Approved M. Tech (CT, Sem I) Syllabus in Ceramic Technology

Govt. College of Engg & Ceramic Technology

An Autonomous Institute Affiliated to WBUT

Code	Subject	Contact period/ week				Full Marks	Credit
		L	T	P	Total		
M(CT) 101	Applied Mathematics	3	1	0	4	100	4
M(CT) 102	Str. & Prop. of Engg. Materials	4	0	0	4	100	4
M(CT) 103	Phase Equil. & transf. in Ceramic Systems	4	0	0	4	100	4
M(CT) 104	Adv. Process Tech. of Ceramics	4	0	0	4	100	4
M(CT) 105	Elect-I A. Environmental Engineering & Occupational Health and Safety B. Separation Technology C. Statistical Pros. Cont. in Ceramics	4	0	0	4	100	4
	Total Theory				**20**	**500**	**20**
Practical							
M(CT) 191	Charat. of Ceram. Raw Materials	0	0	3	3	100	2
M(CT) 192	Powder Processing & Characterization	0	0	3	3	100	2
	Total Practical				**6**	**200**	**4**
Sessional							
M(CT) 183	Seminar	0	2	0	2	100	2
	Total Credit of First Semester				**28**	**800**	**26**

Approved M. Tech (CT, Sem II) Syllabus in Ceramic Technology

Govt. College of Engg & Ceramic Technology
An Autonomous Institute Affiliated to WBUT

Theory							
Code	Subject	Contact period/ week				Full Marks	Credit
		L	T	P	Total		
M(CT) 201	Glass Sc. & Technology	4	0	0	4	100	4
M(CT) 202	New Generation Refractories	4	0	0	4	100	4
M(CT) 203	Nano Ceramics	4	0	0	4	100	4
M(CT) 204	Elect-II A. Bio Ceramics B. Tech. Ceramics C. Ceramic Composite	4	0	0	4	100	4
M(CT) 205	Elect-III D. Electronic ceramics E. Simulation & Optimization F. Thin Film Ceramics	4	0	0	4	100	4
	Total Theory				**20**	**500**	**20**
Practical							
M(CT) 291	Fabrication & Testing of Ceramic Products	0	0	3	3	100	2
M(CT) 292	Design of Kilns & Furnaces	0	0	3	3	100	2
	Total Practical				**6**	**200**	**4**
	Sessional						
M(CT) 283	Comprehensive Viva Voce					100	4
	Total Credit of Second Semester				**26**	**800**	**28**

Approved M. Tech (CT, Sem III) Syllabus in Ceramic Technology

Govt. College of Engg & Ceramic Technology An Autonomous Institute Affiliated to WBUT Theory							
Code	Subject	Contact period/ week				Full Marks	Credit
		L	T	P	Total		
M(CT) 301	Technology Management	4	0	0	4	100	4
M(CT) 302	Research Methodology	**4**	0	0	4	100	4
M(CT) 381	Dissertation I				20	100	16
	Total Credit of Third Semester				**28**	**300**	**24**

Approved M. Tech (CT, Sem IV) Syllabus in Ceramic Technology

Govt. College of Engg & Ceramic Technology
An Autonomous Institute Affiliated to WBUT

Sessional							
Code	Subject	Contact period/ week				Full Marks	Credit
		L	T	P	Total		
M(CT) 481	Dissertation II				28	200	22
	Total Credit of Fourth Semester				**28**	**200**	**22**
	Grand Total of Credit						**100**

APPROVED DETAILED SYLLABI

THEORY

1. M (CT) - 101 Applied Mathematics.

1. **Mathematical Modeling** - Application to ceramic process.

2. **Theory of Matrices** - Liner transformation, Bilinear, Quadratic and Hermitian forms. Matrix functions. Caley Hamilton theorem, Eigen values, Eigen Vectors and their properties.

3. **Partial Differential Equations** - Solutions of first order linear and nonlinear partial differential equations. Lagranges method, Charpits method. Second order linear partial differential equations with constant coefficients.

4. **Boundary Value Problems** - Solutions of diffusion equations by different methods. e.g. Variables separations method, Laplace and Fourier transform methods.

5. **Numerical Methods**

    a. Numerical solution of Algebraical and Trascendental equations - Method of iteration, Newton Raphson method, Muller's method.

    b. Numerical solution of a system of linear equations - LU decomposition method, Gauss-Siedel, Gauss Jordan method and sufficient condition for its convergence.

    c. Numerical solution of ordinary differential equation - Euler's method, Modified Euler's method, Runge-Kutta method 4^{th} order, Predictor-Corrector methods.

6. **Optimization Techniques** -

    a. Linear programming - Simplex algorithm, Degeneracy, Dual problems, Duality theorems.Transportation & Assignment

    b. Nonlinear optimizations - Unconstrained optimization problems - Descent method, Steepest Descent method.

    c. Optimization with equality type constraints - Method of Lagrange's multipliers.(upto three variables)

7. **Statistical Methods** - Random variables, Distribution functions. Interval estimation, Confidence intervals, Tests of statistical hypothesis, χ^2 goodness of fit, Simple idea of quality control.

Reference books :

a) Advanced Modem Engineering Mathematics, Glyn James, David Burley, etc.
b) Introductory methods of numerical analysis, S.S. Sastry,
c) Numerical Methods For Scientific And Engineering Computation, M.K. Jain, S.R.K Iyengar & R.K. Jain.
d) Ordinary differential equations, D. K. Arrowsmith, C. M. Place.
e) Higher Algebra: Abstract And Linear, S.K. Mapa.
f) Engineering optimization, S S Rao.
g) Advanced Differential equations, M.D. Raisinghania, S. Chand.
h) Fundamentals of mathematical statistics, S. C. Gupta, V.K. Kapoor.

2. M (CT) – 102 Structure & Properties of Engineering Materials.

1. Structure of solids: Introduction – Atomic bonding – ionic, covalent, metallic, Van der Waals; Crystal structure, Lattice planes and directions, Crystal structure of Ceramic solids; Lattice imperfections – point defects, line defects, plane defects etc.
2. Practical determination of Structure: Introduction, Theoretical and Practical X-ray diffraction – Powder technique, Other applications, Neutron diffraction, Electron diffraction, Structure of amorphous materials, Field ion microscopy, Infra red spectroscopy.
3. Mechanical Properties: Introduction, Mechanical testing, Elastic and plastic behaviour, Fatigue, Fracture – brittle and ductile, Strengthening of materials, Creep & Stress rupture of metals, Mechanical properties of Plastics.
4. Electrical Properties: Introduction, Metals, Semiconductors – Intrinsic & Extrinsic, Semiconductor devices, Microelectronics, Compound semiconductors, Ionic and Electronic conduction in crystals and glasses. Superconductivity – Resistanceless and superconducting states, Type I and Type II superconductors, Superconducting materials and applications.
5. Dielectrics: Introduction, Mechanisms of polarizations, Local field, The Clausius – Mosotti relation, Dielectric relaxation, Applications, Piezoelectric and ferroelectric materials science and application.
6. Magnetic Properties: Introduction, Classification and types, Magnetic fields and quantities, Effect of temperature on ferromagnetism, domains, Types of energies determining structure of ferromagnetic domains, soft and hard magnetic materials, Ferrimagnetism, Ferrimagnetic ceramics – Ferrites.
7. Optical Properties: Introduction, Dispersion, Absorption, Colour, Ligand Field Theory, Opacity, Translucency, Scattering of light, Lasers, Photo elastic effect, Photoelectric emission, photoconductivity, Photoluminescence, Natural and induced birefringence.

8. Corrosion and Oxidation: Degradation of metals – Electrochemical corrosion, Types, Prevention, Oxidation of metals, Refractory corrosion.

References:

1. Introduction to Ceramics – W. D. Kingery
2. Principles of Materials Science & Engineering – Smith
3. Physical Properties of Materials – Lovell, Avery & Vernon
4. Materials Science & Engineering – An Introduction - Callister

3. M (CT) – 103 Phase Equilibrium & Transformation in Ceramic Systems.

1. Ceramic Phase Equilibrium Diagrams: Gibb's phase Rule, One Component Phase Diagrams, techniques for determining phase diagrams, Pressure-temperature Diagram for carbon, Two component systems, Two component phase diagrams (Eutectic diagrams, Incongruent melting, Phase separation, Solid solution), Binary Isomorphous System, Lever Rule, Development of Microstructure in Isomorphous Systems, Phase Diagram with Intermediate Phases, Eutectoid Reaction, Peritectic Reaction, Complex Diagram, three-component Phase Diagrams

2. Phase composition versus Temperature, Fe-Fe3C Phase Diagrams, Al2O3 – SiO2 system, MgO – Al2O3 – SiO2 system, Non-equilibrium Phases, Metastable Crystalline Phases, Incomplete reactions.

3. Phase Transformations: Formal Theory of Transformation Kinetics, Spinodal Decomposition and its Thermodynamics and Kinetics, Kinetics of Homogeneous Nucleation and Heterogeneous Nucleation, Crystal Growth from Vapour or Dilute Solution, Crystal Growth from Melt.

4. Glass formation, composition as a variable, heat Flow and Precipitation from Glasses, Growth controlled by Diffusion of Solutes, Crystalline Glazes, Opacified Enamels, colloidal colours, Photo-sensitive Glasses and Photo-chromic glasses, Glass Ceramic Materials, Important Glass Ceramic Systems, Phase Separation on Glasses.

Suggested Readings:

1. Introduction to Ceramics – Ed. W. D. Kingery, John Wiley & Sons.
2. Physical Ceramics – Chiang, Birnie and Kingery, John Wiley & Sons
3. Phase Transformation – S. Banerjee and P. Mukhopadhyay, Elsevier

4. M (CT) – 104 Advanced Process Technology of Ceramics.

1. Overview of Ceramic Powder Synthesis & their Characterization:

i) Reactive powder preparation methods – Mechanical methods (Attrition Mill, Planatary Mill)

ii) Chemical Methods: Precipitation, Sol-gel techniques, Spray pyrolysis, CVD, Combustion synthesis (SHS), Plasma synthesis etc.

iii) Powder Characterization: chemical composition, Phase composition, Surface characterization, Different techniques of measurement of particle sizes, shape and size distribution, Powder agglomeration and granulation.

2. Forming Process:

i) Conventional Process – Dry and semi-dry pressing, Slip casting, Extrusion

ii) Advanced Process – Cold Isostatic pressing & Hot Isostatic pressing, Tape casting, Injection moulding, Hot-pressing.

3. Sintering / Firing Process:

i) Liquid Phase sintering, vitrification and Solid-state sintering, Driving force of sintering, sintering additives. A few case studies of sintering process.

ii) Microwave Sintering – other recent trends in sintering.

4. Evolution of Ceramic Microstructures;

Effect of green microstructure on sintered microstructures of the products. A few case studies. Mechanism of mass flow during sintering. Kinetic models for sintering.

References / Books:

1. Ceramic processing & Sintering – M. N. Rahaman
2. Introduction to Principles of Ceramic Processing – J. S. reed
3. Ceramic Processing before Firing – Onada & Hench
4. Advanced Ceramics – Vol 9, Forming of Ceramics
5. JACS

5. ELECTIVE – I:

i) M (CT) – 105A (Environmental engineering & Occupational Health and Safety)

PART A : Environmental engineering

Air Pollution : Collection efficiency of Particulate Collector, Particulate Control Equipment e.g., Settling chambers, Cyclone Separator, Fabric Filter, ESP, Wet Scrubbers – principle and construction ; Solvents for Gaseous Pollutants.

Water Pollution : BOD and COD ; Primary and Secondary Treatment of Wastewater ; Sedimentation Tanks, Floatation, Activated Sludge Process, Sludge Treatment and Disposal ; Ion Exchange and Reverse Osmosis.

Solid Waste Management : Sources and Classification, Methods of Collection and Disposal

PART B : Operational Health and Safety

Policy Design and Implementation : Key Principles, Policy Formulation and Review, Policy Instruments, National Law, Labour Codes and Regulation, Role and Obligation of Competent Authority.

Policy within the Enterprise : Employer's Responsibility, Workers' Duties and Rights, Management of Occupational Health and Safety.

Operational Measures : Surveillance of Working Environment, Surveillance of Workers' Health, Preventive and Protective Meas

ii) M (CT) – 105B (Separation Technology)

Ceramic membrane for Separation and Reaction

1. Ceramic Membrane and Membrane Processes: Membrane Processes like Gas Separation, Pervaporation, Reverse Osmosis and Nanofiltration, Ultrafiltration and Microfiltration, Dialysis, Electrodyalysis, Membrane Contactors, Membrane Reactors

2. Preparation of Ceramic Membrane: Slip Casting, Tape Casting, Pressing, Extrusion, Sol-Gel Process, Dip Coating, CVD, Preparation of Hollow Fiber Ceramic Membrane

3. Characterization of Ceramic Membrane: Morphology of Membrane Surface and Cross Section, Porous Ceramic Membranes (Gas Adsorption / Desorption Isotherms, Permporometry, Mercury Porosimetry, Thermoporometry, Liquid Displacement Techniques, Permeation Method, Measurements of Solute Rejection) Dense Ceramic Membrane (Leakage Test, Permeation Measurements, XRD, Mechanical Strength)

4. Transport and Separation of Gases in Porous Ceramic Membrane: Performance Indicators of Gas Separation Membranes, Ceramic membrane for Gas Separation (Zeolite membrane, Silica Membrane, Carbon Membrane) Transport mechanism (Knudsen and Slip Flow, Viscous Flow, Surface Flow, Capillary Condensation, Micropore Diffusion, Simultaneous Occurrence of Different Mechanism)

5. Ceramic Hollow Fiber Membrane Contactors for Treatment of Gas and Vapors: Operating Modes and Mass Transfer Coefficients, Mass Transfer in Hollow Fiber Contactors, effect of Chemical Reaction

6. Mixed Conducting Ceramic Membrane for Oxygen Separation: Fundamentals of Mixed Conducting Ceramic membranes, Current Status of Oxygen Permeable Membranes, Dual Phase membrane, Oxygen Transport

7. Mixed Conducting Ceramic Membrane for Hydrogen Permeation: Proton and Electron Conducting materials and Membrane, Proton Transport, Application of Proton Conducting Ceramic membrane

Suggested Reading:

1.Kang Li, Ceramic Membrane for Separation and Reaction, John Wiley and Sons

2. N.N. Kanellopoulos, Recent Advances in Gas Separation by Microporous Ceramic Membrane, Elsevier

iii) M (CT) 105 C Statistical Quality Cont. in Ceramics

1. Introduction. Definition of quality, quality control, quality assurance & TQM. Type of quality characteristics and their advantages & disadvantages. Definition of statistical control. Differences between Chance & Assignable causes. 3 L
2. Steps for continuous improvement. Pareto diagram, Brain storming, Cause & Effect diagram, PDCA cycle. 3L
3. 5S & 5 Whys analysis. Kaizen, Quality circle, TQM, Process capability, control charts. 7 L
4. Design of experiments- definitions, Procedure, Two level two factor designs, two level multifactor factorial design, analysis of results. 4L
5. Six sigma- Definitions & its implementation procedure, CTQ, FMEA, SIPOC, QFD, POKA-YOKE. 7L
6. ISO 9000-Intoduction, documentation track, handling of nonconformities, ISO-14001, ISO-18001 & SA8000 –their purpose & implementation techniques. 6L

PRACTICALS

M (CT) – 191 Characterization of Ceramic Raw Materials.

1. **Instrumental Characterization –** DTA Analysis, TGA Analysis, TMA Analysis
2. **Physical Characterization –** X-Ray Diffraction, Optical Microscopy with image analysis (Including Sample preparation), SEM with EXDA (Surface topography), IR-UV-VIS, ESCA, DSC, Mercury porosimetry – Pore Size distribution, Particle size distribution, Sedigraph, Light Scattering.

M (CT)-192 Powder Processing & Characterization.

1. General idea of ceramic powder processing and its characterization

Scope and Application

2. Precipitation and Co-precipitation of ceramic materials: Alumino hydro gel, Magnesio Alumino hydrate, Hybrid Ferrite and composite ceramic materials

3. Sol-Gel processing of ceramic materials: Silica, Alumina, Ferrite and Hybrid structure

4. Filtration, washing, Drying and Calcinations of powder:

5. Characterization of Ceramic powder:

(a)Particle size distribution

(b) DTA & TGA

(c) XRD

(d) SEM / TEM

SESSIONAL

1. M (CT) – 183 – Seminar

APPROVED DETAILED SYLLABI
THEORY

1. M (CT)-201 Glass Science & Technology-

1. An overview on amorphous solids, non-crystalline solid and glasses. Meaning of glass transformation. Entropy and enthalpy consideration, relaxation process, vibration and configurationally entropy.
2. Homogeneous and heterogeneous nucleation. Immiscibility in glasses from thermodynamic point of view. Spinodal decomposition of phase separation. Processing, properties and application of glass ceramics.
3. Overview of viscosity and elasticity. Importance of viscosity in glass technology. Viscoelasticity. Linear-spring Model-Time variability of Hookear solid.
4. Brittle fracture, fracture mechanics, Crack velocity and criticality. Stress intensity factor, Mathematical modeling of fracture strength, flexural and fracture strength of glasses.
5. Principle and manufacturing of sheet glass by float process, TV picture tubes, container glass, glass fibre and optical fibre.
6. Overview on surface physics. Importance of surfaces, surface properties and chemical durability. Modification of surfaces. Different theories of surface structure in glasses.

Suggested Books:

a) F. V. Tooley, Hand book of Glass Manufacture, Vol. 1 & 2.
b) J.I. Duffy, Glass Technology, NDC (USA).
c) N.P. Bansal and R.H. Doremus, Glass properties, Acadamic press (USA).
d) A. Paul, Chemistry of glasses, champman & Hall (UK).

2. M (CT)-202 NEW GENERATION REFRACTORIES.

Introduction of Refractories and Monolithic Refractories/Castable Refractories, Shaped and Unshaped Refractories — Advantages and Disadvantages of Monolithic/Castable Refractories, Classification of Unshaped Refractories.

Aggregates used in monoliths/Castables Refractories.
Refractory cement and other additives, Additives for ramming and gunning materials.

Refractory Cement, Morters, Concrete, RammingMass, Fettling,
Gunning Mass, Spray Mass.

Type of bonding in Castable Refractories e.g. Hydraulic Bonding, Chemical Bonding and Quagulation Bonding
Classification of Castables: Conventional Castables, Low cement Castables, Ultra low cement Castables, No or zero cement Castables, Gel bonded and self floor Castables, Silica free and basic Castables, Nano material incorporated Castables.
Carbon Bonded Refractory Castables,
Nano Structure Matrix refractory castables.
Manufacture of Castables/Monoliths, Installation techniques, Applications.
Different areas of application of Monolithics/ Castable Refractories.
Non-Oxide Refractories: - Silicon Carbides, Silicon Nitride, Boride and Graphite Refractories.

Reference Books:-

1.Monolithic Refractories by Subrata Banerjee.
2. Refractories Handbook by Charles A. Schacht.
3. Ceramics for Advanced Technologis by J.E.Hove & W.C.Riley.

3. M(CT)-203 Nano Ceramics.

1. Nano technology, Introduction of Nano structured materials, Nano scale material in nature, Theories of NSM's formation and its application, Change of properties at nanometric dimension and challenge
2. Method of synthesis of Nano structured materials NSM's: Theories, Top down and bottom up approach, Different physical and chemical route for synthesis of Nano structured materials. High energy milling, planetary mill, Vibrational shaker mill, Attritation mill, Physical Vapour deposition. Sol-Gel method. Solvothermal synthesis, Gama irradiation synthesis, Hydrothermal synthesis,
3. Synthesis and characterization Nano materials: (a) Nano Alumina (b) Nano Silica (c) Nano Zirconia (d) Nano Barium titanate (e) Nano ferrite (f) Nano Silicon carbide (g) Nano Gold
4. Properties and Characterization of Nano structured material:
Compaction and Sintering of NSM's, porosity, Hardness, Mechanical properties, Magnetic and Electrical properties of Nano structured materials. X-ray diffraction, Transmission electron microscopy and Scanning electron microscopy,
5. Quantum mechanics and Nano structured materials, Schrödinger wave equation. Operator, Particle in a Box and well, Nano wire, Nano rod, Nano belt,
6. Nano composite and Nano coating

Reference Books:-

1. Hand Book of Nano Structure Materials & Nano Technology edited by Hari Singh Nalwa.
2. Nano Materials edited by H.Hosono, Y. Mishima, H. Takezoe & K.J.D. Makenzie.
3. From Nano Powders to Functional Materials edited by Radu Robert Piticescu, W. Lojkowski & J.R.Blizzard.

Elective-II-M (CT)-204A

A. Bio-Ceramics

1. Introduction and necessity of bio-ceramics. Definition of Biomaterials, biological materials, biomimetic materials. Osteoporosis and its various causes. Classification of Biomaterials. Different application of biomaterials. Physiology of human bones. 8L
2. Definition of bioceramics and its classification. Different definitions of Biocompatibility. Forms, phases & functions of bio-ceramics. Different types of bioceramics-tissue interfaces. Various types of implant-tissue responses. Different bioceramic-tissue attachments. Processing techniques and microstructure of bioceramics. 8L
3. Dental bioceramics-its need, brief discussion on dental restoration techniques, structure of a tooth, material composition & processing techniques along properties. 5L
4. Alumina and zirconia bioceramic material-its properties, uses and preparation. 5L
5. Bioactive coatings-coating techniques, clinical applications. Bioactive glasses & glass ceramics- composition, preparation, properties and applications. 5L
6. Hydroxyapatite- differences of synthetic vs. natural HAP. Dense & porous HAP preparation, properties &applications. 5L
7. Radiotherapy glasses- introduction, compositions, processing, properties & uses. 2L
8. Biocomposite – desirable properties of bioceramics and its limitation. Different biocomposite materials, fabrication method, properties and uses. 2L
9. Calcium phosphate bio ceramics-processing, properties & applications. 2L

Test Books:

1. An Introduction to Bioceramics by Larry L. Hench & June Wilson, World Scientific publication.
2. Bioceramics Materials, properties, Applications by A. Ravaglioli, A. Krajewski, Chapman & Hall publication.

B. M(CT 204B: Technical Ceramics

Introduction, Raw Materials uesd,
Manufacturing Processes:

I. General Body Preparation
II. Plastic Shaping Methods
III. Non-Plastic Shaping Methods
IV. Glazing, Firing & Inspection.

Porcelain:

I- Compositions, Processing, Properties
II- Products, Modified Compositions

High Temperature Ceramics:

I- Properties, Fabrication Methods of Oxides, Non-Oxides
II- Various Products and its applications- Cermets, Gas turbine blades, Abrasives, Fibres, Whiskers.

High Frequency Ceramics:

I- Steatite Ceramics
II- High Permittivity Dielectrics
III- Magnetic Ceramics (Ferrites)

Metalized Ceramics:

Reasons for metallising, Processes for parts used at normal temperature, at elevated temperature and high temperature ceramic-metal seals.

Recommended Book:-

1. Introduction to Technical Ceramics by B.E.Waye.

C. M(CT) 204 C: Ceramic Composite

Definition, historical background, present context classification and applications.

Mechanical behaviour and failure of materials.

Strengthening and reinforcing – analysis and prediction of strength of composites.

Fibre reinforcement – fibre and matrix types.

Brittle matrix composites, inorganic matrix composites (CMC, MMC).

Polymer matrix composites.

Characterization and analysis of composite interfaces.

Composite fabrication

Tough composites materials

Bio composites

Design concepts

Future trends (Smart and intelligent composites)

Books, Proceedings:

1. Mechanical behavior of ceramics – R.W. Davidge.
2. Concise Encyclo of composite mats. – Anthony Kelly (ed) Pergurdn Pr. (1998)
3. Proc. Am. Ceram. Soc. For composites (1986 onwards)
4. High performance fibre composites – Morley (Aead Pr)
5. Advanced Composites – Ivana K. Patridge.
   Superalloys, supercomposites and super ceramics- John k Tien & Thomas Coulfield (Eds) – Acad Press (1989

Elective-III-M (CT)-205

D. Electronic Ceramics

1. Basic of quantum mechanics.
2. Semiconductors (Hall effect, Fermi level, Polarons, Excitrons, radial distribution functions)
3. Ionic and defect conductors (Solid electrolyte and fast ion conductors, Frenkle disorder in stoichiometric crystal, protonic conduction in glass)
4. Linear dielectrics (Time – temperature dependentce of dipolar polization, Breakdown mechanisms)
5. Non-Linear dielectrics (Structural origin of ferroelectric state, description of ferroelectricity based on local fields, effect of environment on switching and transitions, effect of electric fields on Tc, compositional factors, effect of grain size on ferroelectric behavior).
6. Magnetic ceramics (Spinel lattice interactions, effect of composition in ferrites, effect of thermal treatment).

7. Photonic ceramics (interionic adsorption and ligand field theory, optical filters, ionic polarizability).
8. Optical wave guides (Generation of optical communications, dielectric waveguides, Goo-Haenchen shift, Ray deviation from central core, application of Frensel equations, infrared wave guides)
9. Electro-optical ceramics (Electric field dependence of index of refraction, Pokel's Kerr, Farraday memory effect, LED, Avalanche photodiodes, quantum confinement, photoconductive semiconductors).
10. Glass and crystalline lasers (Laser mode and focusing, etalons, Fabry-Perot inteferometers, Brewster angle windows, Q-switching, quantum well lasers, Parameters of various lasers).
11. Ceramic superconductors (BCS theory, High Tc electron pair, and coupling mechanism, defect chemistry and superconducting ceramics).

Suggested Books:

1. R.E. Hummel, Electronic properties of materials, Springer-Verlog, Berlin.
2. C. Kittel, Introduction tosolid state physics, Willey, New York.
3. L. Azaroff and J.J. Brophy, Electronic properties in materials, Mcgraw Hill, New York
4. L. L. Hench and D.B. Dove, Physics of electronic ceramics, Park – A, Dekker, New York.
5. R.C. Buchanon, Ceramic Materials for electronics Dekker, New York.

E. Simulation & Optimization

1. Introduction;- Introduction to design and specifically system design, Morphology of design with a flow chart, Concept of workable design, practical example on workable system and optimal design.
2. System Simulation:- Classification Successive substitution method-example, Newton Raphson method- one unknown-examples, Newton Raphson method-multiple unknowns- examples Gauss Seidel method- examples, Rudiments of finite difference method for differential equations with an example.
3. Module 3: Regression and Curve Fitting:- Need for regression in simulation and optimization, Concept of best fit and exact fit- Lanrange interpolation, Newton's divided difference-examples, Least square regression- theory, example from linear regression with one and more unknowns-examples, Power law forms-examples, Gauss Newton method for nonlinear least squares regression-examples.
4. Module 4: optimization:- Introduction, Formulation of optimization problems-examples, Calculus techniques-Lagrange multiplier method-proof, examples, Search methods- Concept of interval of uncertainty, reduction ratio, reduction ratios of simple search techniques like exhaustive search, dichotomous search, Fibonacci search and Golden section search- numerical examples, Method of steepest ascent/steepest descent, conjugate gradient method-examples, Geometric

programming-examples, Dynamic programming-examples, Linear programming, New generation optimization techniques- Genetic algorithm and simulated annealing-examples, Introduction to Bayesian framework for optimization examples.

Reference Books:-

1. Essentials of Thermal System Design and Optimization—Prof. C.Balaji, Aue Books, New Delhi in India and CRC Press in the rest of World.
2. Design and optimization of thermal systems, Y. Jaluria, McGraw Hill, 1998.
3. Elements of thermal fluid system design, L.C.Burmeister, Prentice Hall, 1998.
4. Design of thermal systems, W.F.Stoeker, McGraw Hill, 1989.
5. Introduction to optimum design, J.S.Arora, McGraw Hill, 1989.
6. Optimization for engineering design- algorithms and examples, K.Deb, Prentice Hall, 1995.

F. Thin Film Ceramics

1. Thin Film – Definition, applications, Differences with Thick Film
2. Thin Film nucleation and Growth: layer by layer Growth, Island Growth , layer and Island Growth
3. Preparation of Different Ceramic Thin Films:
   a) Vacuum Evaporation: Kinetic theory of gas and emission condition, Equations for material Deposition, Flash Evaporation
   b) Sputtering Process: Sputter Yield, Advantages of Sputtering
   c) Chemical vapor Deposition: Thermal Decomposition, Vapor Phase Reaction, Vapor Transportation Methods
   d) Sol gel Method and Coating For the fabrication of ZnO, TiO_2, SiO_2, PZT, BT, Mullite, ZrO_2: Spin Coating, Dip Coating, LB Film Preparation
4. Different Properties of Thin Films: Electrical, Electronics and Optical,
5. Brief Ideas about Different Methods for the Characterization of Thin Films:
   Optical Microscope, Scanning Electron Microscope, Transmission Electron Microscope, X Ray Diffraction, Ellipsometey, Auger Electron Spectroscopy, Energy Dispersive Analysis of X-rays (EDAX), UV Spectra, resistance - four point probe, Stress Curvature Measurements .

Suggested Books:

1.Thin Film Fundamentals By A. Goswami, New Age Publishers
2. Thin Film Deposition- Principles and Practice By Donald Smith, McGraw Hill
3.Material Science of Thin Film by Milton Ohring, Academic Press
4. Handbook of Thin Film Technology by Frey, Hartmut, Khan, H. R., Springer

PRACTICALS

Fabrication & Testing of Ceramic Products - M (CT) – 291

1. Preparation of glass batch, melting and annealing. Characterization of the product obtained: Density, Chemical durability, Thermal expansion etc.
2. Fabrication of a refractory brick and physical testing of the product like B.D, A.P, CCS, Thermal expansion etc.
3. Fabrication of a whiteware product. Physical testing of the product like Vitrification range, Water absorption, Thermal expansion etc.

Design of Kiln & Furnaces –M (CT)-292

A) Process Design of a Furnace/Kiln :-

a. Shuttle Kiln
b. Rotary Kiln
c. Tunnel Kiln
d. Shaft Kiln
e. Glass Melting Tank Furnace
f. Roller Hearth Furnace etc.

Approved Detailed Syllabus M. Tech. 3rd Semester

M (CT) 301 Technology Management

1. Technology Management: Definition, Macro and Micro Technology Management

2. Theories of Technological Change: Neo Classical Theory, Marxist Theory, Schumpeter's Theory, Evolution Theory, Market Pull Theory, Technology Push Theory

3. Measurement of Technological Change: Economic Indices, Patents, Rate of Improvement of Technology, Rate of Substitution of Technology, Rate of Diffusion of Technology

4. Use of Technology Forecasts: In National Context, In the Context of business firms

5. Classification of Technology Forecasting Methods: Delphi Method, Trend Extrapolation

6. Technology Monitoring: Scanning, Filtering, Analysis and Development, Growth Curve, Pearl Reed Curve, Gompertz Curve, Relevance Trees, Morphological Analysis, Mission Flow Diagram

7. Technology Life Cycle, Long Range Business planning, Intellectual Property Rights

8. Institutional mechanisms in India

Suggested Reading:

1.Ayres, Robert U**.** 1989. The future of technological forecasting.*Technological Forecasting and Social Change*, Vol.36, pp.49-60.

2.Betz, Frederick1998. *Managing Technological Innovation*, John Wiley, McGraw-Hill, New York.

3.Rastogi, P.N**.** 1995. *Management of Technology and Innovation*, Sage Publications, New Delhi.

M (CT) 302 Research methodology

Introduction, Meaning of research; objective, motivation & types of research, 3L
Research process- formulating problem, 3L
Literature survey, development of working hypothesis, 3L
Designing research, deciding sample size, collecting data, execution of project, 5L
Analysis of data, hypothesis testing, 4L
Preparation of report; preparation of project proposal; preparation of completion report 8L
IPR and ethics

IPR and related issues; patent, copyrights, design, trade secrets. Ethics in research, plagiarism. Patent literature and project formulation. 10L

Recommended Books:

1. Research Methodology : Methods and Techniques – C R Kothari
2. Research Methodology – Ranjit Kumar