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

Course Structure
of

5 YEARS MASTER OF TECHNOLOGY (DUAL DEGREE) IN CERAMIC ENGINEERING

Ceramic Engineering: Structure of 5-Year IDD Programme

UG-CRC	Course Code	Course Name	L–T–P			Credits
Section-1AC1	**Ceramic Engineering: 5-Year IDD 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.ME103.14	ME103	Engineering Thermodynamics	3	1	0	11
EP.ME104.14	ME104	Engineering Drawing	1	0	3	6
EP.ME105.14	ME105	Manufacturing Practice - I	0	0	3	3
IH.H101.14	H101	Universal Human Values - I: Self and Family	1	1	0	5
		Total	**13**	**5**	**10**	**59**
LM.HL101.14	HL101	Basic English*	2	0	1	7
		Total	**15**	**5**	**11**	**66**
GY.PE101.14	PE101	Elementary Physical Education	0	1	3	5

L: Lecture hours; T: Tutorial hours; P: Laboratory/ Practical hours; C: Credits

*Students who do not qualify the diagnostic test in English will study Basic English; they will not register for Gym Course. This requirement of Gymkhana Course will be completed in 2nd and 3rd Semester.

Section-1AC1	**Ceramic Engineering: 5-Year IDD 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.CSO101.14	CSO101	Computer Programming	3	1	2	13
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**	**10**	**60**
GY.CP1XX.15	CP1XX	Creative Practice #	0	1	3	5

* The students have to choose one course from H103 & H104 and will study in 2nd Semester.

#Students have to register for any one of the Creative Practice Course.

Gymkhana GY Creative Practice Courses#

GY.PE101.14	PE101	(Elementary Physical Education/	0	1	3	5
GY.CP111.15	CP111	Music - Instrumental/				
GY.CP112.15	CP112	Music - Vocal/				
GY.CP113.15	CP113	Dance/				
GY.CP121.15	CP121	Painting/				
GY.CP122.15	CP122	Sculpture/				
GY.CP123.15	CP123	Advertising)				

Section-2AC1	**Ceramic Engineering: 5-Year IDD III-Semester**					
IE.MO201.14	MO201	Materials Science	3	1	0	11
DC.MCR201.15	MCR201	Ceramic Raw Materials	3	1	2	13
DC.MCR202.15	MCR202	Thermodynamics and Phase Equilibria in Ceramic Systems	3	1	0	11
DC.MCR203.15	MCR203	Particle Mechanics and Fluid Flow Process	3	0	2	11
DP.MCR291.15	MCR291	Exploratory Project	0	0	5	5
IH.H105.15	H105	(Philosophy /	2	1	8	8
IH.H106.15	H106	Education and Self) #				
		Total	**14**	**4**	**17**	**59**

* The students have to choose one course from H105 & H106 and will study 3rd Semester.

Students who could not complete the requirement of Gymkhana Courses in first two semesters will do the same in this semester.

Section-2AC1	Ceramic Engineering: 5-Year IDD 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	1	0	11
DC.MCR205.15	MCR205	Ceramic Phase Diagrams and Phase Transformation	3	0	0	9
IH.H102.14	H102	Universal Human Values - I: Self and Family	1	1	0	5
		Total	**16**	**5**	**2**	**60**
Industrial training/Project should be taken during no class period between end of Ivth Semester and beginning of VIIth semester.						

Streams 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)				

Section-3AC1	Ceramic Engineering: 5-Year IDD V-Semester					
DC.MCR301.15	MCR301	Techniques for Materials Characterization	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
LM.HL301.16	HL301	HU / LM	2	1	0	9
		Total	**17**	**1**	**6**	**60**
DP.MCR391.15	MCR391	Stream Project (Hons.)@	0	0	10	10
		Total	**17**	**1**	**16**	**70**
^^ Two LM courses and Two HU courses would be scheduled in 5-8 semesters totaling 18-22 credit for each category. # Fixed slot of Semester @ Extra Stream Project to be carried out by Hons. Students in V and VIII semester						
Section-3AC1	**Ceramic Engineering: 5-Year IDD VI-Semester**					
DC.MCR 302.15	MCR 302	Process Calculations	2	0	0	6
DC.MCR 303.15	MCR 303	Ceramic Whitewares	2	0	2	8
DP.MCR 392.15	MCR 392	Stream or UG Project	0	0	10	10
DE.MCR3XX.15	MCR3XX	Department Elective(DE-1)	3	0	2	11
OE - 2		Open Elective - 2	3	0	0	9
HU/LM		# Humanities/Language & Management Course ^^	3	0	0	9
		Total credits in the semester	**13**	**0**	**14**	**53**
UG Project to be carried out by every students in VI and VIII semester						

Section-4AC1	Ceramic Engineering: 5-Year IDD Summer Term					
DC.EC393.15	EC393	Project / Industrial Project / Industrial Training	-	-	-	5
		Total	-	-	-	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

Open Elective - 2						
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

Section-4AC1	Ceramic Engineering: 5-Year IDD VII-Semester					
DC.MCR 401.15	MCR 401	Fuel, Furnace & Pyrometry	3	0	2	11
DE.MCR4XX.15	MCR4XX	Department Elective (DE-2)	3	0	0	9
DE.MCR5XX.15	MCR5XX	Department Elective (DE-3) PG	3	0	0	9
DP.MCR 491.15	MCR 491	Stream or UG Project	0	0	10	10
OE - 3	OE - 3	Open Elective - 3	3	0	0	9
HU/LM	HU/LM	# Humanities/Language & Management Course ^^	3	0	0	9
		Total credits in the semester	**15**	**0**	**12**	**57**

Department Elective - 2						
DE.MCR 404.15	MCR 404	Plant, Equipment and Furnace Design	3	0	0	9
DE.MCR 411.15	MCR 411	Glass Technology & Application/	3	0	0	9
DE.MCR 421.15	MCR 421	Steel Plant Refractories/	3	0	0	9
DE.MCR 431.15	MCR 431	Advanced Electro-ceramics;	3	0	0	9
DE.MCR 441.15	MCR 441	Bio-Ceramics	3	0	0	9
DE.MCR 451.15	MCR 451	Non-Oxide & Structural Ceramics	3	0	0	9

Department Elective - 3, PG						
DE.MCR 501.15	MCR 501	Advanced Techniques for Materials Characterisation	3	0	0	9
DE.MCR 502.15	MCR 502	Phase Equilibria and Kinetics of Ceramic Systems	3	0	0	9

Section-4AC1	Ceramic Engineering:5-Year IDD VIII - Semester					
DE.MCR 402.15	MCR 402	Cement and Concrete	3	0	2	11
DE.MCR5XX.15	MCR5XX	Department Elective (DE-4), PG	3	0	0	9
OE - 4	OE - 4	Open Elective - 4	3	0	0	9
HU/LM	HU/LM	# Humanities/Language & Management Course ^^	3	0	0	9
		Total credits in the semester	**12**	**0**	**2**	**38**
DP.MCR494.15	MCR494	Project / Thesis	0	0	10	10
		Total Credits in the Semester (Hons.)	**12**	**0**	**12**	**48**
Department Elective - 4, PG						
DE.MCR 403.15	MCR 403	Ceramic Coating & High Temperature Ceramic Processes	3	0	0	9
DE.MCR 521.15	MCR 521	Industrial Furnaces, Instrumentation and Control	3	0	0	9
DE.MCR 531.15	MCR 531	Nanoelectronics	3	0	0	9

Section-5AC1	Ceramic Engineering: 5-Year IDD IX-Semester					
OE - 3	OE - 3	Elective - 3	3	0	0	9
OE - 4	OE - 4	Elective - 4	3	0	0	9
DT.MCR 591.15	MCR 591	Master Thesis	0	0	10	10
OE - 5	OE - 5	Open Elective - 5	3	0	0	9
OE - 6	OE - 6	Open Elective - 6	3	0	0	9
HU/LM	HU/LM	# Humanities/Language & Management Course ^^	3	0	0	9
		Total credits in the semester	**15**	**0**	**10**	**55**

PG Elective - 3 and 4						
DE.MCR 536.15	MCR 536	Materials for Bio medial Applications	3	0	0	9
DE.MCR 532.15	MCR 532	Sensors and Actuators	3	0	0	9
DE.MCR 533.15	MCR 533	Advanced Materials for Energy Devices	3	0	0	9
DE.MCR 504.15	MCR 504	Diffraction Methods for Solids	3	0	0	9
DE.MCR 535.15	MCR 535	Advanced Thin-film Technologies	3	0	0	9

Section-5AC1	Ceramic Engineering: 5-Year IDD X-Semester					
DT.MCR 592.15	MCR 592	Master Thesis	0	0	50	50
		Total credits in the semester	**0**	**0**	**50**	**50**

Stream Distribution of 4- Years B.Tech. and 5- Years IDD Programme

Streams in Ceramic Engineering			
Year	Stream - 1	Stream-2	Stream-3
	Glass & Glass Ceramics	**Refractories**	**(Inter Disciplinary)** Electro-ceramics/Bio-ceramics/Engineering-ceramics
UG/ IDD Pt. III (V sem)	MCR311: Glass and glass ceramic	MCR321: Refractories	MCR331: Advanced Ceramic
UG/ IDD Pt. III (VI sem)	MCR 312:Glass Engg.	MCR 303:Ceramic White ware MCR 222: Advance Refractory	MCR332: Nano Technology
UG PT. IV (VII sem.)	MCR411: Glass Tech. & Appl.	MCR421: Steel Plant Refractories	MCR431: Advanced Electro Ceramic, MCR441: Bio- Ceramic , MCR451: Non Oxide & Structural Ceramic
UG PT. IV (VIII sem.)			MCR 434:Ceramic Composites, MCR 403:Ceramic Coating & High Temperature Ceramic Processes
IDD IV (VII Sem.)	MCR411: Glass Tech. & Appl.	MCR421: Steel Plant Refractories	MCR431: Advanced Electro Ceramic, MCR441: Bio- Ceramic , MCR451: Non Oxide & Structural Ceramic
IDD IV (VIII Sem.)			MCR 403:Ceramic Coating & High Temperature Ceramic Processes, MCR 531: Nano Electronics
IID V (IX sem.)			MCR 536:Materials for Bio medial Applications, MCR 532:Sensors and Actuators, MCR 533:Advanced Materials for Energy Devices, MCR 535:Advanced Thin-film Technologies

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:: 2nd 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.

4.1 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

1.1 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:: 4^{th}Semester

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:: 5thSemester

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: Both
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: Odd
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.

4. READINGS
4.1 TEXTBOOK:: 1) Chemical Process Principle by

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::	VIth 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:: 6^{th} 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
1.1COURSE Number :	DC.MCR431.16
1.2CREDITS:	3-0-2 Credits 11
1.3SEMESTER – Offered:	VII Semester
1.4PREREQUISITE:	None
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 – 7Characterization 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

1.1 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:	Advanced Techniques for Materials Characterization
1.2 COURSE Number :	DC.MCR501.16
1.3 CREDITS:	3-0-0 Credits 11
1.4 SEMESTER – Offered:	VII Semester
1.5 PREREQUISITE:	None
1.6 Syllabus Committee Members:	Prof. Devendra Kumar, Prof. Om Parkash, Dr. Akansha Dwivedi

2. OBJECTIVE

The objective of this course is to acquaint the student with a comprehensive knowledge in the area of Materials Characterization Techniques for Ceramics with which students will be able to understand the characteristics of ceramic materials for understanding structure property performance correlations.

3. CORSE CONTENT

UNIT – 1 Powder Characterization Techniques [6 lectures]

Nature of particles, Particle size and Particle size distribution. Sedimentation, scattering and electrical sensing zone methods of measurement of particle size and particle size distribution. Surface area and porosity and their measurement techniques.

UNIT – 2 Thermal Analysis [6 lectures]

Introduction to thermal reactions and decompositions.Reversible and irreversible phase transformations.First and second order transformations.Thermogravimetric (TGA), Differential Thermal Analysis (DTA), and Differential Scanning calorimeter (DSC) with suitable examples of glass and ceramic materials.

UNIT – 3Optical Microscopy [4 lectures]

Study of the morphology, aggregation, size and microstructure of ceramic materials usingoptical microscope, quantitative phase analysis.

UNIT – 4X-ray Diffraction [8 lectures]

Basic Crystallography, point group, space group, Zone axis.Diffraction phenomenon. Atomic and Geometrical structure factors. Factors influencing the intensities of diffracted beams. Powder X-ray diffractometer. Identification of crystal structure using JCPDS files. Determination of particle size.Reitveld refinement technique for structural analysis.

UNIT – 5Electron Microscopy [8 lectures]

Principle of electron microscopy. Construction and operation of Transmission Electron Microscope and Scanning Electron Microscope. Mechanism of image formation in SEM. Electron diffraction by crystalline solids; selected area diffraction. Electron microprobe analysis (EDAX and WDS). Preparation of ceramic samples for electron microscopic studies.

UNIT – 6Spectrometry for Ceramics [6 lectures]

Absorption and emission of radiation from matter. Basic laws of spectrophotometry and its application in micro analysis in UV/ Visible range.Construction and working principle of spectrophotometer. Infrared spectrophotometry for structural analysis of ceramic systems, sources of IR radiations, Optical systems and operation of FTIR spectrophotometers. Samples preparation, IR analysis and structural co-relations. X-Ray Fluorescence spectrometry.

Books Recommended: Elements of X-Ray Diffraction– B. D. Cullity.

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

Ceramic Materials for Electronic Application – R. C. Buchanon

1.1 TITLE:: Phase Equillibia and Kinetics of Ceramic Systems
1.2 *COURSE NUMBER (if known):: DE.MCR 502.15
1.3 CREDITS:: 11 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED:: VII Semester

2. OBJECTIVE::

To understand the phase diagrams, their interpretation and applications in processing and designing heat treatment schedules for obtaining desired microstructures. The course also focuses on the kinetic aspects and the role to rate and the effect of kinetics on the obtained microstructures. Study of Glass-ceramic kinetics gives the idea that how various properties can be achieved which are difficult to control in crystalline materials or in glasses.

3. COURSE TOPICS::

a) Two Component systems: Solid solution, eutectic, eutetoid, peritetic and pertectoid reactions. Intermediate compounds in binary ststems. Cooling behaviour, crystallization, microstructure evolution and phase compositions for important ceramic systems.
b) Ternary Systems: 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 microstructure in importantternary systems.
c) Grain Growth: Primary recrystallization in ceramic and metal-ceramic composites. Grain Growth and secondary recrystallizations in various important oxides and non-oxide ceramic systems. Factors influencing the grain growth with relevant of microstructural changes.
d) Glass-Ceramic Systems: Nucleation in glasses:Homogeneous and Heterogeneous nucleation. Liquid phase separation in glass forming systems and crystal growth. Glass-Ceramics arising from control of process variables.
e) Kinetics: Introduction to reaction kinetics, reaction complexes, activation energy and rate equation. Kinetics of solid state reactions occurring at elevated temperatures. Solid-liquid and dissociation reactions.

4. READINGS

4.1 TEXTBOOK:: .

9. Introduction to Phase Equilibria in Ceramic Systems by F. A. Hummel, Marcel Dekker.
10. Phase Diagrams for Materials Science and Technology, A. M. Alper.
11. Phase Diagrams: Materials Science and Technology, A. M. Alper, Vol. I, II and III, Academic Press.
12. Kinetics of Materials by Robert W. Balluffi, Samuel M. Allen, W. Craig Carter, John Wiley and sons.
13. Phase transformations in Metals and Alloys by D.A. Porter and K.E. Esterling, Chapman and Hall
14. Phase Transformations in Materials by Romesh C. Sharma, CBS Publishers and Distributors
15. Principles of Phase Diagrams in Materials Science by P. Gordon, Mc Graw Hill Book Co., NY, 1968.
16. Introduction to ceramics by W.D.Kingery

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.
5. Ceramic Processing and Sintering by M.N.Rahaman
6. Ceramic Science for Materials Technologists by I.J.Mccolm

1.1 TITLE:	Cement and Concrete
1.2 *COURSE NUMBER (if known)::	DE.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:: 8th 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:: Industrial Furnaces, Instrumentation and Control
1.2 *COURSE NUMBER (if known): MCR 521
1.3 CREDITS:: 03 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED:: 8th Semester

2. OBJECTIVE::

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

3. COURSE TOPICS::

Classification of furnace. Detailed study of industrial furnace used in refractories glass, ceramics, cement, ferrous and non-ferrous industries with respect to their design calculations keeping process parameters in view .Role of multilayer lining, combustion, gas flow and heat transfer in furnaces. Physico-chemical considerations in designing of furnaces.Measurement of temperature, pressure, draft etc. in furnace system and their control. Efficiency and fuel conservation. Use of top electrode for electric melting. Pollution control option for furnace noise, flaring and disposal.

4. READINGS

4.1 TEXTBOOK::
1) Source book of Ceramic by S.Kumar
2) Color generation C.R.Bamford

4.2 *REFERENCE BOOKS::
1) Hank book of Glass Manufactur, F.V.Tooley, Vol. 1 & 2
2)Industrial furnaces by Trink
3) Glass Tank furnace by G.R.Gunther.

1.1 TITLE: Nano Electronics
1.2 *COURSE NUMBER (if known):: DE.MCR 531.15
1.3 CREDITS:: 11 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED:: IX Semester

2. OBJECTIVE::

This course has been designed to expose the studentsfor gainingadvanced and applied level of knowledge in nano-scale electronic materials and nano-scale device systems. The entire course will give a broad overview of the nano-devices for various applications in electronic, photonic, bio and medical applications.

3. COURSE TOPICS::

1. Basic Concepts of Solid state Physics and Quantum mechanics: Introduction and terminologies, advanced solid state physics: conductors, semi-conductors, and insulators. Energy Bands and Density of States in various materials.Fermi-Dirac Statistics, concept of Fermi level, Fermi surfaces, and effective masses. Advanceconcepts of work function and contact potentials.
2.Fundamental Conceptsof Semiconductors: Types of semiconductors and doping of Semiconductors.Direct and indirect band-gap semiconductors. Temperature dependence of conductivity in semiconductors, Fermi Energy Significance: Metal-semiconductor contacts: Ohmic and Schottky contacts. Concepts of optical absorption and luminescence.
3.Nanomaterials and their electronic properties: Quantum Wells, Wires, and Quantum Dots, Preparation of quantum nanostructures, Size and dimensionality effects, Fermi-gas and density of states of nanomaterials, Potential wells, quantum confinement, excitons, single-electron tunneling.Size-dependent electronic properties in metals and semiconductors.
4. Carbon Nanomaterials: Various types of carbon nanomaterials, Zero dimensional (0D), 1D, and 2D Carbon nanomaterials, synthesis techniques, Characterizations, and properties for device applications. Electrical and Electronic properties of carbon nanotubes (SWNT and MWNT) and graphene.
5. Nano-scale device fabrications and characterizations: Lithography techniques: Photolithography, e-beam lithography, and nano-imprinter. Thin-film deposition techniques, nano-scale etching techniques, rapid thermal annealing (RTA). Scanning tunneling microscopy, Electrical and electronic characterizations, nano-magnetic characterizations.
6.Applications of nano-scale devices:Infra red-Detectors, Quantum dot lasers, Transistors (MOSFETs), CMOS devices, Photodetectors, Schottky-Junction Solar Cells, Thermoelectric coolers, Lab-on-chip devices, DNA detector sensors etc.

4. READINGS

4.1 TEXTBOOK:

1. Principles of Electrical Engineering Materials and Devices, S. O. Kasap
2. Introduction to Nanotechnology: C. P. Poole Jr. and F. J. Owens

4.2 *REFERENCE BOOKS::

1. Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications; Vladimir V. Mitin; Viatcheslav A. Kochelap; Michael A. Stroscio
2. Nanoelectronic Device Applications Handbook; by James E. Morris, Krzysztof Iniewski

1.1 TITLE:: Sensors and Actuators
1.2 *COURSE NUMBER (if known):: DE.MCR 532.15
1.3 CREDITS:: 11 (L-T-P : 3-1-0)
1.4 SEMESTER-OFFERED:: IX Semester

2. OBJECTIVE::

The main objective is to create a base of knowledge in the field of sensors and actuators. This base include suitable physical properties of materials used in sensor manufacturing, basic technologies of materials engineering. The knowledge is extended to possibilities to translate sensor and actuators categories to micro- and nanoscale. After course, students are able to design, prepare and testing a sensor structure.

3. COURSE TOPICS::

- A review of mains materials used in sensor and actuators manufacturing. Introduction to basic principal of micro sensors and actuators, Metals, semiconductors and dielectrics. Structural properties. Electric and magnetic properties.
- Sensor and actuators characteristics. Transfer function. Accuracy. Calibration. Nonlinearity. Hysteresis. Resolution. Environmental factors.
- Technologies in materials processing and engineering. Single crystal growth. Thin films deposition. Epitaxial growth. Photolithography, selective etching. Nanotechnologies in materials processing.
- Temperature sensors. Basic principles. Types. Temperature micro sensors. Thermal conduction sensors. Areas of thermal radiation nanosensors.
- Force and Pressure sensors. Physics of pressure measurement. Classification. MEMS technologies in pressure sensors. Piezoresistive sensors. Capacitive sensors.
- Gas sensors. Basics of operating. Manufacturing technologies. Materials used for various gases. Methods used in dimensionality decrease.
- Optical radiation sensors. Physics of optical radiation sensing devices. Technologies in micro- and nano-manufacturing. Optical sensors areas.
- Actuators. Classification. Physical principles of actuators., shape memory effects-one way, two way and pseudo elasticity. Types of micro actuators- Electrostatic, Magnetic, Fluidic, Inverse piezo effect, other principles. Actuators manufacturing. MEMS. Nanoactuators

4. READINGS

4.1 TEXTBOOK::

1. Charles Kittel, Introduction to solid state physics, 8-th edition, John Wiley and Sons, 2004.
2. Stephen Beeby, Graham Ensell, Michael Kraft, Neil White, MEMS Mechanical Sensors, 2004, ARTECH HOUSE, INC., Norwood.
3. Fraden, Jacob, Handbook of modern sensors: physics, designs, and applications–3rd ed., 2004, SpringerVerlag New York

4.2 *REFERENCE BOOKS::

- Fundamentals of Photonics, B. Saleh, John Wiley& Sons
- Fiber optic Sensors, E. Udd, John Wiley& Sons
- Selected papers in micro sensors, MEMS devices, smart materials and micro actuators.
- EAP Handbook, SPIE
- Mechanical Sensors, in semiconductor Sensors, B. Kloeck and N.F. de Rooji
- J. Judy, Ph.D. Thesis, Berkeley, 1996
- Feynman, et al., LEctures on Physics, Vol.2
- Microsystem Design, Santuria, Kluwer Academic, 2001

1.1 TITLE: Advanced Materials for Energy Devices
1.2 *COURSE NUMBER (if known):: DE.MCR 533.15
1.3 CREDITS:: 11 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED:: IX Semester

2. OBJECTIVE::

This course has been designed to expose the studentsfor gainingadvanced and applied level of knowledge in the fields of energy materials and devices. This comprehensive course will give a broad overview of both theoretical and applied knowledge on the energy materials, which will make them capable to produce fruitful results in reaching this country's energy demands.

3. COURSE TOPICS::

1. Overview: Energy need and goals for our environment, strategies for sustainable energy development, focus of greenhouse emission and present energy technology, global renewable energy needs and probable solutions. Scope and present status of Wind energy, geothermal energy and solar energy technologies and batteries.

2. Fundamental concepts: Introduction, types of energy devices, fundamental mechanism of energy devices, theoretical model and thermodynamic aspects of energy harvesting and storage.Advanced materials for alternative energy technology and future perspectives:

3. Materials for Energy Harvesting Devices:

3a. Solar energy harvesting materials:Solar Cells: principle of photovoltaic technology, thermodynamics, and their physical properties. Fundamental limits of photovoltaic, theoretical limits of solar-cells. Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiations. Photovoltaic cell materials,their processing and characterizations, abundant materials and low-cost fabrication strategies. Design and materials selection strategies for effective energy harvesting. Specific materials developments and different design aspectsfor covering wider window of solar spectrum,spectrum absorption criteria.

Principles of Si-solar cells, thin-film (chalcogenides and chalcopyrites) solar cells, multi-junction solar cells, Gratzel cells (Dye-sensitized solar cell) present status issues and challenges. Newly emerged other types of solar cells, including, quantum dot solar cells, plasmonic, and perovskite solar cells.

3b. Hydrogen Energy:Hydrogen economy: definition, scope, challenges and issues. Hydrogen production strategy; photochemical hydrogen generation, thermochemical water splitting cycles, industrial hydrogen generation process and materials challenges, hydrogen fuel, Fuel cells: definition and classifications, SOFC: present status, innovation and materials challenges. Solar fuel cells, photo-electrochemical energy harvesting.

4.Energy storage:Present storage technologies: capacitors, supercapacitor, pseudocapacitor and rechargeable batteries. The frontiers of energy storage research; history of development of Li-ion and Na-ion batteries, Futuristic batteries; all solid state batteries, flow through batteries, metal-air batteries and Li-S and Na-S batteries. Materials challenges and role of nanotechnology and materials engineering for improving battery performance.

4. READINGS

4.1 TEXTBOOK:

1. High-Efficiency Solar Cells: Physics, Materials, and Devices (Springer Series in Materials Science) Author: Xiaodong Wang and Zhiming M. Wang
2.Physics of Solar Cells: From Basic Principles to Advanced Concepts Author: Peter Würfel
3. Dye-sensitized Solar Cells by KuppuswamyKalyanasundaram
4. Energy Storage: Fundamentals, Materials and Applications by Robert Huggins
5. Lithium-Ion Batteries: Science and Technologies edited by Masaki Yoshio, Ralph J. Brodd, AkiyaKozawa
6. Hydrogen and Fuel Cells: Emerging Technologies and Applications By Bent Sørensen.

4.2 *REFERENCE BOOKS::

1.Handbook of Renewable Energy Technology By Ahmed F. Zobaa, Ramesh C. Bansal
2. Solar Cells: Materials, Manufacture and Operation By Augustin McEvoy, L. Castaner, Tom Markvart
3. Thin-Film Solar Cells: Next Generation Photovoltaics and Its Applications edited by Yoshihiro Hamakawa

1.1 TITLE:: Diffraction Methods for Solids
1.2 *COURSE NUMBER (if known):: DE.MCR 504.15
1.3 CREDITS:: 11 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED:: IX Semester

2. OBJECTIVE:

To understand the diffraction phenomenon in materials utilise it in characterization of materials and be aware of the limitations. This course is designed to make the students able to understand basics of diffraction theory and utilise in characterizing real samples (from sample preparation to data analysis) using X-ray or electron beam.

3. COURSE TOPICS:

X-ray Vs electron beam interaction with materials: Scattering, absorption and fluorescence. Concept of scattering and structure factor, Diffraction Theory: Kinematic and Dynamical theories, Basic crystallography: Symmetry elements, Point groups, Space groups. Concept of Reciprocal lattice.Stereographic projections.

X-ray diffraction methods: Single crystal and polycrystalline samples, thin films, layered structures and amorphous materials. Instrument settings: slits, masks, energy, detectors, Sample preparation and data collection strategies, Techniques for data analysis: Indexing of XRD pattern, Lattice Parameter calculation, Phase fraction determination, Crystallite size and strain analysis.

Resonant elastic X-ray scattering (REXS): method and application, Small angle X-ray scattering (SAXS): principle, instrument and applications, X-ray reflectivity: Basic Principle, film thickness and density calculations.

Electron diffraction Methods: Diffraction in TEM, Diffraction from crystals, small volumes, Thin films. Kikuchi diffraction, Convergent beam electron diffraction (CBED). Contrast due to diffraction: Origin of contrast due to Thickness variation, bending, strain fields.

4. READINGS

4.1 TEXTBOOK::

1. X-ray diffraction: In crystals, imperfect crystals and amorphous bodies – by A. Guinier
2. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition by Harold P. Klug, Leroy E. Alexander
3. Elements of X-Ray Diffraction (2014) by B.D. Cullity (Author), S.R. Stock (Author)
4. Elements of Modern X-ray Physics, 2nd Edition. by Jens Als-Nielsen and Des McMorrow
5. Transmission Electron Microscopy by D. B. Williams and C. Bary Carter

4.2 *REFERENCE BOOKS::

1. X-ray Diffraction by B.E. Warren (Dover Books on Physics)

1.1 TITLE: Advanced Thin-film Technologies
1.2 *COURSE NUMBER (if known):: DE.MCR 535.15
1.3 CREDITS:: 11 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED:: IX Semester

2. OBJECTIVE::

This comprehensive interdisciplinary course has been designed to expose studentsfor gainingadvanced and applied level of knowledge in thin-filmtechnologies and thin-film device systems. The integrated course will providea broad horizons of thin-film processing, properties and applications in electronic, photonic, bio and medical device applications.

3. COURSE TOPICS::

1. Fundamental of thin-film technologies: Introduction and terminologies, why thin-film is important compared to a bulk materials?Advanced quantum physics: conductors, semi-conductors, and insulators.Energy Bands and Density of States in various materials.Fermi-Dirac Statistics, concept of Fermi level, Fermi surfaces, and effective masses. Advanceconcepts of work function and contact potentials.Thermodynamic aspects of the thin-film technologies.Types of thin-films and their fundamental differences.

2.Advanced Thin-film Processing Techniques: Physical Techniques: Thermal Evaporation, E-beam evaporation, Spin Coating, Sputtering, Pulsed Laser Deposition, etc.

Chemical Techniques: Chemical Vapor Deposition, Epitaxial Growth, spray-pyrolysis, Langmuir–Blodgett film, electrophoresis, etc.

3.Development of Thin-film properties:Effect of deposition parameters for developing various properties of thin-films on different substrates, including, metal, dielectric substrates. Challenges in Ceramic Thin-Film developments.Concepts of multilayer thin-film deposition: challenges and perspectives.

3a.Thin-film defects: Role of processing techniques and fundamental problems in thin-film property evolutions. Stress development, peeling, adhesion problem, and other defects.

3b.Thin-film properties, including thermal properties, phonon transitions, electrical properties, surface scattering, optical properties, thin-film interference, mechanical properties, modulus, hardness, and surface roughness.

4.Characterization techniques of thin-films: Crystallography, Surface Roughness, Surface Morphologies, Thickness, Electrical Characterizations, Mechanical Characterizations, Optical interference.

5. Fabrications and characterizations of Thin-Film electronic devices: Lithography techniques: Photolithography, e-beam lithography, and nano-imprinter. Thin-film deposition techniques, nano-scale etching techniques, rapid thermal annealing (RTA).Scanning tunneling microscopy, Electrical and electronic characterizations, nano-magnetic characterizations.

6.Applications of thin-film: Device applications includingIR-Detectors,thin-film Transistors (BJTs, FET, MOSFETs), MEMS/NEMS, nano-resonators, complementary metal-oxide semiconductor devices, thin-film photodetectors and remote sensing, Thin-film solar cells, Thin-filmbio-sensors, Wear resistant thin films, Thin films for high temperature applications.

4. READINGS

4.1 TEXTBOOK:

1. Handbook of Thin Film Materials: Deposition and processing of thin films, Volume 1, Author: Hari Singh Nalwa
2. Materials Science of Thin Films By Milton Ohring
3. Fundamentals of Microfabrication: The Science of Miniaturization, Second EditionBy Marc J. Madou

4.2 *REFERENCE BOOKS::

1. Handbook of Thin Film Technology edited by Hartmut Frey, Hamid R Khan
2. Principles of Electrical Engineering Materials and Devices, S. O. Kasap
3. Thin-Film Deposition: Principles and PracticeBy: Donald Smith
4.Thin Film Materials Technology: Sputtering of Compound MaterialsByKiyotakaWasa, Makoto Kitabatake, Hideaki Adachi

1.1 TITLE::	Materials for Biomedial Applications
1.2 *COURSE NUMBER (if known)::	DE.MCR 536.15
1.3 CREDITS::	11 (L-T-P : 3-0-0)
1.4 SEMESTER-OFFERED::	IX Semester

2. OBJECTIVE::

In view of the fact that the development of materials for human healthcare applications is one of the most stimulating interdisciplinary research areas, the primary focus of this course is to provide fundamental understanding for the selection, design/development and application for such potential biomaterials in orthopedics, starting from concept towards the realization of their clinical implications.

3. COURSE TOPICS::

Introduction to the fundamental aspects of biomaterials; property requirement for typical biomaterials and concept of biocompatibility;

Design concept of developing new materials for bio-implant applications; Composites as biomaterials; Compatibility issues of implant with the host tissues.

Metallic implants: Ti-based, stainless steels, Co-Cr-Mo alloys; Bioinert, bioactive and bioresorbable ceramics; Processing and properties of different bioceramic materials, Orthopedic applications; Selection and design of implant materials;

The role of adsorbed proteins in tissue response to biomaterials; Cells, tissues, extracellular matrix; Cellular adaptation processes; Cell-biomaterial interaction, Fundamental of biomaterials testing: *In vitro* and *In vivo* assessment;

Introduction to electric phenomenon in cells, their interaction with external electric field and its implication to the various cellular adaptation processes.

4. READINGS

4.1 TEXT BOOK::

4.2 *REFERENCE BOOKS::

1) Ratner B D, Hoffman A S, Schoen F J, Lemons J E, Biomaterials Science: An Introduction to Materials in Medicine, Second Edition, Elsevier Academic Press, 2004.

2) Silver F H, Christiansen D L, ‘Biomaterials Science and Biocompatibility’, Springer-Verlag, New York,1999.

3) Black J, ‘Biological Performance of Materials: Fundamentals of Biocompatibility’, 3rd edition, Marcel Dekker, Inc, New York, 1999.

4) J.B. Park and R.S. Lakes, Biomaterials: An Introduction, Platinum Press, New York, 1992.