**ANNA UNIVERSITY, CHENNAI**

**UNIVERSITY DEPARTMENTS**

**REGULATIONS – 2015**

**CHOICE BASED CREDIT SYSTEM**

**M. Tech. CERAMIC TECHNOLOGY**

## PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

I. To prepare students to excel in research or to succeed in Ceramic Technology profession through global, rigorous post graduate education.
II. To provide students with a solid foundation in scientific and Technology fundamentals required to enrich Ceramic Technology.
III. To train students with good scientific and engineering knowledge so as to comprehend, analyze, design, and create novel products and solutions for the real life problems.
IV. To inculcate students in professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, and an ability to relate Ceramic Technology issues to broader social context.
V. To provide student with an academic environment aware of excellence, leadership, written ethical codes and guidelines, and the life-long learning needed for a successful professional career

## PROGRAMME OUTCOMES (POs):

On successful completion of the programme,

1. Graduates will demonstrate knowledge of science and Technology.
2. Graduates will demonstrate an ability to identify, formulate and solve engineering problems.
3. Graduate will demonstrate an ability to design and conduct experiments, analyze and interpret data.
4. Graduates will demonstrate an ability to design a system, component or process as per needs and specifications.
5. Graduates will demonstrate an ability to visualize and work on laboratory and multidisciplinary tasks.
6. Graduate will demonstrate skills to use modern engineering tools, software and equipment to analyze problems.
7. Graduates will demonstrate knowledge of professional and ethical responsibilities.
8. Graduate will be able to communicate effectively in both verbal and written form.
9. Graduate will show the understanding of impact of engineering solutions on the society and also will be aware of contemporary issues.
10. Graduate will develop confidence for self education and ability for life-long learning.

| Programme Educational Objectives | Programme Outcomes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 |
| I | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| II | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| III | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| IV | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| V | | | | | | ✓ | ✓ | | ✓ | ✓ |

| | | | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR 1 | SEM 1 | Material Characterization Techniques | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | |
| | | Materials Science | ✓ | ✓ | ✓ | | | | | | | |
| | | Mechanical Behaviour of Ceramics | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | |
| | | Introduction to Ceramics | ✓ | | | | | | | | ✓ | |
| | | Elective I | | | | | | | | | | |
| | | Elective II | | | | | | | | | | |
| | | Material Characterization Lab | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | |
| | | Processing and Testing of Ceramics Lab | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | |
| | SEM 2 | Advanced Ceramic Materials | ✓ | | | ✓ | | | ✓ | | ✓ | ✓ |
| | | Ceramic Processing | ✓ | | | | | | | | ✓ | |
| | | Phase Equilibria in Ceramic Systems | ✓ | ✓ | | ✓ | | | | | | |
| | | Refractories | ✓ | | | | | | ✓ | | ✓ | |
| | | Elective III | | | | | | | | | | |
| | | Elective IV | | | | | | | | | | |
| | | Refractories Lab | | | ✓ | | ✓ | ✓ | | | | |
| | | CAD for Ceramics | | | ✓ | | ✓ | ✓ | | | | |
| YEAR 2 | SEM 3 | Nanoscience and Technology of Ceramics | ✓ | | | ✓ | | | | | ✓ | ✓ |
| | | Elective V<br>Elective VI | | | | | | | | | | |
| | | Industrial Training (4 weeks) | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Project Work Phase I | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| | | Seminar | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | | | | | | | | | | | |
| | SEM 4 | Project Work Phase II | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |

## Electives of M.Tech (Ceramic Technology)

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Abrasives | ✓ | | | | | ✓ | | | | |
| Advanced Processing Techniques for Ceramics | ✓ | | ✓ | ✓ | | ✓ | | | | |
| Bio-ceramics | | | | ✓ | | | ✓ | | | |
| Cement and Concrete | ✓ | ✓ | | | | ✓ | ✓ | | | |
| Ceramic Calculations | ✓ | ✓ | ✓ | ✓ | | | | | | |
| Ceramic Coating Technology | ✓ | | ✓ | ✓ | | | | | ✓ | |
| Ceramic Fibres and Composites | ✓ | | ✓ | ✓ | | | | | ✓ | |
| Ceramic Machining and Joining | ✓ | ✓ | | | | | | | ✓ | |
| Ceramic Matrix Composites | ✓ | ✓ | | | | | | | ✓ | |
| Electronic Ceramic Materials and Their Applications | ✓ | ✓ | | | | | | | ✓ | |
| Environmental Engineering | ✓ | ✓ | | | | | | | ✓ | |
| Fuels, Furnaces and Pyrometry | ✓ | ✓ | | | | | | | | |
| Fuel Cells | ✓ | ✓ | | | | | | | | |
| Glass Engineering | ✓ | ✓ | | | | | | | | |
| Heat Recovery Systems | ✓ | ✓ | | | | | | | ✓ | |
| Monolithics and Castables | ✓ | ✓ | | | | | | | | |
| Non Destructive Testing | ✓ | ✓ | | | | | | | ✓ | |
| Nuclear and Space Ceramics | ✓ | ✓ | | | | | | | ✓ | |
| Numerical Techniques | ✓ | ✓ | | | | | | | | |
| Operation Research | ✓ | ✓ | | | | | | | | |
| Process Modelling, Simulation and Optimization | ✓ | ✓ | | | | | | | ✓ | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Properties and Applications of Structural Ceramics | ✓ | ✓ | | | | | | | | |
| | Quality Control and Management in Ceramic Industries | | ✓ | | | | | | | ✓ | |
| | Refractories for Industries | | ✓ | | | | | | | | |
| | Refractory Engineering | ✓ | | ✓ | ✓ | | | | ✓ | ✓ | |
| | Safety Engineering | | ✓ | | | | | | | ✓ | |
| | Special Glasses | ✓ | ✓ | | | | | | | | |

**ANNA UNIVERSITY, CHENNAI**

**UNIVERSITY DEPARTMENTS**

**REGULATIONS – 2015**

**CHOICE BASED CREDIT SYSTEM**

**I – IV SEMESTERS CURRICULUM AND SYLLABUS**

**M. Tech. CERAMIC TECHNOLOGY**

**SEMESTER I**

| S.No | COURSE CODE | COURSE TITLE | CATEGORY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **THEORY** | | | | | | | | |
| 1. | CR7101 | Material Characterization Techniques | FC | 3 | 3 | 0 | 0 | 3 |
| 2. | CR7102 | Materials Science | FC | 3 | 3 | 0 | 0 | 3 |
| 3. | CR7103 | Mechanical Behaviour of Ceramics | PC | 3 | 3 | 0 | 0 | 3 |
| 4. | CR7104 | Introduction to Ceramics | FC | 3 | 3 | 0 | 0 | 3 |
| 5. | | Elective I | PE | 3 | 3 | 0 | 0 | 3 |
| 6. | | Elective II | PE | 3 | 3 | 0 | 0 | 3 |
| **Practicals** | | | | | | | | |
| 7. | CR7111 | Material Characterization Lab | PC | 2 | 0 | 0 | 2 | 1 |
| 8. | CR7112 | Processing and testing of Ceramics Lab | PC | 2 | 0 | 0 | 2 | 1 |
| | | | **TOTAL** | **22** | **18** | **0** | **4** | **20** |

**SEMESTER II**

| S.No | COURSE CODE | COURSE TITLE | CATEGORY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **THEORY** | | | | | | | | |
| 1. | CR7201 | Advanced Ceramic Materials | PC | 3 | 3 | 0 | 0 | 3 |
| 2. | CR7202 | Ceramic Processing | PC | 3 | 3 | 0 | 0 | 3 |
| 3. | CR7203 | Phase Equilibria in Ceramic Systems | PC | 3 | 3 | 0 | 0 | 3 |
| 4. | CR7204 | Refractories | PC | 3 | 3 | 0 | 0 | 3 |
| 5. | | Elective III | PE | 3 | 3 | 0 | 0 | 3 |
| 6. | | Elective IV | PE | 3 | 3 | 0 | 0 | 3 |
| **Practicals** | | | | | | | | |
| 7. | CR7211 | CAD for Ceramics | PC | 2 | 0 | 0 | 2 | 1 |
| 8. | CR7212 | Refractories Lab | PC | 2 | 0 | 0 | 2 | 1 |
| | | | **TOTAL** | **22** | **18** | **0** | **4** | **20** |

## SEMESTER III

| S.No | COURSE CODE | COURSE TITLE | CATE GORY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **THEORY** | | | | | | | | |
| 1. | CR7301 | Nano Science and Technology of Ceramics | PC | 3 | 3 | 0 | 0 | 3 |
| 2. | | Elective V | PE | 3 | 3 | 0 | 0 | 3 |
| 3. | | Elective VI | PE | 3 | 3 | 0 | 0 | 3 |
| **Practicals** | | | | | | | | |
| 4. | CR7311 | Industrial Training | EEC | 2 | 0 | 0 | 2 | 1 |
| 5. | CR7312 | Seminar | EEC | 2 | 0 | 0 | 2 | 1 |
| 6. | CR7313 | Project Work Phase I | EEC | 12 | 0 | 0 | 12 | 6 |
| | | | **TOTAL** | **24** | **9** | **0** | **16** | **17** |

## SEMESTER IV

| S.No | COURSE CODE | COURSE TITLE | CATEGORY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **Practicals** | | | | | | | | |
| 1. | CR7411 | Project Work Phase II | EEC | 24 | 0 | 0 | 24 | 12 |
| | | | **TOTAL** | **24** | **0** | **0** | **24** | **12** |

**TOTAL NO OF CREDITS : 69**

## Foundation Courses (FC)

| S.No | COURSE CODE | COURSE TITLE | CATEGORY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **THEORY** | | | | | | | | |
| 1. | | Material characterization Techniques | FC | 3 | 3 | 0 | 0 | 3 |
| 2. | | Material science | FC | 3 | 3 | 0 | 0 | 3 |
| 3. | | Introduction to Ceramics | FC | 3 | 3 | 0 | 0 | 3 |

## Professional Core (PC)

| S.No | COURSE CODE | COURSE TITLE | CATEGO RY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **THEORY** | | | | | | | | |
| 1. | | Mechanical Behaviour of Ceramics | PC | 3 | 3 | 0 | 0 | 3 |
| 2. | | Material | PC | 2 | 0 | 0 | 2 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Characterization Lab | | | | | | |
| 3. | | Processing and testing of Ceramics Lab | PC | 2 | 0 | 0 | 2 | 1 |
| 4. | | Advanced Ceramic Materials | PC | 3 | 3 | 0 | 0 | 3 |
| 5. | | Ceramic Processing | PC | 3 | 3 | 0 | 0 | 3 |
| 6. | | Phase Equilibria in Ceramic Systems | PC | 3 | 3 | 0 | 0 | 3 |
| 7. | | Refractories | PC | 3 | 3 | 0 | 0 | 3 |
| 8. | | Refractories Lab | PC | 2 | 0 | 0 | 2 | 1 |
| 9. | | CAD for Ceramics | PC | 2 | 0 | 0 | 2 | 1 |
| 10. | | Nano Science and Technology of Ceramics | PC | 3 | 3 | 0 | 0 | 3 |

## Professional Electives (PE)

| S.No | COURSE CODE | COURSE TITLE | CATEGORY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **THEORY** | | | | | | | | |
| 1. | CR7001 | Abrasives | PE | 3 | 3 | 0 | 0 | 3 |
| 2. | CR7002 | Advanced Processing Techniques for Ceramics | PE | 3 | 3 | 0 | 0 | 3 |
| 3. | CR7003 | Bio Ceramics | PE | 3 | 3 | 0 | 0 | 3 |
| 4. | CR7004 | Cement and Concrete | PE | 3 | 3 | 0 | 0 | 3 |
| 5. | CR7005 | Ceramic Calculations | PE | 3 | 3 | 0 | 0 | 3 |
| 6. | CR7006 | Ceramic Coating Technology | PE | 3 | 3 | 0 | 0 | 3 |
| 7. | CR7007 | Ceramic Fibres and Composites | PE | 3 | 3 | 0 | 0 | 3 |
| 8. | CR7008 | Ceramic Machining and Joining | PE | 3 | 3 | 0 | 0 | 3 |
| 9. | CR7009 | Ceramic Matrix Composites | PE | 3 | 3 | 0 | 0 | 3 |
| 10. | CR7010 | Electronic Ceramic Materials and their Applications | PE | 3 | 3 | 0 | 0 | 3 |
| 11. | CR7011 | Environmental Engineering | PE | 3 | 3 | 0 | 0 | 3 |
| 12. | CR7012 | Fuel cells | PE | 3 | 3 | 0 | 0 | 3 |
| 13. | CR7013 | Fuels, Furnaces and Pyrometry | PE | 3 | 3 | 0 | 0 | 3 |
| 14. | CR7014 | Glass Engineering | PE | 3 | 3 | 0 | 0 | 3 |
| 15. | CR7015 | Heat Recovery Systems | PE | 3 | 3 | 0 | 0 | 3 |
| 16. | CR7016 | Monolithics and castables | PE | 3 | 3 | 0 | 0 | 3 |
| 17. | CR7017 | Non Destructive Testing | PE | 3 | 3 | 0 | 0 | 3 |
| 18. | CR7018 | Nuclear and Space Ceramics | PE | 3 | 3 | 0 | 0 | 3 |
| 19. | CR7019 | Numerical Techniques | PE | 3 | 3 | 0 | 0 | 3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20. | CR7020 | Operation Research | PE | 3 | 3 | 0 | 0 | 3 |
| 21. | CR7021 | Process Modelling, Simulation and Optimization | PE | 3 | 3 | 0 | 0 | 3 |
| 22. | CR7022 | Properties and Applications of Structural Ceramics | PE | 3 | 3 | 0 | 0 | 3 |
| 23. | CR7023 | Quality Control and Management in Ceramic Industries | PE | 3 | 3 | 0 | 0 | 3 |
| 24. | CR7024 | Refractories for Industries | PE | 3 | 3 | 0 | 0 | 3 |
| 25. | CR7025 | Refractory Engineering | PE | 3 | 3 | 0 | 0 | 3 |
| 26. | CR7026 | Safety Engineering | PE | 3 | 3 | 0 | 0 | 3 |
| 27. | CR7027 | Special Glasses | PE | 3 | 3 | 0 | 0 | 3 |

## Employability Enhancement Courses (EEC)

| S.No | COURSE CODE | COURSE TITLE | CATEGORY | CONTACT PERIODS | L | T | P | C |
|---|---|---|---|---|---|---|---|---|
| **THEORY** | | | | | | | | |
| 1. | | Seminar | EEC | | 0 | 0 | 2 | 1 |
| 2. | | Project Work - Phase I | EEC | | 0 | 0 | 12 | 6 |
| 3. | | Industrial Training | EEC | | 0 | 0 | 2 | 1 |
| 4. | | Project Work - Phase II | EEC | | 0 | 0 | 24 | 12 |

**CR7101 MATERIAL CHARACTERIZATION TECHNIQUES L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**UNIT I CHEMICAL AND THERMAL METHODS 9**

Elemental analysis by wet chemical methods – Volumetric, Gravimetric and Colorimetric analysis. Thermal Methods – TGA, DTA and DSC.

**UNIT II SPECTROSCOPIC METHODS 8**

U-V, Visible, FTIR, Raman 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 SURFACE AND PARTICLE 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, dynamic light scattering.

**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**

**OUTCOME**

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.

**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.
6. R.S.Khandpur, Handbook of Analytical Instruments, 1989, Tata Mcgraw Hill Publications.

**CR7102 MATERIALS SCIENCE L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**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 – Kirkendal effect – atomistic model of diffusion.

**UNIT II PHASE DIAGRAMS 9**

Gibb's Phase rule – Phase, component, variable, 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 – dielectric constant – dielectric loss – dielectric breakdown – polymer dielectrics – Fast ionic conductors – ionic conduction in zirconia and other systems - dipole moment – static permittivity – 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**

**OUTCOME**

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.

**REFERENCES**


1. Saxena, B.S., R.C. Gupta and P.N. Saxena, Fundamentals of Solid State Physics, 1988, Pragathi Pragasan, Meerut.
2. V.Raghavan and Asoke K. Ghosh, Material Science and Engineering, 2004, Prentice hall of India Pvt. Ltd.

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
8. O.P.Khanna and ISH Kapur, Material Science & Metallurgy, 2002, Dhanpat Rai publications.
9. E.S.Machlin, Materials Science Microelectronics, 2005, 2nd Edition, Elsevier Ltd,.
10. John Martin, Materials for Engineering, 2002, 2nd edition, Woodhead publishing & Maney Publishing,.
11. G. S. Upadhyaya and Anish Upadhyaya, Materials Science & Engineering, 2006, Viva Books Pvt.Ltd,.
12. R.W.Cahn, P.Haasen and E.J.Kramer, Material Science & Technology Vol.5, 1991, VCH Verlagsgesellschaft MBH.

**CR7103 MECHANICAL BEHAVIOR OF CERAMICS L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I FRACTURE MECHANICS 10**

Types of fracture - ductile and brittle fracture; Elasticity – definition – elastic constants – elastic deformation of isotropic and crystalline materials – measurement of elastic constants – variation of elastic constant with temperature and porosity; Theoretical strength and stress concentrations; Griffith theory – linear elastic fracture mechanics, microstructural aspects. Critical stress intensity factor measurement – indentation method, notch test. Fractography.

**UNIT II STRENGTH 9**

Tensile strength – measurement techniques; Factors affecting strength – processing defects & surface defects; Statistical treatment of strength – significance, methods – Gaussian distribution, Weibull distribution. Strength reducing mechanisms – subcritical crack propagation, time dependent strength behaviour, cyclic fatigue, SPT diagram.

**UNIT III TOUGHENING 8**

Toughening mechanisms – crack deflection, crack bowing, crack branching, crack tip shielding by process zone & bridging effect; Stable crack propagation and R-curve behaviour,

**UNIT IV CREEP AND THERMAL SHOCK BEHAVIOUR 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 V FATIGUE AND WEAR 9**

Fatigue of ceramics – types, mechanism, measurement, life time prediction. Wear of ceramics – types, mechanism, measurement, factors affecting.

**TOTAL : 45 PERIODS**

**OUTCOME**

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.
Have basic knowledge about thermal shock resistance parameters

**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.
4. A.C.F Cocks and A.R.C Ponter, 1989, Mechanics of creep brittle material -1 & 2, Elsevier Applied Science.
5. Jahanmir Said, Friction and Wear of Ceramics, 1993, Marcel Dekker Inc.
6. Roy.W.Rice, Mechanical Properties of Ceramics and Composites, 1993, Marcel Dekker Inc.
7. V.Z.Parton and V.G.Borishkovsky, Dynamic Fracture Mechanics (VOl-2) , 1990, Hemisphere Publishing.
8. K.Kussmaul, Fracture Mechanics Verification by Large-Scale Testing, 1991, Mechanical Engg. Publication.
9. R.C.Brat, D.P.H.Hasselman,D.Munz, M.Sakai and V.Ya.Shevchenko, Fracture Mechanics of Ceramics, 1991, Plenom Press Publication.
10. V.S.Sastri and Edward Ghalai, Corrosion-prevention& protection, 2007, John Willey & Sons.


**CR7104 INTRODUCTION TO CERAMICS L T P C**

**3 0 0 3**

**OBJECTIVE**

The courses is aimed to impart basic knowledge about traditional ceramics its raw materials, body preparation, glazing and firing behavior.

**UNIT I RAW MATERIALS 9**

Ceramics raw materials – Plastic & non plastic; Clay formation – classification – occurrence and mineralogy – Properties of clay-water mixtures and influencing factors – absorption, cation exchange capacity, plasticity, rheology, electrical double layer theory, zeta potential & its measurement; Non – plastic raw materials – feldspar and quartz – properties and characteristics; additives.

**UNIT II THEORY OF PACKING 9**

Body composition – packing of two components system – porosity – effect of grain size – unfired porosity – experimental verification – wet to dry contraction - unfired strength – permeability and casting rate – dry to fired contraction – fired strength.

**UNIT III FABRICATION PROCESS 9**

Triaxial bodies – batch formulations – body formulations – porcelains, stoneware, earthenware, terracotta; pressing – types, process, defects; Plastic forming – types – extrusion, jiggering and jollying, injection molding, defects; casting Plaster mould preparation – slip formation – suspensions/ceramic slurries – stability of slurries, types

of stabilization – fluidity and thixotrophy – various casting techniques – defects.

**UNIT IV GLAZING 9**

Glaze – definition – composition – raw materials; Engobe – definition – raw materials – process; Fritting – definition – fritting rules – manufacturing process; Glaze batch

calculation; Glaze application techniques – types; Glaze defects; Glaze properties – fusibility, viscosity, surface tension, thermal and mechanical properties, glaze-body interface layer, opacity and translucency.

**UNIT V DRYING & FIRING 9**

Drying – mechanism of drying – transfer of heat – energy balance calculations – factors that control drying –types of dryers – drying defects; Finishing operations – cutting, trimming, remedies; Effect of heat on clays – the action of heat on ceramic bodies – physical and chemical changes – firing schedules – firing range – liquid phase sintering, vitrification.

**TOTAL : 45 PERIODS**

**OUTCOME**

On completion of the course the students are expected to have a basic understanding about traditional ceramics.

**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.
8. H.Nosbusch and I.V Mitchell, Clay based material for the ceramics industry, 1996, Elsevier Publications.
9. Terry A.Ring, Fundamentals of ceramic powder processing and synthesis, 1996, Academic press.
10. Rex W.Grimshaw, Chemistry and Physics of Clays and Allied Ceramic Materials, 1971, Benn, London 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, dynamic light scattering.


**CR7111 MATERIAL CHARACTERIZATION LAB L T P C**
**0 0 2 1**

**OBJECTIVE**

The course is aimed to impart knowledge about characterization of ceramic Sample.

1. Particle Size Analysis – LASER Diffraction.
2. Determination of Viscosity by Brookfield Viscometer.
3. Thermal Analysis – TGA, DTA.
4. Optical Microscopy
5. Vickers Hardness.
6. Modulus of Rupture – 3 point & 4 point.
7. Compressive Strength.
8. Wear and Abrasion Resistance.

**Equipments:**

1.Vickers Hardness tester
2. MOR tester
3.Pin on Disc apparatus
4.Particle size analyser
5.Optical microscope
6.Brookfield Viscometer
7.TGA /DTA
8. CCS machine.

**TOTAL : 30 PERIODS**

**OUTCOME**

On completion of the course the students are expected to have basic understanding about different methods of characterizing a ceramic sample.

**CR7212 PROCESSING AND TESTING OF CERAMICS LAB L T P C**
**0 0 2 1**

**OBJECTIVE**

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

1. Analysis of Ceramic Raw Materials: (i) Moisture and (ii) Loss on Ignition.
2. Analysis of ceramic materials: (i) Silica Content and (ii) Alumina Content
3. Particle Size Distribution – Hydrometer, Andreason Pipette
4. Preparation and property evaluation of Plastic Mass and slip.
5. Fabrication Techniques: (i) Uniaxial Pressing & Hot pressing and (ii) Cold Extrusion.(iii) Slip Casting
6. Properties of Shaped Ceramic – Density, Porosity, Water absorption, Shrinkage.
7. Analysis of strength of ceramic material: Flexural Strength – 3 point & 4 point, Compressive Strength, Tensile Strength, Rheology study, Hot MOR

**EQUIPMENTS:**

1. Universal testing machine
2. MOR test equipment
3. Hydrometer
4. Hot press

**TOTAL : 30 PERIODS**

**OUTCOME**

On completion of the course the students are expected to have a basic understanding about different tests done on ceramic materials in the laboratory.

**CR7201 ADVANCED CERAMIC MATERIALS L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I STRUCTURAL CERAMICS 9**

Carbides – nitrides – oxides – SiAlON – borides – silicides – composites

**UNIT II ELECTRONIC CERAMICS 9**

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

**UNIT III MAGNETIC CERAMICS 8**

Spinel Ferrites – Hexogonal Ferrites – Garnet – Processing and Applications

**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**

**OUTCOME**

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.

**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.
9. Robert B. Heimann, Classic and Advanced Ceramics, 2010, Wiley VCH Verlag GMBH & co.
10. P.Ramakrishnan and Mohan Primlani, Advanced Ceramics, 1992, Oxford ISH Publications Pvt. Ltd.

**CR7202** **CERAMIC PROCESSING** **L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**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.

**UNIT II PROCESSING ADDITIVES 7**

Types, Properties and Effect of addition of liquids and wetting agents, deflocculants, coagulants, binders, 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; Cutting techniques – water jet cutting, laser ablation; Etching; Joining of ceramics – metal ceramic joints.

**TOTAL : 45 PERIODS**

**OUTCOME**

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

**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
8. R.A.Terpstra, P.P.A.C Pex and A.H de Vries, Ceramics Processing, Chapman & Hall, 1995.
9. Joahnan.R.Groger, James.F.Shackelford and Michael.T.Power, Material Processing, Taylor&Francic grop 2007

**CR7203 PHASE EQUILIBRIA IN CERAMIC SYSTEMS L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I INTRODUCTION 9**

Introduction, criteria of phase equilibrium, criterion of stability, phase equilibria in single component system and multi component system; Gibb's phase rule – phase, component, variable; Single component system – $H_2O$, $SiO_2$, iron; Binary phase diagrams – Hume Rothery's rule, congruent and incongruent, solid solutions; Ternary phase diagrams.

**UNITII PHASE DIAGRAMS 9**

Binary Systems – Phase diagram, microstructural constituents, significance of $Al_2O_3$ – $SiO_2$, MgO – $Al_2O_3$, MgO – $SiO_2$, $Al_2O_3$ – $ZrO_2$; Ternary Systems – Phase diagram, microstructural constituents, determination of crystallization path during heating and cooling of $K_2O$ – $Al_2O_3$ – $SiO_2$, MgO – $Al_2O_3$ – $SiO_2$, $Na_2O$ – $Al_2O_3$ – $SiO_2$, CaO – $Al_2O_3$ – $SiO_2$.

**UNIT III PHASE TRANSFORMATIONS 9**

Introduction, Time Scale for phase transformations; Types of transformations – spinoidal, nucleation & growth, theory of transformation kinetics; Nucleation and growth – nucleation kinetics, homogeneous nucleation, heterogeneous nucleation, growth and overall transformation kinetics; Sintering & crystallization in ceramics and glass forming systems.

**UNIT IV EXPERIMENTAL METHODS 9**

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

**UNIT V APPLICATIONS 9**

Prediction of alkali corrosion of alumino silicate refractories using phase diagrams – Use of phase diagrams in the study of Silicon nitride ceramics – Application of phase diagrams to the production of advanced composites.

**TOTAL : 45 PERIODS**

**OUTCOME**

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.

**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.


**CR7204 REFRACTORIES L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**UNIT I INTRODUCTION 9**

Definition; Classification of Refractories based on raw materials, temperature, shapes; Fundamental Properties of Refractories – Physical, Thermal, Mechanical, Chemical and Electrical; Process industry standards – Indian and International test methods (ISI) – QC procedures – Statistical QC, ISO 9000 Etc.

**UNIT II SILICA & ALUMINO SILICATE REFRACTORIES 9**

Silica – raw materials, manufacturing steps, properties, applications; Alumina – raw materials, manufacturing steps, properties, applications; $Al_2O_3$–$SiO_2$ phase diagram; Alumino-Silicate – raw materials, types of refractories, manufacturing steps, properties, applications.

**UNIT III BASIC REFRACTORIES 9**

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

**UNIT IV SPECIAL REFRACTORIES 9**

Raw materials, manufacturing steps, properties and applications of Oxide based – Cordierite, Zirconia, Thoria, Beryllia; Carbide based – Silicon carbide, boron carbide; Nitride based – silicon nitride; Fused cast refractories – raw materials, manufacturing step, properties, applications; Ceramic Fibers – types, properties, applications; Insulating refractories – preparation, properties, applications.

**UNIT V MONOLITHICS 9**

Castables – types, composition, properties, applications; Plastics – types, composition, properties, applications. Dry mixes – types, composition, properties, applications.

**TOTAL : 45 PERIODS**

**OUTCOME**

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.

**REFERENCES**


1. D.N.Nandi, Handbook of Refractories, Tata McGraw Hill Publishing Co, New Delhi, 1991.
2. Chester, J.H., Steel Plant Refractories, Second Edition., 1973, The United Steel Companies Ltd., Sheffield, UK.
3. Chester, J.H. Refractories, Production and Properties, 1973, Iron and Steel Institute, London.
4. Robert E.Fisher, Advances in Refractory Technology, Ceramic Transaction, Vol.4, 1990, American Ceramic Society, Westerville,Ohio, USA.
5. Handbook of Monolithics, 1980, Plibrico, Japan.
6. Modern Refractories Practice, 1961, Harbison Walker Comp., Pittsburgh.
7. Charless.A.Schacht, Refractories Handbook, 2007, Marcel Dekkar Publications.
8. G.V.Samsonov & J.M.Vinitskii, Handbook of Refractory, 1980, IFI Publications.


**CR7211 CAD FOR CERAMICS L T P C**
**0 0 2 1**

**OBJECTIVE**

To impart CAD modeling and design of ceramic components using FEA software.

1. Stress analysis of beams (Cantilever, Simply supported & Fixed ends)
2. Stress analysis of a plate with a circular hole.
3. Stress analysis of rectangular L bracket.
4. Thermal stress analysis of 1D component.
5. Thermal stress analysis of 2D component.
6. Thermal stress analysis of a composite wall.
7. Stiffness measurement by three point bending.
8. Fatigue studies on 2D component.

**TOTAL : 30 PERIODS**

**OUTCOME**

The students are trained to create modeling of basic ceramic components and analyze the same using finite element analysis software.

**CR7212 REFRACTORIES LAB L T P C**
**0 0 2 1**

**OBJECTIVE:**

To study and compare the physical properties of various refractories.

**OUTCOME:**

The students may achieve knowledge in the field refractory Ceramics by experimenting the evaluation of physical properties.

1. Preparation and property evaluation of silica refractory of various compositions.
2. Preparation and property evaluation of fire clay refractory with different percentage of grog.
3. Preparation and property evaluation of high alumina refractories of various compositions.
4. Influence of shaping methods on physical properties of refractories.
5. Influence of firing temperature on physical properties of refractories.
6. Preparation of insulating refractory with different pore formers.
7. Determination and comparison of properties of different insulating refractories.
8. Comparing the characteristics of a dense and porous refractory.

**TOTAL : 30 PERIODS**

**EQUIPMENTS:**

1. Universal Testing Machine
2. Hot Plate
3. Extruder

**CR7301 NANO SCIENCE AND TECHNOLOGY OF CERAMICS L T P C**
**3 0 0 3**

**OBJECTIVE**

The course is aimed to enable the students to have a basic knowledge about the developing field on nanotechnology , nanoceramics 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 PATTERNING 9**

Lithography – Types,Optical Lithography – contact, Proximity and Projection,Holographic Lithography, X-ray Lithography – sources – mask – Resists – alignment, Electron Beam Lithography – parallel scanning – Resists, Ion beam lithography – sources – Resolution.

**UNIT V 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.

**TOTAL : 45 PERIODS**

**OUTCOME**

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.

**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, 2nd 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.
6. Ivor Brodie and Julius J.Muray,'The physics of Micro/Nano – Fabrication',Springer International Edition,2010


**CR7001 ABRASIVES LT P C**

**3 0 0 3**

**OBJECTIVE**

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

**UNIT I RAW MATERIALS 9**

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

**UNIT II COATED ABRASIVES 9**

Flow sheet for Coated abrasive preparation. Preparation steps – maker coating, abrasive coating, sizer coating, drying and humidification, flexing, forms of coated abrasives - belt making, sheet cutting, disc punching. Special products - flap wheels, individual disc coating; Quality control and testing.

**UNIT III COATED ABRASIVE BACKUPS 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; Other backups – drums, rolls, pads, and platens – types, characteristics, choice and uses.

**UNIT IV BONDED ABRASIVES 9**

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 GRINDING AND POLISHING 9**

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

**TOTAL : 45 PERIODS**

**OUTCOME**

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

**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. Kenneth B.Lewis, William F.Schleicher, The Grinding Wheel, The Grinding Wheel Institute, Cleaveland, Ohio, 1976.
6. Stephen Malkin & Changsheng Guo, Grinding Technology, 2nd Edn., American Society of Civil Engineers, 2008.
7. Edwards R, Cutting Tools, The Institute of Materials, Cambridge, 1993.
8. Brian Rowe W, Principles of Modern Grinding Technology, William Andrew Publications, 2009.
9. Ioan D. Marinescu, Handbook of Advanced Ceramics Machining, Taylor and Francis, 2007.


**CR7002 ADVANCED PROCESSING TECHNIQUES FOR CERAMICS L T P C**

**3 0 0 3**

**OBJECTIVE**

The course is aimed to impart basic knowledge about non-conventional powder preparation techniques and advanced ceramic processing.

**UNIT I SOL-GEL PROCESS 9**

Introduction - Hydrolysis & condensation of silicates and non-silicates – particulate sol & gel – gelation – aging of gel – drying – structural evolution during consolidation – comparison of gel derived and conventional ceramics

**UNIT II AGGLOMERATION PROCESS 9**

Introduction – Agglomeration Theories – Agglomeration Technologies: Tumble/Growth Agglomeration, Pressure Agglomeration, Agglomeration by Heat / Sintering – Engineering Criteria and Development.

**UNIT III BIOMORPHIC CERAMICS 9**

Preparation and Characteristics of Biomorphous carbide ceramics: SiC, TiC, SiSiC – Biomorphous oxide ceramics: $Al_2O_3$, $ZrO_2$, $TiO_2$, ZnO – Biomorphous ceramic composites

**UNIT IV MICROWAVE PROCESSING OF CERAMICS 9**

Introduction - Fundamentals of Microwave Heating - Dielectric Properties - Development of the Basic Theoretical Concepts - Applicators - Heat Transfer - Applications

**UNIT V ADVANCED CONSOLIDATION TECHNIQUES 9**

Hot Isostatic Pressing – Spark Plasma Sintering – Explosive Shock Consolidation

**TOTAL : 45 PERIODS**

**OUTCOME**

On completion of the course the students are expected to
Have a better understanding on powder preparation by sol-gel process and agglomeration process.
Have learnt about biomorphic ceramics and microwave processing of ceramics. Have basic knowledge about advanced consolidation techniques.

**REFERENCES**


1. C. Jeffrey Brinker, George W. Scherer, Sol-Gel Science: The Physics and Chemistry of Sol-Gel Processing, Academic Press, 1990.
2. Wolfgang Pietsch, Agglomeration Processes, Wiley-VCH, 2008.
3. Jon G. P. Biner and I.S.Ivanov, Advanced Ceramic Processing and Technology, Noyes Publications, 1990.
4. Mohamed N.Rahaman, Ceramic Processing, Taylor & Francis, 2007.
5. David W. Richerson, Modern Ceramic Engineering, 3rd Edn., Taylor & Francis, 2005.
6. 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.
7. Reed J.S, Introduction to the Principles of Ceramic Processing, Wiley, New York, 1988.


**CR7003 BIO CERAMICS L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**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**

**OUTCOME**

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.

**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.
6. Joon Park, Bioceramics-Properties, Charactersization and Applications, Springer Publications,2008
7. Tadashi Kokubo, Bio-Ceramic & Their Applications, Woodhead Publications,2008

8. Bikramjlt Basu, Dhirendra, S.Katti, Ashok and A Joham, Advanced Biomaterial, Fundamentals, Processing and Applications, Wiley & Sons Inc,2009
9. Heimo O.Ylaner, Bioactive Glasses - Materials, Properties and Applications, Woodhead Publishing Materials, 2011.

**CR7004 CEMENT AND CONCRETE L T P C**
**3 0 0 3**

**OBJECTIVE**

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.

**UNIT I CEMENT 7**

Raw materials, manufacturing process-wet & dry 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**

**OUTCOME**

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 theircharacteristics.
- Have learnt the types of aggregates and admixtures used for concrete making and the preparation, properties and testing methods of concrete

**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, 2006.
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.
7. S Unnilerishra Pillai, Reinforced Concrete Design, Tata McGraw-Hill Publications, 2003.

**CR7005 CERAMIC CALCULATIONS L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I ULTIMATE & RATIONAL ANALYSIS 9**

Ultimate analysis, proximate analysis, rational analysis of clay, silica 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 – pore structure density – apparent volume – true volume – apparent solid volume, porosity – apparent, true, sealed pores – effect of porosity on the function of ceramic materials.

**UNIT III SLIP CALCULATIONS 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 – glass yield calculation.

**TOTAL : 45 PERIODS**

**OUTCOME**

On completion of the course the students are expected to
Have learnt the basic methods of calculating the properties of ceramicraw 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.

**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.


**CR7006 CERAMIC COATING TECHNOLOGY L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**UNIT I INTRODUCTION 9**

Introduction to surface engineering & modification – wear, abrasion, oxidation resistance – types of coating-need for coating on the body – advantages & disadvantages.

**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, composition, 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 - lithography techniques.

**UNIT V ENAMELS 9**

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

**TOTAL : 45 PERIODS**

**OUTCOME**

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.

**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.


**CR7007 CERAMIC FIBRES AND COMPOSITES L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**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 and graphite fibres – PAN based, pitch based , vapor grown – manufacture (PAN based), grades of carbon fibres – Bio soluble fibres.

**UNIT II REFRACTORY FIBRES 9**

Alumina silicate, mullite, alumina, silica, zirconia aramid and boron fibres - structure, fibre manufacturing process, properties and applications; silicon carbide fibre – manufacturing process – CVD, polymer pyrolysis , properties and 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 9**

Introduction to composite materials – definition, characteristics, classification; Matrix Materials – polymers, metals and ceramics; Fabrication of thermosetting resin matrix composites, thermoplastic resin matrix composites, metal matrix composites, ceramic matrix composites, carbon – carbon composites.

**UNIT V CHARACTERIZATION 9**

Physical – density, constituent weight and volume fractions, void volume fraction, thermal expansion co-efficient, moisture absorption and diffusivity, moisture expansion

co-efficients; Mechanical properties – properties in tension, compression, in place shear properties, flexural properties, impact properties; damage identification using non destructive evaluation techniques – ultrasonics, acoustic emission, x-ray, thermography, laser shearography.

**TOTAL : 45 PERIODS**

**OUTCOME**

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.

**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.
6. Bhagwan D Agarwal, Lawerence J Broutman, K Chandrasekara., Analysis and Performance of Fiber Composites, 2006, Wiley Publications.


**CR7008 CERAMIC MACHINING AND JOINING L T P C**
**3 0 0 3**

**OBJECTIVE:**

The course is aimed to impart basic knowledge about various machining and joining techniques of ceramics.

**UNIT I BASIC MACHINING METHODS 9**

Basic machining requirement of ceramics- Ductile grinding –material removal mechanisms. Diamond wheels, Electrolytic In-Process Dressing Grinding of Ceramic materials – Mechanism, Ultrasonic machining,Abrasive water jet machining

**UNIT II ADVANCED MACHINING 9**

LASER assisted Grinding, Ion Beam machining–Sputtering–Laser, Electron Beam machining–chemical– Electrochemical –Electrical discharge Machining of ceramic materials.

**UNIT III SURFACE FINISHING 9**

Super polishing of Magnetic heads, Magneto rheological abrasive finishing, Polycrystalline Diamond lapping of ceramics, Flame polishing–Annealing–Healing of surface cracks–Gaseous etching, Ionic polishing of optical surfaces–Ceramic surface texture by reflective replica technique.

**UNIT IV JOINING METHODS 9**

Mechanical Joints - Adhesive joints - Brazing of ceramics with super alloys- wettability, reactivity, thermodynamic stability. Liquid Silicon infiltration, Arc joint-Transient Liquid phase bonding-nano powder infiltration and Transient Eutectic phase.

**UNIT V ADVANCED JOINING METHODS 9**

Spark plasma sintering-Microwave Assisted joining-Laser Assisted joining-Glass and Glass ceramic Joining materials –Solid state Ti–Si–C reaction joints– Pre ceramic – polymer joints– testing of joints.

**TOTAL: 45 PERIODS**

**OUTCOME:**

On completion of the course, the students are expected to

- Have a basic understanding about various joining and machining techniques.
- Have learnt about the surface finishing methods.
- Have basic knowledge about fundamentals in machining and Joining.

**REFERENCES**:


1. Ioan D.Marinesar, Handbook of Advanced Ceramics Machining, 2006, CRC press.
2. Ioan D.Marinesar, Hans Kurt Tonshoff, Ichiro Inasaki, Handbook of Ceramic Grinding and polishing, 2000, Noyes Publication.
3. Narottam P.Bansal and Jacques Lamon, Ceramic Matrix Composites-Materials, Modeling and Technology, 2015, John Wiley & sons, Inc., Hoboken, New Jersey.
4. V.K.Jain,Introduction to micromachining, 2010,Alpha Science International Ltd.
5. S.J. Schneider, R.W.Rice, The science of Ceramic Machining and surface finishing, 1970, National Bureau of Standards Special Publication.


**CR7009 CERAMIC MATRIX COMPOSITES L T P C**
**3 0 0 3**

**OBJECTIVE:**

The course is aimed to impart basic knowledge about Ceramic Fibres, processing methods, testing and applications of ceramic matrix composites.

**UNIT I REINFORCEMENTS AND COMPOSITES 9**

Reinforcements– Fibres, Particulates, whiskers– Processing of Fibres– oxide fibres– Alumina, Silica, MgO, glass – Non–Oxide Fibres– SiC, $Si_3N_4$, Carbon, $ZrO_2$, WC, Si–C–O, Si–B–C–N, Processing of whiskers, Ceramic Particles

Composites- MMC, PMC, CC, CMC.

**UNIT II PROCESSING OF CMC 9**

Cold Pressing and sintering–Hot Pressing–Reaction Bonding–Infiltration–Directed Oxidation– Insitu chemical reaction Technique–Sol–gel and Polymer Pyrolysis–Self–propagating high temperature synthesis

**UNIT III THERMAL TREATMENT AND COATING 9**

Thermal Treatment–Drying, Sintering, Vitrification Glass Ceramics–Forming methods for glasses– Ceramic foam sandwich composite–Coating of CMC–Environmental coating, Oxidation Protective coating, Thermal Management, Wear and abrasion

**UNIT IV TOUGHENING AND INTERFACE PROPERTIES 8**

Toughening Mechanisms –Compressive pre–stressing–Crack impeding –filter/whisker pull out–micro crack – crack deflection –phase transformation

Interphase Properties–Interfacial tensile and shear strength–Strengthening of interphase–coating–Formation of interphase

**UNIT V TESTING AND APPLICATIONS 10**

Fracture toughness measurements–Impact resistance–AE Principle and practice–Lifetime Prediction using Fatigue test–Adhesive Properties of coatings in service temperature.

Cutting tool inserts – $SiC_W/Al_2O_3$ – Ceramic composite filters–Friction application–C/SiC, C–C–Brake disks–Turbine engine–Nozzle, flap–Liners in combustion chamber–Exhaust system–Nuclear applications.

**TOTAL: 45 PERIODS**

**OUTCOME:**

On completion of the course the students are expected to

- Have a basic understanding about fibres and reinforcements.
- Have learnt about various processing of ceramic matrix composites.
- Have basic knowledge about ceramic testing and applications.

**TEXT BOOK:**

1. Narottam P.Bansal and Jacques Lamon , Ceramic Matrix Composites-Materials, Modeling and Technology, 2015, John Wiley & sons, Inc., Hoboken, New Jersey.

**REFERENCES:**

1. Krishnan K Chawla, Composite Materials Science and Engineering, 2nd Edition, 2006, Springer (India) pvt. Ltd.
2. M. Rosso, Ceramic and metal matrix composites: route and properties, Mechanical and Mechanical Engineering, 2003, Italy.
3. K.K.chawla , Ceramic Matrix composites, Chapman & Hall,1993 London.
4. K.S.Mazdiyasni (Ed.), Ceramic Fibre reinforced composites, 1990, Noyes Pub., Park Ridge, NJ.
5. D.C.Philips, " Fiber Reinforced Ceramics", In Fabrication of Ceramics, vol. 4 of Handbook of Composites, 1993 North-Holland, Amsterdam, p.373.
6. R.Warren (Ed.), Ceramix Matrix Composites, 1991, Blackie & sons, Glasgow, UK.

**CR7010 ELECTRONIC CERAMIC MATERIALS AND THEIR APPLICATIONS L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**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**

**OUTCOME**

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.

**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.


**CR7011 ENVIRONMENTAL ENGINEERING L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**TOTAL : 45 PERIODS**

**OUTCOME**

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

**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
5. V.S.Sastri and Edward Ghalai, Corrosion-Prevention & Protection, A John Willey Sons, 2007.


**CR7012 FUEL CELLS L T P C**
**3 0 0 3**

**OBJECTIVE:**

The course is aimed to impart basic knowledge about fuel cells, their types, characterization and application.

**UNIT I HYDROGEN STORAGE AND APPLICATIONS 9**

Production of hydrogen – steam reforming- water electrolysis- gasification and biological hydrogen production, Hydrogen storage – compressed gas-liquid hydrogen, Hydride, Applications of hydrogen.

**UNIT II PRINCIPLE AND PERFORMANCE 9**

History- principle – working – thermodynamics and kinetics of fuel cell process-performance evaluation of fuel cell – comparison on battery Vs fuel cell.

**UNIT III TYPES 9**

AFC- PAFC- SOFC- MCFC- DMFC- PEMFC – relative merits and demerits.

**UNIT IV CHARACTERISATION 9**

Fuel cell characterization– in-Situ and ex-situ characterization techniques, i-V curve, BET Surface area determination, Structure determinations-chemical determinations.

**UNIT V FUEL CELLS 9**

Fuel cell usage for domestic power systems - large scale power generation - Automobile space. Economic and environmental analysis on usage of Hydrogen and fuel cell - Future trends in fuel cells.

**TOTAL: 45 PERIODS**

**OUTCOME:**

On completion of the course, the students are expected to

- Have a basic understanding about hydrogen storage.
- Have learnt about fuel cell and their characterization techniques.
- Have basic knowledge about applications of fuel cells.

**REFERENCES**


1. O'Hayre, R.P.S.Cha, W. Colella, F.B. Prinz, Fuel Cell Fundamentals, Wiley, NY 2006
2. Bard, A.J., L.R., Faulkner, Electrochemical Methods, Wiley, N.Y.2004.
3. Fuel cell technology handbook, edited by Gregor Hoogers, CRC Press 2003


**CR7013 FUELS, FURNACES AND PYROMETRY L T P C**

**3 0 0 3**

**OBJECTIVE**

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.

**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, various parts of furnaces 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. Prevention of energy losses in furnace.

**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**

**OUTCOME**

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.

**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
7. Wilfrid Fransis & Martin C.Peters, Fuels and Furnace Technology, Pergmon Press, 1990.


**CR7014 GLASS ENGINEERING L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**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 – $CaO\text{-}Al_2O_3\text{-}SiO_2$, $Na_2O\text{-}CaO\text{-}SiO_2$ etc.

**UNIT II RAW MATERIALS AND BATCH PREPARATION 9**

Raw materials – Network former, network modifier, intermediate glass former, minor additives, cullet. Handling and storage – problems and remedies – Briquetting and Pelletizing. 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. 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**

**OUTCOME**

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.

**REFERENCES**


1. James E.Shelby, Introduction to Glass Science & Technology, The Royal Society of Chemistry, 1997.
2. Paul, Chemistry of Glasses, 2nd 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.
8. Adalbert Feltz, Amorphous Inorganic Materials and glasses, VCH Verlagsgesellschaft mbH, 1993.
9. BO Mysen and P.Richet, Silicate Glasses & Melts, Properties and Structure, Elsevier, 1986.
10. Narottan P.Bansal & R.H. Doremus, Handbook of Glass Properties, Elsevier, 1986.
11. Charles.A.Harper, Handbook of Ceramics, Glasses and Diamonds, McGraw Hill, 2001.
12. Glass & Ceramic Technology, NIIR Board of Consultants & Engineers, Asia Pacific Business Press Inc.
13. James F.Shackelford, Ceramic & Glass Materials, Springer, 2008.
14. M.Cable and J.M. Parker, High Performance Glasses, Blackie, Glasglow & London published by Chapman and Hall, Newyork 1992.

**CR7015 HEAT RECOVERY SYSTEMS L T P C**

**3 0 0 3**

**OBJECTIVE**

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.

**UNIT I ENERGY BALANCE IN FURNACE 9**

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

**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, fouling of heat exchangers.

**UNIT III REGENERATORS 11**

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

**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**

**OUTCOME**

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.

**REFERENCES**


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

**CR7016 MONOLITHICS AND CASTABLES L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**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 PROPERTIES AND TESTING METHODS 8**

Tests done on monolithics – chemical analysis, density, porosity, strength, high temperature properties, wear - corrosion, erosion, penetration, spalling.

**TOTAL : 45 PERIODS**

**OUTCOME**

On completion of the course the students are expected to

Have learnt the types of castables, its composition and characteristics. Have studied about the composition and characteristics of plastic refractories, ramming and gunning mixes, mortars, coatings and dry vibratables.

Have a clear idea on the methods of installing different monolithic materials, the application design and have studied the wear mechanisms and methods to test a monolithic

**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, 4th 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.

7. David R. Lankard, Monolithic Refractories, ACI Committee 547, Refractory Concrete, 1982.
8. Robert E. Fisher, New Developments in Monolithic Refractories, ACI Committee 547, Refractory Concrete, 1985.

**CR7017 NON DESTRUCTIVE TESTING L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I SURFACE NDT METHODS 7**

Introduction- Definition of terms, discontinuities and defects/flaws- fracture mechanics concept of design and the role of NDT- NDE - 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**

**OUTCOME**

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.

**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.
5. Jayakumar T, Baldev Raj and Thavasimuthu M, Practical Non-destructive Testing, Narosa Publishing House, 2012.


**CR7018 NUCLEAR AND SPACE CERAMICS L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I 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 II CERAMICS IN NUCLEAR REACTORS 9**

Structure, preparation and properties of oxides, carbides, nitrides and composites used in Fission and Fusion nuclear reactors.

**UNIT III NUCLEAR FUEL 9**

Different physical forms of nuclear fuels, nuclear fuel cycle, spent fuel characteristics, post irradiation examination, reprocessing techniques.

**UNIT IV RADIATION PROTECTION 9**

Types of nuclear 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**

**OUTCOME**

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.

**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.


**CR7019 NUMERICAL TECHNIQUES L T P C**

**3 0 0 3**

**OBJECTIVE**

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

**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**

**OUTCOME**

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

**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.


**CR7020 OPERATION RESEARCH LT P C**

**3 0 0 3**

**OBJECTIVE**

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

**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**

**OUTCOME**

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.

**REFERENCES**


1. Carter, M. W. and Price, C. C., Operations Research: A Practical Introduction Contributor, CRC Press, 2001.
2. Edgar, T. F., Himmelblau, D. M. and Ladson, L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill, New York, 2003.
3. Hillier, F. S., and Lieberman, G. J., Introduction to Operations Research, McGraw-Hill, 2005
4. Taha, H. A., "Operations Research, An introduction", 6th Ed., Prentice Hall of India, New Delhi, 2006

**CR7021 PROCESS MODELLING, SIMULATION AND OPTIMISATION LT P C**
**3 0 0 3**

**OBJECTIVE**

The course is aimed to impart basic knowledge about Modelling, Optimization and modelling of heat, mass and momentum 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 ESTIMATION 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**

**OUTCOME**

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.

**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.

**CR7022 PROPERTIES AND APPLICATIONS OF STRUCTURAL CERAMICS**

**L T C**
**3 0 0 3**

**OBJECTIVE**

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

**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**

**OUTCOME**

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.

**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.
7. P. Ramakrishnan and Mohan Primlani, Advanced Ceramics, Oxford ISH Publications Pvt.Ltd, 1992.
8. Robert B. Heimann, Classic and Advanced Ceramics, Wiley VCH verleggmbh& co, 2010.

## CR7023 QUALITY CONTROL AND MANAGEMENT IN CERAMIC INDUSTRIES

**L T P C**
**3 0 0 3**

### OBJECTIVE

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.

### 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**

### OUTCOME

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.

### 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
7. H.Lal, Total Quality Management, New Age International Publications, 1990

**CR7024 REFRACTORIES FOR INDUSTRIES L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I SELECTION CRITERIA & INSTALLATION 9**

Criteria for refractory selection – thermal criteria and calculations, structural criteria, chemical criteria. Installation – refractory bricks & shapes, castables, plastics, ceramic fibers.

**UNIT II REFRACTORIES FOR FERROUS INDUSTRIES 9**

Design, construction and refractories used in coke ovens, blast furnace, steel making furnaces, secondary steel making furnaces, continuous casting, heat treating & forging industries.

**UNIT III REFRACTORIES FOR NON-FERROUS METALLIC INDUSTRIES 9**

Design, construction and refractories used in copper, aluminum, lead, zinc extraction and processing industries.

**UNIT IV REFRACTORIES FOR NON-METALLIC INDUSTRIES 9**

Refractories used in refining & petrochemical, fertilizer, cement, glass, ceramic industries. Refractories used in combustors, boilers, incinerators, boilers etc.

**UNIT V MAINTENANCE & SAFETY 9**

Refractory maintenance & repair; Refractory Economics; Safety, health hazards, pollution control & ecology.

**TOTAL : 45 PERIODS**

**OUTCOME**

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.

**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.
6. Amavis, R., Refractories for the Steel Industry, 1990, Elsevier Publications
7. G.V.Samsonov &J.M.Vinitskii, Handbook of Refractory, 1980, IFI Publications.
8. D.N.Nandi, Handbook of Refractories, 1987, Tata Mc Graw-Hill Publications.
9. Charless.A.Schacht, Refractories Handbook, 2007, Marcel Dekkar Publications.

**CR7025 REFRACTORY ENGINEERING L T P C**
**3 0 0 3**

**OBJECTIVE**

The course is aimed to impart basic knowledge about refractory materials and their engineering aspects.

**UNIT I MATERIALS 9**

Shaped dense materials-Refractory brick based on $sio_2$-$Al_2O_3$ system-Basic Refractory Bricks, Carbon containing basic bricks, Carbon containing bricks, Fused cast products-Shaped heat insulating bricks-Un shaped refractory materials-Ceramic fiber materials-metals-Other materials.

**UNIT II DESIGN 9**

Preparation-selection criteria, Regulation and conditions on site-Design with shaped dense materials-Design with shaped heat insulating materials-Design with unshaped refractory materials-Design with ceramic fiber materials.

**UNIT III WORKING 9**

Preparation for working guidelines, working and applications –Shaped dense and heat insulating materials-Unshaped refractory materials, Ceramic fiber materials-Welding of anchors.

**UNIT IV THERMAL CALCULATION 9**

Problem definition and explanation of terms-Heat conduction-Single Layer wall, multi-layer wall, Cylindrical Wall-Heat transmission-convection, radiation, heat flux, wall design-Heat insulation-Non stationary calculations

**UNIT V APPLICATIONS 9**

Application examples of Bottoms - Hearth furnaces, Glass furnaces, Rotary hearth furnaces walls - Arches and crowns - Suspended roofs-piping-pipe walls - Hexmesh linings.

**TOTAL: 45 PERIODS**

**OUTCOME**

On completion of the course, the students are expected to

- Have a basic understanding about different refractory materials.
- Have learnt about thermal calculations.
- Have knowledge about working and Industrial applications of Refractory materials

**TEXT BOOK:**

1. Deutsche Gesellschaft and Feuerfest- und Schornsteinbau e.V, “Refractory Engineering”, Tech Books International Publishers and Distributors, 2007.

**REFERENCES:**

1. Charles A Schacht, Refractories Handbook, CRC Press, 2004.
2. Camiglia, Stephen C. Bama, Gordon L, Handbook of Industrial refractories Technology, William Andrew Publishing /Noyes, 1992.
3. D.N.Nandi, Handbook of Refractories, Tata McGraw Hill Publishing Co, New Delhi, 1991.

4. Robert E. Fisher, Advances in Refractory Technology, Ceramic Transaction, Vol.4, 1990, American Ceramic Society, Westerville, Ohio, USA.
5. Modern Refractories Practice, 1961, Harbison Walker Comp., Pittsburgh.

**CR7026 SAFETY ENGINEERING L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**UNIT I GENERAL 10**

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 10**

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 WASTE MANAGEMENT AND ECONOMICS 10**

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

**UNIT IV RISK ANALYSIS 15**

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**

**OUTCOME**

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.

**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).

**CR7027 SPECIAL GLASSES L T P C**
**3 0 0 3**

**OBJECTIVE**

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

**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**

**OUTCOME**

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.

**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.
6. Zdencek Strand, Glass-Ceramic Materials, Elsevier, 1986.
7. Christroper.W.Sinton, Glass Ceramics, Sources, Processes and Quality Control, A John Wiley & Sons, 2006.