Department of Ceramic Engineering
Indian Institute of Technology
(Banaras Hindu University)
Varanasi-221005

Course Structure
of

4 YEARS BACHELOR OF TECHNOLOGY
IN
CERAMIC ENGINEERING

UG Course Structure for Ceramic Engineering (2018-2019)					
Cat.	**Deviation**	**Programme Components**	**CER**	**Recommended (IV Years)**	
				Min	Max
HU	0	Humanities and Social Science	22	22	22
IS	0	Science	69	62	84
IE	0	Institute Requirement Engineering/ Pharmacy	59	41	60
EP	0	Engineering Drawing (Manual and Computer Aided), Manufacturing Practices and Practice course of Department/ School	18	18	24
LM	0	Language and Management	18	18	24
DC/ MC	0	Department/Programme Core (Includes Stream Courses)	156	105	175
DE/ BE	0	Department/Programme Elective (Includes Stream Courses)	47	30	75
OE	0	Open Elective (Interdisciplinary Stream courses from Science/ Engineering/Pharmacy)	36	35	80
DP	0	Project/ Industrial visit/ Training	30	20	50
DT		Dissertation	0	0	0
		Total	**455**	**430**	**460**
		All Semester Total (Hons.)	**475**	**450**	**480**
L: Lecture Hours, T: Tutorials Hours, P: Practical Or Laboratory Hours, C: Credits					

Stream Electives in Ceramic Engineering						
Stream	**Stream Code**	**Stream Title**				
GGC	X1X	Glass & Glass Ceramics				
RE	X2X	Refractories				
ID	X3X	Electro-ceramics/Bio-ceramics/Engineering-ceramics (Inter Disciplinary)				
One course to be selected, for respective stream in corresponding semester, on recommendation of DUGC						
Stream - 1						
Glass & Glass Ceramics						
Pt. III(V Sem.)	MCR311	Glass and Glass Ceramic	3	0	2	11
Pt. III(VI Sem.)	MCR312	Glass Engineering	3	0	2	11
Pt. IV(VII Sem.)	MCR411	Glass Techology & Application	3	0	0	9
Pt.IV (VII Sem)	MCR 441	Bio-Ceramics*	3	0	0	9
Pt. IV (VIII Sem)	MCR 511	Advanced Glass Technology*	3	0	0	9
Stream-2						
Refractories						
Pt. III (V Sem.)	MCR321	Refractories	3	0	2	11
Pt. III (VI Sem.)	MCR322	Advance Refractory	3	0	2	11
Pt. IV (VII Sem.)	MCR421	Steel Plant Refractories	3	0	0	9
Pt. IV (VII Sem)	MCR 451	Non-Oxide & Structural Ceramics*	3	0	0	9
Pt. IV (VIII Sem)	MCR 403	Ceramic Coating & High Temperature Ceramic Processes*	3	0	0	9
Stream-3						
Advanced Ceramics (Inter Disciplinary)						
A. Bio Ceramics						
Pt. III (V Sem)	MCR331	Advanced Ceramics	3	0	2	11
Pt. III (VI Sem)	MCR 332	Nano Technology	3	0	2	11
Pt. IV (VII Sem)	MCR 441	Bio-Ceramics	3	0	0	9
Pt. IV (VII Sem)	MCR536	Materials for Bio medical Applications*	3	0	0	9
# Modified title Bio Ceramic, Glass and Glass Ceramic						
* Additional Optional Courses of the Stream						
B. Electro Ceramics						
Pt. III (V Sem)	MCR331	Advanced Ceramics	3	0	2	11
Pt. III (VI Sem)	MCR 332	Nano Technology	3	0	2	11
Pt. IV (VII Sem)	MCR 431	Advanced Electro-ceramics;	3	0	0	9
Pt. IV (VII Sem)	MCR532	Sensors and Actuators*	3	0	0	9
Pt. IV (VII Sem)	MCR533	Advanced Materials for Energy Devices*	3	0	0	9
Pt. IV (VII Sem)	MCR535	Advanced Thin-film Technologies*	3	0	0	9
Pt. IV (VIII Sem)	MCR531	Nano Electronics*	3	0	0	9
* Additional Optional Courses of the Stream						
C. Engineering Ceramics						
Pt. III (V Sem)	MCR331	Advanced Ceramics	3	0	2	11
Pt. III (VI Sem)	MCR 332	Nano Technology	3	0	2	11
Pt. IV (VII Sem)	MCR 451	Non-Oxide & Structural Ceramics	3	0	0	9
Pt. IV (VIII Sem)	MCR 403	Ceramic Coating & High Temperature Ceramic Processes*	3	0	0	9
Pt. IV (VIII Sem)	MCR434	Ceramic Composites*	3	0	0	9
* Additional Optional Courses of the Stream						

UG Course Structure for Ceramic Engineering (2018-2019)						
UG-CRC Code	**Course Code**	**Course Name**	**L–T–P**			**Credits**
Ceramic Engineering : 4-Year B.Tech. I-Semester						
IH.H101.14	H101	Universal Human Values - I: Self and Family	2	0	0	6
GY.PE101.14	PE101	Elementary Physical Education	0	1	3	5
GY.CP101.14	CP101	Creative Practices #	0	1	3	5
		Total	**2**	**2**	**6**	**16**
LM.HL101.14	HL101	Basic English*	2	0	1	7
		Total	**4**	**2**	**7**	**23**
#Creative Practices course to be announced by Dean Academic Office						
*Basic English course to be taken by student as recommended after Diagnostic Test						
Ceramic Engineering : 4-Year B.Tech. I-Semester						
IS.PHY102.14	PHY102	Physics - II: Introduction to Engineering Electromagnetics	3	1	2	13
IS.CY101.14	CY101	Chemistry - I	2	1	2	10
IS.MA102.14	MA102	Engineering Mathematics - II	3	1	0	11
IE.CSO101.14	CSO101	Computer Programming	3	1	2	13
EP.ME104.14	ME104	Engineering Drawing	1	0	3	6
EP.ME105.14	ME105	Manufacturing Practice - I	0	0	3	3
		Total	**12**	**4**	**12**	**56**
L: Lecture Hours, T: Tutorials Hours, P: Practical Or Laboratory Hours, C: Credits						
Ceramic Engineering : 4-Year B.Tech. II-Semester						
IS.PHY101.14	PHY101	Physics - I: Classical, Quantum & Relativistic Mechanics	3	1	2	13
IS.MA101.14	MA101	Engineering Mathematics – I	3	1	0	11
IE.ME103.14	ME103	Engineering Thermodynamics	3	1	0	11
DC.MCR101.14	MCR101	Introduction to Ceramics	2	0	0	6
EP.MCR102.14	MCR102	Basic Ceramic Practices	1	0	3	6
EP.ME106.14	ME106	Manufacturing Practice - II	0	0	3	3
IH.H103.14	H103	Development of Societies #	2	1	0	8
IH.H104.14	H104	History and Civilization #				
		Total	**14**	**4**	**8**	**58**
# The students have to choose one course from H103 & H104.						
Ceramic Engineering : 4-Year B.Tech. III-Semester						
IE.MO201.14	MO201	Materials Science	3	1	0	11
DC.MCR201.15	MCR201	Ceramic Raw Materials	3	0	2	11
DC.MCR202.15	MCR202	Thermodynamics and Phase Equilibria in Ceramic Systems	3	0	0	9
DC.MCR203.15	MCR203	Particle Mechanics and Fluid Flow Process	3	0	2	11
DC.MCR292.19	MCR292	Minerology and Microscopy Lab	0	0	2	2
IH.H105.15	H105	Philosophy #	2	1	0	8
IH.H106.15	H106	Education and Self #				
		Total	**14**	**2**	**6**	**52**
# Students have to choose one course from H105 and H106 and will study in III semester.						
Ceramic Engineering : 4-Year B.Tech. IV-Semester						
IS.MA203.14	MA203	Mathematical Methods	3	1	0	11
IE.EO101.14	EO101	Fundamental of Electrical Engineering	3	1	2	13
IE.CHO101.14	CHO101	Heat and Mass Transfer	3	1	0	11
DC.MCR204.15	MCR204	Structure and Properties of Ceramic Materials	3	0	0	9
DC.MCR205.15	MCR205	Ceramic Phase Diagrams and Phase Transformation	3	0	0	9
DP.MCR291.15	MCR291	Exploratory Project	0	0	5	5
		Total	**15**	**3**	**7**	**58**

Ceramic Engineering : 4-Year B.Tech. V-Semester						
DC.MCR301.15	MCR301	Techniques for Materials Characterization	3	0	0	9
DC.MCR304.19	MCR304	Ceramic Processing	3	0	0	9
DC.MCR311.15	MCR311	Glass and Glass Ceramics	3	0	2	11
DC.MCR321.15	MCR321	Refractories	3	0	2	11
DC.MCR331.15	MCR331	Advanced Ceramics	3	0	2	11
OE - 1	OE - 1	Open Elective - 1	3	0	0	9
		Total	**18**	**0**	**6**	**60**
DP.MCR391S.15	MCR391S	Stream Project (Hons.)	0	0	10	10
		Total	**18**	**0**	**16**	**70**
Ceramic Engineering : 4-Year B.Tech. VI-Semester						
DC.MCR 302.15	MCR 302	Process Calculations	2	0	0	6
DC.MCR 303.15	MCR 303	Ceramic Whitewares	3	0	2	11
DC.MCR 402.15	MCR 402	Cement and Concrete	3	0	2	11
DE.MCR3XX.15	DE - 1	Department Elective(DE) - 1	3	0	2	11
OE - 2	OE - 2	Open Elective - 2	3	0	0	9
DP.MCR 392/S.15	MCR 392/ MCR392S	Stream or UG Project	0	0	10	10
		Total credits in the semester	**14**	**0**	**14**	**58**
Ceramic Engineering : 4-Year B.Tech. Summer Term						
DC.EC393.15	EC393	Project / Industrial Project / Industrial Training	0	0	0	5
		Total	**0**	**0**	**0**	**5**
Department Elective- 1						
DE.MCR 312.15	MCR 312	Glass Engineering	3	0	2	11
DE.MCR 322.15	MCR 322	Advanced Refractories	3	0	2	11
DE.MCR 332.15	MCR 332	Nano Technology	3	0	2	11
Ceramic Engineering : 4-Year B.Tech. VII-Semester						
DC.MCR 401.15	MCR401	Fuel, Furnace & Pyrometry	3	0	2	11
DE.MCR4XX.15	DE - 2	Department Elective (DE) - 2	3	0	0	9
DE.MCR5XX.15	DE - 3	Department Elective (DE) - 3	3	0	0	9
OE - 3	OE - 3	Open Elective - 3	3	0	0	9
LM	LM	Language & Management Course	3	0	0	9
DP.MCR 491/S.15	MCR491/ MCR491S	Stream or UG Project	0	0	10	10
		Total credits in the semester	**15**	**0**	**12**	**57**
Department Elective - 2 and 3						
DE.MCR 404.15	MCR404	Plant, Equipment and Furnace Design	3	0	0	9
DE.MCR 411.15	MCR411	Glass Technology & Application	3	0	0	9
DE.MCR 421.15	MCR421	Steel Plant Refractories	3	0	0	9
DE.MCR 431.15	MCR431	Advanced Electro-ceramics	3	0	0	9
DE.MCR 441.15	MCR441	Bio-Ceramics	3	0	0	9
DE.MCR 451.15	MCR451	Non-Oxide & Structural Ceramics	3	0	0	9
DE.MCR 532.17	MCR532	Sensors and Actuators	3	0	0	9
DE.MCR 533.17	MCR533	Advanced Materials for Energy Devices	3	0	0	9
DE.MCR 535.17	MCR535	Advanced Thin-film Technologies	3	0	0	9
DE.MCR 536.17	MCR536	Materials for Bio Medical Applications	3	0	0	9

Ceramic Engineering : 4-Year B.Tech. VIII-Semester						
DC.MCR 404.15	MCR404	Plant, Equipment and Furnace Design	3	0	0	9
DE.MCR4XX.15	DE - 4	Department Elective (DE) - 4	3	0	0	9
DE.MCRXXX.15	DE - 5	Department Elective (DE) - 5	3	0	0	9
OE - 4	OE - 4	Open Elective - 4	3	0	0	9
LM	LM	Language & Management Course	3	0	0	9
		Total credits in the semester	**15**	**0**	**0**	**45**
DP.MCR494S.15	MCR494S	Stream Project (Hons.)	0	0	10	10
		Total Credits in the Semester (Hons.)	**15**	**0**	**10**	**55**
Department Elective - 4, 5 (any two courses)						
DE.MCR 406.15	MCR406	Pollution Control in Ceramic Industries	3	0	0	9
DE.MCR 405.15	MCR405	Industrial whitewares	3	0	0	9
DE.MCR 434.15	MCR434	Ceramic Composites	3	0	0	9
DE.MCR403.15	MCR403	Ceramic Coating & High Temperature Ceramic Processes	3	0	0	9
DE.MCR 511.17	MCR511	Advanced Glass Technology	3	0	0	9
DE.MCR 531.17	MCR531	Nano Electronics	3	0	0	9
DE.MCR 532.17	MCR532	Sensors and Actuators	3	0	0	9
DE.MCR 533.17	MCR533	Advanced Materials for Energy Devices	3	0	0	9
DE.MCR 535.17	MCR535	Advanced Thin-film Technologies	3	0	0	9
DE.MCR 536.17	MCR536	Materials for Bio Medical Applications	3	0	0	9
L: Lecture hours; T: Tutorial hours; P: Laboratory/ Practical hours; C: Credits						

1.1 TITLE:: Introduction to Ceramics

1.2 *COURSE NUMBER (if known):: DC.MCR 101.14

1.3 CREDITS:: 06 (L-T-P : 2-0-0)

1.4 SEMESTER-OFFERED:: 2^{nd} Semester

2. OBJECTIVE::

An introductory course designed to expose students to the fundamental knowledge and concept of different areas of ceramics and applications. It is designed to introduce the special characteristics and fabrication methods of different classes of ceramics.

3. COURSE TOPICS::

a) General: (3) Definition & scope of ceramics and ceramic materials, classification of ceramic materials – conventional and advanced ceramics.

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.

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.

f) Advanced Ceramics: (6) Engineering ceramics, ceramics used in advanced applications, ceramics for medical and scientific products, ceramics for electrical and electronic, aerospace.

4. READINGS

4.1 TEXTBOOK::

1) Elements of Ceramics - F.H Norton
2) Fundamentals of Ceramics - Barsoum
3) Introduction to Ceramics - W.D Kingery
4) Smith - Materials Science
5) Industrial Ceramics - Singer & Singer.

4.2 *REFERENCE BOOKS::

1) Refractories - J. H. Chester
2) Chemistry of Glasses - A. Paul
3) Ceramic Whitewares - Sudhir Sen
4) Chemistry of cement - F.M. Lea
5) Cera. Mat. for Electronics - R.C Buchanon

1.1 TITLE:: Basic Ceramic Practices

1.2 *COURSE NUMBER (if known):: DC.MCR 102.14

1.3 CREDITS:: 06 (L-T-P : 1-0-3)

1.4 SEMESTER-OFFERED:: 2nd Semester

2. OBJECTIVE::

This course is an introductory course in ceramic practice. The course introduces the ceramic student to basic processes involved in ceramic fabrication. It seeks to build the student's knowledge on the types of equipments and instruments employed in the fabrication of ceramics, their uses and applications.

3. COURSE TOPICS::

Theory (13 Lecturers):

- Introduction to ceramic processing.
- Synthesis of ceramic powder.
- Grinders and Mixers.
- Drying, calcination & sintering.
- Classification, components and operation of laboratory furnaces.
- Characterization of ceramic powders.

Laboratory (10):

- Making of ceramic body mixes.
- Determination of plasticity of ceramic body mixes.
- Operation and control of furnaces & instruments.
- Melting of simple glasses.
- To determine the time of grinding in a ball mill for producing a product with 80% passing a given screen.
- Pressing and fabrication of ceramic powders
- Firing of ceramic bodies and determination of shrinkage.
- Determination of cold crushing strength of refractory.
- Preparation of ceramic specimens for observation of microstructure by optical microscope.

4. READINGS

4.1 TEXTBOOK::

1) Elements of Fuels, Furnaces & Refractories – O.P. Gupta.
2) Ceramic Powder preparation : A Hand Book- Dibyendu Gangully & Minati Chatterjee.
3) Introduction to the principles of ceramic processing- J. S. Reed.

4.2 *REFERENCE BOOKS::

1) Ceramic Processing and Sintering- M. N. Rahaman.

1.1 TITLE: Ceramic Raw Materials

1.2 *COURSE NUMBER (if known):: DC.MCR 201.14

1.3 CREDITS: 13 (L-T-P : 3-1-2)

1.4 SEMESTER-OFFERED:: 3rd Semester

2. OBJECTIVE:

The course mainly covered the aspects of chemical and geological knowledge of the Ceramic Raw Materials. This course is actually the backbone of the Ceramic Engineering and the main objective of the course is to provide better theoretical and practical learning about the ceramic raw materials.

3. COURSE TOPICS::

- 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. (13)
- 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. (13)
- 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. (13)

4. READINGS

4.1 TEXTBOOK::
1) Rutly's elements of mineralogy by C.D. Gribble.
2) A book of optical mineralogy by Paul F Kerr.
3) A book of ceramic raw materials by W E Worrall

4.2 *REFERENCE BOOKS::
1) A book of Material Science and engineering by William D. Calluster
2) A text book of geology by P.K. Mukharjee.
3) A book of industrial ceramics by Felix Singer

1 TITLE:	Thermodynamics & Phase Equilibria in Ceramic Systems
1.2 *COURSE NUMBER (if known)::	DC.MCR 202.15
1.3 CREDITS::	11(L-T-P : 3-1-0)
1.4 SEMESTER-OFFERED::	III semester

2. OBJECTIVE::

This course has been designed to expose the students about the fundamental and applied knowledge of thermodynamics and phase equilibria in ceramic systems .

3. COURSE TOPICS::

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, criteria for phase stability, contimous solid solution, eutectic reaction, liquid phase separation, peritectic reactions, compound formation; congruently and incongruently melting compound.

6. 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, solid oxide fuel cells.

4. READINGS

4.1 TEXTBOOK: 1. Introduction to thermodynamics of materials: D.R. Gaskell

4.2 *REFERENCE BOOKS:: 1) Physical Chemistry of metals: L.S. Darken and R. W. Gurry

1.1 TITLE: Particle Mechanics and Fluid Flow Processes

1.2 *COURSE NUMBER (if known):: DC.MCR 203.15

1.3 CREDITS:: 11(L-T-P : 3.0.2)

1.4 SEMESTER-OFFERED:: III semester

2. OBJECTIVE::

This course in an introduction to fluid flow and particle mechanics with an emphasis on the fundamentals. The objective of the course is to cores the basic concepts and their applications in the process industries. The course takes an approach that covers empirical formula, theory to design and analyze fluid flow systems and equipment handling fluid particle systems.

3. COURSE TOPICS::

1. 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.

2. Characterization of particles, Shape and Size, specific surface area, powders polloids and agglomerats.

3. 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

4. Particle storage, janssen equation

5. Particle packing characteristics.

6. Mixing process and equipment, efficiency and performance indices.

Fluid Flow Operation : Physical properties of fluids, Sl Units and dimensions. Type of fluids; Compressible, Incompressible, Newtonian and non-Newtonian fluids. Rheological behaviour of particles- liquids systems, slurries and pastes. Pressure-density-height relationship. Pressure measurements; Manometers, Forces on submerged objects. Buoyancy and stability. Conservation of linear momentum and angular momentum, Bernoulli’s equation, energy relationship. Buckingham’s Theorem, important dimensionless numbers and their physical significance, similitude criteria. Viscous flow, laminar and turbulent flow through closed conduits. Velocity profiles, friction factor for smooth and rough pipes. Head losses due to friction in pipes, annular spaces and fittings. Hydraulic radius. Orifice meter, Venturimeter, Pitot tube, Rotameter. Flow through notches and weirs, physical methods of flow measurement, wet gas meter, dry gas meter, hot wire anemometer and other types of advanced techniques for flow measurement. Detailed study of pumps, compressors, blowers and fans; their selection and characteristics.

1.1 TITLE: Structure and Properties of Ceramic Materials
1.2 COURSE NUMBER (if known):: DC.MCR 204.15
1.3 CREDITS: 11 (L-T-P : 3-1-0)
1.4 SEMESTER-OFFERED:: 4thSemester

2. OBJECTIVE:

The properties of materials depend on structure of materials. Ceramic materials have both simple as well as complex structures. The objective of this course is impart knowledge on structure and electrical, magnetic, optical, mechanical and thermal properties of ceramic materials.

3. COURSE TOPICS::

Unit 1: Structure of ceramic materials [12 lectures]

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, AX_2, A_2X, $A_mE_nX_p$ 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.

Unit 2: Diffusion and Electrical properties [6 lectures]

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

Unit 3: Magnetic properties [4 lectures]

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.

Unit 4: Optical properties [4 lectures]

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

Unit 5: Mechanical properties [7 lectures]

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.

Unit 6: Thermal properties [5 lectures]

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.

4. READINGS

4.1 TEXTBOOK::

1) Fundamentals of Ceramics By: Michel W Barsoum, Published by Institute of Physics Publishing, The Institute of Physics, London
2) Introduction to Ceramics by: W. D. Kingery, H. K. Brown and D. R. Uhlmann, Wiley Interscience Publication, John Wiley & Sons.
3) Solid State Chemistry and its Applications By: A. R. West, John Wiley & Sons (Asia) Pte. Ltd.

1.1 TITLE:: Ceramic Phase Diagrams and Phase Transformations

1.2 *COURSE NUMBER (if known):: DC.MCR 205.15

1.3 CREDITS:: 09(L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: 5^{th}Semester

2. OBJECTIVE::

To understand the phase diagrams those are important to design and control of heat treating process and to obtain desirable microstructures.This course is to define the importance of phase diagrams both during the production and application of materials.

3. COURSE TOPICS::

a) Phase rule, Phase equilibrium in a single component system, Clausius-Clapeyron equation, Phase equilibrium diagrams for Water, Silica, Zirconia (3).

b) Two Component systems: Cooling behaviour and phase compositions for important ceramic systems such as SiO_2-Al_2O_3, MgO-Al_2O_3, CaO-SiO_2, CaO-Al_2O_3, CaO-MgO etc.(5)

c) 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-SiO_2-Na_2O, MgO-SiO_2-Al_2O_3, SiO_2-FeO-Fe_2O_3,CaO-MgO-SiO_2(12).

d) 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)

e) The application of phase diagrams in refractories& glass industries (4).

4. READINGS

4.1 TEXTBOOK::

1. Phase Transformations in Materials by Romesh C. Sharma, CBS Publishers and Distributors.
2. Introduction to Phase Equilibria in Ceramic Systems by F. A. Hummel, Marcel Dekker.
3. Phase transformations in Metals and Alloys by D.A. Porter and K.E. Esterling, Chapman and Hall
4. High Temperature Oxides, Part- I, II and III, Ed. A. M. Alper, Academic Press.
5. Phase Diagrams for Materials Science and Technology, A. M. Alper.
6. Phase Diagrams: Materials Science and Technology, A. M. Alper, Vol. I, II and III, Academic Press.
7. Principles of Phase Diagrams in Materials Science by P. Gordon, McGraw Hill Book Co., NY, 1968.
8. Phase Diagram for Ceramists by E. M. Levin, H. F. McMurdie and F. P. Hall, The American Ceramic Society, OH, USA.

4.2 *REFERENCE BOOKS::

1. A.M. Alper, Phase diagrams in Advanced Ceramics, Academic Press Inc, 1995
2. J.-C. Zhao, Methods for Phase Diagram Determination, Elsevier, 2007.
3. C.G. Bergeron, S.H. Risbud, Introduction to Phase Equilibria in Ceramics, The American Ceramic Society, 1984.
4. D.R.F. West, N. Saunders, Ternary Phase Diagrams in Materials Science, The Institute of Materials, 2002.

1.1 TITLE: Techniques for Materials Characterization

1.2 COURSE Number : DC.MCR301.15

1.3 CREDITS: 3-0-0 Credits 09

1.4 SEMESTER – Offered: V semester

1.5 PREREQUISITE: None

1.6 Syllabus Committee Member: Dr. Devendra Kumar

2. OBJECTIVE

The objective of this course is make student expert in different materials characterizations techniques which are dependent on their composition, phase, crystal, particulate and microstructure. The properties and applications

3. CORSE CONTENT

UNIT – I: Powder Characterization [5 Lectures]

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 powdered and sintered material. Packing density.

Unit – II: Thermo- chemical Analysis [6 Lectures]

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

Unit – III: X – Ray Diffraction [8 Lectures]

Characteristics X – rays, Fundamental principles of X-ray diffraction (XRD); Brag’s Law, Determination of Crystal 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.

Unit – IV: Spectroscopy [6 Lectures]

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 and IR spectroscopy.

Unit – V: Optical Microscopy [4 Lectures]

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

Unit – VI: Electron Microscopy [10 Lectures]

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.

1.1 TITLE:: Glass & Glass Ceramics

1.2 *COURSE NUMBER (if known):: DC.MCR 311.15

1.3 CREDITS:: 11 (L-T-P : 3-0-2)

1.4 SEMESTER-OFFERED:: V semester

2. OBJECTIVE::

This course design to expose students to the fundamental knowledge of glass and glass ceramics. Composition of different types of glasses and their physical and chemical properties and uses.

3. COURSE TOPICS::

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 properties of glasses.

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

4. READINGS

4.1 TEXTBOOK::

1) Introduction to Glass science- L. D. Pye
2) Fundamental of Inorganic glasses – A. K. Varshneya
3) Hand book of Glass Manufacture – Vol. I & II- by Tooley
4) Properties of Glass – by Moorey
5) Chemistry of Glasses by A. Paul
6) Introduction to Ceramic by Kingery

4.2 *REFERENCE BOOKS::

1) Colour glasses by Weyl
2) Hand book of Glass Manufacture – Vol. I & II- by Tooley

1.1 TITLE::	Refractories
1.2 *COURSE NUMBER (if known)::	DC. MCR-321
1.3 CREDITS::	11 (L-T-P : 3-0-2)
1.4 SEMESTER-OFFERED::	5th Semester

2. OBJECTIVE::

A course designed to expose students to the fundamental knowledge and concept of manufacturing, properties and applications of refractories various industries. It is designed with special characteristics and fabrication methods of different classes of refractories with its special features.

3. COURSE TOPICS::

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)

Manufacturing and properties of silica, alumina, alumino-silicate, magnesite, magnesite-chrome, chrome-magnesite, magnesia-spinel, dolomite, forsterite, carbon, high alumina, high and low temperature insulating refractories.

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,

4. READINGS

4.1 TEXTBOOK: NIL

4.2 *REFERENCE BOOKS:

1) Refractories - J. H. Chester
2) Industrial Ceramics - Singer & Singer.
3) Hand Book of Refractory - Japanese Refractory Association
4) Refractories –F.H.Norton

1.1 TITLE: Advanced Ceramics

1.2 COURSE Number : DC.MCR331.15

1.3 CREDITS: 3-0-2 Credits 11

1.4 SEMESTER – Offered: V semester

1.5 PREREQUISITE: None

1.6 Syllabus Committee Member: Dr. Devendra Kumar, Prof. Om Parkash

2. OBJECTIVE

The objective of this course is to acquaint the student with three important areas of Advanced Ceramics; Electro-ceramics, Engineering Ceramics and Bio-ceramics with which students will be motivated to do the project work for development of ceramic materials.

3. CORSE CONTENT

UNIT – 1 Electro-Ceramics [16 lectures]

Ceramic Capacitors: Ferroelectric ceramic materials; Relaxor ferroelectrics; Basic Ceramic Dielectric formulation for capacitors; Grain Boundary Barrier Layer Capacitors, Multi-layer Capacitors; Performance Categories 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 magnetic properties. 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.

UNIT – II Engineering Ceramics [12 lectures]

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 their engineering applications.

UNIT – III Bio-Ceramics [11 lectures]

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 and characteristics of dense and porous hydroxyapatite and calcium phosphate ceramics. Resorbable bioceramics. Characterization of bio-ceramics.

Books Recommended: Introduction to Magnetic Materials – B. D. Cullrty.

Modern Magnetic materials : Principles and Applications – Robert C.o Handly.

Ceramic Materials for Electronic Application – R. C. Buchanon

4. READINGS

4.1 TEXTBOOK::

4) Fundamentals of Ceramics By: Michel W Barsoum, Published by Institute of Physics Publishing, The Institute of Physics, London
5) Introduction to Ceramics by: W. D. Kingery, H. K. Brown and D. R. Uhlmann, Wiley Interscience Publication, John Wiley & Sons.
6) Solid State Chemistry and its Applications By: A. R. West, John Wiley & Sons (Asia) Pte. Ltd.

1.1 TITLE:	Process Calculation
1.2 *COURSE NUMBER (if known)::	DC.MCR 302.15
1.3 CREDITS::	06 (L-T-P : 2-0-0)
1.4 SEMESTER-OFFERED::	VI semester

2. OBJECTIVE::

This course design to expose students to fundamental knowledge of material balances and energy balances taking place in different processes.

3. COURSE TOPICS::

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.

1.1 TITLE:: Ceramic Whitewares

1.2 *COURSE NUMBER (if known):: DC.MCR 303.15

1.3 CREDITS:: 08 (L-T-P : 2-0-2)

1.4 SEMESTER-OFFERED:: VI Semester

2. OBJECTIVE::

Being a core course of ceramic engineering, this subject covers basic knowledge of white ware industries. It includes physical and chemical properties of raw materials used in pottery and ceramic whiteware industries. A detailed information of ceramic bodies with their batch composition compilation is given to students. It is also designed to provide knowledge of manufacturing of various whiteware articles along with process of glazing and decoration.

3. COURSE TOPICS::

(i) 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.

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

(iii) Fabrication methods: Details of fabrication methods used to manufacture whitewares such as floor and wall tiles, 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.

(iv) 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.

4. READINGS

4.1 TEXTBOOK:: 1) Fine Ceramics - F.H Norton

2) Fundamentals of Ceramics - Barsoum

3) Introduction to Ceramics - W.D Kingery

4.2 *REFERENCE BOOKS:: 1))Industrial Ceramics - Singer & Singer.

2) Ceramic Whitewares - Sudhir Sen

1.1 TITLE::	Glass Engineering
1.2 *COURSE NUMBER (if known)::	DE.MCR 312.15
1.3 CREDITS::	11 (L-T-P : 3-0-2)
1.4 SEMESTER-OFFERED::	VI semester

2. OBJECTIVE::

This course design to expose students to fundamental knowledge of glass melting, homogenization and different types of effect and annealing. Manufacturing of different types of glasses by blowing pressing process with semi automatic and fully automatic machines.

3. COURSE TOPICS::

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

4. READINGS

4.1 TEXTBOOK::

1) Introduction to Glass science- L. D. Pye
2) Fundamental of Inorganic glasses – A. K. Varshneya
3) Hand book of Glass Manufacture – Vol. I & II- by Tooley
4) Properties of Glass – by Moorey
5) Chemistry of Glasses by A. Paul
6) Introduction to Ceramic by Kingery

4.2 *REFERENCE BOOKS::

1) Colour glasses by Weyl
2) Hand book of Glass Manufacture – Vol. I & II- by Tooley

1.1 TITLE::	Advanced Refractories
1.2 *COURSE NUMBER (if known)::	DC. MCR-322
1.3 CREDITS::	11 (L-T-P : 3-0-2)
1.4 SEMESTER-OFFERED::	6th Semester

2. OBJECTIVE::

A core course designed to expose students to the fundamental knowledge and concept of areas of advanced refractories and its applications. It is designed to introduce the special properties and manufacturing methods of advanced refractory for steel and iron industries.

3. COURSE TOPICS:

Monolithics refractories(castables, plasatic and rammimg mixes, gunning mixes, refractory mortar) ceramic fibres, 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.

4. READINGS

4.1 TEXTBOOK: NIL

4.2 *REFERENCE BOOKS:

1) Refractories - J. H. Chester

2) Industrial Ceramics - Singer & Singer.

3) Hand Book of Refractory - Japanese Refractory Association

4) Refractories –F.H.Norton

1.1 TITLE:: Nano Technology

1.2 *COURSE NUMBER (if known):: DE.MCR 332.15

1.3 CREDITS:: 11 (L-T-P : 3-0-2)

1.4 SEMESTER-OFFERED:: 6th Semester

2. OBJECTIVE::

This subject will cover a broad range of disciplines to enable the trained graduates to make an objective judgment of the scientific importance and technological potential of developments in nanotechnologies and to perform a range of activities related to nanotechnology and nanoscience. Aims to create a scientific basis to ensure the safe and responsible development of engineered nanoparticles and nanotechnology-based materials and products. A better knowledge of the risks of nanomaterials for health and the environment will form a solid basis and allow for a sustainable development of the nanotechnology industries and markets.

3. COURSE TOPICS::

- Evolution of science and technology, Introduction to Nanotechnology, Nanotechnology–Definition–Difference between Nanoscience and Nanotechnology, Feynman predictions on Nanotechnology, Moores law, Role of Bottom up and top down approaches in nanotechnology, challenges in Nanotechnology (2).
- Nanotechnology Timeline and Milestones, Overview of different nanomaterials available, Potential uses of nanomaterials 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).

4. READINGS

4.1 TEXTBOOK::

1) Nanoscience and Nanotechnology: Fundamentals of Frontiers by M.S. Ramachandra Rao, Shubra Singh

2) Introduction to Nanotechnology By Charles P. Poole, Jr., Frank J. Owens

4.2 *REFERENCE BOOKS::

1) Nanosciences and Nanotechnology by Lourtioz, J.-M., Lahmani, M., Dupas-Haeberlin, C., Hesto, P. (Eds.)

2) Principles of Nanotechnology, G Ali Mansoori

1.1 TITLE:	Fuels, Furnaces and Pyrometry
1.2 *COURSE NUMBER (if known)::	DC.MCR 401.15
1.3 CREDITS::	11(L-T-P : 3.0.2)
1.4 SEMESTER-OFFERED::	VII semester

2. OBJECTIVE::

The course is to prepare students for careers in engineering where knowledge of fuels, furnaces and pyrometry can be applied to the advancement of technology. This subject course will enable students to solve industrial problems upon graduation while at the same time provide a firm foundation for the pursuit of graduate studies in ceramics engineering.

3. COURSE TOPICS::

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.

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.

1.1 TITLE:: Plant, Equipment and Furnace Design

1.2 *COURSE NUMBER (if known): MCR 404

1.3 CREDITS:: 03 (L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: 7th Semester

2. OBJECTIVE::

A course designed to expose students to the fundamental knowledge and concept to design of furnaces and design of plant for various ceramic industries.

3. COURSE TOPICS::

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

.4. READINGS

4.1 TEXTBOOK:: 1) Hand Book of Glass Manufacturing By:Tooley

4.2 *REFERENCE BOOKS:: 1) Source book of Ceramic by S.Kumar

1.1 TITLE::	Glass Technology and Application
1.2 *COURSE NUMBER (if known)::	DE.MCR 411.15
1.3 CREDITS::	09 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED::	VII semester

2. OBJECTIVE::

This course design to expose students to fundamental knowledge of glass melting, homogenization and different types of effect and annealing.Manufacturing of different types of glasses by blowing pressing process with semi automatic and fully automatic machines.

3. COURSE TOPICS::

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 of glass in solid fuel cell. Photochemical reactions in glasses; colloidal colors in glass, solarised glass.

4. READINGS

4.1 TEXTBOOK::

1) Introduction to Glass science- L. D. Pye
2) Fundamental of Inorganic glasses – A. K. Varshneya
3) Hand book of Glass Manufacture – Vol. I & II- by Tooley
4) Properties of Glass – by Moorey
5) Chemistry of Glasses by A. Paul
6) Introduction to Ceramic byKingery

4.2 *REFERENCE BOOKS::

1) Colour glasses by Weyl
2) Hand book of Glass Manufacture – Vol. I & II- by Tooley

1.1 TITLE:: Steel Plant Refractories

1.2 *COURSE NUMBER (if known):: DE.MCR 421.15

1.3 CREDITS:: 09 (L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: 7th Semester

2. OBJECTIVE::

Refractories are expensive, and any failure in the refractories results in a great loss of production time, equipment, and sometimes the product itself. The type of refractories also will influence energy consumption and product quality. Therefore, the problem of obtaining refractories best suited to each application is of supreme importance. Economics greatly influence these problems, and the refractory best suited for an application is not necessarily the one that lasts the longest, but rather the one which provides the best balance between initial installed cost and service performance. This balance is never fixed, but is constantly shifting as a result of the introduction of new processes or new types of refractories. History reveals that refractory developments have occurred largely as the result of the pressure for improvement caused by the persistent search for superior metallurgical processes. The rapidity with which these ever recurring refractory problems have been solved has been a large factor in the rate of advancement of the iron and steel industry. To discuss the many factors involved in these problems and to provide information helpful to their solution are the objectives of this subjects.

3. COURSE TOPICS::

- History of steel making, from bessemer steel making to present day equipments and practices, integrated and 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).

4. READINGS

4.1 TEXTBOOK:: 1) Steel Plant Refractories :- J. H. Chester

2) Recent Trend in Refractory Monolithics by Dr. Subrata Banerjee

TITLE:	Advanced Electro Ceramics
1.1 COURSE Number :	DC.MCR431.16
1.2 CREDITS:	3-0-2 Credits 11
1.3 SEMESTER – Offered:	VII Semester
1.4 PREREQUISITE:	None

1.5 Syllabus Committee Member: Dr. Devendra Kumar, Prof. Om Parkash

2. OBJECTIVE

The objective of this course is to acquaint the student with a comprehensive knowledge in the area of Electronic Ceramics with which students will be able to understand the characteristics of ceramic materials for their applications different electronic devices.

3. CORSE CONTENT

UNIT – 1 Conducting Ceramics [8 lectures]

Broad band and narrow band conduction, Mott's transition. Effect of partial pressure of oxygen and doping in oxide conductors. Grain boundary effects on electrical conduction.Grain Boundary Barrier Layer Capacitors, Ceramic superconductors.

UNIT – 2Ceramic Magnets [6 lectures]

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.

UNIT – 3Sensors and Actuators [8 lectures]

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)

UNIT – 4Varisters and their Applications [5 lectures]

VaristorCharacteristics, ZnOVaristor materials systems, their processing, microstructure and applications. Varistor models.

UNIT – 5Thick film and Multilayer Ceramics [5 lectures]

Formulation of conductive, resistive and dielectric inks. Screen printing and firing of hybride devices. Fabrications of multilayer devices and their applications.

UNIT – 6Ceramics for Green Energy [6 lectures]

Solid oxide fuel cells (SOFC) Cells:Solid electrolytesbased on stabilized zirconia, Co-doped ceria, Cathode, Anode and Interconnect materials. Batteries and solar cells.

UNIT – 7 Characterization Techniques for electroceramics [Laboratory]

Books Recommended: Introduction to Magnetic Materials – B. D. Cullrty.

Modern Magnetic materials : Principles and Applications – Robert C.oHandly.

Ceramic Materials for Electronic Application – R. C. Buchanon

1 TITLE: Bio-ceramics

1.2 *COURSE NUMBER (if known):: DE.MCR 441.15

1.3 CREDITS:: 09 (L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: VII semester

2. OBJECTIVE::

This course has been designed to expose students to the fundamental knowledge of bioglass and bioglass-ceramics to be used as better implants in the human body.

3. COURSE TOPICS::

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.

4. READINGS

4.1 TEXTBOOK: 1. Introduction to Bio-Ceramics – L. L. Hench and J. Wilson.

2. Biomaterials: An introduction by Ethridge.

3. Introduction to biomaterials by J. B. Park.

4.2 *REFERENCE BOOKS:: 1) Bio-Ceramics byKukobo

1.1 TITLE:: Non-oxide & structural ceramics

1.2 *COURSE NUMBER (if known):: DE.MCR 451.15

1.3 CREDITS:: 09 (L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: 7th Semester

2. OBJECTIVE::

The course mainly covered the aspects of properties, synthesis & application knowledge of the Non oxide ceramics. The main objective of the course is to provide better theoretical and practical learning about the Non-oxide & structural ceramics.

3. COURSE TOPICS::

- 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 of different 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, their proportioning, processing, manufacture of abrasives, grinding wheels, their drying, firing and testing. The use of abrasives and grinding wheels in grinding. Evaluation of abrasives products. Loose abrasives 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).

4. READINGS

4.1 TEXTBOOK:: 1) Non-Oxide Materials: Applications and Engineering by Makuteswara Srinivasan, William Rafaniello

2) Abrasives by L. Cous

4.2 *REFERENCE BOOKS:: 1) Grinding Technology: Theory and Application of Machining with Abrasives by Stephen Malkin, Changsheng Guo.

1.1 TITLE:	Cement and Concrete
1.2 *COURSE NUMBER (if known)::	DC.MCR 402.15
1.3 CREDITS::	11(L-T-P : 3.0.2)
1.4 SEMESTER-OFFERED::	VIII semester

2. OBJECTIVE::

The course covers the manufacture of cement starting from the raw materials and their processing to produce cement as per specification. Its properties and testing procedures are also covered. The main objective is to produce engineers who can take the cement manufacture and quantity to newer height.

3. COURSE TOPICS::

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.

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, their constitution 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 fiber reinforce concrete, different types of fibers, glass fiber, steel fiber, polymer.

1.1 TITLE:: Ceramic Coating & High Temperature Ceramic Processes

1.2 *COURSE NUMBER (if known):: DC.MCR 403.15

1.3 CREDITS:: 09 (L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: 8^{th} Semester

2. OBJECTIVE::

The polishing and coating of ceramic surfaces is recommended in order to improve the physical properties of ceramics. Conventional methods for the surface treatment of ceramic materials are not capable of creating a smooth surface without micro-cracks. The course mainly covered the aspects of ceramic coating and high temperature ceramic processes. The main objective of the course is to provide better theoretical and practical application about the ceramic coating and high temp ceramic processing.

3. COURSE TOPICS::

- 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)

4. READINGS

4.1 TEXTBOOK::

1. Porcelain enamels by A. I. Andrews, The Ganard Press Publishers, IL, USA>
2. Ceramic Glazes by C. W. Parmelee, 3rd Ed. Edited and revised by E.D. Lynch and A. L. Friedberg,
3. Vitreous Enameling: A Guide to Modern Enameling Practice by K. A. Maskall and D. White, Pergamon Press, Oxford.
4. Technology of Enamels by V. V. Vargin, Translated by Kenneth Shaw, McLaren & Sons Ltd, London.
5. High Tech Ceramics Vol 38(A), Ed. P. Vincenzini, Elsevier.

4.2 *REFERENCE BOOKS:: 1) Ceramic Processing and Sintering by Mohamed N. Rahaman

1.1 TITLE:: Pollution Control in Ceramic Industries

1.2 *COURSE NUMBER (if known): DE.MCR 406.15

1.3 CREDITS:: 03 (L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: 8^{th}Semester

2. OBJECTIVE::

Acourse designed to expose students to the fundamental knowledge and concept to control the pollution various ceramic industries. It is designed to introduce the special equipment used for manufacturing ceramic material with control pollution.

3. COURSE TOPICS::

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. Theimprovement of combustion processesto reduce the formation of Nox, Sox, Co. The fine particles released from the crushing and grinding of the ceramic raw materials.Theequipment andmethods to arrest the release of fine particulate materials and unwanted gases to atmosphere.Chemicals used indifferent ceramic industries e.g. Tiles, Potteries, Refractory, andGlass 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 wastesin the ceramic industriesand the possibility of recycling them.Sound and noise pollutions and their minimization techniques.

4. READINGS

4.1 TEXTBOOK:: 1) Air Pollution by B.K.Sharma and H.Kaur

4.2 *REFERENCE BOOKS:: 1) Pollution Control in Chemical and Allied Industries: With Focus on Air and Water Pollution by N Hanley

1.1 TITLE:: Industrial whitewares

1.2 *COURSE NUMBER (if known):: DE.MCR 405.15

1.3 CREDITS:: 09(L-T-P : 3-0-0)

1.4 SEMESTER-OFFERED:: VIII Semester

2. OBJECTIVE::

Being anelective course of ceramic engineering, this subject providesexpertise knowledge of white ware industries. It is designed to provide knowledge of manufacturing, instrumentation and automation techniques of various whiteware articlesalong with process ofglazing and decoration.

3. COURSE TOPICS::

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.

4. READINGS

4.1 TEXTBOOK::

1) Fine Ceramics - F.H Norton

2) Fundamentals of Ceramics - Barsoum

3) Introduction to Ceramics - W.D Kingery

4.2 *REFERENCE BOOKS::

1)Industrial Ceramics - Singer & Singer

2) Ceramic Whitewares -SudhirSen

1.1 TITLE:: Ceramic Composites

1.2 *COURSE NUMBER (if known):: DE.MCR 434.15

1.3 CREDITS:: 3-0-0 Credits 9

1.4 SEMESTER-OFFERED:: 8th Semester

2. OBJECTIVE::

This course will cover a broad range of topics to provide a basic understanding of ceramic matrix composites (CMCs). The course gives an overview of various CMC materials, their processing and characterization techniques, properties (physical, mechanical,thermal, etc.) and role of interfaces and interphases. The course aims to provide understanding of the structure-property relationship in CMCs to select an appropriate processing method for variety of composite and products. This course introduces various applications of CMCs, ranging from traditional friction applications to advanced space and nuclear applications.

3. COURSE TOPICS::

UNIT – 1 Introduction [6 lectures]

Introduction to Ceramic matrix composites (CMCs), Fibers for CMCs, SiC_f/SiC, SiC/Al_2O_3, WC/Al_2O_3 composites, Ternary MAX phases ($M_{n+1}AX_n$).

UNIT – 2Fabrication and processing [8 lectures]

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 [10 lectures]

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 [8 lectures]

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 [6 lectures]

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.

4. READINGS

4.1 TEXTBOOKS::

1) Ceramic Matrix Composites_ Second Edition, K. K. Chawla, Springer US (2003)

2) Ceramic Matrix Composites: Materials, Modeling and Technology, N.P Bansal and J. Lamon (Eds.), John Wiley & Sons (2015).

4.2 *REFERENCE BOOKS::

1) Ceramic Matrix Composites- Fiber Reinforced Ceramics and their Applications; Walter Krenkel, Wiley-VCH (2008)

2) Advances in ceramic matrix composites, I.M. Low (Ed.), Woodhead Publishing Ltd. (2014).