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SYLLABUS OF CERAMIC ENGINEERING

Introduction to Ceramics

a) General: (3) Definition & scope of ceramics and ceramic materials, classification of ceramic materials – conventional and advanced ceramics. Historical perspective, Civilization; Traditional ceramics: An overview, history

b) Pottery & Whitewares: (4) Classification and type of pottery & whitewares, elementary idea of manufacturing process technology including body preparation, basic properties and application areas.

c) Glass: (5) Definition of glass, glass raw materials and their functions, elementary concept of glass manufacturing process specially for container glass, different types of glasses, application of glasses. Glass processing, container glass, fibre glass, speciality glass products, glass- ceramics, glass microspheres, laminated glass, photochrome and photo sensitive glass Modern / high tech ceramics, high tech functions

d) Refractories: (5) Definition of refractory, properties of refractories, classification of refractory, manufacturing process, basic areas of application specially in steel plant.

e) Cement & Concrete: (3) Concept of hydraulic materials, raw materials and manufacturing process, basic compositions, setting and hardening, concrete.

Advanced Ceramics: (6) Engineering ceramics, ceramics used in advanced applications, ceramics for medical and scientific products, ceramics for electrical and electronic, aerospace. The development of modern ceramic technology, processing of ceramic powders, shape forming operations: pressing, slip casting, isostatic pressing, injection molding, sheet forming, MLC technology. Firing of ceramics: kiln design and conveyor technology, sintering and densification, hot pressing and hot isostatic pressing. Sol –gel processing and monolithic ceramics. functional ceramics, structural ceramics, electrical and electronic ceramics, chemical and nuclear ceramics, bio-ceramics, ceramic membranes, artificial gems and ceramics, aerospace and other strategic applications of ceramics, advanced ceramic processing techniques. Energy and pollution controls.

Basic Ceramic Practices

Introduction to ceramic processing. Significance of different ceramic processing operations. Powder synthesis, Colloidal and sol-gel processing. Powder characterization: Particle size, size distribution, Shape, Surface Area, Porosity, Chemical and Phase composition. Preparation of bodies: Blending of different weight fractions and size ratios, use of binders, types of binders; clay, molecular binder, film forming binders. Plasticizers, Foaming and antifoaming agents, granulation and spray drying. Dry pressing, Semi-dry pressing, Slip casting, Extrusion, Non-traditional shape forming: Gel casting, Tape casting, Freeze Casting, Injection moulding, Electro-phonetic deposition, Hot -pressing, Iso-static pressing; porosity, pore structure, drying defects; High temperature processing.

Ceramic Raw Materials

- Chemistry of Ceramic Materials: Raw materials used in Glass, Refractories, Whitwares, Potteries and Cement. Chemical characteristics of raw materials of alkali and alkaline earth elements, silica, silicates, alumina, aluminates, titania, zirconia and zircon. Spectrophotometric analysis, Differential Thermal Analysis (DTA) and Thermo Gravimetric Analysis (TGA) with suitable examples.
- Geology of Ceramic Materials: Geology and its utility in ceramic industry, Broad outlines of crystal forms and symmetry, Elementary ideas about rocks and their formation. Description and Classification of various minerals based on their chemical compositions, physical properties and occurrence.
- Optical characterization of minerals using Polarizing Microscope: Polarizing microscope. Iso-tropic and anisotropic minerals, Bi-referingence, Pleo-chroism. Propagation of light through uni-axial and bi- axial minerals, extinction, cleavage and interference figures. Beck's effect. Systematic description of minerals under polarizing microscope.

Properties of Ceramic Raw Materials

Classification of raw materials, beneficiation of raw materials, importance, use and limitations of natural raw materials: Bauxite, Limestone, Chromite, Magnesite, Dolomite, Fluorite, Graphite, Gypsum, Haematite, Kaolinite, Fireclay, Ball clay, Montmorillonite, Magnetite, Nepheline Syenite, Microcline, Feldspars (soda, potash, lime), Pyrophyllite, Quartz, Quartzite, Sillimanite, Kyanite, Andalusite, Talc, Wollastonite, Zircon, Beryl, Mica, Vermicullite, Silica sand etc; Brief idea on processing of synthetic raw materials: Bayer process, Calcined Alumina, Tabular Alumina, FusedAlumina, Sea- water Magnesia, ZirconandZirconia, Titania, Magnesio-AluminateSpinel, FumedSilicaetc. The application areas and limitations of synthetic raw materials; Effect of heat on different raw materials with reference to phase transformation, thermal expansion, melting, decomposition behavior, compound formation, stabilization.

Thermodynamics & Phase Equilibria in Ceramic Systems

1. Review of Fundamentals: Introduction, definition of terms, first law of thermodynamics: Heat and work, internal energy, isometric process, isobaric process, isothermal process and enthalpy, heat capacity. Second law of thermodynamics: spontaneous process, entropy and irreversibility, entropy and reversible heat, reversible isothermal compression, adiabatic expansion of ideal gases, second law of thermodynamics, maximum work, criterion of equilibrium, combined statement of first and second laws. Third law of thermodynamics.
2. Statistical interpretation of entropy: Entropy and disorder, microstate, most probable state and equiplibrium, Boltzmann equation, thermal entropy and configurational entropy.
3. Thermodynamics behaviour of solutions:Raoult's law and Henry's law, The thermodynamics activity, Gibbs-Duhem equation, Gibbs free energy of formation of a solution, properties of ideal solutions, non-ideal solutions, Gibbs-Duhem equation and activity relationship, regular solutions. A statistical model for solution, sub regular solutions.
4. Phase equilibrium in a one component system: Variation of Gibbs free energy with temperature and pressure, equilibrium between different phases- solid liquid equilibrium, Clapeyron equation, Clausius-Clapeyron equation. Graphical representation of equilibrium in one component system.
5. Two component system: Gibbs free energy-composition diagrams and phase equilibrium. Gibbs free energy and thermodynamics activity, Gibbs free energy of formation of regular solutions, Gibbs-Helmoltz equation criteria for phase stability, contimous solid solution, eutectic reaction, liquid phase separation, paratactic reactions, compound formation; congruently and incongruently melting compound.

Electrochemistry: chemical reactions and electrochemical reactions, chemical and electro- chemical driving forces. Electrochemical cell- EMF, different types of electro chemical cells, stabilized zirconia as solid electrolyte, oxygen sensor, and solid oxide fuel cells.

Particle Mechanics and Fluid Flow Processes

Communition: different type of communition equipment and theory of size reduction. Efficiency and particle size, size reduction and size distribution. Bulk solid transport and mixing. Mixing mechanism and mixedness. Mixing equipment types and operation. Consistency, particle mechanics and deformation behaviour of powders, slurries and paste. Particle classification-screening technique, cyclone separators, centrifuge. Filtration and washing process. Plastic forming, extrusion mechanics, control of types and operations. Basic concept of drying, costs involved in drying of ceramic, drying mechanisms in particulate systems, characterization of drier operations, drier controls, drying defects and drying shrinkage, advanced drying technologies. Communication: size reduction processes, crushing grinding and milling. Communication equipment and communication processes-particle loading and facture, energy requirements, efficiency and performance indices. Particle size distribution.

- Characterization of particles, Shape and Size, specific surface area, powders polloids and agglomerats.
- Separation and classification of particles- screening operations and screening efficiency. Size distribution curves. Size and distribution functions. Motion of particles in fluid, settling equation and settling criterion, hindered settling cyclone and hydroclone, centrifuge, filtration and washing
- Particle storage, janssen equation

- Particle packing characteristics.
- Mixing process and equipment, efficiency and performance indices.

Heat Transfer and Fluid Flow Processes

Steady state and unsteady state conduction. Heat flow through composite walls, cylinders and spheres, Thermal resistances in series for ceramic materials. Convective heat transfer: Free and forced convection, application of dimensional analysis to convection problems. Radiation Heat Transfer black and grey bodies, Stefan-Boltzman's law, Kirchoff's law. Radiation through furnace openings. Combined effect of conduction, convention and radiation, overall heat transfer coefficient. Heat transfer through fluidized bed. Computation of heat loss from furnaces and kilns- sankey diagram. Heat transfer concept and selection of refractories. Fluid properties, density, viscosity, surface tension, compressibility. Classification of fluids: Newtonian and non-Newtonian fluids. Equation of continuity for compressible and incompressible fluid flow. Flow measurements: Venturimeter, Orifices, Pitot tube and Rotameter. Significance of Reynolds, Nussle's and Prandlt's Numbers; Euler's numbers, Archimedes number; Pressure drop in flow and pressure drop calculation in various cases, Flow through bends, Straight and bend pipes, Packed beds.

Structure and Properties of Ceramic Materials

1: Structure of ceramic materials

Bonding in ceramics: electronegativity; ionic and covalent bonding, Energy versus distance curves for an ionic bond.Lattice Energy and Madelung constant. Face-centered cubic (FCC), body-centered cubic (BCC), and hexagonal close-packed (HCP) structure. Grouping of ions and Pauling's rule, coordination number, factors affecting structure. Different ionic structures according to anion packing: AX, AX2, A2X, AmEnXp structures; Rock salt, Rutile, Zinc blende, Antifluorite, Wurtzite, Nickelarsenide, Cadmiumiodide, Corundum, CsCl, Perovskite, Spinel (normal-inverse), Illmenite, Olivine and Structure of Silicates.

Defects in Ceramics: Kroger Vink notations for point defect. Schottkyand Frenkel defects. Defect Reactions. Stoichiometric defect reactions. Nonstoichiometric defects. Extrinsic defects. Electronic Defects. Defect Equilibria and Kroger- Vink Diagrams. Stoichiometric Versus Nonstoichiometric Compounds.

2: Diffusion and Electrical properties

Diffusion: Atomistics of Solid State Diffusion, self-diffusivity, Diffusion in a Chemical Potential, Electric Potential and Electrochemical Potential Gradient.

Electrical Conductivity: Electric mobility, Transference or transport number. Ionic Conductivity, Electronic Conductivity; Intrinsic semiconductors, Extrinsic semiconductors, Nonstoichiometric semiconductors

3: Magnetic properties

Para-, Ferro-, Antiferro-, and Ferrimagnetism, Curie-Weiss law, Curie temperature, Neel temperature, Magnetic Domains and the Hysteresis Curve, saturation & remnant magnetization coercive magnetic field, soft and hard magnet, orientation anisotropy, magnetostriction, Magnetic Ceramics: Cubic Ferrites, Garnets, Hexagonal Ferrites.

4: Optical properties

Refractive index and dispersion, Molar refractivity, boundary reflectance and surface gloss, absorption and colors. Phosphors, Fiber optics/ optical wave guides.

5: Mechanical properties

Strength of Perfect Solids, An atomic view of Young's modulus and strengths of solids. Brittle fracture. Flaw Sensitivity. Energy Criteria for Fracture — the Griffith Criterion. Stress intensity factor, critical stress intensity factor/fracture toughness. Atomistic Aspects of Fracture; Effect of processing, grain Size, pores, inclusions, agglomerates and large grains, surface flaws and compressive surface stresses on strength of ceramics. Creep: primary, steady-state or secondary and tertiarycreep. Diffusion Creep, Viscous Creep and Dislocation Creep.

6: Thermal properties

Heat Capacity, Thermal conduction, phonon and photon Conductivity. Conductivity of multiphase ceramics, Thermal Expansion of crystal, glasses and composite bodies, Thermal Stresses, Thermal shock, Microcracking of Ceramics.

Science of Ceramic Materials

Crystal lattice, crystal class and crystal system. Some Real Structures: Rock Salt, Zinc Blende, Antifluorite, Rutile, Perovskite, Spinels, Wurtzite etc. Crystal imperfections: types and notations, Solid solutions, defects and dislocations. Vitreous state, glasses and structural models; Condensed phase rule and single component system: Silica, Zirconia and Carbon etc. Two component systems and Lever rule. Free energy-composition diagrams, phase stability, solid solutions, Eutectic and Eutectoid, Peritectic reaction, congruently and incongruentlymelting compound. Some important binary ceramic systems SiO_2-Al_2O_3, MgO-Al_2O_3, CaO-SiO_2, CaO-ZrO_2, MgO-SiO_2, BaO-TiO_2, CaO-Al_2O_3, CaO- MgO; Ternary System: Representation of composition on triangle, proof of the basis, Temperature, Solid models, Iso- thermal Sections, Base projection method. Ternary systems with binary and ternary Eutectic, Peritectic, congruently and incongruently melting compounds. Some important ternary ceramic systems: CaO-SiO_2-Al_2O_3, MgO-SiO_2-Al_2O_3, CaO-MgO-SiO_2. Brief idea on the application of real system binary, ternary and quaternary phase diagrams in the processing and process control of different ceramic materials.

Ceramic Phase Diagrams and Phase Transformations

- Phase rule, Phase equilibrium in a single component system, Clausius-Clapeyron equation, Phase equilibrium diagrams for Water, Silica, Zirconia (3).
  Two Component systems: Cooling behaviour and phase compositions for important ceramic systems such as SiO2-Al2O3, MgO-Al2O3, CaO-SiO2, CaO-Al2O3, CaO-MgO etc.(5) The relevance of above phase diagrams in the ceramic system. Use of phase diagram in the sintering of ceramics; multiphase system containing a liquid phase, tungsten-carbide-cobalt system, porcelain, silicon nitride. Crystal growing techniques and use of phase diagrams in crystal growth; growth from stoichiometric melts, impurity distribution coefficient, constitutional supercooling and non-stoichiometric melts, single crystal growing of Yttrium-iron-garnet, cubic barium-titanate, gallium-phosphide, quartz crystal from hydrothermal solution; Phase diagrams in the development and use of refractories; Alumino- silicates, Silica and basic refractories, Fusion cast refractories. Liquid immiscibility in oxide systems. Study of dissolution of refractories in molten slag; Application of the phase diagrams in cement chemistry; calcium-alluminate cement and Portland cement
- Phase diagrams in glass making, iron-carbon system, in the stabilization of zirconia phases. Phase diagrams in high pressure systems, recent developments in this area
- Ternary System: Representation of composition on triangle, Liquidus projection, Isoplethal analysis,Iso- thermal Sections, Crystallization Paths. Model ternary system with binary and ternary solid solutions, Eutectic, Peritectic, Congruently and Incongruently melting compounds. Cooling behaviour and phase compositions in important ternary systems such as CaO-SiO2-Na2O, MgO-SiO2-Al2O3, SiO2-FeO- Fe2O3,CaO-MgO-SiO2(12).
- Phase Transformation:Review of Thermodynamics, Gibbs free energy-composition diagrams, stability criteria, metastability. Diffusion in solids, role of defects, Interfaces.Theory of nucleation. Solidification: Eutectic, Peritectic. Diffusional transformations in Solid: Eutectoid,Peritectoid, Precipitation, Ordering. Diffusionless Transformations: Martensitic Transformation.Spinodal decomposition, Glass Transition (15)
- The application of phase diagrams in refractories& glass industries (4).

Techniques for Materials Characterization

I: Powder Characterization

Characteristics of powders; shape, size and its distribution. Methods of determination of particle size and its distribution; Sieve analysis, optical scattering methods. Measurement of surface area and porosity of powderedand sintered material. Packing density.

II: Thermo- chemical Analysis

Principles of Differential thermal analysis (DTA), Thermogravimetric analysis (TGA) and Differential scanningcalorimetry (DSC) and their applications in processing and Characterization of ceramics, glasses and glass Ceramics. Construction and operation of simultaneous DTA/TGA and DSC equipment.

III: X – Ray Diffraction

Characteristics X – rays, Fundamental principles of X-ray diffraction (XRD); Brag's Law, Determination ofCrystal Structure and particle size from XRD, Atomic Scattering and geometrical structure factors and their application in intensity calculation. Construction of working of X – ray diffractometer.

IV: Spectroscopy

Basic laws of spectrophotometry and its application in elemental analysis in UV/ Visible range, Construction and working principle of spectrophotometer. Additive rule of absorbance in multiple analysis of materials.

General aspects of IR spectroscopy and its application in structural analysis of ceramic systems. Optical systems and operation of FTIR spectrophotometers. Samples preparation methods for spectrophotometry andIR spectroscopy.

V: Optical Microscopy

Construction and operation of optical microscope; Characteristics of microstructure; Quantitative microstructure and phase analysis: Study of the morphology, size and aggregation of ceramic materials.

VI: Electron Microscopy

Principle of electron microscopy: electrostatic and magnetic lens systems; Generation of electron beam (Electron gun); Interaction of electron beam with material. Construction and operation of Transmission Electron Microscope and Scanning, Electron Microscope. Electron diffraction by crystalline solids; selected area diffraction. Mechanism of image formation in SEM and its processing. Electron microprobe analysis (EDAX and WDS). Preparation of ceramic samples for TEM and SEM electron microscopic studies.

Glass Ceramics

Fundamentals of Glass Formation: Structural and Kinetic Approaches. Nucleation and crystal growth. TTT diagram. Glassy State; Kinetic and thermodynamic criteria for glass formation, use of Na_2O-SiO_2 and Na_2O-CaO- SiO_2 phase diagrams in glass manufacture, types of glasses and their chemical compositions, Physical properties of glasses, density, refractive index and dispersion, design of lenses, thermal expansion and thermal stresses, thermal endurance of glass, toughening of glasses, strength and fracture behavior of glass and its articles, surface tension, viscosity and its measurement, effect of temperature and composition on the physical propertiesof glasses. Fabrication and properties of Glass ceramics. Crystallization of glass: Homogeneous and heterogeneous nucleation, Growth. Binary (Mullite) and ternary (Mullite, Hexacelsian, Celsian-Rutile) glass ceramics. Phase separation. Control of mechanical, thermomechanical, electrical, optical properties through microstructure development in glass ceramics. Nanocrystalline microstructure. Surface strengthening– thermal strengthening and chemical strengthening of glass ceramics. Technical application of glass ceramics: Structure, composition and properties of glass ceramic used in Radom, Photosensitive materials, Machinable glass ceramics, Magnetic Memory Disk. Household application of glass ceramics : Decorative glass ceramics, High – Quartz and Keatite- type alumino- silicates, composition of ceramic colours glass ceramic cook top panels. Precision Optical applications: low thermal expansion glass ceramics, large casting technology, dimensional stability, transparent glass ceramic, thin walled cylinders, reflective optics, laser gyroscopes, light weight mirrors, Radiation stability technology, Refractory glass ceramics, Glass ceramics in biomedical application. Absorption and colours in glasses; role of transition metal ions in glass, sulphur and selenium in glass,oxidation-reduction equilibria in glass, , effect of temperature, composition and partial pressure of oxygen on redox equilibria in glass, application of redox reactions in glass industry for coloration, decolorization and refining of glasses. Oxygen ion activity in glasses. Chemical durability of glasses; mechanism of reactions of solutions with glass surfaces, factors affecting the chemical durability, measurements of chemical durability of glass. Glass ceramics; Nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics.

Glass Engineering

Glass making raw materials, criteria for selection of raw materials, concept of batch house operations, glass melting and homogenization, addition of cullet to the batch, reactions amongst the constituents of glass, thermal currents and flow pattern in the glass tank furnace, electrical boosting and bubbling of glasses, Defects in glass, bubbles and seeds, cords, stresses and colour inhomogeneity and their remedies, annealing of glasses.

Manufacture of glasses: Glass forming machines, Manufacture of glass bottles, rods, tubes, bulbs and bangles, glass blocks and laboratory glass wares, sheet, plate and rolled glass, toughened safety glass, laminated safety glass, glass fiber and wool, foam glass, optical and ophthalmic glasses by blowing and / or pressing process with semi-automatic and fully automatic machines, preparation of photosensitive and photochromic glasses.Glass ceramics; Nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics

Glass Technology and Application

Non conventional processing of glasses; Sol-Gel method, Chemical vapor deposition method. Acid-base concept in glass. Technology of making radiation shielding glasses, Heat absorbing glasses, Solder glasses, Chalcogenideand Halide glasses and their applications. Low durability glasses for agricultural purpose.Glass for optical fibre communication, TV picture tube, Glass filters. Fixation of nuclear wastes in glass, LASER glasses and their use, Solarized glasses.Dossimeter glass, Fiber reinforced glass, Smart glass,Zero expansion glass-ceramics, Vycor glass glass screen for solar photovoltaic cell, Application ofglass in solid fuel cell. Photochemical reactions in glasses; colloidal colors in glass, solarised glass.

Drawing of Refractory Lining & Joints

Study and drawing of different refractory bricks of standard shape; Study and drawing of non-standard shapes of refractory bricks; Drawing of brick wall and brick joints; Drawing of different parts of rotary kiln; Drawing of converter; Drawing of ladle; Drawing of Blast Furnace Trough Lining; Drawing of slide plates refractories; Drawing of sub entry nozzle; Drawing of monoblock stopper; Chimney calculation and drawing of chimney.

Ceramic Workshop

Sieve analysis and particle size distribution of milled product; Verification of Rittinger's Crushing Law and determination of crushing efficiency of a Jaw Crusher; Validation of Bond's Law and determination of crushing efficiency of a Roller Crusher; Determination of angle of nip and maximum feed size for a Roll Crusher; Determination of critical speed and crushing rate of a Ball Mill; Study of Filter Press and preparation of filter cake; Determination of filtration rate of ceramic slurry; Study and operation of de-airing Pug Mill and preparation of extruded body; Operation of Counter Current Mixer and determination of mix consistency; Study and operation of Hydraulic Press and determination of bulk density.

Refractories

Introduction to refractories, selection of refractory raw materials (natural, synthetic, additives, binders) for specific products, manufacturing equipment for different production. (particle size, batch preparation, mixing, fabrication, drying, and firing)

Classification of refractories, properties of refractories, packing of solid particles – monosized particles, bimodal mixtures of spheres, bimodal mixture of non-spherical particles, ternary and multiple mixtures, continuous particle size distribution, particle interaction during dry compaction; Shaped Refractories: Alumino-silicate, high alumina, magnesia, silica, doloma, carbonaceous, Refractories; raw materials, processing, process quality control, Detailed analysis of phase diagrams with respect to the raw materials controlling the firing temperature and schedule; properties, microstructure applications; Composite refractories: alumina-carbon, magnesia-carbon, Spinel, alumina- silicon carbide- carbon, zirconia-carbon; Unshaped refractories; castables, gunning mass, ramming mixes, shotcreting mass, compositions/classifications, additives, manufacturing process, quality control, properties and applications; Properties and tests: Specification of different kinds of bricks, fusion point in relation to equilibrium diagram, PCE Test, HMOR, torsional creep properties and tests, Re-heat shrinkage, Spalling resistance, slag resistance; Reaction between refractories and glasses, heat transmission, behaviour of refractories in different environments, corrosion and failure of

refractories, detailed analysis and interpretation of the refractories behavior with respect of microstructure.

Properties and their measurement: High temper measurement ,PCE, HMOR, RUL , Physical properties:(porosity, bulk density, permeability, water absorption, specific gravity),Chemical properties: wet chemical analysis, x-ray fluorescence, evolution of hydration resistance, Mechanical properties: compressive strength, bending strength, tensile strength, creep behaviour, elastic modulus, fracture toughness, abrasion resistance, Thermal properties: Thermal expansion, PLCR, thermal conductivity, thermal expansion and spalling,

Advanced Refractories

Monolithic refractories (castables, plastic and ramming mixes, gunning mixes, refractory mortar) ceramic fibers, advantage of monolithic refractories over shaped refractories, insulating refractories of different kinds

,their manufacturing and properties. Microstructural study and its importance to charecterize refractory product observation of refractories,

Carbon containing refractories(Magnesia-C ,Dolomite-C), Al_2O_3-C for steel refining:(Al_2O_3-SiC-C and Al_2O_3- MgO-C), Al_2O_3-C for steel Casting: (slide gate, sliding nozzle, sliding valve plate), ladle shroud, submerged entry nozzles., Reaction of refractories by slags, flue gases glasses ,CO, acid, alkali, corrosion of regenerator refractories by flue gases .

Applications of refractories in blast furnace, LD converter, coke oven, hot metal mixer ,basic oxygen furnace, electric arc furnace, ladles, continuous casting , refractory application in copper, aluminium, cement ,rotary kiln, glass industries, pottery, petrochemical ,fertilizer industries ,boiler plant.

Advanced Ceramics

1 Electro-Ceramics

Ceramic Capacitors: Ferroelectric ceramic materials; Relaxor ferroelectrics; Basic Ceramic Dielectric formulation for capacitors; Grain Boundary Barrier Layer Capacitors, Multi-layer Capacitors; PerformanceCategories of Ceramic Capacitors

Piezoelectric and Electro-optic ceramics: Piezoelectric constants; Hysteresis, Poling and equivalent circuit for piezoelectric ceramics; Electro optic effect; linear, quadratic and memory electro-optic devices; Piezoelectric material systems, their processing and applications.

Ceramic Magnets: Soft and hard ferrites. Ni-Zn ferrites, Mn-Zn ferrites, Garnets and Hexagonal Ferrites. Processing and manufacture of ferrites. Effect of composition, processing and microstructure on the magneticproperties. Applications of magnetic ceramics.

Ceramics of Green Energy-Solid oxide fuel cells (SOFC) Cells and Batteries: Solid electrolytes based on stabilized zirconia, Co-doped ceria, silver halides and β-alumina. Cathode, Anode and Interconnect materials.

II Engineering Ceramics

Fracture behavior of ceramic materials, The Weibull distribution, Weibull parameters, Sub-critical, and stable crack propagation. R-curve behavior. Toughening mechanism. Toughening by transformation. Mechanical behavior of aluminum oxide, silicon carbide, silicon nitride, zirconia and zirconia toughened materials and theirengineering applications.

III Bio-Ceramics

Definition and scope of bio-materials. Classification of bio-ceramic materials. Alumina and zirconia in surgical implants and their coatings. Bioactive glasses and glass ceramics with their clinical applications. Synthesis andcharacteristics of dense and porous hydroxyapatite and calcium phosphate ceramics. Resorbable bioceramics.

Characterization of bio-ceramics.

Process Ceramics & Process calculation

Significance of different ceramic processing operations. Powder synthesis, Colloidal and sol-gel processing. Preparation of bodies: Blending of different weight fractions and size ratios, use of binders, types of binders Plasticizers, Foaming and antifoaming agents, granulation and spray drying. Dry pressing, Semi-dry pressing, Slip casting, Extrusion, Non-traditional shape forming: Gel casting, Tape

casting, Freeze Casting, Injection moulding, Electro-phoretic deposition, Iso-static pressing. Basic concept of drying, drying mechanisms in particulate systems, drier operations, controls, drying defects.

Fundamental of material and energy balance for ceramic industry. Non-reactive, reactive and transient processes. Concepts of limiting and excess reactivates, recycles, by pass energy balances. Material and energy balances for ceramic materials and processing. Ceramic body calculation. Batch calculation of glass and enamel, calculation of different physical properties such as density, refractive index, thermal expansion coefficient, thermal conductivity etc. of different ceramic products.

Ceramic Whitewares

Classification, properties and application areas of different whiteware bodies. Plasticity, workability and. rheology of clay - water system. Mechanism of plasticity, additives/binders, plasticizers, flocculants and deflocculants and slip properties Shape forming of whiteware bodies-plastic forming, casting - pressure casting, casting defects. Tri-axial bodies - porcelain, insulator, tiles, sanitary ware etc. Fundamentals of drying and shrinkage. Firing of whiteware bodies, microstructure evolution during firing of whiteware bodies. Time, temperature and atmosphere effects on firing of whitewares, special firing techniques, Tiles – classification processing and firing- monoporosa and birapida tiles.

Raw materials: Physical, chemical, electrical and thermal properties of main raw materials for whiteware industries such as Clays, quartz, feldspar, nepheline syenite, whiting, talc, pyrophyllite, wollastonite, sillimanite, bone-ash and zircon.

(i) Ceramic Bodies: Detailed studies of earthenwares, stonewares, porcelain, vitreous china, cordierite, steatite and cermet bodies including their body preparation, body composition and batch calculations.

(ii) Fabrication methods: Details of fabrication methods used to manufacture whitewares such as floor and walltiles, table wares, sanitary wares, art wares, dental porcelains, bone china, electrical porcelains, chemical stone wares, chemical porcelains, refractory porcelains, cordierite ceramics and other new ceramic products.

(iii) Glazing and Decoration: Body-glaze relationship, types of glaze, glaze materials, colouring ingredients, decorating methods, compounding of glazes. Processing and application of glaze, firing properties and defects of glazes

Physical Ceramics

Mechanical Properties: Concept of strength and its relation with fundamental parameters, plastic deformation, viscous flow, creep, Fracture of materials: Thermal Properties: Thermal expansion, thermal shock, annealing and chemical strengthening, specific heat and heat capacity, thermal conduction process; Electrical Properties: Electrical, electronic and ionic conduction phenomena in crystals, Fast ionic conductors, glasses and non-stoichiometric componds.PTCR, NTCR, Varistors, thermisters etc; Dielectric Properties: Dielectric loss of crystals and glasses, in solids, Structure and magnetic properties, of spinel ferrites, rare-earth garnets, ortho-ferrites and hexagonal ferrites with special reference to their microstructure; Optical Properties: Refractive index and dispersion reflectance, opacity and translucency, absorption and colour form modern concepts in crystalline and vitreous ceramic systems.

Microstructural Design in Ceramics

Characteristic of microstructure; Quantitative analysis; Properties and factors affected by microstructure; microstructural aspects of sintering and grain growth, microstructure variable; Mechanical, thermal optical properties and the effect of microstructure; high temperature degradation; Wear behavior; Techniques for characterizing ceramic microstructure. Resolution and its implication for routine microcopy, Optical microscopy scanning electron microscopy, stereoscopy and stereology. Preparation of ceramic samples for microscopy. Fine powders and granulates; microstructural characterization of green bodies-sample preparation ofr SEM and TEM study; Dense fired ceramics, porous ceramics, microstructural maps of sintered body, polished surface and fractured surface microstructure, common pore structure in ceramic bodies, pore morphology and properties, quantitative

estimation of different phases and grain size; study and interpretation of wetting behavior, grain boundary film, TEM; microstructure of different types sintered ceramics bodies. Triaxial whitewere bodies, refractories, clay products, glass, lazed and enamels, glass ceramics, advanced and special ceramics.

Science of Sintering

Diffusion: Mechanism of diffusion in solids, Ficks Laws, Nernst-Einstein equation, Random walk model, diffusion as a thermally activated process, thin film and error function solutions, diffusion distance, diffusion in ceramics, temperatures and imperfection related effects; Sintering: Driving force for sintering, solid state and liquid phase sintering, sintering models- mechanisms and kinetics. Grain growth and secondary recrystallization; Phase Transformation: Nucleation and Growth, spinodal decomposition; mechanism, thermodynamics and kinetics. Glass formation; Creep and Superplasticity: mechanisms andkinetics; Kinetics of Heterogeneous Reactions: Reactions with and between solids, calcination and dehydration reactions, particulateinteractions, coarsening, nonisothermal process kinetics.

Computational Materials Science

Description of atomic interactions; Basics of the density functional theory, approximations in terms of pair potentials; embedded atom method and tight-binding. Material behavior and computational model in nano-, micro-, meso- and macro-scales in the content of real materials-related problems (mechanical and thermodynamic properties, Phase transformation microstructure evolution during processing; Linear Elasticity Theory for Crystal Plasticity, Dislocation Statics and dynamics, Finite Element and Difference Methods at the Meso—Macroscale, Polycrystal Elasticity and Plasticity Models; introduction to computational modeling; molecular statistics; Molecular Dynamics: models of interatomic potentials, Equations of Motion for Atomic Systems: Application of Molecular Dynamics in Materials Science: Simulation of Brittle Fracture, Simulation of Interaction of Dislocations with Grain Boundaries; Monte Carlo Simulation and Integration and lattice dynamics, Interpretation of modeling in terms of structures using radial distribution function, Fundamentals of the Algorithm, Spin Monte Carlo methods, Thermo dynamic and statistical analyses, Simulation of Surface Segregation, Phase Transition, Thin Film Deposition.

Nano Technology

- Evolution of science and technology, Introductionto Nanotechnology, Nanotechnology–Definition–Difference between Nanoscience and Nanotechnology, Feynman predictions on Nanotechnology, Moores law, Role ofBottom up and top down approaches in nanotechnology, challenges inNanotechnology (2).
- Nanotechnology Timeline and Milestones, Overview of different nanomaterials available, Potential uses ofnanomaterials in electronics, robotics, computers, sensors in textiles, sports equipment, mobile electronic devices, vehicles and transportation. Medical applications of Nanomaterials (2).
- Synthesis and processing of nano powders: Processes for producing ultrafine powders – mechanical milling, wet chemical synthesis, gas condensation process, chemical vapour condensation, laser ablation.Design and Synthesis of self assembled nano structured materials (4).
- Improvements in solar energy conversion and storage; better energy-efficient lighting; stronger and lighter materials that will improve energy transportation efficiency; Energy Storage: Fuel Cells, Carbon Nanotubes for energy storage, Hydrogen Storage in Carbon Nanotubes, Use of nanoscale catalysts to save energy and increase the productivity in industry, Rechargeable batteries based on Nanomaterials, Nanoscale optical, liquid crystal and magnetic devices, Spintronic devices including spin valves and MRAM devices, nanoscale semiconductor electronic devices (6).

- Recent past, the present and its challenges, Future, Overview of basic Nanoelectronics. Introduction to micro, nano fabrication: Optical lithography, Electron beam lithography, Atomic lithography, Molecular beam epitaxy, MEMS:- Introduction, Principles, Types of MEMS:- Mechanical, Thermal, Magnetic MEMS; Fabrication of MEMS. Synthesis of Nanowires, Nonosheets, Nanoribbons, Nanobelts, etc (5).
- Detail applications of nanoparticles in following areas : X-ray lithography, carbon nanotubes, microspeakers, tiny hearing aids, laptop computer seals, DWDM filter, Optical fibres, photon Detectors, Superconductive wires etc (5).
- Environmental nanotechnology- An introduction, Nanotechnology for Reduced waste and improved energy efficiency. Waste remediation: Nanoporous polymers and their applications in water purification, Societal concerns & Ethical issues in Nanoscience and Nanotechnology, Problems and possible solutions (6).

Introduction to Thin Films, History, Types of Thin Films, Basic Concepts of deposition, Methods of deposition/ Methods of Preparation of Thin Films: CVD, Langmuir Blodgett Film deposition system, Spin coating, Dip coating, RF plasma, Electron Beam, Sputtering, Vacuum Deposition (Thermal Evaporation)system etc, Magnetic Thin Films, Applications of Thin Films (6).

Fuels, Furnaces and Pyrometry

Composition, classification and characterization of industrial fuels; wood, charcoals, coal and its qualities, petroleum, oil and natural gas, LPG, producer gas, water gas and carbureted-water gas, characteristics of coal, coal washing and blending, carbonization of coal, manufacture of coke and recovery by products, pulverized coal, chemistry of combustion, types of combustion, combustion of solids, liquid and gaseous fuels, fuels flame characteristics, fluidized bed combustion. coal constituents and related numerical problem solving. Caking properties: caking index, free swelling index. Storage of coal and spontaneous ignition.

Classification, design and description of different types of furnaces used in ceramic and metallurgical industries as down-draft kiln, tunnel kiln, chamber furnace, glass tank furnace, rotary kiln, blast furnace, open-hearth furnace,bessemer-converter, coke-oven batteries, Heat saving devices i.e. regenerators, recuperators. General idea of temperature measuring devices i.e. thermocouple, radiation and optical pyrometer. Combustion calculation. Numerical problem. Overview about different furnaces used in steel plants.

Interface Science & Sol-Gel Processing

Thermodynamics of surface. Adsorption Isotherm. Physical aspects of interfaces, Grain boundary, Contact angle, Dihedral angle and Grain shape prediction, Concept of wetting. Structure of surface and interface; Colloids, Sols and gels, Types of colloids; attractive surface forces, stabilization of colloids, Electrostatic stabilization, charge development on the particle surface in aqueous medium, origin of electrical double layer, Iso-electric points and zeta potential,, Effect of electrolytes on double layer. Ion exchange capacity and exchange equilibrium, adsorption of polymers and steric stabilization, electrosteric stabilization, structure of consolidated colloids, rheology of consolidated colloids, Flocculation and de-flocculation phenomena, kinetics of flocculation; Wetting agents, Plasticizers, Foaming and antifoaming agents, Lubricants; Types of gel, sol-gel processing of aqueous silicates, metal alkoxides, hydrolysis and condensation, effect of pH on gelation, aging, drying and gel densification. Sol- gel preparation technique, single and multi-component gel, use of double alkoxides, applications of sol-gel processing

Plant, Equipment and Furnace Design

Section A: Plant & Equipment Design:

Plant Design: Plant location, plant layout, assembling of economic and engineering data, calculations pertaining to the processes, process vessels, etc. piping and instrument flow diagrams, process flow diagrams, design of a ceramic plant, feasibility report and cost estimation of the plant. Economics of the plant, commercial aspects etc. Equipment Design: Principles of design of the following

process equipments: Crushers, materials handling systems, filter press, sieves and pug-mills, moulding equipments. Principles of design of glass moulds such as blank mould, blow mould and neckring moulds. Drying and different types of driers used in Ceramic industries. Principles of design of simple supports, i.e. footings and foundations for process equipments such as overhead tanks, motors, compressors and crushers. Different types of size-radiation equipment used in ceramic industry
i.e. crushers and grinders including their design calculations. Section B: Furnace Design:
Detailed study of common types of furnaces i.e. glass melting furnaces, tunnel kiln, chamber kiln and down- draft kiln, shuttle-kiln, roller-hearth kiln, rotary cement kiln and annealing lehrs. Blast furnace, open hearth furnace and converters for steel melting, Natural and forced draft stack, stack calculations. Chimney foundations. Essential operations of a furnace i.e. firing, charging, melting, reversal. Preheating of air, gas and fuel oil, flame systems, temperature and its control. Thermal current in a glass melting furnace. Furnace atmosphere. Furnace life and selection of refractories. Heating up and cooling down of a furnace, furnace construction, furnace capacity, fuel efficiency and firing efficiency, design, construction and thermal calculation pertaining to at least one of the above mentioned furnace.

Sensor Technology

Overview, definition and classifications of sensors, principles of ceramic sensors, physical-chemical and technological principles of ceramic sensors: basic concepts, technological principles, operating principles of porous ceramic sensors. Ceramic humidity sensor: classification, basic parameters and characteristics, testing and stabilization of humidity sensor, control of the sensitivity of ceramic humidity sensors. Ceramic gas sensor: classification, parameters and characteristics of resistive gas sensor, selectivity and sensitivity of gas sensor, operating principles, reducing gas sensor, alcohol sensor, odor and product quality sensor, oxygen sensor, ceramic sensor for other gases, manufacturing of gas sensor. Ceramic temperature sensor: NTC thermistors, PTC thermistors, CTR thermistors, capacitive ceramic temperature sensors. Ceramic pressure sensors. Multifunctional ceramic sensors; Humidity-gas and Temperature- humidity ceramic sensors, Temperature-Humidity-Gas ceramic sensors. Application of ceramic sensors Flow Sensor, Acoustic Sensor, Magnetic field sensor; Chemical Sensor; Biosensors: Origin of biosensor, transduction mechanism of biosensor, application range of biosensor and future prospects; Sensor Instrumentation; MEMS based sensor, Nanotechnology in Sensor applications, recent developments in this area.

Steel Plant Refractories

- History of steel making, from bessemer steel making to present day equipments and practices, integratedand mini steel plants in India, a present scenario (4).
- Introduction to steel making and type of furnaces used at different stages, blast furnace, coke oven, requirements for refractory raw materials for steel production-modern trends (4).
- BOF/converter practice, equipment, operation and process, thermodynamic and kinetics of refining reactions, oxygen lance: design, construction and operation, top and bottom blown processes, its advantages and disadvantages, details of electric arc furnaces, its variations, sequence of EAF operations (5).
- Secondary steel making processes, ladle furnaces (L.F.), vacuum systems and vacuum treatment of steel, gases in steel, LF-VD processes and AOD, VOD, VAD techniques, influence of inclusions on mechanical properties of steel (4).
- Ladle shroud, rinsing, slide plates, tundish, monoblock tundish stopper, submerged entry nozzle, casting, ingot casting: types of moulds, advantages and disadvantages (7).
- Identification of different refractory linings for primary and secondary steel making operations.
    - Magnesite base refractories, dolomite, high alumina, composites, composites lining.
    - Use of non-oxide ceramic materials in metallurgy (6).
- Non shaped refractories – classification, castables of different types, high cement and low cement castables, no cement castables. Alumina spinel castables, repeated repair involving guniting.
    - Standardization, testing – including non – destructive testing.
    - Future trends in utilization of refractories towards efficient lining for steel making (6).

Advanced Electro Ceramics

1 Conducting Ceramics
Broad band and narrow band conduction, Mott's transition. Effect of partial pressure of oxygen and dopingin oxide conductors. Grain boundary effects on electrical conduction.Grain Boundary Barrier Layer Capacitors, Ceramic superconductors.
2 Ceramic Magnets
Ni-Zn ferrites, Mn-Zn ferrites, Garnets and Hexagonal Ferrites. Processing and manufacture of ferrites. Effect of composition, processing and microstructure on the magnetic properties. Applications of magneticceramics.

3 Sensors and Actuators
Types of sensors and actuators, Thermal NTC and PTC sensors, electrochemical sensors, gas and humidity sensors, piezoelectric and electro-optic sensors and actuators. Thermoelectric effect in ceramic systems, Magnetoresistance, Colossal Magnetoresistance (CMR)
4 Varisters and their Applications
VaristorCharacteristics, ZnOVaristor materials systems, their processing, microstructure and applications.Varistor models.
5 Thick film and Multilayer Ceramics
Formulation of conductive, resistive and dielectric inks. Screen printing and firing of hybride devices.Fabrications of multilayer devices and their applications.
6 Ceramics for Green Energy
Solid oxide fuel cells (SOFC) Cells:Solid electrolytesbased on stabilized zirconia, Co-doped ceria, Cathode,Anode and Interconnect materials. Batteries and solar cells.
7 Characterization Techniques for electroceramics

Bio-ceramics

Definition and scope of bio-materials.Structure-property relationship of biological materials, structure of proteins, polysaccharides, structure-property relationship of hard tissues cell, bone, teeth and connective tissues.
Structure, properties and functional behaviour of bio-materials.Tissues response to implants (bio-compatibility, wound healing process), body response to implants, blood compatibility.Classification of bio-ceramic materials for medical applications. Alumina and zirconia in surgical implants, bioactive glasses and their clinical applications, A.W. machinable and phosphate glass ceramics. Dense and porous hydroxyl apatite calcium phosphate ceramics, coatings and resorbable ceramics. Carbon as an implant.CMC and PMC composites.Characterization of bio-ceramics.Regulation of medical devices.Cell culture of bio ceramics, network connectivity and hemolysis. Preparation of bio ceramics and characterization of bioactivity.

Biomaterials for Artificial Implants

Bio-compatability-definition and issues, introduction to biological environments, function and degradation of materials in vivo- swelling and leaching, corrosion and dissolution, reactions of biological molecules with bio-material surfaces, mechanics of materials- deformation and failure, friction and wear. Biological effects of implants- inflammatory process, adaptation, allergic foreign-body response; Surface chemistry of materials- surface energy, contact angle, critical surface tension, electrokinetic theory; Biomaterials, types- metals, polymers- hydrogels, polymer degradation, resorbable polymers, sutures, drug delivery, dialysis membranes. Ceramics, - dense ceramics, porous ceramics, bio- active ceramics, resorable ceramics, composites - structure and properties; processing of bio-materials. Coated Hydroxyapatite – need for coating, type of coating – Plasma sprayed coating, bio-mimetic coating. Characterization of biomaterials; in-vitro and in-vivo testing, Polymeric biomaterials – naturally occurring polymeric biomaterials, synthetic non bio-degradable and bio degradable polymers, polymer matrix composite biomaterials; Application of bio-materials- dental implants, orthopaedic implants, soft tissue application, Tissue engineering-biomaterials for tissue engineering, recent developments in this area.

Non-oxide & Structural Ceramics

- Development, importance and scope of non-oxide ceramics, preparation of silicon carbide, processing and sintering of silicon carbide and sinterable silicon carbide with reference to pressure sintering and pressureless sintering . Polytypism in silicon carbide, application. Synthesis of silicon nitride: Effect of precursors and processing routes, sintering and effect ofdifferent parameters, application (4).
- Sialon: Quaternary phase diagrams, processing, microstructure, properties and applications. Tungsten Carbide: Synthesis, liquid phase sintering, fused WC; microstructure, properties and application, plasma sintering (4).
- Boron Carbide, Boron Nitride, Carbon Nitride, Zirconium Boride, $MoSi_2$, Titanium di-boride, Aluminium Nitride, Tantalum Carbide, Niobium Carbide, Vanadium Carbide, Chromium Carbide, Carbon and Graphite (5).
- Abrasives, abrasive operations, natural abrasives, abrasives like aluminium oxides, silicon carbide, diamond and boron nitride, miscellaneous synthetic abrasives, raw materials for abrasives, theirproportioning, processing, manufacture of abrasives, grinding wheels, their drying, firing and testing. The use of abrasives and grinding wheels in grinding. Evaluation of abrasives products. Looseabrasives operations. The chemistry of grinding (10).
- Definition, classification, importance and industrial scenario in India and abroad. Brief review of Griffith theory of fracture, toughness, statistical nature of strength. Alumina Ceramics: Crystal structure, phases, types of alumina, properties and its relation to microstructure, importance and application (3).
- Zirconia Ceramics: Crystal structure and polymorphic modifications, Transformation Toughening; effect of microstructure, different system in zirconia, application (5).
- Composites: Definition, classification, importance, strengthening and toughening mechanisms, stress- strain curve, fabrication, densification. Composites of some oxides and nonoxides (5).

Cement and Concrete

Cement raw materials and their classification, selection of raw materials. Crushing of lime stone.Proportioning of raw materials, grinding of raw materials and preparation of raw meal, blending & beneficiations of raw materials. Introduction to hydraulic materials. Classification of Cement, Chemistry of hydrated and anhydrous cement compound. Manufacturing of Portland cement; Dry, Semi-dry, wet and semi-wet process

Burning of raw mix, reactions occurring in cement making at different temperature, clinkering reactions. Pre heater and firing system in cement industry, Kiln residence time, working of rotary kiln and clinker coolers, heat recovery devices and waste heat utilization. Cement grinding mills. Dust and dust collection in cement industries.

Different types of cement. OPC, blast furnace slag cement, high alumina cement, oil well cement, theirconstitution and hydration product.

Hydration of anhydrous cement and cement compounds. Formation of C-S-H and generation of skelton of artificial cement stone. Phase equilibria in cement hydration. Effect of alkalis, fluorides and other minor constituents on the hydration of cement, role of free magnesia and free lime in cement, various theories of cement hydration and modern views, structure of hydrated cement phases and gels.

Testing of cement.Action of acid, alkali and sulphate water on cement phases.

Additives and their classification- accelerators retarders, workability aids, water proofers, pigments and colorants, air-entraining agent, surface active agents and cement base protective coating, plain and fiberreinforce concrete, different types of fibers, glass fiber, steel fiber, polymer.

Ceramic Coating & High Temperature Ceramic Processes

- Diffusion: Mechanism of diffusion in solids, Ficks Laws, Nernst-Einstein equation, Random walk model, diffusion as a thermally activated process, thin film and error function solutions, diffusion distance, diffusion in ceramics, temperatures and imperfection related effects (6).
- Grain growth and secondary recrystallization. Phase Transformation: Nucleation and Growth, spinodal decomposition; mechanism, thermodynamics and kinetics. Glass formation. Creep and Superplasticity : mechanisms and kinetics (6).
- High Temperature degradation process, mechanism and kinetics of high temperature degradation, pesturing, oxidation, particulate interactions, coarsening, nonisothermal processes (8)
- ENAMEL : Introduction : Position of the industry of enamels in India. Raw materials : Enamels and ceramic coatings, major and minor ingredients, properties of enamel glasses. Metal bases and non-metal bases. Pretreatment of metal and Non-metal surfaces : Cast iron, sheet iron and steel, de-enamelling, aluminium alloys, base metal and high temperature alloys. Enamel Glass composition : Method of calculation, typical examples of composition. Frit making : Smelting furnaces, smelting, quenching, drying, milling and mill additions. Application and Firing : Control of Slips, application methods and equipments. Drying and brushing, decoration firing operation. Special firing methods. Properties and tests : Thermal properties, mechanical properties, optical properties, chemical properties. Defects : Their causes and remedies (9).
- Thermal Barrier Coatings Al_2O_3, ZrO_2 , TiO_2 , PSZ., Special powder preparation. Application Techniques :- Thermal spray, DC & RF Plasma, CVD, PVD, LASER ascalation, flame spraying, HVOF (8).
- Ceramics of high temperature applications (2)

Pollution Control in Ceramic Industries

Different kinds of industrial pollution and their origin and influence on human being.The emission from burning coal, pet coke, furnace oil and their analysis. The improvement of combustion processes to reduce the formation of Nox, Sox, Co. The fine particles released from the crushing and grinding of the ceramic raw materials. The equipment and methods to arrest the release of fine particulate materials and unwanted gases to atmosphere. Chemicals used indifferent ceramic industries e.g. Tiles, Potteries, Refractory, and Glass industries. Possibility of leaching of the chemicals to ground water and to rivers and lakes. Possible ways to stop the leaching of suitable chemicals. Different types of pollution created from the solid wastes in the ceramic industries and the possibility of recycling them. Sound and noise pollutions and their minimization techniques.

Industrial whitewares

Manufacturing Technology: Complete manufacturing with advanced techniques and automation in ceramic whiteware industries. Industries include floor and wall tiles, table wares, sanitary wares, art wares, dental porcelains, bone china,parian, electrical porcelains, chemical stone wares, chemical porcelains, refractory porcelains and etc. Other important industries included are insulator bodies like, low tension products, high voltage and high frequency insulators, low loss insulators,cordierite ceramics,steatite ceramics, honeycomb ceramics and other new ceramic materials.
Glazes: Details of glazes, their properties and uses: Lead, leadless, opaque, transparent, crystalline, matt and colored glazes.Decoration in glaze, under glaze and on glaze, computerized decoration. Fast firing of glaze decoration.Colouring ingredients, decorating methods, compounding of glazes. Firing properties and defects of glazes. Advances in whiteware industries:Instrumentation and automation in ceramic processing. Microstructure and its effects on the properties.Processing and application of glaze. Digital inks. Advances in industrial kilns and their installation.

Ceramic Composites

UNIT – 1 Introduction

Introduction to Ceramic matrix composites (CMCs), Fibers for CMCs, SiCf/SiC, SiC/Al2O3, WC/Al2O3 composites, Ternary MAX phases ($M_{n+1}AX_n$).

UNIT – 2Fabrication and processing

Fabrication and processing of CMCs; Slurry infiltration/High pressure sintering technique (SI-HPS), High temperature (HT) processing, Chemical vapor infiltration (CVI), Polymer impregnation and pyrolysis(PIP- process),Reactive melt infiltration(RMI - process).

UNIT – 3Microstructure and properties

Microstructure and properties (Physical, mechanical, thermal, etc.), wear and tribological properties, self- healing CMCs ; analysis of Interfaces and Interphases, [Role of Interfacial Domain in CMCs, Mechanism of deviation of transverse cracks and associated phenomena, Tailoring fiber/matrix interfaces, Influence on mechanical properties and behavior;Toughening and strengthening mechanisms in CMCs, Self- crack-healing behavior in ceramic matrix composites General concepts of CMC design, resulting properties, Weak interface composites (WIC), Weak matrix composites (WMC).

UNIT – 4Testing techniques

Testing techniques for CMC materials;Testing issues in CMCs, ASTM C28 CMC testing standards, Non- destructive testing techniques-Optical/haptic, Ultrasonic analysis, Thermography, X- Ray Analysis and X- Ray Computed Tomography.

UNIT – 4Applications

Applications of CMCs- CMCs for structural applications, CMCs for friction applications, CMC for metal cutting applications, CMCs for restorative dentistry, glass–ceramic composites for microelectronics, CMC for space and aeronautical applications; CMC for nuclear applications.