS (FULL TIME)
M.TECH. CERAMIC TECHNOLOGY

SEMESTER I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	CR 9111	Materials Science	3	0	0	3
2.	CR 9112	Science and Technology of Traditional Ceramics	3	0	0	3
3.	CR 9113	Refractories	3	0	0	3
4.	CR 9114	Mechanical Behaviour of Ceramics	3	0	0	3
5.	E1	Elective I	3	0	0	3
6.	E2	Elective II	3	0	0	3
PRACTICAL						
7.	CR 9115	Processing and Testing of Ceramics	0	0	3	2
		TOTAL CREDITS	**18**	**0**	**3**	**20**

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	CR 9121	Advanced Process Technology of Ceramics	3	0	0	3
2.	CR 9122	Modern Ceramic Materials	3	0	0	3
3.	CR 9123	Material Characterization Techniques	3	0	0	3
4.	CR 9124	Phase Equilibria & Kinetics of Ceramic Systems	3	0	0	3
5.	E3	Elective III	3	0	0	3
6.	E4	Elective IV	3	0	0	3
PRACTICAL						
7.	CR 9125	Materials Characterization Lab	0	0	3	2
		TOTAL CREDITS	**18**	**0**	**3**	**20**

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	CR 9131	Nanoscience & Technology of Ceramics	3	0	0	3
2.	E5	Elective – V	3	0	0	3
3.	E6	Elective – VI	3	0	0	3
PRACTICAL						
4.	CR 9133	Seminar	0	0	2	1
5.	CR 9134	Project Work – Phase I	0	0	12	6
		TOTAL CREDITS	**9**	**0**	**14**	**16**

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1.	CR 9141	Project Work – Phase II	0	0	24	12
		TOTAL CREDITS	**0**	**0**	**24**	**12**

TOTAL NUMBER OF CREDITS TO BE EARNED FOR AWARD OF THE DEGREE 68

LIST OF ELECTIVES

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1.	CR 9151	Ceramic Coating Technology	3	0	0	3
2.	CR 9152	Numerical Techniques	3	0	0	3
3.	CR 9153	Environmental Engineering	3	0	0	3
4.	CR 9154	Process Modelling, Simulation and Optimization	3	0	0	3
5.	CR 9155	Operation Research	3	0	0	3
6.	CR 9156	Safety Engineering	3	0	0	3
7.	CR 9157	Electronic Ceramic Materials and Their Applications	3	0	0	3
8.	CR 9158	Monolithics and Castables	3	0	0	3
9.	CR 9159	Abrasives	3	0	0	3
10.	CR 9160	Ceramic Fibres and Composites	3	0	0	3
11.	CR 9161	Glass Engineering	3	0	0	3
12.	CR 9162	Advanced Refractory Engineering	3	0	0	3
13.	CR 9163	Fuels, Furnaces and Pyrometry	3	0	0	3
14.	CR 9164	Quality Control and Management in Ceramic Industries	3	0	0	3
15.	CR 9165	Bio-ceramics	3	0	0	3
16.	CR 9166	Special Glasses	3	0	0	3
17.	CR 9167	Non Destructive Testing	3	0	0	3
18.	CR 9168	Microwave Processing of Ceramics	3	0	0	3
19.	CR 9169	Nuclear and Space Ceramics	3	0	0	3
20.	CR 9170	Heat Recovery Systems	3	0	0	3
21.	CR 9171	Ceramic Calculations	3	0	0	3
22.	CR 9172	Cement and Concrete	3	0	0	3
23.	CR 9173	Manufacturing and Testing of Structural Ceramics	3	0	0	3
24.	CR 9174	Properties and Applications of Structural Ceramics	3	0	0	3

CR9111 **MATERIALS SCIENCE** **L T P C**
3 0 0 3

AIM

The course is aimed to impart basic knowledge about crystal structures, phase diagrams and properties of materials.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about crystal structures and various laws related to structures.
- Have learnt about various properties.
- Have basic knowledge about phase diagrams.

UNIT I CRYSTAL STRUCTURE 9

Introduction – material classification of materials – structure- property relationship - atomic Structure - space lattice and crystal structure- Miller indices, crystal planes – symmetry – crystal imperfections – point, line, surface, volume – solid solutions - ceramic crystal structures.

Diffusion: Fick's laws of diffusion – mechanism and applications.

UNIT II PHASE DIAGRAMS 9

Gibb's Phase rule – thermodynamic criteria for phase stability – phase diagrams - single, binary and ternary phase diagrams – lever rule – applications of phase diagrams

UNIT III MECHANICAL PROPERTIES 9

Elastic behavior – plastic deformation by slip – dislocation movement – effect of stress and temperature – work hardening – creep – fracture, modes of fracture - fracture toughness – hardness – wear - corrosion.

UNIT IV ELECTRICAL AND ELECTRONIC PROPERTIES 9

Classification of materials using free electron theory and band theory -conductivity of metals – Matheisen's Rule – concentration and mobility of charge carriers and their variation with temperature .– energy gap in solids – dielectric materials - types of polarizations – polarization calculations – polymer dielectrics – Fast ionic conductors – ionic conduction in zirconia and other systems - dipole moment – static permittivity – dielectric constant – dielectric loss – dielectric breakdown – superconductivity – semiconducting materials –

UNIT V MAGNETIC ,THERMAL AND OPTICAL PROPERTIES 9

Introduction – types of magnetic materials - Classification of dia- para -ferro- antiferro and ferri magnetic materials – magnetic semiconductors – specific heat capacity – thermal conductivity – measurement by Laser Flash and other methods - thermal expansion – Light Interaction with solids – optical properties of metals & non metals – refraction, reflection, absorption, transmission , color, opacity, translucency - applications.

TOTAL: 45 PERIODS

REFERENCES

1. Saxena, B.S., R.C. Gupta and P.N. Saxena, Fundamentals of Solid State Physics, 1988, Pragathi Pragasan, Meerut.
2. Raghavan,V., Materials Science and Engineering, 1982, Prentice Hall India, NewDelhi.
3. Schewmon, P.G. Diffusion of Solids, 1963, McGraw- Hill Book Company, New York.

4. Bergeron, C.G., and S.H.Risbud, Introduction to Phase Equillibria in Ceramics, 1984, Am.Ceram.Soc, Inc., Westerwile Ohio, USA.
5. Arzamasov, B., Materials Science, 1989, Mir Publishers, Moscow.
6. Weidmann, G., P.Lewis and N.Reid, Structural Materials, 1990, Butterworths, London.
7. William D Callister.Jr, Materials Science & Engineering, 2000, John Wiley & Sons

CR9112 SCIENCE AND TECHNOLOGY OF TRADITIONAL CERAMICS **L T P C 3 0 0 3**

AIM

The course is aimed to impart basic knowledge about ceramic raw materials, body preparation,, glazing and firing behaviour.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about ceramic raw materials and their properties.
- Have learnt about various body preparation techniques.
- Have basic knowledge about firing behaviour and manufacturing processes of specific products.

UNIT I RAW MATERIALS 9

Development of ceramic process – ceramic raw materials – plastic & non plastic – clay formation – classification – winning of clays – quarrying of non-plastic materials – washing methods – communition – crushers – primary, secondary - additives – properties of clay-water mixtures and influencing factors – absorption, cation exchange capacity – rheology.

UNIT II THEORY OF PACKING 8

Body composition – Packing of two component system – porosity – effect of grain size – unfired porosity – experimental verification – wet to dry contraction – unfired strength – permeability and casting rate – dry to fired contraction

UNIT III FABRICATION PROCESS 10

Triaxial bodies – body formulations – porcelains, stoneware, earthenware, majolica, terracotta, artware – Pressing – plastic forming - pug mill – de-airing – extrusion - jiggering and jollying – Casting - Plaster mould preparation - slip formation – - suspensions/ceramic slurries – stability of slurries, electrical double layer, theory , types of stabilization- zeta potential & its measurement – various casting techniques –– defects - Flowcharts of manufacturing stages of white ware- wall & floor tiles – art ware – dental porcelain – bone china – chemical porcelain – high and low tension insulators – cordierite cooking ware

UNIT IV GLAZING 9

Glaze, glaze materials – glaze formulation – engobe - fritting – glaze batch calculation – application techniques - glaze properties – glaze defects – glaze, body interface layer – decoration techniques – opacity and translucency – absorption and colour.

UNIT V DRYING & FIRING 9

Drying – mechanism of drying – transfer of heat – factors that control drying – types of dryers – drying defects – finishing – cutting – trimming –remedies – Effect of heat on clays – the action of heat on ceramic bodies – physical changes – chemical changes – firing schedules – firing range – liquid phase sintering – vitrification – micro structural control.

TOTAL: 45 PERIODS

REFERENCES

1. Worral, W.E, Ceramic Raw Materials, Pergamon Press, NY, 1992.
2. W.Ryan, Properties of Ceramic Raw Materials, Pergamon Press, 2nd Edn. 1978
3. M.J.Wilson, Clay Mineralogy, Chapman and Hall, 1995.
4. Allen Dinsdale, Pottery Science, Ellis Horwood Ltd., NY, 1986.
5. Sudhir Sen, Ceramic Whiteware, Oxford & IBH Pulishing Co., New Delhi, 1992
6. Singer, F and Singer, S.S, Industrial Ceramics, Oxford & IBH Publishing Co., 1991
7. Ryan, W and Radford, C, Whitewares: Production, Testing and Quality Control, Pergamon Press, NY, 1987.

CR9113 REFRACTORIES L T P C
3 0 0 3

AIM

The course is aimed to impart basic knowledge about refractories, fabrication methods, testing and monolithics.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about refractory raw materials, classification and properties.
- Have learnt about various fabrication techniques and testing.
- Have basic knowledge about monolithics and its applications.

UNIT I INTRODUCTION 9

Definition – Survey of Refractories and their Uses – Layout of a refractory plant – Classification of Refractories – Fundamental Properties of Refractories namely Physical, Thermal, Mechanical, Chemical and Electrical Properties.

UNIT II ALUMINO SILICATE REFRACTORIES 9

Silica – Raw materials – Manufacturing Steps – Properties – Applications. Al_2O_3 – SiO_2 Phase diagram – Types of Raw materials – Types of Alumino-Silicate Refractories – Manufacturing Steps – Properties – Applications.

UNIT III BASIC REFRACTORIES 9

Raw materials, Manufacturing Steps, Properties and Applications of Forsterite, Dolomite Magnesite, Magnesia Carbon, and Chrome based refractories.

UNIT IV SPECIAL REFRACTORIES AND MONOLITHICS 9

Carbide based, Nitride based, Zirconia, Thoria, Beryllia Refractories – Raw materials, Manufacturing Steps, Properties and Applications. Fused cast refractories – Ceramic Fibers. Types of Castables – Ramming Mass – Gunning Mixes.

UNIT V APPLICATIONS OF REFRACTORIES IN FERROUS & NON FERROUS INDUSTRY & TESTING OF REFRACTORIES 9

Refractories for coke oven, blast furnace, open hearth furnace, LD converter, THF, EAF, IF, Ladle furnace, slide plate system, nozzle, shroud, continous casting; Monolithic Applications – gunning technique; Refractory, slag and metal interactions.
Refractories in non ferrous industries – copper, aluminum, lead - Refractories in non metal industries – hydrocarbon industry, fertilizer industry, cement industry.
Process industry standards – Indian and International test methods (ISI) – QC procedures – Statistical QC, ISO 9000 Etc.

TOTAL: 45 PERIODS

REFERENCES

1. D.N.Nandi, Handbook of Refractories, Tata McGraw Hill Publishing Co, New Delhi, 1991.
2. Chesters J.H, Refractroies: Production & Properties, Iron & Steel Institute, London, 1973.
3. Chester, J.H., Steel Plant Refractories, Second Edition., 1973, The United Steel Companies Ltd., Sheffield, UK.
4. Chester, J.H. Refractories, Production and Properties, 1973, Iron and Steel Institute, London.
5. Robert E.Fisher, Advances in Refractory Technology, Ceramic Transaction, Vol.4, 1990, American Ceramic Society, Westerville,Ohio, USA.
6. Handbook of Monolithics, 1980, Plibrico, Japan.
7. Modern Refractories Practice, 1961, Harbison Walker Comp., Pittsburgh.

CR9114 MECHANICAL BEHAVIOR OF CERAMICS L T P C
3 0 0 3

AIM

The course is aimed to impart basic knowledge about elasticity, fracture methods, strength, creep behaviour and thermal shock behaviour of ceramic materials.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about elasticity, deformation point of isotropic and crystalline materials.
- Have learnt about various fractures, fracture testing techniques, strength behaviour and creep on application of loads.
- Ave basic knowledge about thermal shock resistance parameters.

UNIT I FRACTURE MECHANICS 9

Elasticity and brittle fracture, elastic constants, elastic deformation of isotropic and crystalline materials, measurement techniques, variation of elastic constant with temperature and porosity - Theoretical strength and stress concentrations, Griffith theory - charpy, instrumented charpy, DBDT - linear elastic fracture mechanics, microstructural aspects, fractography, fracture testing technique, impact resistance, toughness, dynamic fracture toughness, linear, elastoplastic and mechanical.

UNIT II STRENGTH AND TOUGHENING 9

Tensile strength, statistical treatment – Weibull analysis, statistical treatment ,subcritical crack propagation, stable crack propagation and R-curve behaviour, microstructural aspects, time dependent strength behaviour, cyclic fatigue, experimental techniques, SPT diagram toughening mechanisms, phase transformation toughening.

UNIT III CREEP AND THERMAL SHOCK BEHAVIOUR OF CERAMICS 9

Introduction to creep, Dislocation creep, diffusion creep, microstructure dependence, multicomponent system techniques, creep deformation maps, creep rupture at high temperatures and safe life design.Thermal stress, thermal shock resistance parameters, thermal stresses and cracking, thermal shock testing techniques, application.

UNIT IV FATIGUE AND WEAR 9

Fatigue of ceramics – mechanism, measurement , life time prediction, wear of ceramics – mechanism, measurement, microstructural dependence

UNIT V MECHANICAL PROPERTIES OF CMC,GLASS & GLASS CERAMICS 9

CMC – elastic behaviour, fracture behaviour, toughening mechanism of reinforcement. Glass – elastic behaviour, strength and fracture, strength improvement, strength of glass ceramics

TOTAL: 45 PERIODS

REFERENCES

1. John B.Watchman, Mechanical Properties of Ceramics, 1996, John Wiley & Sons Inc., NY.
2. Davidge, R.W., Mechanical Behaviour of Ceramics, Ceramic Book Literature Service, 1979, London, UK.
3. Hasselman, D.P.H and R.A.Heller(Ed), Thermal Stresses in Service Environments, 1989, Plenum Press.

CR9115 PROCESSING AND TESTING OF CERAMICS L T P C
0 0 3 2

AIM

The course is aimed to impart basic practical knowledge about processing and testing of ceramic materials.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about different tests done on ceramic materials in the laboratory.

1. Analysis of Ceramic Raw Materials
    1. Moisture
    2. Loss on ignition
    3. Silica Content
    4. Particle Size Distribution – Hydrometer, Andreason Pipette
2. Fabrication Techniques
    1. Uniaxial Pressing
    2. Cold Extrusion
    3. Slip Casting
3. Analysis of Ceramic Materials – Density, Porosity, Water absorption, Shrinkage, Flexural Strength – 3 point & 4 point , Compressive Strength, Tensile Strength, Rheology study
4. Firing Studies

TOTAL: 45 PERIODS

CR9121 ADVANCED PROCESS TECHNOLOGY OF CERAMICS **L T P C**
3 0 0 3

AIM

The course is aimed to impart basic knowledge about powder preparation techniques and modern ceramic processing.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about powder preparation, characterization and compaction.
- Have learnt about various techniques for modern processing.
- Have basic knowledge about sintering and fired product characterization.

UNIT I POWDER PREPARATION 9

Powder preparation by mechanical methods – communition, mechano-chemical synthesis. Powder synthesis by chemical methods – solid state reaction, liquid solutions, vapour phase reactions, combustion synthesis - Synthesis of nano scale ceramic powder – liquid solution technique, vapour phase technique. Influence of particle size on packing.

UNIT II PROCESSING ADDITIVES 7

Types, Properties and Effect of addition of liquids and wetting agents, deflocculants, coagulants, binders, bonds, plasticizers, foaming and antifoaming agents, lubricants, preservatives.

UNIT III FORMING 10

Forming of ceramics – dry and semidry pressing - die compaction and isostatic compaction; casting methods - slip casting, pressure casting, gel casting, electrophoretic deposition; plastic forming methods - extrusion, co-extrusion, injection molding, solid freeform fabrication - particle filled polymer methods, powder methods, suspension methods- Porous ceramic forming- foaming, intrusion, organic additives – advanced composite manufacture – CVI, polymer impregnation followed by pyrolysis(PIP).

UNIT IV SINTERING 11

Solid state sintering – driving force, effect of surface curvature and boundary defects, mechanism, stages of sintering. Liquid phase sintering – stages, kinetic and thermodynamic factors, phase diagram in liquid phase sintering. Grain growth – different grain growth process, control of grain growth, grain growth and pore evolution in a porous compact, interaction between pore and grain boundary. Pressure assisted sintering – hot pressing and hot iso-static pressing. Reaction bonded sintering, microwave sintering.

UNIT V POST FORMING PROCESSES 8

Mechanism of material removal and its effect on strength, surface grinding and mechanical polishing, non abrasive finishing, ceramic surface coating, joining of ceramics – metal ceramic joints.

TOTAL:45 PERIODS

REFERENCES

1. Mohamed N.Rahaman, Ceramic Processing, Taylor & Francis, 2007.
2. David W. Richerson, Modern Ceramic Engineering, 3rd Edn., Taylor & Francis, 2005.
3. Paul De Garmo E, Black J.J and Ronald A.Kohser, Materials and Processes in Manufacturing, 8th Edn., Prentice – Hall India Pvt. Ltd., New Delhi, 1997.
4. Reed J.S, Introduction to the Principles of Ceramic Processing, Wiley, New York, 1988.

5. John G.P.Binner (Ed), Advanced Ceramics Processing and Technology, Noyes Publications, New Jersey, 1990.
6. Burtrand Lee and Sridhar Komarnei (Eds.), Chemical Processing of Ceramics, 2nd Edn., Taylor & Francis, 2005.
7. K.K.Chawla, Ceramic Matrix Composites

CR9122 MODERN CERAMIC MATERIALS L T P C
3 0 0 3

AIM

The course is aimed to impart basic knowledge about various advanced ceramic materials and its structure, properties and applications.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about ceramics in turbine blades, piezoelectrics.
- Have learnt about various advanced and structural ceramics.
- Have basic knowledge about special glasses and glass ceramics.

UNIT I CERAMICS & COMPOSITES FOR HOSTILE ENVIRONMENTS 9

Heat engine ceramics – turbine blade ceramics – heat exchanger ceramics – heat shield ceramics – metal matrix , polymer matrix, ceramic matrix composites.

UNIT II ELECTRONIC CERAMICS 9

Ferro-electrics – electrical insulators – smart ceramics - piezo electrics – ferrite – PLZT sensors metallised ceramics – gas sensors – superconducting ceramics.

UNIT III STRUCTURAL CERAMICS 8

Carbides – nitrides – oxides – SiAlON – borides – silicides.

UNIT IV SPECIAL GLASSES AND GLASS CERAMICS 10

High purity silica glasses – laser glasses – optical glasses – fibre glasses – oxide and non-oxide glasses – oxy-nitride glasses - photosensitive glasses – conducting glasses - glass ceramics, applications of glass ceramics – glass for satellite applications.

UNIT V BIOMATERIALS 9

Introduction – biomaterials, bioceramics – composition, interaction with biological systems, properties, applications, shape memory alloys.

TOTAL: 45 PERIODS

REFERENCES

1. Larsen ,D.C., C.W., Adams., L.R.Johnson, A.P.S. Teotia and L.G.Hill, Ceramic Materials for Advanced Heat Engines, 1985,Noyes Pub., New Jersey, USA.
2. Dorre, E., and H.Hibner, Alumina Processing, Properties and Applications,1984, Springer-Verlag, NY.
3. Stevens, R.,Zirconia and Zirconia Ceramics, 1986,Magnesium Elektron Ltd.
4. Lewis,M.H., Glasses and Glass Ceramics,1987,Chapman and Hall, London.
5. Somiya, S., Advanced Ceramics 3,1990,Elseivr Applied Science, NY.
6. Gernot Kostorz, High-Tech. Ceramics,1989, Academic Press, NY.
7. Brook, R.J.(Ed), Concise Encyclopedia of Advanced Ceramic Materials, 1991,Pergamon Press, NY.
8. Noboru Ichinose, Introduction to Fine Ceramics, 1987, John Wiley & Sons.

CR9123 MATERIAL CHARACTERIZATION TECHNIQUES **L T P C**
3 0 0 3

AIM

The course is aimed to impart basic knowledge about various characterization techniques employed to characterize a ceramic material.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about chemical methods, spectroscopic techniques, surface analysis.
- Have learnt about various non-destructive methods.
- Have basic knowledge about X-Ray diffraction spectroscopy.

UNIT I CHEMICAL AND THERMAL METHODS 9

Chemical Methods – Volumetric, Gravimetric and Colorimetric analysis. Thermal Methods – TGA, DTA and DSC.

UNIT II UNSPECTROSCOPIC METHODS 8

U-V, Visible, IR, FTIR and NMR spectroscopy – fluorescence and phosphorescence methods – flame photometry – atomic absorption – ICP.

UNIT III X-RAY METHODS 10

Single crystal techniques – powder diffraction – materials identification, composition and phase diagram analysis – X-ray Fluorescence.

UNIT IV METHODS FOR SURFACE ANALYSIS 10

Optical Microscope, SEM, TEM – particle size and surface study – electron microprobe analysis – ion scattering spectrometry (ISS), secondary ion mass spectrometry (SIMS), auger emission spectrometry (AES), electron spectroscopy for chemical analysis (ESCA), AFM, Surface area, pore volume measurements by B.E.T. method, Mercury porosimetry - Particle size measurement – laser diffraction, x-ray diffraction.

UNIT V NON-DESTRUCTIVE METHODS 8

Analysis of finished goods – ultrasonic techniques – reflection techniques – back reflection and pulse-echo – thickness measurement by resonance; Acoustic emission techniques- Radiographic testing - thermographic testing.

TOTAL: 45 PERIODS

REFERENCES

1. Willard, H.H., L.L.Meritt, J.A.Denn and F.A.Settle, Instrumental Methods of Analysis, 1986, CBS Publishers, New Delhi.
2. Sibilia,J.P., A Guide to Materials Characterization and Chemical Analysis, 1988, VCH Publishers and Co.
3. Cullity, B.D. Elements of X-ray Diffraction, 1978, Addison –Wesley Publishing Company Inc, Massachusetts.
4. Ewing, G.W., Instrumental Methods of Chemical Analysis, 1985, McGraw-Hill Book Company,New York.
5. Gabriel, B.L., SEM: A User’s Manual for Material Science, 1985, American Society for Metals Park.

CR9124 PHASE EQUILIBRIA & KINETICS OF CERAMIC SYSTEMS **L T P C**
3 0 0 3

AIM

The course is aimed to enable the students to have a thorough knowledge about the importance of phase equilibrium and analyzing different systems.

OBJECTIVES

On completion of the course the students are expected to

- Have learnt the basics of phase equilibrium and phase diagrams.
- Have studied the thermodynamics behind phase equilibria.
- Have a better understanding on the different two component and three component phase diagrams.
- Have studied the types and theory behind phase transformations and also about nucleation and growth.
- Have gained knowledge on the different experimental methods to determine phase diagrams.

UNIT I INTRODUCTION 9

Introduction, phase, component, variable, Gibb's phase rule, single component system – H_2O, SiO_2, iron, Hume Rothery's rule; binary phase diagrams – eutectic, incongruent, solid solutions, complex diagrams.

UNIT II THERMODYNAMICS OF PHASE EQUILIBRIA 9

Introduction, criteria of phase equilibrium, criterion of stability, phase equilibria in single component system and multi component system; binary solutions – constant pressure system, constant temperature system, partially miscible system, immiscible system, liquid-liquid equilibrium diagrams, ternary equilibrium diagrams.

UNIT III PHASE DIAGRAMS 9

Al_2O_3 – SiO_2, MgO – Al_2O_3, MgO – SiO_2, Al_2O_3 – ZrO_2, stabilized zirconia, K_2O – Al_2O_3 – SiO_2, MgO – Al_2O_3 – SiO_2, Na_2O – Al_2O_3 – SiO_2. Prediction of alkali corrosion of alumino silicate refractories using phase diagrams.

UNIT IV PHASE TRANSFORMATIONS 9

Introduction, Time Scale for phase transformations, types of transformations – spinoidal, nucleation & growth, theory of transformation kinetics, kinetics of solid state reactions occurring at elevated temperatures , solid, liquid and dissociation reactions ; nucleation and growth – nucleation kinetics, homogeneous nucleation, heterogeneous nucleation, growth and overall transformation kinetics, sintering & crystallization in ceramics and glass forming systems.

UNIT V EXPERIMENTAL METHODS 9

Techniques for determining phase diagrams – dynamic, static, microscopic methods – optical, electron microscopy, X-ray methods, thermal analysis.

TOTAL: 45 PERIODS

REFERENCES

1. Kingery W.D, Yet Ming Chiang and Dunbar P.Birnie III, Physical Ceramics – Principles for Ceramic Science and Engineering, John Wiley & Sons, 1995.
2. Floyd A.Hammel, Phase Equilibria in Ceramic Systems, Marcel Dekker, 1984.
3. Kingery W.D, Bowen H.K and Uhlmann D.Rm Introduction to Ceramics, 2nd Edn., John Wiley & Sons, 2004.
4. Allen M.Alper, Phase diagrams in Advanced Ceramics, Academic Press Inc., 1995.
5. Barsoum M.W, Fundamentals of Ceramics, McGraw Hill, 1997.

CR9125 MATERIALS CHARACTERIZATION LAB **L T P C**
0 0 2 1

AIM

The course is aimed to impart practical knowledge about characterization of a ceramic sample.

OBJECTIVES

On completion of the course the students are expected to

- To have a basic understanding about different methods of characterizing a ceramic sample.

1. Analysis of Trace Elements using Spectrophotometer, Flame Photometer and Atomic Absorption Spectroscopy.
2. Thermal Analysis – TGA, DTA, DSC.
3. Determination of Viscosity by Brookfield Viscometer.
4. Particle Size Analysis – Laser Diffraction.
5. Microscopy – Optical, SEM.
6. Vicker's Hardness.
7. Modulus of Rupture – 3 point & 4 point
8. Creep, Wear and Abrasion Resistance.
9. Surface Area Measurement – BET.
10. Atomic Force Microscope
11. Mercury Porosimetry

TOTAL: 30 PERIODS

CR9131 NANO SCIENCE & TECHNOLOGY OF CERAMICS **L T P C**
3 0 0 3

AIM

The course is aimed to enable the students to have a basic knowledge about the developing field on nanotechnology , nanoceramics and composites.

OBJECTIVES

- On completion of the course the students are expected to have a complete knowledge about the preparation, characterization and applications of nano ceramics and composites.

UNIT I INTRODUCTION **9**

General definition and size effects–important nano structured materials and nano particles- importance of nano materials- applications.

UNIT II SYNTHESIS & CONSOLIDATION **9**

Bottom up and Top down approach for obtaining nano materials - Precipitation methods – sol gel technique – high energy ball milling, CVD and PVD methods, gas phase condensation, magnetron sputtering and laser deposition methods – laser ablation, sputtering.

UNIT III NANOCERAMICS **9**

Introduction to nano ceramics- properties of nano ceramics- advanced nano ceramics- carbon nano tubes, fibres, nanosilica-nano alumina- nano titania and zinc oxide- applications.

UNIT IV NANO COMPOSITES 9

Definition- importance of nanocomposites- nano composite materials-classification of composites- metal/ceramics, metal-polymer- thermoplastic based, thermoset based and elastomer based- influence of size, shape and role of interface in composites- applications.

UNIT V CHARACTERIZATION METHODS 9

X-ray diffraction, Raman spectroscopy- UV- visible spectroscopy, scanning probe microscopy, atomic force microscopy, scanning electron microscopy and transmission electron microscopy techniques.

TOTAL :45 PERIODS

REFERENCES

1. R.H.J.Hannink & A.J.Hill, Nanostructure Control, Wood Head Publishing Ltd.,Cambridge, 2006.
2. C.N.R.Rao, A.Muller, A.K.Cheetham, The Chemistry of Nanomaterials: Synthesis, Properties and Applications Vol. I & II, 2^{nd} edition, 2005, Wiley VCH Verlag Gibtl &Co
3. J.Stows Hall, Nanofuture, Manas Publications, 2006.
4. Mick Wilson, Kamali Kannangara,Geoff Smith, Michelle Simmom, Burkhard Raguse, " Nano Technology: Basic Science & Engineering Technology", 2005, Overseas Press.
5. Karl.M.Kadish, Rodney S.Rnoff, " Fullereness : Chemistry, Physics and Technology", John Wiley & Son Inc. Publications, 2000.

CR9151 CERAMIC COATING TECHNOLOGY L T P C
3 0 0 3

AIM

The course is aimed to impart basic knowledge about glaze and advanced coating techniques.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about glazes, manufacturing processes.
- Have learnt about various selection and control methods.
- Have basic knowledge about advanced coating techniques.

UNIT I INTRODUCTION 9

Introduction to surface engineering & modification – wear, abrasion, oxidation resistance – need for coating on the body – advantages

UNIT II GLAZE 9

Definitions, classification, raw materials, frit preparation, compounding, frit characteristics and quality testing - glaze body reactions, glaze formulation, additives, thermal characterization, chemical resistance, evaluation methods.

For glasses and coating, unit operations and processes, glaze application methods, selection of glaze to suit end product characteristics, glaze stains, ceramic colors, lusters.

UNIT III CONTROL METHODS 9

Raw material selection, process selection and controls, defects / fracture classification – defect cure methods – instrumentation – typical quality control system.

UNIT IV ADVANCED COATING TECHNIQUES 9

Slurry coating – dip coating, spray coating, plasma spray – EVD, CVD, PVD, thermal spray, magnetic sputtering, laser ablation, nanocoatings

UNIT V ENAMELS 9

Cleaning methods for iron and steel, sheet metals – chemical claning – electrolytic cleaning – pickling – sand blasting – de enamellin – repairing – cleaning treatment for aluminum alloys and base metals – frit making – additives – applications – firing.

TOTAL: 45 PERIODS

REFERENCES

1. Taylor, J.R., and A.C.Bull, Ceramic Glaze Technology, 1986, Pergamon Press, NY.
2. Klein, L., (Ed), Sol-Gel Technology for Thin Films, Fibres, Performs, Electronic and Speciality Shapes, 1988, Noyes Publications, New Jersey, USA.
3. Bunshah.R.F. (Ed), Films and Coatings for Technology, 1982, Noyes Date Corp., New Jersey, USA.
4. Hocking, M.G., V.Vasantasree and P.S.Sidky, Metallic and Ceramic Coatings, 1989, Longman.
5. Kenneth Shaw, Ceramic Glazes, 1971, Elsiever Publishing Co., NY.
6. Emmanuel Cooper, The Potter Book of Glaze Recipes, 1986, B.T. Batsford Ltd, London.

CR9152 NUMERICAL TECHNIQUES L T P C

3 0 0 3

AIM

The course is aimed to impart basic knowledge about numerical solutions of partial differential equations.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about interpolation and approximation..
- Have learnt about various numerical solutions for ordinary and partial differential equations.
- Have basic knowledge about pertubation theories.

UNIT I INTERPOLATION AND APPROXIMATION 9

Piecewise spline approximation, uniform approximation, rational approximation

UNIT II NUMERICAL SOLUTIONS OF ORDINARY DIFFERENTIAL EQUATION 9

Euler Method, Improved Euler Method, Modified Euler method, Runge Kutta Method of Second and Fourth orders, Predictors – Corrector Methods of Miline and Adams – Bashforths.

UNIT III NUMERICAL SOLUTIONS OF PARTIAL DIFFERENTIAL EQUATIONS 9

Second order equations, elliptic, parabolic, hyperbolic types using finite difference methods.

UNIT IV FINITE ELEMENT METHODS 9

One dimensional stress deformation, global and local co-ordinates, one dimensional problems, interpolation functions, relations between global local coordinates, requirements for approximation functions, stress and strain relations, principle of minimum potential energy, potential energy approach for assembly, boundary conditions.

UNIT V PERTURBATION METHOD 9

Perturbation theory, Regular and singular Perturbation Theory. Perturbation methods for linear Eigen Value problems, asymptotic matching

TOTAL: 45 PERIODS

REFERENCES

1. Jain M.K, S.R.K.Iyengar and R.K.Jain, Numerical Methods for Simple and Engineering Computation, Eastern Ltd 1995.
2. Desai C.S. Elementary Finite Methods, Prentice Hall 1922 Ch.2&3
3. Bender C.M and S.A Orzag, Advanced Mathematical Methods for Scientists and Engineers, McGraw Hill, International Edition 1998.

CR9153 ENVIRONMENTAL ENGINEERING L T P C
3 0 0 3

AIM

The course is aimed to impart basic knowledge about pollution and it's control techniques.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about atmospheric dispersion of pollutants.
- Have learnt about various choice of equipments selection.
- Have basic knowledge about control procedures and various filtration techniques.

UNIT I POLLUTION DYNAMICS 9

Air pollutants – transportation - introductory treatment of atmospheric dispersion of pollutants - Diffusion of stack effluents.

UNIT II EQUIPMENT SELECTION 9

Choice of techniques - selection of equipment for the treatment of gaseous particulate and liquid effluents of chemical, petrochemical and ceramic industries.

UNIT III TREATMENT AND DESIGN 9

Waste disposal and treatment for the recovery of valuable chemicals, design of pollution control devices, design of chimneys, stacks for pollution control

UNIT IV CONTROL TECHNIQUES AND EQUIPMNENTS 9

Counter current wet scrubber, venturi scrubber, absorption system design, adsorption and combustion devices, bag filters, electrostatic precipitation, reverse osmosis, recycle systems and sustainable development.

UNIT V CONTROL PROCEDURES 9

Sampling procedures, analytical methods, odours and their control, noise pollution and abatement, high voltage transmission and safety, legislative aspects of management.

TOTAL: 45 PERIODS

REFERENCES
1. Theodore L. and Buomlore A.J, Air Pollution Control Equipments, Prentice Hall Inc., N.Y,1982
2. Coulson, J.M.Richardon, J.F. and R.K. Sinott, Chemical Engineering., Vol.6, Pergamon Press, 1989.
3. Rao, C.S, Environmental Pollution Control Engineering, Wiley – Eastern Ltd., 1991.
4. Rao, M.N. and H.V.N.Rao, Air – Pollution, Tata McGraw Hill Pub.Co.,Ltd.1989

CR9154 PROCESS MODELLING, SIMULATION AND OPTIMISATION **L T P C**
3 0 0 3

AIM

The course is aimed to impart basic knowledge about Modelling, Optimization and modelling of heat, mass and momentum transfer operations.

OBJECTIVES

On completion of the course the students are expected to

- Have basic understanding about formulation, analytical and numerical techniques.
- Have learnt about various optimization techniques.
- Have basic knowledge about model discrimination, parameter estimation and transfer operations.

UNIT I BASIC MODELLING **9**

Introduction of modeling, Application and Scope Of Coverage, Formulation, Review of Algebraic Equators, Ordinary and Partial Differential Equation. Analytical and Numerical Techniques, Smoothing Techniques, Spline function approximations.

UNIT II MODELLING OF HEAT, MASS AND MOMENTUM TRANSFER OPERATIONS **9**

Review of heat, mass and momentum transfer operations, Modelling of heat Exchangers, Evaporators, Absorption Columns, Extractors, Distillation columns, Membrane processes.

UNIT III MODEL DISCRIMINATION AND PARAMETER ESTIMATIMATION **9**

Rate equations, Linear and Non-Linear Regression Analysis, Design of Experiments, Factorial, Central, Fractional Design, Evolutionary Operation Techniques, Case studies.

UNIT IV OPTIMIZATION TECHNIQUES **9**

Functions, Analytical and numerical methods for single variable and multivariable system, Constrained optimization techniques.

UNIT V APPLICATION OF OPTIMIZATION **9**

Heat transfer and energy conservation, separation techniques, Fluid Flow Systems, Chemical Reactor Design.

TOTAL: 45 PERIODS

REFERENCES

1. Edgar, T.F. and D.M.Himmelblau, Optimization of Chemical Processes, McGraw Hill Book Co. NewYork, 1989.
2. Lubeyn W.L., Process Modelling, Simulation and Control Engineering, McGraw Hill Book Co. NewYork, 1990.
3. Chemical Engineering Tutorial Numerical Methods, Chemical Engineering, August 17, October 26, 1987 Feb.15, April 25, July 18, Nov.21 1988, July 14, 1989.
4. Chemical Engineering Tutorial Statistics for Chemical Engineers, Chemical Engineering, July.23, Sep.17, Nov.26, 1984. Jan.21, Mar.18, Jun.10, Sep.30, 1985, Feb.3, Apr.14, Jun.23, Sep.1, 1986.

CR9155 OPERATION RESEARCH L T P C

3 0 0 3

AIM

The course is aimed to impart basic knowledge about linear programming and the various control methods.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about linear programming and its branches.
- Have learnt about various control methods and path calculations of a process in inline.
- Be capable of understanding failure distributions.

UNIT I MATHEMATICAL PROGRAMMING 12

Introduction, linear programming, solution by simplex methods, duality, sensitivity analysis, dual simplex method, integer programming, branch and bound method.

UNIT II DYNAMIC PROGRAMMING 9

Elements of DP models, Bellman's optimality criteria, Recursion formulae, solution of multistage decision problem by DP method.

UNIT III PERT, CPM 9

Network representation of projects, critical path calculation, construction of the time chart and resource leveling, probability and cost consideration in project scheduling, project control.

UNIT IV ELEMENTS OF QUENING THEORY 8

Basic elements of the Quening model, M/M/I and M/M/C Quenes.

UNIT V ELEMENTS OF RELIABILITY THEORY 7

General failure distribution of components, Exponential failure distributions, General model, maintained and non-maintained systems.

TOTAL: 45 PERIODS

REFERENCES

1. Hamdej A. Taha, Operations Research, An introduction, Macmillan Publishing Co., Third Edition, 1982(Ch 3,4,8,9,12 and 15 except 15.4, 15.5 and 15.6).
2. Narayan Bhat.U., Elements of Applied Stochastic Processes, John Wiley and Sons, 1972, Chennai 12.

CR9156 **SAFETY ENGINEERING** **L T P C**
3 0 0 3

AIM

The course is aimed to impart basic knowledge about hazards, its effects, safety and waste management together with risk analysis.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about hazard identification and checks for safety.
- Have learnt about various waste management techniques.
- Have basic knowledge about risk analysis, format and methods.

UNIT I GENERAL 9

Safety - total definition - hazard identification, general hazards of plant operation, toxic hazards, fire & explosions – hazards transport of chemicals with safety unforeseen deviations emergency management, planning for safety, selecting basis of safety preventive and protective measures, safety based on emergency, relief systems, safety based on containment, operational safety procedural instructions Sla-routine checks, process and product charges, safety checks, checklist for safety, leaks and detection.

UNIT II HAZARDS AND EFFECTS 9

Hazards of plant operation, toxic hazards, fire and explosion hazards, reaction hazards, literature calculations & explosions screening, normal reaction, gas evolution, characterizing runaways, control and mitigation of gas emanations, absorption with chemical reaction, health and environ effects.

special problem of developing countries, safety gadgets, dispersions, degree of hazard, disposals, hierarchy of options, I.C.A. application, nil hazards & alternate methods, threshold limits, laws of safety, accident reporting.

UNIT III ACCIDENT REPORTING INVESTIGATION AND DOCUMENTATION 9

Reporting an accident – selling up closed loop reporting system – Automated system – Forming an investigation board – Conducting an investigation – investigation report – Documenting the accident – Retention of records – Public release of information

UNIT IV WASTE MANAGEMENT AND ECONOMICS 9

Storage, central handling safety, unintentional spills, run offs emits, containment economics, waste disposal and environmental projection, incineration, alternatives.

UNIT V RISK ANALYSIS 9

Risk analysis, evaluation, mitigation, hazop, hazan, definition, probability, quantification-risk, engineering, clean technology, initiatives, standards, emergency handling, accident investigation, legislation, nil risk quantification methods, case histories of accidents, examples of hazards assessment, examples of use of hazan, explosion hazards in batch units, technical process, documentation for hazardous chemicals, format and methods.

TOTAL: 45 PERIODS

REFERENCES

1. Rohatga.A.K. Safety Handling of Hazardous Chemicals Enterprises, Bombay (1986).
2. Shukla.S.K.-Enviro Hazards and Techno Legal Aspects, Shashi Publications, Jaipur-India(1993).
3. Wells G.L. and R.M.C.Seagrave –Flow Sheeting for Safety, I.Ch.E.London, U.K.(1977).
4. Learning from Accidents- Trevur Kletz Butterworths London U.K.(1988).
5. Chemical Reaction Hazards – A Guide to Safety, Institution of Chemical Engineering London U.K. Ed by John Barton and Richards Rogers (1997).

CR9157 ELECTRONIC CERAMIC MATERIALS AND THEIR APPLICATIONS **L T P C 3 0 0 3**

AIM

The course is aimed to impart basic knowledge about ceramic materials used for electronic applications.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about gas sensors and fuel cells, Piezo-electric Ceramics..
- Have learnt about various thermistors and varistors..
- Have basic knowledge about insulators and capacitors.

UNIT I CERAMIC INSULATORS 9

Porcelain insulators, low tension and high tension, steatite, forsterite, cordierite and high alumina insulators, glass insulators. thermal and mechanical properties, dielectric properties, insulation resistance, electrical conduction, defects, diffusion, oxide conduction.

UNIT II CERAMIC CAPACITORS 9

Properties of barium titanate, effect of various additives and composition on dielectric properties, manufacturing techniques – film cpacitors, single layer discrete capacitors, multilayer capacitors, barrier layer, multilayer GBBL capacitors.

UNIT III THERMISTORS AND VARISTORS 9

NTC materials: solid solutions of oxides with the spinel structure, Fe_3O_4, $ZnCr_2O_4$, Fe_3O_4, $MgCr_2O_4$,PTC materials - $BaTiO_3$, $SrTiO_3$ and BLT materials, principles of operation, properties and applications, ZnO varistors, properties and applications.

UNIT IV PIEZO – ELECTRIC CERAMICS. 9

Preparation of various types of PZT ceramics, effect of additives, various types of PZT and PLZT devices, PMN, PMMN their properties and applications, actuators.

UNIT V GAS SENSORS AND FUEL CELLS 9

Sensors – principle, types - Zirconia and titania based gas sensors, properties and applications, humidity sensors, fuel cells – principle of operation , fuel cell reaction, types, hydrogen oxygen fuel cell, carbon-oxygen, hydrazine and ammonia fuel cells, high temperature fuel cell, applications.

TOTAL: 45 PERIODS

REFERENCES

1. Moulson, A.J., and J.M. Herbert, Electroceramics, 1990, Chapman and Hall, London.
2. Levinson, M.L.,Electronic Ceramics, 1988, Marcel Dekker, NY.
3. Buchanan, R.C., Ceramic Materials for Electronics, 1986, Marcel Dekker, NY.
4. Steele, B.C.H., Electronic Ceramics, 1991, Elseiver Applied Science, London.
5. Setter, N. and E.L.Colla, Ferroelectric Ceramics, 1993, Birkhauser Verlag, Base.

CR9158 MONOLITHICS AND CASTABLES L T P C
3 0 0 3

AIM

The course is aimed to enable the students to have a sound knowledge about the types, properties and applications of monolithics and castables.

OBJECTIVES

On completion of the course the students are expected to

- Have learnt the types of castables, its composition and characteristics.
- Have a better understanding on the use of plastic refractories, ramming and gunning mixes as monolithic materials.
- Have studied about the composition and characteristics of mortars, coatings and dry vibratables.
- Have a clear idea on the methods of installing different monolithic materials, the application design and the lining materials used while laying monolithics.
- Have studied the wear mechanisms that cause failure in a monolithic lining and the methods to test a monolithic.

UNIT I CASTABLES 10

Introduction, types – conventional castables, low cement castables, ultra low cement castables, cement free castables – manufacture, composition, characteristics, applications. Other castables – insulating castables, pumpable castables – manufacture, composition, characteristics and applications.

UNIT II PLASTIC REFRACTORIES, RAMMING AND GUNNING MIXES 10

Plastic refractories – introduction, manufacture, composition, properties and applications. Ramming mix – manufacture, characteristics and applications. Gunning mix – manufacture, characteristics and applications.

UNIT III MORTARS, COATINGS AND DRY VIBRATABLES 7

Mortars – introduction, classification, characteristics. Coatings – introduction, characteristics. Dry vibratables – introduction, principle and applications.

UNIT IV MONOLITHIC INSTALLATION 10

Methods of installations of castables, plastic refractories, ramming mix and gunning mix.Drying and heating up of installed monolithic lining. Application designs – blast furnace trough design, trough lining, and form design, tundish, steel ladle, electric arc furnace. Linings in installation – anchors, steel fibre reinforcements.

UNIT V WEAR MECHANISMS AND TESTING 8

Wear mechanisms – introduction, abrasion, penetration, corrosion, spalling. Tests done on monolithics – chemical analysis, density, porosity, strength, high temperature properties, corrosion, erosion.

TOTAL: 45 PERIODS

REFERENCES

1. Subrata Banerjee, Monolithic Refractories, World Scientific Publishing Co. Pte. Ltd., 1998.
2. Taikabutsu Overseas Vol.9 No.1, Recent Progress in Castable Refractories, Techno Japan, Fuji Marketing Research Co. Ltd., Japan, 1995.
3. Charles A.Schacht, Refractories Handbook, Marcel Dekker Inc, New York, 2004.
4. Norton F.H, Refractories, 4^{th} Edn., McGraw Hill Book Co., 1968.
5. Nandi D.N, Handbook of Refractories, Tata McGraw-Hill Publishing Co., New Delhi, 1991.
6. Akira Nishikawa, Technology of Monolithic Refractories, Plibrico, Japan Co. Ltd., Tokyo, 1984.

CR9159 **ABRASIVES** **L T P C**

3 0 0 3

AIM

The course is aimed to impart basic knowledge about classification of abrasives and importance of grinding and polishing.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about contact wheels, belt tension etc.
- Have learnt in detail about coated abrasives.
- Have basic knowledge about grinding and polishing
- Have learnt in detail about bonded abrasives.

UNIT I INTRODUCTION 9

Abrasives – definition, classification, applications. Abrasive grains – classification, characteristics like hardness, toughness etc. Backings – cloth, paper, fibre, combination backing, their characteristics. Adhesives – classification, characteristics.

UNIT II COATED ABRASIVES 9

Raw material selection and preliminary treatments, maker coating, abrasive coating – methods – continuous , individual disc coating and types of coating, sizer coating, drying and humidification, flexing, forms of coated abrasives - belt making, sheet cutting, disc punching, flap wheels - quality control and testing.

UNIT III METHODS OF USING COATED ABRASIVES 9

Contact wheels - cloth contact wheels, rubber contact wheels, hardness, face serrations, shape, wheel diameter, speed, belt tension, dressing and protection of contact wheels, their characteristics - drums, rolls, pads, and platens, types, characteristics, choice and uses.

UNIT IV BONDED ABRASIVES 9

Abrasive grain type and characteristics required for bonded abrasives. Types of bonds – vitrified, silicate, resinoid, shellac, rubber, metal and oxychloride. Bonded wheel manufacture with different bonds and their characteristics. Shapes and sizes of wheels. Factors determining grinding action – characteristics of abrasive grain, bond type, structure. Other types of wheels – Diamond wheels, reinforced wheels, mounted wheels

UNIT V FUNDAMENTALS OF GRINDING AND POLISHING 9

Grinding wheel – definition, abrasives chosen, grinding chips, chemical reactions, grade selection, wheel wear, chemical grinding aids. Grinding fluids – properties, types and purpose. Types of grinding – cylindrical grinding, centre less grinding, surface grinding, internal grinding. Polishing – definition, types.

TOTAL: 45 PERIODS

REFERENCES

1. Coes L Jr., Abrasive, Springer Verlag, New York, 1971.
2. Coated Abrasives – Modern Tool of Industry, Coated Abrasive Manufacturer's Institute, Cleaveland, Ohio, 1982.
3. Metzger J.L, Super Abrasive Grinding, Butterworths, UK, 1986.
4. Francis T.Farago, Abrasive Methods Engineering, Vol.2, Industrial Press Inc., NY, 1980.
5. Edwards R, Cutting Tools, The Institute of Materials, Cambridge, 1993.
6. Kenneth B.Lewis, William F.Schleicher, The Grinding Wheel, The Grinding Wheel Institute, Cleaveland, Ohio, 1976.

CR9160 CERAMIC FIBRES AND COMPOSITES L T P C
3 0 0 3

AIM

The course is aimed to impart basic knowledge about composites, whiskers and fibres with their properties, manufacturing routes and applications.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about whiskers and their forming mechanism.
- Have learnt about various fibres, their properties and applications.
- Have basic knowledge about manufacturing of composites.

UNIT I CERAMIC FIBRES 9

Introduction – difference between material in bulk form and fibre form – types of fibres – fibre flexibility -fibre manufacturing technology, – glass fibres – manufacture & applications – carbon fibres – PAN based, pitch based , vapor grown – manufacture (PAN based), grades of carbon fibres, .

UNIT II REFRACTORY FIBRES 9

Alumina silicate, mullite, alumina, silica, zirconia and boron, structure, fibre manufacturing process, properties and applications silicon carbide fibre – manufacturing process – CVD, polymer pyrolysis , applications.

UNIT III WHISKERS 9

Whisker forming mechanism, VLS, CVD, silicon carbide, boron carbide and strontium hexa-aluminate whiskers and platelets microstructure, properties and application.

UNIT IV COMPOSITES – TEAM WORK & SYNERGY IN MATERIALS 9

Introduction to composite materials – classification – PMC, CMC, MMC – manufacturing, properties & applications – carbon – carbon composites, hybrid composites

UNIT V CHARACTERIZATION 9

Physical – density, porosity, pore size distribution, fibre length, fibre orientation, fibre concentration, Thermal – thermal expansion coefficient, thermal conductivity, Mechanical – tensile, flexural, interlaminar shear stress, oxidation resistance, electrical conductivity, interface characteristics, fracture toughness, charpy test, XRD, microstructure evaluation.

TOTAL: 45 PERIODS

REFERENCES

1. Chawla,K.K., Ceramic Matrix Composites, 1993, Chapman & Hall, NY.
2. Richard Warren, Ceramic-Matrix Composites, 1992, Blackie, Glagow.
3. Mazdiyasmi, K.S., Fibre Reinforced Ceramic Composites, 1990, Noyes Publications, New Jersey.
4. Murray, J.G., High Performance Fibre Composites, 1987, Academic Press, NY.
5. Ashes, K.H.G., Fundamentals Principles of Fibre Reinforced Composites, 1989, Technomic Publishing Co. Inc.

CR9161 **GLASS ENGINEERING** **L T P C**
3 0 0 3

AIM

The course is aimed to impart basic knowledge on manufacture, properties and applications of glass.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about raw materials and batch charging.
- Have learnt about various fuels and glass melting furnaces.
- Have basic knowledge about forming and annealing processes
- Have learnt about the properties and applications of special glasses.

UNIT I GLASS FORMATION 10

Definition. Glass Formation – atomistic hypothesis of glass formation, kinetic approach to glass formation. Structures of glasses – fundamental laws, elements of structural models for glasses, structural models for silicate glasses. Phase diagrams of glass forming oxide systems – $CaO-Al_2O_3-SiO_2$, $Na_2O-CaO-SiO_2$ etc.

UNIT II RAW MATERIALS AND BATCH PREPARATION 9

Raw materials – Handling and storage –Briquetting and Pelletizing – Batch charging. Glass compositions – Glass Batch Calculation.

UNIT III GLASS MELTING FURNACES 10

Construction and operation of pot furnace and day tank furnace. Tank furnace – types, design & construction, refractories used. Electric tank furnace – design & operation, electrodes used, electric boosting in tank furnace. Heat recovery systems. Major reactions and physiochemical changes during glass melting.

UNIT IV FORMING PROCESS 9

Forehearth & Feeder, hand operations, flatware – sheet glass, float glass, plate glass, patterned glass. Hollow ware – press & blow, blow & blow, IS machine, bulbs & tubes. Annealing – Importance – Strain release – Annealing cycle – Annealing lehr.

UNIT V SPECIAL TREATMENTS 7

Mirror, chemical vapour deposition, physical vapour deposition process, laminated glass, tempered glass, decorated glasses, vycor & micro porous glass, sealing glass, neutral glass, photosensitive glass, glass ceramic, glass fibers.

TOTAL: 45 PERIODS

REFERENCES

1. James E.Shelby, Introduction to Glass Science & Technology, The Royal Society of Chemistry, 1997.
2. Paul, Chemistry of Glasses, 2^{nd} Edn, Chapman & Hall, 1990.
3. Fundamentals of Glass Manufacturing Process 1991, Proceedings of the First Conference of the European Society of Glass Science and Technology, Society of Glass Technology, 1991.
4. Tooley F.V, Handbook of Glass Manufacture, Vol I&II, Ogden Publishing Co., NY, 1960.
5. A. Charles A Harper, Handbook of Ceramic Glasses & Diamonds, McGraw Hill, 2001.
6. Glass Furnaces-Design, Construction & Operation, Wolfgang Trier, Society of Glass Technology, 2000.
7. Volf V.B, Technical Approach to Glass, Elsevier, 1990.

CR9162 ADVANCED REFRACTORY ENGINEERING **L T P C**
3 0 0 3

AIM
The course is aimed to impart basic knowledge about refractory for various industries and conservation.

OBJECTIVES
On completion of the course the students are expected to
- Have a basic understanding about applications of refractories in steel, cement, glass industries.
- Have learnt about various choice of refractory for kiln furniture.
- Have basic knowledge about energy conservation using ceramic fibres.

UNIT I MONOLITHIC REFRACTORIES 9
Different kinds of monolithic refractories , advantages of monolithic refractories over shaped refractories , detailed study of raw materials, manufacturing steps, properties and applications.

UNIT II CARBON BASED REFRACTORIES 9
Magnesia – carbon , alumina – carbon – manufacturing process, properties and applications

UNIT III OXIDE AND NON OXIDE REFRACTORIES 9
Oxides – Zirconia , zircon, corundum – Manufacturing of synthetic materials , properties and applications Non oxides - nitrides, carbides, borides refractories – Manufacturing Process, Properties and applications

UNIT IV APPLICATIONS 9
Application of sintering, microstructure and phase diagram of refractories

UNIT V RECENT TRENDS 9
Recent trends of application of refractories to secondary steel making, continous casting, fertilizer , petrochemical and steel plant industries

TOTAL: 45 PERIODS

REFERENCES

1. Chester, J.H., Steel Plant Refractories, Second Ed., 1973, The United Steel Companies LTD., Sheffield, UK.
2. Chester, J.H., Refractories, Production and Properties, 1973, Iron and Steel Institute, London.
3. Robert E.Fisher, Advances in Refractory Technology, Ceramic Transaction Vol.4.,1990, American Ceramic Society, Westerville, Ohio, USA.
4. Handbook of Monolithics, 1980, Plibrico, Japan.
5. Modern Refractories Practice, 1961, Habbison Walker Comp., Pittsburgh.

CR9163 FUELS, FURNACES AND PYROMETRY **L T P C**
3 0 0 3

AIM
The course is aimed to enable the students to have a thorough knowledge on the fuels used and equipments involved in firing of a ceramic article, and the temperature measurement methods.

OBJECTIVES

On completion of the course the students are expected to

- Have a thorough knowledge on the different types of fuels and burners used based on the fuel type and the types of flame produced from burners.
- Have studied the different types of furnaces and their operation.
- Have a better knowledge on different types of kilns, their construction and working.
- Have a clear understanding on the temperature and heat measurement techniques in kilns and furnaces.

UNIT I FUELS 9

Definition. Solid fuels – wood, coal, agro based fuels and its qualities. Liquid fuels – liquid petroleum products, synthetic liquid fuels, bio fuels. Gaseous fuels – LPG, producer gas, water gas, other gaseous fuels – characterization of coal, coal washing, blending, carbonization of coal, manufacture of coke and recovery by products, pulverized coal.

UNIT II BURNERS AND COMBUSTION 9

Burner – classification, atomization, low pressure burner for gaseous fuel, high pressure burner for liquid fuels, advantage & disadvantage of different burners. Air requirement, combustion processes of solid, liquid, gaseous fuels, control of combustion process, combustion stoichiometry. Flames – nature of flames, laminar & turbulent, premixed & diffusion, burning velocity.

UNIT III FURNACES 9

Introduction, definition, classification and description of different types of furnaces– metal heating furnaces, reheating furnace, continuous furnace, sintering furnace, crucible furnaces, electric furnace, unit melters and smelters, muffle furnace, glass tank furnace, chamber furnace, blast furnace, coke oven batteries.

UNIT IV KILNS 9

Introduction, definition, classification – draught kiln, chamber kiln, tunnel kiln, roller kiln, rotary kiln, continuous kiln, shuttle kiln, top hat kiln, muffle kiln, Hoffman's kiln – principle, materials used in foundation and construction, working.

UNIT V PYROMETRY 9

Introduction and thermometry, thermocouples, radiation pyrometers, low temperature measurement, temperature control, heat work recorders – Segar cone, Holdcroft's bar, Buller rings, Watkin recorders.

TOTAL: 45 PERIODS

REFERENCES

1. Samir Sarkar, Fuels and Combustion, 2nd Edn., Orient Longman, Bombay, 1990.
2. Om Prakash Gupta, Elements of Fuels, Furnaces and Refractories, Khanna Publishers, 1995.
3. Suryanarayana A.V.K, Fuels, Furnaces, Refractories and Pyrometry, BS Publications, 2005.
4. Robert D.Reed, Furnace Operation, Gulf Publishing Co., Paris, 1991.
5. Shaha A.K, Combustion Engineering and Fuel Technology, Oxford & IBH Publishing Co., New Delhi, 1974.
6. Daniel Rhodes, Kilns: Design, Construction and Operation, Chilton Book Co., Pennsylvania, 1974

CR9164 **QUALITY CONTROL AND MANAGEMENT IN CERAMIC INDUSTRIES** **L T P C 3 0 0 3**

AIM

The course is aimed to impart basic knowledge about standardization, quality and preparation of quality manual to keep up with the best end use property.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about concepts of quality and standardization.
- Have learnt about various tools for quality control.
- Have basic knowledge about quality cost and preparation of quality manual.

UNIT I CONCEPTS OF STANDARDISATION 9

Historical development of standards, aims, techniques, management, formulation, implementation of company standards, economic benefits of standardization.

UNIT II CONCEPTS OF QUALITY 9

Definition of quality, quality related terminology, key terms of quality systems, quality management, assurance and audit as per ISO 9000 guidelines.

UNIT III TOOLS OF QUALITY CONTROL 9

Tools of quality management, concepts and management of quality assurance, quality system, quality loop, quality management and its relationship to overall management.

UNIT IV PREPARATION OF QUALITY MANUAL 9

Internal quality audit, audit management, external quality audit, quality certification, quality system maintenance.

UNIT V QUALITY COST 9

Quality improvement, concepts of TQC, TQM, KANBAN, JIT, continuous improvement, HRD in quality management, quality circles, Dr.Deming's 14 point Management Concept.

TOTAL: 45 PERIODS

REFERENCES

1. Juran, J.M. and F.M. Gryna, Jr., Quality Control Handbook, 4th Edition, 1988, McGraw Hill Book Co., NY.
2. Murthy, M.N., (Ed) Excellence Through Quality and Reliability, 1989, Applied Statistic Centre, Madras.
3. Madhav N.Sinha and Walten W.O.Willborn, The Management of Quality Assurance, 1985, John Wiley & Sons, NY.
4. Guide on Company Standardization by Institute of Standards Engineers, 1989.
5. Total Quality Control at Enterprise Level BY International Trade Centre (UNCTAD/GATT/GENEVA), 1986 (Division of United Nations) – Published in India by CMTI – Perfect Machine Tool Trust, Bangalore in Association With National Centre for Quality Management.
6. International Organization for Standardization, 1992, Case Postale 56, CH-1211-Geneve 20, Switzerland, ISO 9000 Compendium, Vision 2000, ISBN 92- 67, 101722.

CR9165 **BIO CERAMICS** **L T P C**
3 0 0 3

AIM

The course is aimed to enable the students to have a sound knowledge about the applications of ceramic materials in biological field.

OBJECTIVES

On completion of the course the students are expected to

- Have learnt the various applications of ceramic materials in the medical field.
- Have a complete knowledge about the various calcium phosphate based ceramic materials along with the preparation, properties and applications.
- Have studied about the different bioactive glasses and glass ceramic materials.
- Have studied about the different bioactive composites.
- Have studied about the different bioactive coatings.

UNIT I MATERIALS IN MEDICINE 9

Implant areas – dental, orthopedic. Implant materials – bio polymers, bio metals, ceramic implants – porous ceramics, surface active ceramics, resorbable ceramics. Biological performance of the materials, body reaction to implant materials – corrosion, biodegradation and biocompatibility. Invitro and invivo test methods of implant materials.

UNIT II CALCIUM PHOSPHATE CERAMICS 9

Chemistry of calcium phosphate bio ceramics – preparation, mechanical properties and biological performance of tri calcium phosphate, tetra calcium phosphate, biphasic calcium phosphate, hydroxyapatite and other phosphates. Calcium phosphate bone cements – preparation, properties, setting behavior and bio compatibility.

UNIT III BIOACTIVE GLASSES AND GLASS CERAMICS 9

Surface active glasses, bioactive glass – preparation, mechanical properties, bonding mechanism to living tissue – interfacial bonding. Doped bioactive glasses. High strength bioactive glass ceramics – mechanical and biological properties, bone bonding mechanism, mechanism of surface apatite formation, compositional dependence.

UNIT IV BIOACTIVE COMPOSITES 9

Hydroxyapatite composites with zirconia, alumina and titania – preparation and properties. SiC whisker reinforced hydroxyapatite and bioactive glass ceramics, zirconia toughened and bioactive glass ceramics, bioglass-hydroxyapatite composites, carbon composites.

UNIT V BIOACTIVE COATINGS 9

Importance of bioactive coatings. Hydroxyapatite coated metal implants – coating methods, characterization and properties. Bioglass and bioactive glass ceramics coating over metals and alloys.

TOTAL: 45 PERIODS

REFERENCES

1. Yamamura T, Hench L.L and Wilson J, CRC Handbook of Bioactive Ceramics, Vol I & II, CRC Press, Boca Raton, 1990.
2. Park J.B, Biomaterials: An Introduction, Plenum Press, New York, 1979.
3. Bonfield V, Hastings C.H and Tanner K.E (eds.), Bioactive Ceramics, Vol4, Butterworth – Heinemann Ltd., Oxford, 1991.
4. Hans Bach, Low Thermal Expansion Glass Ceramics, Springer, 1995.
5. Hench L.L and Ethridge E.C, Biomaterials: An Interfacial Approach, Academic Press, New York, 1982.

CR9166 **SPECIAL GLASSES** **L T P C**
3 0 0 3

AIM

The course is aimed to enable the students to have a thorough knowledge about the special applications of glasses in various fields.

OBJECTIVES

On completion of the course the students are expected to

- Have a clear understanding on the types and properties of heat resistant and safety glasses.
- Have studied the manufacture, types and applications of optical glasses.
- Have studied the composition of glass fibres and optical fibres, and their applications.
- Have learnt the composition, preparation and properties of glass ceramics.
- Have a knowledge on the methods and types of coatings on glass, their applications and quality control.

UNIT I HEAT RESISTANT AND SAFETY GLASSES 9

Borosilicate glasses – pyrex glass and jona type, composition – fabrication of laboratory ware – vycor glass. Safety glasses – toughened glass, laminated glass.

UNIT II OPTICAL GLASSES 9

Manufacture of crown and flint glass – ophthalmic glass filters – photo chromic glass – laser glass – electro chromic glass – GRIN lenses and components – chalcogenide, chalcohallide and halide glasses – applications in optical components.

UNIT III GLASS FIBRES 9

Composition for fibre glass, glass wool, manufacturing process and applications. Optical fibres – optical properties of fibres, silica based glass fibres – applications in optical communication.

UNIT IV GLASS CERAMICS 9

Glass composition, heat treatment schedule, crystal nucleation in glass, nucleating agent, microstructure and properties, applications, machinable glass ceramics.

UNIT V COATED GLASS 9

Coating methods – physical vapour deposition, chemical vapour deposition. Types of coatings, characteristics of coated glass, applications of coated glasses, quality control of coated glass.

TOTAL: 45 PERIODS

REFERENCES

1. Lewis M.H, Glasses and Glass Ceramics, Chapman and Hall, London, 1989.
2. Philips C.J, Glass, Its Industrial Applications, Reinhold Publishing Co., NY, 1960.
3. Cable M and Parker M.J, High Performance Glasses, Chapman and Hall, NY, 1992.
4. Heinz G.Plaender, Schott Guide to Glass, Chapman and Hall, 1996.
5. Hans Bach, Low Thermal Expansion Glass Ceramics, Springer, 1995.

CR9167 NON-DESTRUCTIVE TESTING L T P C
3 0 0 3

AIM

The course is aimed to enable the students to have a basic knowledge about the various non-destructive methods of testing.

OBJECTIVES

On completion of the course the students are expected to

- Have studied the basic concepts of non-destructive testing and surface NDT methods
- Have learnt about small business and preparation of feasibility chart.
- Have a basic knowledge about establishment of a business.
- Have learnt about how to manage a business unit.
- Have some basic concepts about promotion of entrepreneurship and practical knowledge about some case studies.

UNIT I SURFACE NDT METHODS 7

Introduction- Definition of terms, discontinuities and defects/flaws- fracture mechanics concept of design and the role of NDT- life extension and life prediction- penetrant testing and magnetic particle testing - basic principle, limitations & advantages – development and detection of large flux – longitudinal and circular magnetization – demagnetization.

UNIT II RADIOGRAPHIC TESTING 12

Electromagnetic spectrum – sources - x-ray, gamma ray – x-ray generation, spectrum,equipment controls, properties, attenuation and differential attenuation-interaction of radiation with matter – radiographic testing – principle and mechanism, recording medium- films and fluorescent screens- non-imaging detectors- film radiography detectors- film radiography- calculation of exposure for X-ray and gamma rays- quality factors- image quality indicators and their use in radiography.

UNIT III ULTRASONIC TESTING 10

Ultrasonic waves- velocity, period, frequency and wavelength- reflection and transmission- near and far field effects and attenuation- generation- piezoelectric and magnetostriction methods- normal and angle probes- methods of Ultrasonic testing-Principle of pulse echo method- Equipment – examples- rail road inspection, wall thickness measurement- range and choice of frequency.

UNIT IV EDDY CURRENT TESTING 8

Introduction- principles of eddy current inspection- conductivity of a material- magnetic properties- coil impedance- lift off factor and edge effects- skin effect- inspection frequency- coil arrangements - inspection probes- types of circuit- Reference pieces-phase analysis-display methods-typical application of eddy current techniques.

UNIT V OTHER METHODS 7

Imaging- principle and applications- testing of composites- acoustic emission testing-application of AET- on-line monitoring or continuous surveillance and application in materials science- optical methods of NDT- photo elasticity- evaluation procedure-Holographic NDT procedure- Speckle phenomenon- speckle interferometry-speckle shear interferometry.

TOTAL:45 PERIODS

REFERENCES
1. B.Hull and V.John, Non Destructive Testing, McMillan Education Ltd, 1968.
2. Metals Handbook, Volume 2, 8th Edn, ASTM, Metals Park, Ohio.
3. Dainty, Laser Speckle & Related Phenomena, Springer – Verlag, New York, 1984.
4. Mc Gonnagle, W.J, Non-destructing testing methods, Mc Graw Hill Co., NY, 1961.

CR9168 MICROWAVE PROCESSING OF CERAMICS L T P C
3 0 0 3

AIM
The course is aimed to enable the students to the basic concepts about processing the ceramic materials in microwave atmosphere.

OBJECTIVES
On completion of the course the students are expected to
- Have learnt the introduction about microwave processing.
- Have learnt the concepts of microwave heating circuit.
- Have learnt the applicator types of microwave.
- Have studied the industrial applications of microwave processing.
- Have studied the hazard and safety of microwave processing.

UNIT I INTRODUCTION 9
Dielectric Behavior of materials- power dissipation- propagation factor and skin depth- heat and mass transfer phenomena- temperature distribution- wall loss.

UNIT II MICROWAVE HEATING CIRCUIT 9
Power sources- klystron and magnetron- operating characteristics- protection system- high frequency breakdown phenomena- automatic control of the process- automation, tuning and machining.

UNIT III APPLICATION TYPES 9
Travelling wave applicators- multimode applications- power transfer- uniformity of heating.

UNIT IV INDUSTRIAL APPLICATIONS 9
Microwave drying- microwave sintering- application to laboratory models and pilot system- comparison with pilot heating.

UNIT V HAZARDS AND SAFETY 9
Exposure standards- industrial- frequency band- leakage from industrial equipment- batch system- continuous flow system- safety precautions.

TOTAL:45 PERIODS

REFERENCES
1. Metaxas A.C and Meredith RJ, Industrial Microwave Heating, Peter Peregrinus Ltd., UK, 1983.
2. Snyder W.B, Sutton W.H, Iskander M.F and Johnson D.L (Ed), Microwave Processing of Materials, Volume I & II, MRS, Pittsburgh, 1991.
3. Binner J.G.P (Ed), Advanced Ceramic Processing and Technology, Volume I, Noyes Publications, New Jersey, 1990.
4. Randall M German, Sintering Technology, Marcel Dekker, Inc, 1996.

CR9169 NUCLEAR AND SPACE CERAMICS L T P C
3 0 0 3

AIM

The course is aimed to enable the students to the basic concepts of ceramic materials used for nuclear and space applications.

OBJECTIVES

On completion of the course the students are expected to

- Have studied the basic concepts of nuclear physics.
- Have learnt about the nuclear reactors.
- Have studied in detail about the production and properties of various fuels.
- Have studied about the radiation protection.
- Have studied the basics about space ceramics.

UNIT I FUNDAMENTALS OF NUCLEAR CERAMICS 9

Atomic structure - atomic number- mass number- isotopes- nuclear energy and nuclear forces, binding energy- nuclear stability- radio activity- nuclear reactions- nuclear fission-nuclear fusion.

UNIT II NUCLEAR REACTORS 9

Types of reactors- ordinary water moderated reactors- heavy water cooled and moderated reactors- design, construction and control of nuclear reactors- moderators-coolants- reflectors and structural materials.

UNIT III FUELS 9

Methods of production and properties, uranium oxide, thorium oxide, beryllium oxides-encapsulation, nuclear fuel cycle, spent fuel characteristics, reprocessing techniques.

UNIT IV RADIATION PROTECTION 9

Types of waste- disposal - ICRP recommendations- radiation hazards and prevention-radiation dose units.

UNIT V SPACE CERAMICS 9

Materials aspects of missile and satellite re entry- aerospace nuclear propulsion technology, auxiliary space powder devices- rocket nozzle technology- the space environment and its effects.

TOTAL: 45 PERIODS

REFERENCES

1. Merrite L.C, Basic Principles of Nuclear Science and Reactors, Wiley Eastern, 1977.
2. Benedict M and Pigter T.A, Nuclear Chemical Engineering, McGraw Hill, 1981.
3. Norton, F.H, Fine Ceramics, Technology and Applications, McGraw Hill, London, NY, 1970.
4. Terpstra, Ceramic Processing, Chapman and Hall, 1995.
5. Gan-Moog, chow and Kenneth E Gonslaves, Nanotechnology, American Chemical Society, 1996.

CR9170 **HEAT RECOVERY SYSTEMS** **L T P C**
3 0 0 3

AIM

The course is aimed to enable the students to have a sound knowledge about the methods to recover the waste heat from furnaces and also methods to minimize wastage of heat.

OBJECTIVES

On completion of the course the students are expected to

- Have a thorough knowledge on thermal operation of furnaces.
- Have studied the various heat exchange equipments like heat exchangers, boilers, calandrias and extended surface equipments.
- Have learnt the types, design and construction of regenerators.
- Have learnt the types, design and construction of recuperators.
- Have understood the methods of minimizing heat loss and heat consumption in furnace by proper design.

UNIT I ENERGY BALANCE IN FURNACE 9

Temperature and thermal conditions in furnace, calculation of thermal operation of furnaces – heat balance, furnace productivity.

UNIT II HEAT EXCHANGERS 9

Definition, types of exchangers – parallel & counter flow exchangers, single pass 1-1, multi pass 1-2 & 2-4. Heat transfer coefficients in heat exchangers. Boilers and calandrias, extended surface equipments – types, efficiency and calculation.

UNIT III REGENERATORS 11

Principle of operation, types of regenerators, design and construction, materials of construction and applications.

UNIT IV RECUPERATORS 8

Principle of operation, types of recuperators, design, applications, comparison over regenerator.

UNIT V ENERGY CONSERVATION DESIGNS 8

Prevention of energy loss in furnace – insulation, coatings, low thermal mass materials – importance, design and applications.

TOTAL: 45 PERIODS

TEXT BOOKS

1. Glinkov M.A and Glinkov G.M, A General Theory of Furnaces, Mir Publishers, Moscow, 1980.
2. Perry R.H and Green D (eds), Perry's Chemical Engineers' Handbook, 6th Edn.,McGraw-Hill, New York, 1984.

REFERENCES

1. Shaw K, Refractories and their Uses, App. Science Publishers, UK, 1972.
2. Robert E.Fisher (ed), Advances in Refractory Technology, Ceramic Transaction Vol 4, American Ceramic Society, 1990.
3. Warren L.McCabe, Julian C.Smith and Peter Harriott, Unit Operations of Chemical Engineering, 7th Edn., McGraw Hill International Edition, 2005.
4. Industrial Furnaces, Vol I, 4th Edn.

CR9171 **CERAMIC CALCULATIONS** **L T P C**
3 0 0 3

AIM

The course is aimed to enable the students to have a basic knowledge about the methods of calculating the various ceramic properties.

OBJECTIVES

On completion of the course the students are expected to

- Have learnt the basic methods of calculating the properties of ceramic raw materials.
- Have learnt to calculate the properties of ceramic bodies.
- Have learnt to calculate the properties of suspensions.
- Have learnt to formulate glaze batches by varying the parameters.
- Have learnt to formulate glass batches.

UNIT I ULTIMATE & RATIONAL ANALYSIS 9

Ultimate analysis, proximate analysis, rational analysis of clay, stone and feldspar -mica convention – substitution of clays in body recipes – triangular plot.

UNIT II DETERMINATION OF PHYSICAL PROPERTIES 9

Shrinkage – Drying, Firing, Total, Volume, Moisture content – relationship between percentage moisture content and volume shrinkage - loss on ignition –density - specific gravity – effect of porosity on the function of ceramic materials – pore structure density – apparent volume – true volume – apparent solid volume, porosity – apparent, true, sealed pores.

UNIT III CALCULATIONS OF BODY & SUSPENSIONS 9

Density of a slip – calculations relating to mixtures of solid particles and water –dilution problems – Brongniarts Formula – dry measurement, wet measurement –effect of specific gravity – density of the body slip – dimensions of the mixing ark –adjustments to the wet recipe – addition of body stain.

UNIT IV GLAZE CALCULATIONS 9

Molecular weights – formula and use of chemical equations – oxides – percentage composition and formula – calculation of a recipe from a simple glaze formula – given the recipe of a glaze calculate the formula – synthesis of a fritted glaze – given the recipe calculate the formula for a fritted glaze – calculation of the percentage composition of the mill batch

UNIT V GLASS CALCULATIONS 9

Determination of molecular formula of glass from chemical composition of the glass and from glass batch – determination of batch from molecular formula of glass – determination of batch from the given chemical composition.

TOTAL:45 PERIODS

REFERENCES

1. R.Griffiths & C.Radford, Calculations in Ceramics, Johns Hill, 1965.
2. A.I.Andrews, Ceramic Tests and Calculations, John Wiley & Sons, 1928.
3. R.Charan, Handbook of Glass Technology
4. Hiraoki Yanagida, The Chemistry of Ceramics, John Wiley and Sons, 1996.
5. Terpstra, Ceramic Processing, Chapmann and Hall, 1995.
6. Tooley F.V, Handbook of Glass Manufacture, Vol I&II, Ogden Publishing Co., NY, 1960.
7. Alexis G.Pincus, Melting Furnace Operation in the Glass Industry, Magazines for Industry Inc., NY, 1980.

CR9172 **CEMENT AND CONCRETE** **L T P C**
3 0 0 3

AIM

The course is aimed to enable the students to have a complete knowledge on the manufacture, quality control and types of cement, and preparation, properties and different types of concrete.

OBJECTIVES

On completion of the course the students are expected to

- Have studied the raw materials, manufacturing process and mechanism of hydration of cement.
- Have learnt the tests done on cement and the quality control procedures.
- Have studied the different types of cements and their characteristics.
- Have learnt the types of aggregates and admixtures used for concrete making and the preparation of a concrete mixture.
- Have understood the different properties of concrete and the testing methods of the same.

UNIT I CEMENT 7

Raw materials, manufacturing process. Composition of cement phases – effect of composition on burnability of clinker, influence of minor components. Hydration of cement.

UNIT II TESTING AND QUALITY CONTROL 8

Tests on properties of cement – consistency of standard paste, setting time, soundness, strength of cement. Quality control – litre-weight test, microscopic and X-ray investigation of clinker materials.

UNIT III TYPES OF CEMENT 10

Types of Portland cement, blast furnace slag cement, trief cement, high alumina cement, white and coloured cement, oil well cement, hydrophobic cement, water proof cement, super sulphate cement, sulphate resisting cement.

UNIT IV CONCRETES 10

Aggregates – types, characteristics. Admixtures – types, characteristics. Proportioning of concrete mixtures – consideration, procedure. Recent advances in concretes – types, significance, characteristics.

UNIT V PROPERTIES OF CONCRETE 10

Strength, permeability, creep, thermal expansion, shrinkage, moisture movement, penetration of X-ray, abrasion resistance, fire resistance, freeze-thaw resistance, electrical properties.

TOTAL :45 PERIODS

REFERENCES

1. P. Kumar Mehta and Paulo J.M.Monteiro, Concrete – Microstructure, Properties and Materials, 3rd Edn., Tata McGraw Hill, 2006.
2. A.M.Neville, Properties of Concrete, 4th Edn., Pearson Education, 1995.
3. J. Bensted and P.Barnes (Editors), Structure and Performance of Cements, 2nd Edn., Spon Press, 2002.
4. A.M.Neville and J.J.Brooks, Concrete Technology, Pearson Education, 1987.
5. Peter C.Hewlett (Editor), Lea's Chemistry of Cement and Concrete, 4th Edn., Elsevier, 1998.
6. Deborah DL. Chung, Multifunctional Cement Based Materials, Marcel Dekker Inc., 2003.

CR9173 MANUFACTURING AND TESTING OF STRUCTURAL CERAMICS

L T P C
3 0 0 3

AIM

The course is aimed to impart basic knowledge about powder processing, densification in kilns, machining, polishing and testing.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about powder making and densification.
- Have learnt about various inspection and testing methods to maintain the standards.
- Have basic knowledge about ceramic machining and surface finishing techniques.

UNIT I POWDER PROCESSING AND SHAPE FORMING PROCESSES 9

Spray drying, precipitation, freeze drying, Sol-Gel, CVD, grinding and milling, agglomeration and de agglomeration, slip casting, injection molding, hot iso-static pressing, doctor blade processing.

UNIT II DENSIFICATION 9

Solid state and liquid state sintering, effect of sintering variables, pressure assisted sintering, super plastic forming, self propagating high temperature synthesis, forming from vapour phase, consolidation of ceramic fibres and whiskers.

UNIT III CERAMIC MACHINING AND SURFACE FINISHING 9

Surface grinding and mechanical polishing, non-abrasive finishing, effect of surface finishing properties, ceramic coating - joining of ceramics, mechanical joints, vacuum joints, diffusion bonding, joining by laser.

UNIT IV INSPECTION AND TESTING 9

Visual inspection, intrinsic and extrinsic defects, non-destructive evaluation using X-Ray technique, microwave technique, ultrasonic technique, SEM, TEM laser and acoustic imaging, failure analysis, special acceptance tests.

UNIT V STANDARDS 9

Product standards and standardization, manufacturing system standards and standardizations, ISO, BS, ASTM, IEC, DIN, EN and NEMA.

TOTAL : 45 PERIODS

REFERENCES

1. McColm, I.J and N.J., Clark, Forming Shaping and Working of High Performance Ceramics, Blackie, London.
2. Richardson, D.W., Modern Ceramic Engineering Properties, Processing and use in design, 1992, Marcel Dekker, Inc., NY.
3. Wang, F.F.Y., Treatise on Materials Science and Technology, Vol.A., Ceramic Fabrication Processes, 1976, Academic Press, NY.
4. Rahaman. M.N., Ceramic Processing and Sintering, 1995, Marcel Dekker, Inc., NY.
5. Loehman, R.E., Characterization of Ceramics, 1993, Butterwoth-Heinemann, Boston.

CR9174 PROPERTIES AND APPLICATIONS OF STRUCTURAL CERAMICS **L T P C 3 0 0 3**

AIM

The course is aimed to impart basic knowledge about structural ceramics, its properties, and applications.

OBJECTIVES

On completion of the course the students are expected to

- Have a basic understanding about microstructure, nature of grain boundaries.
- Have learnt about elastic modulus, thermal shock resistance, etc.
- Have basic knowledge about mechanical, optical and chemical applications of structural ceramics.

UNIT I MICROSTRUCTURE 9

Quantitative analysis of texture, nature of grain boundaries, development of microstructure, grain growth, microstructure in glass ceramics, effect of particle size, pressure and sintering, dependence of mechanical and thermal properties on microstructure.

UNIT II MECHANICAL PROPERTIES AT ROOM TEMPERATURE 9

Elastic modulus, tensile and flexural strength, hardness, fatigue, fracture, wear, mechanical shock.

UNIT III MECHANICAL PROPERTIES AT ELEVATED TEMPERATURES 9

Thermal expansion, thermal conductivity, thermal shock resistance, creep, oxidation, long term stability under severe environmental conditions, toughening of ceramics, tensile & flexural strength (ASTM Standard).

UNIT IV MECHANICAL APPLICATIONS 9

Wear resistance, rolling element bearings, cutting tool, IC engine, gas turbine, design considerations and failure analysis, material selection.

UNIT V SPECIAL APPLICATIONS 9

Infra red window materials, lamp envelops, chemical degradation, nuclear waste storage materials, nuclear fuels and fuel cell, ceramic membranes, ceramic armours, ceramic radomes.

TOTAL: 45 PERIODS

REFERENCES

1. Richardson D.W., Modern Ceramic Engineering Properties, Processing and Use in Design, 1992, Marcel Dekker, New York.
2. Howlettt, S.P. and D.Taylor (Ed), Special Ceramics, Vol.8 1986, The Institute of Ceramics Shelton, Stock On- Trent, Staff, U.K.
3. Wachtmen, J.B., Structural Ceramics, Treatise on Materials Science and Technology, Vol.29, 1989, Academic Press Inc., NY.
4. Mellinger, G.B. Nuclear Waste Management 3, Ceramic Transactions, Vol.9., 1990, The American Ceramic Society Inc., Westerville, Ohio, USA.
5. Ales Koller, Structure and Properties of Ceramics, 1994, Elsevier, Amsterdam.
6. Loehman, R.E., Characterization of Ceramics, 1993, Butterworth-Heinemann, Boston.