DEPARTMENT OF CERAMIC TECHNOLOGY

ANNA UNIVERSITY, CHENNAI – 600 025

VISION:

Our vision is to become a prime centre of excellence in imparting knowledge, nurturing cutting-edge research, driving best practices, and fostering technological innovations in the fields of ceramic science and technology.

MISSION:

- To empower the student community through strong academic curriculum balanced with pioneering research and industrial collaborations.
- To nurture technically competent talents by augmenting the potential of traditional & advanced ceramics to promote entrepreneurship, technology transfer and contribute to the attainment of sustainable future.
- To support the development of Ceramic Technologists possessing depth of character and social responsibility with values and integrity
- To develop a processing and testing Centre for Excellence to cater the needs of ceramics and allied industries globally.

ANNA UNIVERSITY, CHENNAI:600 025
UNIVERSITY DEPARTMENTS
REGULATIONS – 2023
M.TECH. CERAMIC TECHNOLOGY
CHOICE BASED CREDIT SYSTEM

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

i. Expertise in advanced engineering concepts and relevant technology to design and conduct independent research.
ii. Ability to critically evaluate and contribute to scholarly discourse in the field of ceramics through research articles and publications.
iii. Competent to troubleshoot complex issues by analysing information from multiple sources and propose innovative solution/insights.
iv. Exhibit advanced level of technical and practical skills with ethical conduct, professional behaviour, and effective communication.
v. Innovation skills with interdisciplinary collaboration to develop new venture for a sustainable future.

PROGRAMME OUTCOMES (POs):

After going through the two years of study, our Ceramic Technology Postgraduates will exhibit ability in:

PO	Programme Outcomes
1.	An ability to independently carry out research/ investigation and development to solve practical problems
2.	An ability to write and present a substantial technical report/ document
3.	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the programme. The mastery should be at a level higher than the requirements in the appropriate bachelor programme.
4.	Amalgamate and execute the acquired knowledge and experience for better understanding of the core discipline
5.	Accomplish and articulate the skills, knowledge and understanding confidently to develop new products and processes with cutting edge technology
6.	Ensure competence to make a prospective career in Industry and Academia by inculcating the analytical ability, research aptitude and skills for social and professional life

MAPPING OF PROGRAMME EDUCATIONAL OBJECTIVE WITH PROGRAMME OUTCOMES

PROGRAMME EDUCATIONAL OBJECTIVES	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
I	3	2	2	3	3	3
II	3	2	3	3	3	3
III	3	2	3	3	3	3
IV	3	3	3	3	3	3
V	3	3	3	3	3	3

MAPPING OF COURSE OUTCOMES AND PROGRAMME OUTCOMES

Year	Sem	Course Title	Program Outcomes					
			PO1	PO2	PO3	PO4	PO5	PO6
FIRST	I	Structure Property Relation of Materials	3	-	3	3	3	2
		Research Methodology and IPR						
		Oxide and Non Oxide Materials	2,4	-	2.4	2.4	2.4	2
		Science of Ceramic Processing	2.2	-	2.2	2.2	2.2	2
		High Temperature Processes in Ceramics	2.4	-	2.4	2.4	2.4	2
		Microstructural Evolution and its Characterization	2.4	-	2.4	2.4	2.4	2
		Testing and Property Evaluation Laboratory	3	3	3	3	3	2
		Ceramic Processing Laboratory	3	3	3	3	3	2
	II	Advanced Material Characterization Techniques	2.4	-	2.4	2..4	2.4	2
		Whitewares Production and Practices	2.8	-	2.8	2.8	2.8	2
		Strategic Applications in Ceramics	2.6	-	2.6	2.6	2.6	2
		Fracture Mechanics in Brittle Materials	2.8	-	2.8	2.8	2.8	2
		Professional Elective I						
		Professional Elective II						
		Advanced Material Characterization Laboratory	3	3	3	3	3	2
		Whiteware Laboratory	3	3	3	3	3	2
SECOND	III	Product Design, Development and Sustainability	2.6	2.6	2.6	2.6	2.6	2
		Professional Elective III						
		Professional Elective IV						
		Product Design and Development Laboratory	3	3	3	3	3	2
		Internship/ Training (2 weeks during summer)	3	3	3	3	3	2
		Project Work I	3	3	3	3	3	2
	IV	Project Work II	3	3	3	3	3	2

1, 2 and 3 are correlation levels with weightings as Slight (Low), Moderate (Medium) and Substantial (High) respectively

ANNA UNIVERSITY, CHENNAI
UNIVERSITY DEPARTMENTS
REGULATIONS – 2023
M.TECH. CERAMIC TECHNOLOGY
CURRICULA AND SYLLLABI FOR I TO IV SEMESTER

SEMESTER I

S. NO.	COURS ECODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	CR3101	Structure Property Relation of Materials	FC	3	0	0	3	3
2.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
3.	CR3102	Oxide and Non oxide Materials	PCC	3	0	0	3	3
4.	CR3103	Science of Ceramic Processing	PCC	3	0	0	3	3
5.	CR3104	High Temperature Processes in Ceramics	PCC	3	0	0	3	3
6.	CR3105	Microstructural Evolution and its Characterization	PCC	3	0	0	3	3
PRACTICALS								
7.	CR3111	Testing and Property Evaluation Laboratory	PCC	0	0	4	4	2
8.	CR3112	Advanced Ceramic Processing Laboratory	PCC	0	0	4	4	2
			TOTAL	**17**	**1**	**8**	**26**	**22**

SEMESTER II

S. NO.	COURS ECODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	CR3201	Advanced Material Characterization Techniques	PCC	3	0	0	3	3
2.	CR3202	Whitewares Production and Practices	PCC	3	0	0	3	3
3.	CR3203	Strategic Applications in Ceramics	PCC	3	0	0	3	3
4.	CR3204	Fracture Mechanics in Brittle Materials	PCC	3	0	0	3	3
5.		Professional Elective I	PEC	3	0	0	3	3
6.		Professional Elective II	PEC	3	0	0	3	3
PRACTICALS								
7.	CR3211	Advanced Material Characterization Laboratory	PCC	0	0	4	4	2
8.	CR3212	Whiteware Laboratory	PCC	0	0	4	4	2
			TOTAL	**18**	**0**	**8**	**26**	**22**

SEMESTER III

S. NO.	COURS ECODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	CR3301	Product Design, Development and Sustainability	PCC	3	0	0	3	3
2.		Professional Elective III	PEC	3	0	0	3	3
3.		Professional Elective IV	PEC	3	0	0	3	3
PRACTICALS								
4.	CR3311	Product Design and Development Laboratory	PCC	0	0	4	4	2
5.	CR3312	Internship/ Training (4 weeks during summer)	EEC	0	0	0	0	2
6.	CR3313	Project Work I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**16**	**25**	**19**

SEMESTER IV

S. NO.	COURS ECODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	CR3411	Project Work II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL NO. OF CREDITS:75

PROFESSIONAL CORE COURSES

S.NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1	CR3102	Oxide and Non oxide Ceramics	PCC	3	0	0	3	3
2	CR3103	Science of Ceramic Processing	PCC	3	0	0	3	3
3	CR3104	High Temperature Processes in Ceramics	PCC	3	0	0	3	3
4	CR3105	Microstructural Evolution and its Characterization	PCC	3	0	0	3	3
5	CR3111	Testing and Property Evaluation Laboratory	PCC	0	0	4	4	2
6	CR3112	Advanced Ceramic Processing Laboratory	PCC	0	0	4	4	2
7	CR3201	Advanced Material Characterization Techniques	PCC	3	0	0	3	**3**
8	CR3202	Whitewares Production and Practices	PCC	3	0	0	3	**3**
9	CR3203	Strategic Applications in Ceramics	PCC	3	0	0	3	**3**
10	CR3204	Fracture Mechanics in	PCC	3	0	0	3	**3**

		Brittle Materials						
11	CR3211	Advanced Material Characterization Laboratory	PCC	0	0	2	4	**2**
12	CR3212	Whiteware Laboratory	PCC	0	0	2	4	**2**
13	CR3111	Product Design, Development and Sustainability	PCC	3	0	0	3	**3**
14	CR3112	Product Design and Development Laboratory	PCC	0	0	4	4	**2**

PROFESSIONAL ELECTIVES COURSES

S.NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1	CR3001	Ceramic Additive Manufacturing	PEC	3	0	0	3	3
2	CR3002	Advanced Carbon Materials	PEC	3	0	0	3	3
3	CR3003	Bio-ceramic materials and their applications	PEC	3	0	0	3	3
4	CR3004	Ceramic Coating Technology	PEC	3	0	0	3	3
5	CR3005	Ceramic Fuel Cell	PEC	3	0	0	3	3
6	CR3006	Ceramic Membranes and its Applications	PEC	3	0	0	3	3
7	CR3007	Ceramic Composites	PEC	3	0	0	3	3
8	CR3008	Design and Selection of Abrasives	PEC	3	0	0	3	3
9	CR3009	Glass Science and Technology	PEC	3	0	0	3	3
10	CR3010	Rare Earth Ceramics	PEC	3	0	0	3	3
11	CR3011	Refractory Engineering	PEC	3	0	0	3	3
12	CR3012	Tribology in Ceramics	PEC	3	0	0	3	3

FOUNDATION COURSE

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1	CR3101	Structure Property Relations of Materials	FC	3	0	0	3	3

RESEARCH METHODOLOGY COURSE

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3

EMPLOYABILITY ENHANCEMENT COURSES

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1	CR3312	Internship/ Training (4 weeks during summer)	EEC	0	0	0	0	2
2	CR3313	Project Work I	EEC	0	0	12	12	6
3	CR3411	Project Work II	EEC	0	0	24	24	12

SUMMARY

	Name of the Programme: M.TECH						
	SUBJECT AREA	**CREDITS PER SEMESTER**				**CREDITS TOTAL**	**CREDITS %**
		I	**II**	**III**	**IV**		
1.	FC	3	-	-	-	3	4
2.	PCC	16	16	5	-	37	49
3.	PEC		6	6	-	12	16
4.	RMC	3	-	-	-	3	4
5.	EEC	-	-	8	12	20	27
6.	**TOTAL CREDIT**	**22**	**22**	**19**	**12**	**75**	**100**

CR3101 STRUCTURE PROPERTY RELATION IN MATERIALS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To give a comprehensive exposure to the crystal classes, structure and property relation in materials
2. To gain knowledge on the dependence of the structure on electronic, mechanical, thermal, magnetic and optical properties

UNIT I SYMMETRY AND CRYSTAL PHYSICS 9

Crystal classes, space groups, symmetry distribution of crystals, bond length calculations, density, physical properties, symmetry of physical properties, tensors, magnetic symmetry

UNIT II ELECTRONIC TRANSPORT IN MATERIALS 9

Atomic orbitals, molecular orbitals and energy bands, electronic materials, semiconductors, bandgap and mobility, semiconductor doping, semimetals and narrow gap semiconductors, magnetic semiconductors, molecular circuits, metal – metal bonding, anisotropic semiconductors, superconductivity

UNIT III MECHANICAL PROPERTIES 9

Elasticity, mechanical analog, elastic anisotropy, pressure dependence of the elastic stiffness, temperature dependence of the elastic stiffness, temperature compensated materials, surface wave materials, molecular geometry and molecular flexibility, hardness, grinding and polishing, friction and wear, dislocations and plastic deformation, hard metals, cleavage, brittle fracture, toughness.

UNIT IV THERMAL PROPERTIES AND ION TRANSPORT 9

Lattice vibrations, thermal properties, thermal conductivity, ultrasonic attenuation, thermal expansion, diffusion, ionic conductivity, ionic switches, superionic conductors, solid state battery materials, photographic process, thermoelectric materials

UNIT V MAGNETIC AND OPTICAL PROPERTIES 9

Magnetic – Diamagnetism, transition metal atoms, crystal field theory, paramagnetic salts, transition temperatures, magnetization, crystalline anisotropy, hard and soft magnets, bubble memories, microwave garnets, magnetooptic materials, magnetoelectricity

Optical – Luster, birefringence and crystal structure, optical windows, color, crystalline lasers, semiconductor lamps, luminescence, cathodochromic and photochromic materials, optical activity, photoelasticity, non linear optical materials

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Interpret the relation between the structure and property of the materials.
CO2 Demonstrate the electronic behaviour of the materials with structural modifications
CO3 Apply the concepts for solving designing structural components
CO4 Implement the knowledge on the structure property relationship with temperature
CO5 Solve the materials problem based on the structure property relationship under a magnetic field and light

REFERENCES

1. William F.Smith, "Foundations of Materials Science and Engineering" McGraw Hill Book Company, Sixth Edition, 2019.
2. William D Callister Jr, David D Rethwisch, “Materials Science & Engineering – An Introduction”, Eighth Edition, John Wiley & Sons, 2010.
3. Raghavan,V., “Materials Science and Engineering”, Prentice Hall India, New Delhi. 1982.

4. Saxena, B.S., R.C. Gupta and P.N. Saxena, “Fundamentals of Solid State Physics”, Pragathi Pragasan, Meerut., 1988.
5. Yet - Ming Chiang, "Physical Ceramics - Principles for Ceramic Science and Engineering", John & Willey Sons Inc., 1997.
6. Schewmon, P.G. “Diffusion of Solids”, McGraw- Hill Book Company, New York, 1963.
7. Bergeron, C.G., and S.H.Risbud, “Introduction to Phase Equilibria in Ceramics”, Am. Ceram.Soc, Inc., Westerwile Ohio, USA. 1984.
8. Arzamasov, B., “Materials Science”, Mir Publishers, Moscow 1989.
9. Weidmann, G., P.Lewis and N.Reid, “Structural Materials”, Butterworths, London 1990.

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**3**	**-**	**3**	**3**	**3**	**2**

RM3151 RESEARCH METHODOLOGY AND IPR L T P C
2 1 0 3

COURSE OBJECTIVES:

To impart knowledge on

- Formulation of research problems, design of experiment, collection of data, interpretation and presentation of result
- Intellectual property rights, patenting and licensing

UNIT I RESEARCH PROBLEM FORMULATION 9

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II RESEARCH DESIGN AND DATA COLLECTION 9

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV INTELLECTUAL PROPERTY RIGHTS 9

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V PATENTS 9

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

TOTAL: 45 PERIODS

COURSE OUTCOMES

Upon completion of the course, the student can

CO1: Describe different types of research; identify, review and define the research problem

CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data

CO3: Explain the process of data analysis; interpret and present the result in suitable form

CO4: Explain about Intellectual property rights, types and procedures

CO5: Execute patent filing and licensing

REFERENCES:

1. Cooper Donald R, Schindler Pamela S and Sharma JK, "Business Research Methods", Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, "Research methodology for natural sciences", IISc Press, Kolkata, 2022,
3. Catherine J. Holland, "Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets", Entrepreneur Press, 2007.
4. David Hunt, Long Nguyen, Matthew Rodgers, "Patent searching: tools & techniques", Wiley, 2007.
5. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, "Professional Programme Intellectual Property Rights, Law and practice", September 2013.

CR3102	OXIDE AND NON OXIDE MATERIALS	L	T	P	C
		3	0	0	3

COURSE OBJECVES

1 To understand to various ceramic raw materials used in the manufacture of traditional and engineered ceramics.

2 To understand and familiarize with the structure, characteristics and properties of ceramic materials used in the manufacture of ceramic products

UNIT I OXIDE CERAMICS 9

Structure, sources, types and properties - Silicate ceramics, Fluxes, Fillers; Triaxial formulations – clay - quartz - feldspar, clay – alumina – feldspar, clay – zircon – feldspar, pyrophyllite and talc-based formulations, clay – wollastonite – nepheline syenite; Structure, Sources, Production and Properties – Magnesia, alumina, zirconia – polymorphism, binary zirconia alloys, ZTA composites.

UNIT II NITRIDE CERAMICS 9

Transition metal nitrides, silicon nitride – structure, types, reaction bonding process, reaction mechanism, formation routes, role of additives, phase relationships, microstructure and effects on properties; Sialons – types, structure, formations; silicon oxynitride – structure, properties; oxynitride glass and glass ceramics – solubility of nitrogen in glasses, sialon glasses, nitrogen coordination in oxynitride glass structures, nucleation and crystal structure; Aluminium nitride – structure, synthesis, fabrication and properties; Aluminium oxynitride –

structure, phase relation, formation and properties, boron nitride, future potential of nitride ceramics.

UNIT III CARBIDE CERAMICS 9

Chemical bonding and crystal chemistry – chemical bonding of carbides, structure of boron carbides and isotypic compounds, structure and polytypes of silicon carbide, structure of transition metal carbides, Phase systems – binary phase systems containing carbides – B-C, Si-C, Ti-C, W-C, other transition metal carbon systems; Preparation - technical scale production, high purity material, organometallic precursors, polytype formation during synthesis; Sintering behaviour, microstructural reinforcement.

UNIT IV BORIDE CERAMICS 9

Chemical bonding of borides, crystal structures of borides, AlB_2 type structures; Binary phase diagrams containing borides – Ti-B, Zr-B, other transition metal – boron systems; Preparation – technical scale, high purity material, transition metal borides; Sintering behaviour, microstructural reinforcement.

UNIT V GLASS CERAMICS 9

Introduction, Nucleation and crystallization of glass ceramics – theoretical considerations, practical considerations; Classification by chemical composition – silicate glass ceramics, aluminosilicate glass ceramics, fluorosilicate glass ceramics, phosphate glass ceramics, oxide glass ceramics; Microstructure – dendritic, ultrafine grained, cellular membrane, relict, house of cards, acicular interlocking, coast and island, lamellar-twinned.

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify the different class of ceramic materials for a particular application
CO2 Recognize and locate the materials for a particular application
CO3 Interpret the structure and properties of the ceramic materials
CO4 Apply the acquired knowledge to develop new materials for specific applications
CO5 Implement the knowledge and understanding gained to design and develop new products

REFERENCES

1. John G.P.Binner (Ed), "**Advanced Ceramics Processing and Technology**", NoyesPublications, New Jersey, 1990.
2. Octave Levenspiel, "**Chemical Reaction Engineering**", John Wiley & Sons, 1999
3. Burtrand Lee and Sridhar Komarnei (Eds.), "**Chemical Processing of Ceramics"**, 2ndEdn., Taylor & Francis, 2005
4. Terry A.Ring, **Fundamentals of Ceramic Powder Processing and Synthesis,** AcademicPress, 1979.
5. Alan G. King, **Ceramic Technology and Processing**, Noyes Publications, 200

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3103 **SCIENCE OF CERAMIC PROCESSING**

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To understand the main processes and technologies involved in the preparation of ceramic powders
2. To understand the critical importance of ceramic processing and technologies used in the manufacture of ceramic products.

UNIT I PREPARATION OF POWDERS AND NANOPOWDERS 9

Introduction, powder characteristics, powder preparation by mechanical methods, high compression roller mills, jet mills, ball mills – tumbling ball mills, vibratory ball mills, attrition mills, planetary ball mills; high energy ball milling, synthesis of nanoparticles – solid – solid methods, solid-vapor-solid method, liquid-solid method, liquid -vapor-solid method.

UNIT II POWDER SYNTHESIS BY CHEMICAL METHODS 9

Introduction, Solid state reaction – decomposition, reactions between solids, reduction; Precipitation from liquid solutions – principles of precipitation from solution, method for preparing powders by hydrolysis, precipitation methods based on evaporation of the liquid; Freeze drying, Gel routes – sol gel processing, Pechini method, citrate gel method, glycine nitrate process; Non aqueous liquid reaction, Vapor phase reactions – gas-solid reaction, reaction between gases.

UNIT III FORMING OF CERAMICS BY CONVENTIONAL METHODS 9

Introduction, Dry or semidry pressing – die compaction, isostatic compaction; Suspension based techniques – slip casting, pressure casting, tape casting, centrifugal consolidation, dip and spin coating, electrophoretic deposition, freeze casting, gel casting, direct coagulation casting, aqueous injection molding; Plastic forming methods – extrusion, coextrusion, injection molding.

UNIT IV FABRICATION METHODS FOR SPECIFIC SHAPES 9

Introduction, atomistic deposition processes – physical vapour deposition – evaporation process, sputter deposition process; chemical vapor deposition process – thermally assisted CVD, plasma assisted CVD, photo CVD, spray pyrolysis; Fabrication routes for ceramic composites – powder-based methods – sintering, hot pressing, HIPing, hot forming, reaction processing: Non powder based methods – polymer pyrolysis, chemical vapor deposition/chemical vapor infiltration, melt processing

UNIT V ADDITIVE MANUFACTURING 9

Introduction, Comparison of additive manufacturing with other manufacturing process, methodology, advantages, limitations, sustainability; classification – powder methods – selective laser sintering, three-dimensional printing, particle filled polymer methods – fused deposition modelling, laminated object manufacturing, suspension base methods – stereolithography, inkjet printing, robocasting, freeze extrusion fabrication; post processing

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify the key features pertaining to the powder processing techniques
CO2 Design and describe the basic processing routes suitable for the forming of specific types of ceramic products
CO3 Identify the potential processing problems and its prevention
CO4 Predict and explain the effect of processing conditions in material development
CO5 Solve and undertake design in the areas of ceramic processing

REFERENCES

1. Mohamed N.Rahaman, “Ceramic Processing”, Taylor & Francis, 2007.
2. David W. Richerson, “Modern Ceramic Engineering”, 3rd Edition, Taylor & Francis, 2005.
3. John G.P.Binner (Ed), “Advanced Ceramics Processing and Technology”, Noyes Publications, New Jersey, 1990.
4. Octave Levenspiel, “Chemical Reaction Engineering”, John Wiley & Sons, 1999
5. Burtrand Lee and Sridhar Komarnei (Eds.), “Chemical Processing of Ceramics”, 2nd Edn., Taylor & Francis, 2005
6. Terry A.Ring, Fundamentals of Ceramic Powder Processing and Synthesis, Academic Press, 1979.
7. Alan G. King, Ceramic Technology and Processing, Noyes Publications, 2002

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	2	-	2	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.2**	**-**	**2.2**	**2.2**	**2.2**	**2**

CR3104 HIGH TEMPERATURE PROCESSES IN CERAMICS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- To impart knowledge on the concepts of sintering
- To gain adequate knowledge on the different sintering mechanisms and processes
- To address the processing variables for sintering specific products

UNIT I CONCEPTS OF SINTERING 9

Introduction, sintering process, driving force for sintering – surface curvature, applied pressure, chemical reaction; Defects in crystalline solids – point defects and defect chemistry, Kroger-Vink notation, defect reaction, defect concentration, intrinsic defects, extrinsic defects, defect chemistry and sintering; Diffusion in crystalline solids - diffusion equations, mechanism of diffusion; chemical potential, diffusional flux equations – flux of atoms, flux of vacancies; diffusion in ionic crystals – ambipolar diffusion.

UNIT II SOLID STATE AND VISCOUS SINTERING 9

Introduction, mechanism of sintering, effect of grain boundaries, theoretical analysis of sintering, Herring’s Scaling Law; Analytical models – stages of sintering, modelling the sintering process, initial stage models, intermediate stage models, final stage models; Phenomenological sintering equations, sintering diagrams, sintering with an externally applied pressure, stress intensification factor and sintering stress, measurements.

UNIT III LIQUID PHASE SINTERING 9

Introduction, Elementary features of liquid phase sintering, stages of liquid phase sintering, thermodynamic and kinetic factors, grain boundary films, basic mechanism – rearrangement and liquid distribution, solution precipitation, Ostwald ripening; Hot pressing with a liquid phase, Use of phase diagrams in liquid phase sintering, activated sintering, vitrification – controlling parameters, vitrification of silicate systems.

UNIT IV PROCESS VARIABLES AND SINTERING PROCESS 9

Introduction, sintering measurement techniques – furnace, shrinkage and density, grain size; conventional sintering – particle and green compact effects, anisotropic sintering shrinkage, heating schedule, sintering atmosphere, controlled sintering atmosphere; Microwave sintering – interaction of microwaves with matter, microwave sintering techniques, microwave sintering of ceramics, plasma sintering, plasma assisted sintering; Pressure assisted sintering – hot pressing, sinter forging, hot isostatic pressing.

UNIT V SPECIFIC SINTERING PROCESS 9

Introduction, In homogeneities and their effects on sintering, Constrained sintering I – rigid inclusions – volume fraction of inclusions, densification rate of the composite and the matrix, rule of mixtures, transient stresses during sintering, percolation and network formation, factors influencing the sintering of ceramic composites; Constrained sintering II – adherent thin films, Constrained sintering III – multilayers, Constitutive models for porous sintering models, solid solution additives and the sintering of ceramics, sintering with chemical reaction, viscous sintering with crystallization.

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify the basic concepts of sintering process
CO2 Understand the stages of sintering and micromechanics
CO3 Differentiate the different types of sintering mechanism
CO4 Interpret the processing variables to achieve good sinter ability
CO5 Implement the concepts and the process variables in the development of new products with good sintering characteristics

REFERENCES

1. Suk-Joong L.Kang, “Sintering Densification, Grain Growth, and Microstructure”, Elsevier, 2005.
2. Mohamed N. Rahaman, “Sintering of Ceramics”, CRC Press, 2007.
3. R.M. German, “Liquid Phase Sintering”, Springer, 1985.
4. Mohamed N. Rahaman, “Ceramic Processing and Sintering”, Taylor & Francis Group, 2003.
5. Zhigang Zak Fang, “Sintering of Advanced Materials – Fundamentals and Processes” Woodhead Publications, 2010
6. Randall M German, Gary L Messing, Robert G Cornwall, “Sintering Technology”, Marcel Dekker, 1996
7. Mohammed N Rahaman, “Ceramic Processing and Sintering”, CRC Press, 2003.

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3105 MICROSTRUCTURAL EVOLUTION AND ITS CHARACTERIZATION L T P C
3 0 0 3

COURSE OBJECTIVES

- To impart knowledge and understanding on the various parameters involved in the control of microstructure development.
- To develop in depth knowledge on the concepts of microstructural targets and the different microstructures obtained during densification.
- To familiarize the microstructures of green and fired body and the characterization techniques.

UNIT I GRAIN GROWTH AND MICROSTRUCTURE CONTROL 9

Introduction, general features of grain growth, Ostwald ripening – The LSW theory, modifications to the LSW theory, Time dependent Ostwald ripening; Topological and Interfacial tension requirements, normal grain growth in dense solids, abnormal grain growth in dense solids, grain growth in thin films, mechanisms controlling the boundary mobility, grain growth and pore evolution in porous solids, kinetics and mechanism of grain growth in porous solids, simultaneous densification and grain growth, fabrication principles for ceramics with controlled microstructure.

UNIT II CERAMIC MICROSTRUCTURES 9

Introduction, bulk microstructural features – grain size, shape and growth, connectivity, boundary layers and inclusions, porosity and density; Interfaces and planar defects – grain boundaries and domain boundaries, heterogenous interfaces, stacking fault and twins; Dislocations, Methods of phase identification – phase distribution, crystal structure of phases, chemical composition of phases; Stereology of phase identification – grain size and mean lineal intercept, volume fraction of phases.

UNIT III MICROSTRUCTURAL TARGETS 9

Introduction – controlled porosity – macroporous body, microporous body, mesoporous body;
mechanical strength at room temperature – Young's modulus (effect of porosity), size of flaw;
fracture energy – resistance to high temperature deformation – resistance to thermal shock – hardness and wear resistance – thermal conductivity – thermal expansion – optical functions – specific electrical functions – magnetic functions – resistance to corrosion - joinability.

UNIT IV GREEN MICROSTRUCTURE AND ITS CHARACTERIZATION 9

Introduction – structure of green bodies – definition, green bodies in ceramic processing, microstructure, macrostructure and texture, homogenous green material: structure of particle packing – packing of spherical particles of uniform sizes, bimodal stacking of spherical particles, sol gel structures, hierarchical cluster packing, measureable quantities, processing technology in relation to green structures; characterization methods – types of green bodies and usability of characterization techniques.

UNIT V FIRED MICROSTRUCTURE AND ITS CHARACTERIZATION 9

Introduction – characterization techniques; defect containing microstructures – processing defects, high temperature defects; tough ceramic microstructures – process zone toughening
mechanism, bridging zone toughening mechanism; novel microstructures and processing methods – fibrous monolithic ceramics, duplex bimodal structures; processing techniques involving metallic precursors - reaction bonding, direct metal oxidation, co-continuous ceramic composites; microstructures formed by controlled nucleation – model ceramic microstructures – electronic and optical ceramic microstructures.

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify and recognize the development of microstructures during ceramic processing

CO2 Classify the microstructures based on the processing conditions

CO3 Ability to relate the microstructure with the properties of the materials

CO4 Implement the concepts of microstructure to achieve enhanced properties in designing new materials

CO5 Solve problems related to microstructure development in order to achieve better properties

REFERENCES

1. Jon G P Binner, "Advanced Ceramic Processing and Technology", Vol I, Noyes Publications, 1990.
2. R J Brook “Processing of Ceramics”, Wiley – VCH Verlag Gmbh & Co, 1996.
3. Mohamed N. Rahaman, Ceramic Processing, Taylor & Francis Group, 2003.
4. R.A. Terpstra, P.P.A.C. Pex and A.H. De Vries, Ceramic Processing, Springer Science Business media, B.V,1995.
5. Terry A. Ring, Fundamentals of Ceramic Powder Processing and Synthesis, Academic Press, 1979.
6. Alan G. King, Ceramic Technology and Processing, Noyes Publications, 2002.
7. Robert W. Cahn, R.J. Brook, Materials Science and Technology, VCH, 1996.
8. Gary L. Messing, Fred F. Lange, Shin-Ichi-Hirano, Ceramic Processing Science, American ceramic society, 1998

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3111 TESTING AND PROPERTY EVALUATION LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES

- To provide a broad understanding on the structure – property evaluation of materials that stresses scientific reasoning and problem solving.
- To expose the students to a breadth of experimental techniques to evaluate the properties of the materials.
- To develop the students to interpret the results with scientific knowledge

LIST OF EXPERIMENTS

1. To determine the elastic constant using static and dynamic methods.
2. To determine the fracture toughness using three point bending test
3. To determine the compressive strength of the samples prepared by different sintering routes.
4. To determine the hardness of the sample using Vicker’s Hardness Tester
5. To determine the hardness and Young’s Modulus of the sample using Nanoindenter
6. To determine the thermal conductivity of the sample.
7. To measure the thermal shock resistance of the sample.

8. To determine the ionic conductivity of the YSZ and doped YSZ sample using LCR Meter
9. To determine the wear resistance of the composite material using Pin on Disc Wear Tester
10. To study the B-H Characteristics of the given sample.
11. To study the band gap of the sample using band gap equipment.

TOTAL: 60 PERIODS

EQUIPMENTS

1. Universal Testing Machine
2. Vicker's Hardness Tester
3. Nanoindenter
4. Thermal conductivity Equipment
5. Pin on Disc Equipment
6. Band Gap Equipment
7. LCR Meter

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Implement the core concepts of property evaluation in engineering design and product development.

CO2 Interpret the results and solve the design problems using the acquired experimental skill and knowledge

CO3 Apply the skills gained for future research

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	**3**	**3**	**3**	**3**	**3**	**2**

CR3112 ADVANCED CERAMIC PROCESSING LABORATORY **L T P C**
0 0 2 1

COURSE OBJECTIVES

- To expose the students to a breadth of experimental techniques to process the materials.
- To develop the students to interpret the results with scientific knowledge

EXPERIMENTS

1. Sol Gel Processing
   a. Processing Method
   b. Controlling particle size
   c. Determination of microstructure
2. Solid State Processing
   a. Processing Method
   b. Controlling grain size and porosity
3. Solution Processing
   a. Processing method
   b. Control Parameters
4. Co-precipitation
   a. Processing Methods

b. Control Parameters
5. Hydrothermal Method
    a. Processing Method
    b. Control Parameters
6. Microwave Synthesis
    a. Processing Method
    b. Control Parameters
7. Advanced Ceramic Processing
    a. Preparation of Ceramic Foams
    b. 3D Printing

EQUIPMENTS REQUIRED

1. Particle Size Analyzer
2. Microwave Furnace
3. Hydrothermal Instrument
4. Kappa 3D Printer
5. High Energy Ball Mill

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Implement the core concepts of processing in engineering design and product development.

CO2 Interpret the results and solve the design problems using the acquired experimental skill and knowledge

CO3 Apply the skills gained for future research

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	**3**	**3**	**3**	**3**	**3**	**2**

CR3201 ADVANCED MATERIAL CHARACTERIZATION TECHNIQUES LT PC
3 0 0 3

COURSE OBJECTIVES

- Introduce the fundamental technological principles and applications of advanced characterization techniques.
- Explain and correlate the structure property relationship of materials by different characterization techniques
- Gain knowledge and understanding on the characterization techniques and apply the concepts in new material development

UNIT I THERMAL ANALYSIS 9

Principles of Thermogravimetric analysis (TGA), Differential thermal analysis (DTA), differential scanning calorimetry (DSC), Dilatometer - their applications in processing and characterization of ceramics, glasses, and glass ceramics.

UNIT II X – RAY DIFFRACTION 9

Characteristics of X – rays - Fundamental principles of X-ray diffraction (XRD) - Bragg's Law - Determination of crystal Structure and particle size from XRD - Atomic Scattering and geometrical structure factors and their application in intensity calculation - Single crystal and powder diffraction.

UNIT III SPECTROSCOPY 9

Basic laws of spectrophotometry and its application in elemental analysis in UV/ Visible range,
Construction and working principle of spectrophotometer, Beer-Lambert's law- limitations, deviations. 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 - Raman spectroscopy, X-ray photoelectron spectroscopy, Atomic emission spectroscopy, Atomic absorption spectroscopy – ICP.

UNIT IV SURFACE CHARACTERIZATION 10

Construction and operation of optical microscope - Principle of electron microscopy: electrostatic and magnetic lens systems - Generation of electron beam (Electron gun) - Interaction of electron beam with material – Principle, Instrumentation and applications of Scanning Electron Microscope and Transmission Electron Microscope - Preparation of ceramic samples, electron microscopy studies - Characteristics of microstructure in SEM and TEM; Electron microprobe analysis (EPMA and WDS) ; Quantitative microstructure and phase analysis - Study of morphology, size and aggregation of ceramic materials – BET surface area analysis, Atomic force microscopy (AFM), Piezo-response Force Microscopy(PFM), Magnetic Force Microscopy (MFM).

UNIT V ELECTRICAL, MAGNETIC AND NON-DESTRUCTIVE CHARACTERIZATION 8

Electrical resistivity in bulk and thin films (2-probe method & 4-probe method), - Hall effect - Impedance spectroscopy - Vibrating sample magnetometer (VSM) - Magnetic PE loop; Non destructive characterization – ultrasonic techniques – reflection techniques – back reflection and pulse-echo – thickness measurement by resonance - Acoustic emission techniques- Radiographic testing - thermographic testing.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1	Understand and discuss the basic principles of advanced characterization techniques
CO2	Explain and correlate the structure property of materials by analyzing the different characterization techniques
CO3	Define the basic properties and characteristics of materials by analysing their properties through a set of characterization techniques
CO4	Apply and select the appropriate techniques for characterizing specific chemical and physical properties of materials
CO5	Demonstrate the basic aspects of advanced materials and their applications.

REFERENCES

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3. S Zhang, L. Li and Ashok Kumar, “Materials Characterization Techniques”, CRC Press, 2008
4. “Characterization of Materials Science and Technology: A Comprehensive Treatment”, Vol 2A&2B, VCH, 1992
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8. Elton N Kaufmann, “Characterization of Materials”, Wiley Inter-science, 2003

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3202 WHITEWARES PRODUCTION AND PRACTICES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- Impart knowledge on the physical and chemical properties of traditional raw materials
- Understand the principles behind the stages of manufacture of traditional ceramic products starting the from raw materials to the final product
- Provide knowledge on the techniques and testing procedures involved for enhancing the properties of the products

UNIT I RAW MATERIALS 9

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

UNIT II THEORY OF PACKING 9

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

UNIT III FABRICATION PROCESS 9

Triaxial bodies – batch formulations – body formulations – porcelains, stoneware, earthenware, terracotta; pressing – types, process, defects; Plastic forming – types –

extrusion, jiggering and jollying, injection molding, defects; casting Plaster mould preparation – slip formation – suspensions/ceramic slurries – stability of slurries, types of stabilization – fluidity and thixotrophy – various casting techniques – defects – case studies

UNIT IV GLAZING 9

Glaze – definition – composition – raw materials; Engobe – definition – raw materials – process; Fritting – definition – fritting rules – manufacturing process; Glaze batch calculation; Glaze application techniques – types; Glaze defects; Glaze properties – fusibility, viscosity, surface tension, thermal and mechanical properties, glaze-body interface layer, opacity and translucency – select and solve an industrial problem on tiles

UNIT V DRYING & FIRING 9

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

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify, formulate and use the traditional raw materials to develop new products

CO2 Interpret the process control parameters during the manufacturing process and apply to solve processing issues

CO3 Solve the problems arising due to the heat treatment process.

CO4 Operate the processing equipment and process conditions to improve the efficiency of the process

CO5 Design and develop new products based on the knowledge acquired in traditional ceramics

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3. Worral, W.E, “Ceramic Raw Materials”, Pergamon Press, NY, 1992.
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5. M.J.Wilson, “Clay Mineralogy”, Chapman and Hall, 1995.
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COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.8**	**-**	**2.8**	**2.8**	**2.8**	**2**

CR3203 STRATEGIC APPLICATIONS IN CERAMICS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- To realize the next generation devices and novel ceramic materials with ultimate physical and chemical properties
- To know the fundamentals of materials design rules for developing advanced ceramics with ultimate physical and chemical properties

UNIT I CERAMICS FOR HIGH TEMPERATURE AND HIGH STRENGTH APPLICATIONS 9

Introduction-Silicon based ceramics-fabrication and micro structural control of silicon based monolithic ceramics- mechanical properties of silicon based monolithic ceramics-spontaneous fracture, time dependent deformation and fracture anelasticity, oxidation-toughening of silicon based ceramics by fiber reinforcement-laminated composite structure with enhanced fracture resistance-fabrication-application.

UNIT II CERAMICS FOR POROUS APPLICATIONS 9

Introduction-porous materials- classification, characteristics, fabrication-particle stacking sintering, appending pore forming agent, polymeric sponge impregnation process, foaming process, sol gel method, new processing of porous ceramics, preparation of new types of porous ceramics- hydrophobic porous ceramics, ceramic with gradient pores, fiber porous ceramics, slender porous ceramic tubes, porous ceramics with directionally arrayed pores, porous ceramic powder- preparation of porous ceramic membranes-porous ceramics composites-ceramics honey combs- applications of porous ceramics-filtration in separation, functional chemical engineering, combustion and fire retardant.

UNIT III CERAMICS FOR BIO MEDICAL APPLICATIONS 9

Introduction-ceramics for artificial joints-ceramics for artificial bones-requirements for artificial material to bond to living bone-requirement for artificial material to for apatite-functional groups effective for apatite nucleation-apatite forming metals-apatite polymer composites-apatite forming inorganic-organic hybrids-apatite polymer fiber composites-bioactive cements-cements in-situ radiotherapy of cancer, ceramic for insitu hyper thermotherapy of cancer; Ceramic dental implants – materials and processes.

UNIT IV CERAMICS FOR THERMO PHYSICAL APPLICATIONS 9

Introduction- modeling and design-general approach and design procedure, distribution functions of composites, models, fabrication process- vapor deposition methods, sol phase method, liquid phase method-application-structural materials, function materials.

UNIT V CERAMICS FOR HIGH THERMAL CONDUCTIVE APPLICATIONS 9

Introduction- process flow-material properties-thermal resistance-reliability-LTCC with high thermal expansion coefficient new high thermal expansion co-efficient (TCE) ceramic materials for wire bonded chip assembly type CSP with potting compounds-reliability of new high TCE ceramic materials- LTCC with low permittivity and loss tangent at high frequency for microwave applications -Introduction, characterization, reliability.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Classify different families of functional ceramics and describe their properties and applications
CO2 Describe the basic phenomena underlying the particular properties of functional ceramics
CO3 Relate the chemical composition, structure and microstructure to the particular properties
CO4 Implement the basic principles of design and fabrication of useful products
CO5 Execute the latest technological developments in functional ceramics and innovatively apply the above knowledge to applications

REFERENCES

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6. Mario Leclerc, Robert Gauvin, "Functional Materials".
7. Qingrui Yin, Binghe Zhu, Huarong Zeng, "Microstructure, Properties and Processing of Functional Ceramics", Springer, 2003

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.6**	**-**	**2.6**	**2.6**	**2.6**	**2**

CR3204	**FRACTURE MECHANICS IN BRITTLE MATERIALS**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

COURSE OBJECTIVES

- Familiarize with the basics of fracture mechanics
- Impart knowledge on concepts of fracture and the fracture parameters associated with fracture

UNIT I FRACTURE: AN OVERVIEW 9

Introduction, theoretical cohesive strength, defect population in solids – statistical nature of fracture, effect of size on the statistical nature of fracture, the stress-concentration factor, notch strengthening, external variables affecting fracture, characterizing the fracture process, macroscopic fracture characteristics- fracture of metals, polymers, glasses and ceramics, engineering composites, microscopic fracture mechanisms-metals, polymers, glasses and ceramics, engineering composites and metal creep fracture.

UNIT II ELEMENTS OF FRACTURE MECHANICS 9

Griffith crack theory, Charpy Impact fracture testing, Stress analysis of cracks – multiplicity of Y calibration factors, Role of K, failure analysis case study; Relation between energy rate and stress field approaches, Crack tip plastic zone size estimation – Dugdale plastic strip model; Fracture mode transition: Plane stress versus plane strain – case study of failure analysis; Plane strain fracture toughness testing, Plane stress fracture toughness testing, toughness determination from crack opening displacement measurement, Fracture toughness determination and Elastic – Plastic analysis with the J integral, Other fracture models, Fracture mechanics and adhesion measurements.

UNIT III STRESS ANALYSIS FOR MEMBERS WITH CRACKS K_I 9

Introduction, Stress concentration factor K_t, Stress intensity factor K_I, Stress intensity factor equations – through thickness crack, single edge notch, embedded elliptical or circular crack in infinite plate, surface crack, cracks growing from round holes, single crack in beam in bending, holes or cracks subjected to point or pressure loading, estimation of other K_I factors, superimposition of stress intensity factors; crack tip deformation and plastic zone size, Effective K_I factor for large plastic zone size, J_I and δ_I driving forces.

UNIT IV RESISTANCE FORCES 9

Introduction, Service conditions affecting fracture toughness – temperature, loading rate, constraint; ASTM standard fracture tests, Fracture behaviour regions, General ASTM Fracture Test Methodology – Test specimen size, test specimen notch, test fixtures and instrumentation, analysis of results; Relations between K-J-δ

UNIT V INDENTATION FRACTURE 9

Crack propagation in contact fields – blunt and sharp indenters; Indentation cracks as controlled flaws – inert strength, toughness and T curves, Indentation cracks as controlled flaws – time dependent strength and fatigue, Subthreshold indentations – crack initiation, strength; Special applications of the indentation method; Contact damage – strength degradation, erosion and wear; surface forces and contact adhesion.

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Classify the types of fractures and predict the ductile to brittle transition
CO2 Apply the principles of fracture to identify the problems related to fracture
CO3 Knowledge to interpret the fracture mechanics concepts with failure
CO4 To quantitatively assess the effects of fracture based on the underlying principles
CO5 Ability to apply the techniques, skills and modern engineering tools necessary for engineering practice

REFERENCES

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COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	3	-	3	3	3	2

CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.8**	**-**	**2.8**	**2.8**	**2.8**	**2**

CR3211 ADVANCED MATERIAL CHARACTERIZATION LABORATORY L T P C
0 0 4 2

COURSE OBJECTIVES

- To introduce the technological principles and applications of advanced material characterization techniques
- To provide a platform to have hands on experience in operating equipments
- To develop the students to interpret the results using the scientific data

EXPERIMENTS

1. Laser Particle size analyser
    a. To determine the particle size and particle size distribution of the powders milled at different time intervals and different milling speed.
    b. To determine the particle size and particle size distribution of the powders prepared by sol gel process.
2. Xray Diffraction Analysis
    a. Estimation of lattice parameter of cubic crystals
    b. Phase identification of the samples
    c. Indexing of powder patterns
    d. Crystallite size determination
3. Scanning Electron Microscopy
    a. Basics of SEM
    b. Powder preparation techniques
    c. Porosity, Grain size and Reinforcement Measurement
    d. Effect of beam voltage on conducting and insulating samples
    e. Elemental Mapping: Spot, Line and Area Analysis
4. Transmission Electron Microscopy
    a. Basics of TEM
    b. Bright field imaging and dark field imaging
    c. Sample Preparation
    d. Indexing of Diffraction Patterns
5. Energy Dispersive Spectroscopy
6. Spectroscopic Techniques
    a. Identification of unknown components using IR, NMR and Mass Spectroscopy
    b. Sample Preparation, IR spectrum Measurement, Spectral Analysis using FTIR
7. Atomic Force Microscopy
    a. Surface topography of a ceramic sample
8. Thermogravimetric Analysis
    a. Interpretation of the TGA/DSC curve for the given sample.

TOTAL : 30 PERIODS

EQUIPMENTS

1. Laser Particle Size Analyzer
2. Xray Diffraction Analyzer
3. Scanning Electron Microscope
4. Transmission Electron Microscope
5. Simultaneous TG/DT Analyzer

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Execute the knowledge and understanding of the fundamental principles and concepts of the material characterization techniques

CO2 Interpret the collected data, analyse and corelate the structure and property of the materials through a set of characterization techniques

CO3 Identify and use the techniques that are most appropriate for investigation of the structure and properties of different class of materials

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	**3**	**3**	**3**	**3**	**3**	**2**

CR3212 WHITEWARE LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES

- To introduce the technological principles and applications of traditional ceramics
- To formulate and analyze ne batch formulations to obtain new products
- To develop the students to interpret the results using the scientific data

EXPERIMENTS

1. To study of physical and properties of raw materials
2. To analyze the following properties of Clay: (i) Moisture (ii) Loss on Ignition (iii) Grit content (iv)Water of Plasticity
3. To analyze the following elements in raw materials: (i) Silica Content (ii) Alumina Content (ii)Iron Content
4. Determine the particle size distribution using Hydrometer Method
5. Determine the particle size distribution using Andreson Pipette Method
6. To determine the rheological characteristics of ceramic slip.
7. To fabricate a ceramic body by the following Techniques: (i) Uniaxial Pressing & Hot pressing and (ii) Cold Extrusion (iii) Slip Casting
8. To determine the properties of fired body– Density, Porosity, Water absorption, Shrinkage.
9. To determine the properties of tri-axial bodies: Flexural Strength – 3 point, Compressive Strength.
10. To compare the properties of the ceramic body prepared by various fabrication methods.
11. To prepare a glaze slip and analyze its properties
12. To apply the glaze on a fired body and evaluate the properties of the glazed ware

TOTAL : 45 PERIODS

EQUIPMENTS

1. Uniaxial Press
2. Universal Testing Machine
3. Hydrometer
4. Hand Extruder
5. Atterberg Plasticity Tester

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Execute the knowledge and understanding of the fundamental principles and concepts of the traditional ceramics.

CO2 Interpret the collected data, analyse and correlate the structure and property of the materials through a set of characterization techniques

CO3 Identify and use the techniques that are most appropriate for investigation of the structure and properties of different class of materials

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	**3**	**3**	**3**	**3**	**3**	**2**

CR3301 PRODUCT DESIGN, DEVELOPMENT AND SUSTAINABILITY

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- To introduce to the multidisciplinary aspects of product development and innovation
- Familiarize with the basic methodology and tools that can be used in product development
- Identify practical problems in cooperation with companies in order to stimulate real product development situations

UNIT I PRODUCT DESIGN, DEVELOPMENT AND SUSTAINABILITY INTRODUCTION 9

Definition – Design by Evolution – Design by innovation – essential factors of product design – Production consumption cycle – seven phases of morphology of design – Role of allowance, process capability and Tolerance in detailed design and assembly.

UNIT II PRODUCT DEVELOPMENT 9

Approach to design with ceramics – properties of Ceramics and glass – Production design factors for Ceramic parts – problems of manufacturers of Ceramic Parts – Special consideration for design of glass parts – dimensional factors and tolerances.

UNIT III COSTING DESIGNS 9

Introduction – component costing – Development of the model, Basic processing cost, relative cost coefficient, material cost, model validation, component costing, despoke costing development – manual assembly costing – assembly costing model, assembly structure diagram.

UNIT IV SUSTAINABLE DEVELOPMENT 9

Introduction – Major challenges – emerging drives – scale of changes needed – Design for sustainability – Product life cycle – Material selection – Impact of use – Length of life – end of life – Needs.

UNIT V METHODS AND TOOLS FOR DESIGN FOR SUSTAINABILITY 9

Environmental Assessment tools – Strategic Design Tools – Idea generation – User centered design – Information provision – case study of product Improvement and redesign.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

- **CO1** Demonstrate the technical and business aspects of the product development process
- **CO2** Acquire skill development in implementation of gathering data for customers and establish technical specifications
- **CO3** Analyse the cost involved in product design and development
- **CO4** Implement the gained skills for product sustainability
- **CO5** Solve engineering problems

REFERENCES

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2. Traey Bhamra, "Design for Sustainability – A Practical Approach", Gower Publishing Ltd., 2007.
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COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	2	2	2	2
CO2	2	2	2	2	2	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2
AVG	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2**

CR3311 PRODUCT DESIGN AND DEVELOPMENT LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES

1. To develop self learning skills, disseminate the knowledge about the technologies and new skills acquired
2. To bridge the gap between the curriculum and industry standards and practices
3. To build a lifelong learning skills to develop, maintain and solve real time problems.

The course covers the practical implementation of product centric design projects including the role of product manager, product concepts and theory, team building and management, cultural considerations and managing development and launch schedules. The focus of product design and development is integration of the design and manufacturing functions in creating a new product. The course is intended to provide the students with the following benefits (i) competence with a set to tools and methods for product design and development (ii) Confidence in his own abilities to create a new product (iii) Awareness of the role of multiple functions in creating a new product (iv) reinforcement of specific knowledge from other courses through practice and reflection in an action oriented setting.

COURSE OUTCOMES

After the completion of the course, the students will be able to

- **CO1** Describe the characteristics used for product design and development
- **CO2** Identify the requirement in product design and apply the structural approach to concept generation, selection and testing
- **CO3** Explain and Implement the principles and technologies used for the preparation of prototype

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	**3**	**3**	**3**	**3**	**3**	**2**

CR3312	**INTERNSHIP/ INDUSTRIAL TRAINING**	**L**	**T**	**P**	**C**
		0	**0**	**0**	**2**

COURSE OBJECTIVES

1. Provide comprehensive learning platform to students where they can enhance their employ ability skills and become job ready along with real corporate exposure.
2. Cultivate student’s leadership ability and responsibility to perform or execute the given task.
3. Provide learners hands on practice within a real job situation.

Industrial Training is an organized method or activity of enhancing and improving skill set and knowledge of engineering students, which boost their performance and consequently helping them to meet their career objectives. It is crucial for students because it is the best way to acquire as much mastery about their field as possible, which helps in building confidence of the students. Training helps learners to acquire the latest techniques, skills, and methodologies and to build a strong foundation for their career growth. In a nutshell, we can say that it helps in boosting career of students, since by the end of this training; students are turned into professionals in their specialized area. The students are expected to carryout 4 weeks training during Summer Vacation in an Industry. After completion, the students have to submit a report about the training carried out.

COURSE OUTCOMES

After the completion of the course, the students will be able to

- **CO1** Execute to communicate efficiently and to be trained to be a multi-skilled engineer with good technical knowledge, management, leadership and entrepreneurship skills.
- **CO2** Identify, formulate and model problems and find engineering solution based on a systems approach.
- **CO3** Create an awareness of the social, cultural, global and environmental responsibility as an engineer

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	**3**	**3**	**3**	**3**	**3**	**2**

CR3313 PROJECT WORK I

L	T	P	C
0	0	12	6

OBJECTIVES:

The course aims to enable the students to identify the research problem relevant to their field of interest, search databases to define the problem, design experiment, conduct preliminary study and report the findings.

COURSE CONTENT

Individual students will identify a research problem relevant to his/her field of study with the approval of project review committee. The student will collect, and analyze the literature and design the experiment. The student will carry out preliminary study, collect data, interpret the result, prepare the project report and present before the committee.

TOTAL: 180 PERIODS

OUTCOMES:

At the end of the course the students will be able to

CO1: Identify the research problem

CO2: Collect, analyze the relevant literature and finalize the research problem

CO3: Design the experiment, conduct preliminary experiment, analyse the data and conclude

CO4: Prepare project report and present

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	**3**	**3**	**3**	**3**	**3**	**2**

CR3411 PROJECT WORK II

L	T	P	C
0	0	24	12

I. Continuation of Project Work I (at Institution/Industry)

OBJECTIVES:

The course aims to enable the students to conduct experiment as per the plan submitted in Project work I to find solution for the research problem identified.

COURSE CONTENT

The student shall continue Project work I as per the formulated methodology and findings of preliminary study. The student shall conduct experiment, collect data, interpret the result and provide solution for the identified research problem. The student shall prepare the project report and present before the committee.

TOTAL: 360 PERIODS

OUTCOMES:
At the end of the course the students will be able to
CO1: Conduct the experiment and collect data
CO2: Analyze the data, interpret the results and conclude
CO3: Prepare project report and present

Course articulation Matrix

II. Not the continuation of Project Work I (at Industry)

OBJECTIVES:
The course aims to enable the students to identify the research problem at the company, search databases to define the problem, design experiment, and conduct experiment to find the solution.

COURSE CONTENT
Individual students will identify a research problem relevant to his/her field of study at the company and get approval of project review committee. The student will collect, and analyze the literature and design the experiment. The student will carry out the experiment, collect data, interpret the result, prepare the project report and present before the committee.

TOTAL: 360 PERIODS

OUTCOMES:
At the end of the course the students will be able to
CO1: Identify the research problem
CO2: Collect, analyze the relevant literature and finalize the research problem
CO3: Design and conduct the experiment, analyse the data and conclude
CO4: Prepare project report and present

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
AVG	3	3	3	3	3	2

PROFESSIONAL ELECTIVES

CR3001	CERAMIC ADDITIVE MANUFACTURING	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES
1. Knowledge on additive manufacturing and explain its advantages and disadvantages
2. Understand the processes used in additive manufacturing for a range of materials and applications
3. Understand the role of additive manufacturing in the design process and the implications for design

UNIT I BASIC OF 3D PRINTING TECHNOLOGY 9

Basic terms and definitions – additive manufacturing, the principle of layer-based processes; Direct processes - rapid prototyping, rapid manufacturing and rapid tooling; indirect processes – indirect prototyping, indirect tooling and indirect manufacturing; classification of machines for additive manufacturing and properties of parts. 3D printing and conventional manufacturing; basics of 3D printing process; problems with the STL file Format; other Translators – modern file formats, older file formats still in use; future manufacturing format developments;

UNIT II ADDITIVE MANUFACTURING PROCESSES 9

Direct additive processes, polymerization – LS, polymer printing and polymer jetting, digital light processing, micro stereolithography; Sintering and melting – LS/SLS, SLM, Electron beam melting; extrusion/fused layer modeling; powder-binder process- 3D printer-3D systems/ Z corporation, Metal and sand printer –ExOne, 3D printing system-voxeljet; later laminate manufacturing – LOM, SDL, LLM machines for metal parts; hybrid processes – CMB, DMD, BAAM; Further processes – aerosol prining and bioplotter; indirect processes / follow-up processes.

UNIT III MATERIALS FOR 3D PRINTING 9

Types of materials – polymers-Thermoplastic, thermosetting, metals, ceramics, composites; liquid-based materials-polymers, metals and composites; solid-based materials-polymers, metals, composites; powder-based materials- thermoplastics, polymer composites, elastomers, powders, selected properties; metals – selective laser sintering, SLS and Hot-isostatic pressing, direct metal laser sintering, direct metal deposition; Ceramics – Al_2O_3, Zr_2O; common materials used in 3D printers; materials selection considerations.

UNIT IV APPLICATIONS OF ADDITIVE MANUFACTURING 9

Automotive industry and sub-suppliers –interior and exterior components; aerospace industry; consumer goods; toy industry; art and history of art; mold and die making (rapid tooling); medical engineering; architecture and landscaping; miscellaneous applications – mathematical functions, 3D decoration objects and ornaments, aerodynamic and freeform objects;

UNIT V PERSPECTIVES AND STRATEGIES OF ADDITIVE MANUFACTURING 9

Potential of additive manufacturing – complex geometries, integrated geometry, integrated functions, multi-material parts and graded materials; strategies of additive manufacturing processes – customized mass production, personal production, distributed individualized production.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

- **CO1** Understand the basic principle and operation of AM prcesses
- **CO2** Identify the relationship between the various AM Process phenomena
- **CO3** Demonstrate the basic technical knowledge of the physical principles, materials and operation of the types of AM Process
- **CO4** Apply the process phenomena to stimulate AM process operations
- **CO5** Demonstrate the ability to identify the parts that are fabricated by AM process

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COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.6**	**-**	**2.6**	**2.6**	**2.6**	**2**

CR3002	ADVANCED CARBON MATERIALS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1 To impart knowledge on the different forms of carbon
2 To familiarize with the different carbon materials, properties and applications

UNIT I INDUSTRIAL CARBON 9

Structure, properties and applications, charcoal, activated carbon, coal, pitches, graphites polymer-derived carbon. Structure and characterization: Small angle, wide angle X-ray diffraction methods, Electron microscopy, Optical Scanning microscopy, TEM etc.,

UNIT II PROCESSING OF CARBON & GRAPHITE MANUFACTURING 9

Raw Materials, production process – Flow diagram, Milling & sizing, Mixing, shaping, Sintering – liquid phase- solid phase- gas phase, Graphitization – Mechanism – factor affecting- Impregnation- liquid phase - pitch & resin- Gas phase

UNIT III MODERN CARBON MATERIALS AND APPLICATIONS 9

Vitreous carbon – precursor – processing, types – foam- solid, Pyrolytic carbon – process – properties – structure. Graphite – Metal processing Industry- Semiconductor and related Industry- Electrical application- Mechanical – Chemical- Nuclear – Pyro graphite - Vitreous carbon- Carbon fibre - Carbon composite- Battery, Testing- standards- density – Hardness-

Porosity – Electrical Resistivity – Flexural strength – compressive strength – tensile strength – thermal expansion – modulus of elasticity – ash content – moisture content.

UNIT IV CARBON AND GRAPHITE FIBRES 9

Carbon fibres: history and development, salient features – Classifications - Raw materials-Rayon/cellulose, Pitch, and Poly acrylo nitrile - Tensile properties: Low modulus, Standard Modulus, Intermediate modulus, High modulus, and Ultra high modulus - Functional carbon fibre: Compressive strength, Thermal conductivity, and Electrical conductivity, Low-cost carbon fibres and Niche grade carbon fibres - Carbon fibre manufacturing processes (PAN based- Rayan based- Pitch based), precursors and their characteristics, typical carbon fibre properties - Applications: Carbon fibre supply chain, as carbon reinforced forms, Continuous filaments, Chops, Mills, Flame resisted Panox fibres.

UNIT V CARBON COMPOSITES 9

Textile preforms – classification, woven, multi-directional reinforced preforms. Structural geometry of 2D and 3D fabrics; Carbon matrix precursors - Thermosetting resin matrix precursors, Thermoplastic matrix precursor; Fabrication methods of Cf/C composites - Liquid phase infiltration (atmospheric and high pressure), Gas phase infiltration techniques (CVI and Film boiling CVI); Properties of Cf/C composites – Microstructures, Interface in Carbon-Carbon. Mechanical & Thermal properties (RT / High temperature), Electromagnetic properties; Oxidation & Oxidation protection - High temperature coatings on carbon fibres and Cf/C composites; Application of Cf/C composites.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify the different carbon materials, its properties and applications
CO2 Classify the materials based on their properties
CO3 Recognize the various applications based on their structure property relationship
CO4 Implement the underlying principles and concepts to practical problems
CO5 Solve the global warming problems to obtain zero carbon emission

REFERENCES

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COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	2.4	-	2.4	2.4	2.4	2

CR3003 BIOCERAMIC MATERIALS AND THEIR APPLICATIONS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To impart knowledge on the regeneration of the missing and dysfunctional parts by providing a biodegradable material
2. To have deep understanding on the use of materials as vehicles to deliver large and small molecules to specific tissues in order to restore normal physiological function

UNIT I INTRODUCTION TO BIOMATERIALS & BIOCERAMICS 9

Introduction – processing of biomaterials – metals, ceramics, polymers, biocomposites, sterilization. Micro/ Nano surface modification. Bioceramics – Types – bio inert, bioactive, bio resorable. Experimental evaluation of biocompatibility

UNIT II CALCIUM PHOSPHATE CERAMICS 9

Preparation, mechanical properties and biological performance of tri calcium phosphate, tetra calcium phosphate and hydroxyapatites. Calcium phosphate bone cements – preparation, properties, setting behavior and bio compatibility, Application – interaction with biological system

UNIT III BIOGLASS AND GLASS CERAMICS 9

Bioactive Glasses – Introduction, processing, compositions, properties, reaction kinetics, Tissue bonding, Clinical applications of bioactive glasses- Maxillofacial repair, orthopaedics. A/W glass ceramic- Processing and properties – Mechanical and surface Chemistry. Ceravital® glass ceramics - interaction with biological system

UNIT IV BIOCERAMIC COATING AND COMPOSITES 9

Hydroxyapatite coating – introduction, processing, plasma spraying, other coating techniques, composites, properties, tissue response, clinical applications; bioactive glass coatings – introduction, enameling; bioceramic coatings for metallic implants; titania based composites, ceramic-polymer composites - interaction with biological system

UNIT V BIO CERAMIC APPLICATIONS 9

Cardiovascular Medical Device, Orthopedic Implants, Maxillofacial implant- Dental Implants, Ear prostheses, Fillers, Drug Delivery ,Tissue Engineering.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Understand the multidisciplinary nature of biomaterials and define design criteria for a material with relationship to their clinical application

CO2 Identify the major types of materials that are used in the body and their major modes of failure

CO3 Apply the material property fundamentals to analyze the performance of a material

CO4 Interpret how to analyze the interaction of materials with the human body and what biocompatibility is in relation with specific materials

CO5 Execute to develop a innovative product with standard of care

REFERENCES

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COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3004 CERAMIC COATING TECHNOLOGY **L T P C**
3 0 0 3

COURSE OBJECTIVES

1 To identify the material processing technologies that have the potential to produce ceramic coatings for a specific application

UNIT I INTRODUCTION 9

Introduction – Processing, Characterization and Areas of application in ceramic coatings; recent trends in Ceramic Coatings – Diamond Coatings, High Tc Superconducting ceramic coatings, Ceramic coating on cutting tool, Ceramic coating in Semiconductor integrated circuit, Ceramic coating on Architectural and automotive glass.

UNIT II COATINGS BY CVD 9

Introduction – TiC Coatings – CVD process condtions for TiC coatings, TiC depositon rate, TiC coatings – Substrate interface - TiN coatings - CVD process condtions for TiN coatings; Al2O3 Coatings - CVD process condtions for Al_2O_3 coatings; Multi layer Coatings – TiN – TiC type multi layers, Al_2O_3 type Multi-layer coatings; CVD process condtions for multi layer coatings – Coating thickness optimization - Cutting tool wear modes, influence of thickness upon flank wear resistance, Thickness influence on crater wear resistance and strength, Thickness of multi layer coatings ; Other Coatings – Hafnium and Zirconium based coatings , TiB2 coatings , Tungsten carbide coatings.

UNIT III COATINGS BY ENAMELLING 9

Introduction to Porcelain Enamels – History of Porcelain Enamelling, Reasons for Porcelain Enamelling, General Applications of Porcelain Enamelling; Porcelain Enamelling principles and theories – Porcelain Enamel smelting and fritting, Metals selection and preparation for Porcelain Enamelling, Porcelain Enamel milling, Porcelain enamel applications, Porcelain Enamel bond theories, Covercoat opacity mechanisms, Drying, firing and defects in Porcelain Enamels; Other details on material processing – Applications and improvement methods for Porcelain enamel coatings- Applications and competitive coatings, Porcelain Enamel properties, enhancement of Porcelain Enamel protective properties.

UNIT IV COATINGS BY PLASMA SPRAYING 9

Introduction – Plasma spraying – Feed stock preparation, Ceramic coating, Special features of plasma sprayed coatings – Alumina based coatings – Thermal barrier coatings – Applications, Materials Properties – Plasma sprayed high Tc superconductors- Spray parameter optimization, Post spray annealing and improving super conducting properties, Texturing: Improving the transport critical current density, Coating/Substrate interdiffusion – Test methodologies – Characterisation of coatings, Properties of coatings .

UNIT V COATINGS BY SOL GEL PROCESS 9

Introduction – Sol – gel processing – Coating Chemistry, Drying and firing – Coatings via Sol-Gel processing- Special solution requirements, Coating techniques, Unique advantages of Sol-gel Coatings – Application- Electrical applications,Optical applications – Problems faced- Film cracking, Removal of Residual species, Precursor characterisation and aging, Impact of deposition conditions on film properties, Low Temperature Densification of films, Comparison of Thin Film vs Bulk Ceramics, The Nature of sol – gel research.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify the principles of the different coating technologies.

CO2 Classify the process based on the specific application

CO3 Interpret and enhance the process control parameters in order to obtain better performance

CO4 Design and demonstrate the process to meet specific desired needs within realistic constraints

CO5 Develop an inclination towards innovation and technopreneur ship which includes utilization and commercialization of ceramic technology in the form of product, service or process

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COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2

AVG	**2.6**	**-**	**2.6**	**2.6**	**2.6**	**2**

CR3005 CERAMIC FUEL CELL

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To develop a basic understanding of the electrochemical, thermodynamic and transport processes governing fuel cell operation
2. To acquire technical competence in fuel cell technology

UNIT I CERAMIC FUEL CELLS 9

Introduction. A simple fuel cell. Classification of ceramic fuel cells. Fuel cell components. Basic
fuel cell operation. Fuel cell Performance. conduction in electrolyte – defects in fluoride type
oxides, perovskite type oxides, conduction process, transference number – Types of fuels and
oxidants Advantages and disadvantages. Factors influencing the life time of solid oxide fuel cells.

UNIT II REACTION KINETICS 9

Electrode kinetics. Activation energy Vs charge transfer reaction and reaction rate. Calculating net rate of reaction. rate of reaction at equilibrium. Potential of reaction at equilibrium. Butler – Volmer equation. Improvement of kinetic performance. Tafel equation. Different kinetics in different fuel cells. Catalyst – electrode design.

UNIT III ELECTROLYTE AND ELECTRODE MATERIALS 9

Electrolyte materials - Oxygen ion conducting materials-Yttria Stabilized Zirconia, Doped ceria, perovskite oxides, proton conducting perovskites. Electrode / catalyst materials – Ni-YSZ Cermet anode materials, ceria based anode materials, perovskite anode materials. Poisoning of anode materials. Cathode materials – perovskite and double perovskite materials.

UNIT IV INTERCONNECTS AND SEALING MATERIALS 9

Metallic interconnect materials – introduction, basic requirements, oxidation in anode, cathode and dual atmospheres. Compatibility with cell and stack components. Development of new alloys as interconnects. Sealants – Glass and glass-ceramic sealants, properties related to short-term and long-term performance. Mica, metal braze and composite sealants.

UNIT V CHARACTERIZATION OF SOFC MATERIALS & STACK DESIGN 9

Ex situ characterization techniques – Porosity determination, surface area measurements, gas
permeability, structure determination, chemical determination. In situ characterizations (electrochemical) - current - voltage measurement, current interrupt measurement, electrochemical impedance spectroscopy, cyclic voltammetry.Schematic designs performance and technological status of conventional SOFC, Tubular SOFC, Planar SOFC, single chamber SOFCs, direct flame SOFCs and Ammonia SOFCs.

TOTAL:45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Understand the performance behaviour, operational issues and challenges of ceramic fuel cell.
CO2 Understand the impact of this technology in a global and social context
CO3 Identify, formulate and solve problems related to fuel cell technology keeping in mind economic viability

CO4 Apply know how of thermodynamic, electrochemistry, heat transfer and fluid mechanics principle to design and analysis of the emerging technology.

CO5 Develop skills to design systems or components of fuel cell.

REFERENCES

1. Ryan O' Hayre, Suk-Won Cha, Whitney G. Colella and Fritz B. Prinz, "Fuel cell Fundamentals", Third Edition, John Wiley & Sons,2016.
2. Xianguoli, "Principles of Fuel Cells", Taylor & Francs,2005.
3. Gregor Hoogers, "Fuel Cell Technology Hand Book", CRC Press, 2003.
4. Suddhasatwa Basu, "Recent Trends in Fuel Cell Science and Technology", Springer, 2007.
5. Buchanan RC, Ceramic Materials for Electronics, Marcel Dekker Inc., NY, 1991.
6. San Ping jiang, "Materials for High Temperature Fuel Cells" Wiley – VCH, 2013
7. Duncan W. Bruce., "Energy Materials", Wiley, John Wiley & Sons, UK. 2011

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3006 CERAMIC MEMBRANES AND ITS APPLICATIONS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1 Introduce the fundamentals on properties, preparation, utilization and characterization of membranes

2 Impart knowledge on the use of membranes for versatile applications

UNIT I FUNDAMENTALS OF MEMBRANE SEPARATION 9

Introduction to mass transfer phenomena; Fick's law; mass diffusivity; diffusion in gases, liquids, solids ; integral and differential expressions of mass balance equation; convective mass transfer ; momentum and mass diffusivity profiles ; fluxes of liquids through porous membranes ; the flux of pure solutes and mixtures ; concentration polarization, resistance-in-series model and pore blocking model ; fluxes of gases through porous membranes ; kundsen and surface diffusion ; capillary condensation ; molecular sieving ; transport of gases through ceramic membranes with several simultaneous processes ; the parallel transport and resistance-in-series model; fluxes through non-porous membranes;

UNIT II MEMBRANE SEPARATION AND MODULES 9

Membrane Definition; Microfiltration – History and process; ultrafiltration - History and process; Nano filtration - History and process; reverse osmosis - History and process; gas separation - History and process; membrane distillation - History and process; modules – Plate and Frame, spiral wound, tubular, perforated block, hollow fiber, and rotating disk.

UNIT III MEMBRANE PREPARATION 9

Raw materials used in the preparation of ceramic membranes – alumina, zeolites, Titania, Zirconia, silica, other materials; processes applied in ceramic membrane preparation – Extrusion, slip casting, Tape casting, dip-coating, pressing and sol-gel.

UNIT IV CHARACTERIZATION OF CERAMIC MEMBRANES 9

Introduction; pore size and pore size distribution; permeability; the gas-liquid displacement bubble point technique; liquid-liquid displacement; mercury porosimetry; gas adsorption – desorption; gas –liquid permporometry; solid-liquid thermoporometry; nuclear magnetic resource; solute rejection tests; visualization of membrane surfaces – optical microscopy, confocal scanning laser microscopy, SEM, TEM, AFM; chemical methods for membrane characterization – backscattered radiation, vibrational spectroscopy; physical parameters of ceramic membranes – porosity and pore tortuosity, mechanical strength, hydrophobicity and charge.

UNIT V CERAMIC MEMBRANES APPLICATIONS 9

Classical applications; gas separation; sustainable reduction of CO_2 emissions ,hydrogen purification; Fuel cell – real hydrogen economy, dense, oxygen separation by dense mixed ionic-electronic conducting; reactors – types and their applications, inert, catalytic, composite infiltrated, membrane reactors using dense ceramic membranes; liquid separation and purification – water treatment, surface water treatment, low-cost ceramic filters, treating additional pollutants, membrane distillation, pervaporation; cleaning of wastewater with ceramic membranes; ceramic membranes in food applications.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

- **CO1** Understand the different types of membranes and their composition
- **CO2** Locate the fundamental reasons for the need of technological changes in the field of separation of materials
- **CO3** Understand the strategic applications of different types of membranes
- **CO4** Implement the concept about the sequence of technological upgradation based on operational flexibility and profitability
- **CO5** Demonstrate the best suited process for advanced separation techniques

REFERENCES

1. Kang Li, Ceramic membranes for separation and reaction, John Wiley, 2007
2. N.K. Kanellopoulos, Recent advances in gas separation by microporous ceramic membranes, Elsevier, 2000
3. Vitaly Gitis, Gadi Rothenberg, Ceramic Membranes: New Opportunities and Practical Applications, Wiley-VCH, 2016
4. Chandan Das, Sujoy Bose, Advanced Ceramic Membranes and Applications, CRC Press, 2017
5. Gitis, Vitaly;Rothenberg, Gadi;Gadi Rothenberg, Ceramic Membranes, John Wiley & Sons, 2016
6. Xuefeng Zhu, Weishen Yang, Mixed Conducting Ceramic Membranes: Fundamentals, Materials and Applications, Springer-Verlag Berlin Heidelberg, 2017

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2

CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3007 CERAMIC COMPOSITES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. Gain theoretical knowledge as well as practical background of the structure and properties of ceramic composites
2. Train the students to design and develop composite structures

UNIT I MATRIX AND REINFORCEMENT 9

Introduction – composite materials – engineering requirements – implementation of new materials – design and lifetime predictions – applications and requirements – manufacturing requirements – Matrix – metal, ceramic, polymer; implications of fibre properties - continuous reinforcements – time and temperature dependent properties of oxide and non oxide fibers – performance characteristics – processing – microstructure, discontinuous reinforcements – whiskers, particles, laminates – processing and properties

UNIT II PROCESSING 9

Introduction – particle based processes – cold compaction, slurry impregnation, sol gel processing, electrophoretic deposition, slurry based process, plastic forming; reaction bonding process – self propagating high temperature synthesis – in situ processing - melt processing – polymer infiltration and pyrolysis – chemical vapor infiltration – chemical vapor deposition – Sullivan process.

UNIT III INTERFACE 9

Introduction – wettability – effect of surface roughness; crystallographic nature of interface – interactions at the interface – types of bonding at the interface – mechanical bonding, physical
bonding, chemical bonding; optimum interfacial bond strength – very weak interface, very strong interface, optimum interfacial bond strength; Tests for measuring interfacial strength – flexural tests, single fibre pull out tests, curved neck specimen test, instrumented indentation tests, fragmentation test, Laser spallation technique.

UNIT IV EVALUATION OF COMPOSITES 9

Introduction – Mechanical Properties – elastic, strength, creep, creep rupture, fatigue, notch sensitivity, interfacial shear properties, environmental properties – thermal expansion, conductivity, environment, environmental effects, oxidation – thermal shock resistance, reactions at the interface, electrical properties, dielectric properties, impact resistance, static and dynamic fatigue, interlaminar shear properties

UNIT V TAILORING COMPOSITE MATERIALS 9

Tailoring by component selection – Polymer Matrix Composites, Metal Matrix Composites, Ceramic matrix Composites; Tailoring by interface modification – interface bond modification,
interface composition modification, interface microstructure modification; Tailoring by surface modification – Tailoring by microstructure control – crystallinity control, porosity control.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify the importance of matrix and reinforcement of composites for different applications

CO2 Recognize the different moulds, tools, matrix and reinforcements for composites

CO3 Identify the suitable processes and parameters for the manufacture of composites
CO4 Apply the fundamental knowledge to design composites for specific applications
CO5 Interpret and solve the problems arising during application for a specific use.

REFERENCES

1. Chawla,K.K., "Ceramic Matrix Composites", 1993, Chapman & Hall, NY.
2. Richard Warren, "Ceramic-Matrix Composites", 1992, Blackie, Glasglow.
3. M Balasubramaniam, "Composite Materials and Processing", CRC Press, 1st Edition, 2013.
4. Mazdiyasmi, K.S., "Fibre Reinforced Ceramic Composites", 1990, Noyes Publications, New Jersey.
5. Murray, J.G., "High Performance Fibre Composites", 1987, Academic Press, NY.
6. Ashes, K.H.G., "Fundamentals Principles of Fibre Reinforced Composites", 1989, Technomic Publishing Co. Inc.
7. Bhagwan D Agarwal, Lawerence J Broutman, K Chandrasekara., "Analysis and Performance of Fiber Composites", 2006, Wiley Publications
8. I M Low, "Advances in Ceramic Matrix Composites", Woodhead Publishing, Second Edition, 2018

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3008 DESIGN AND SELECTION OF ABRASIVES

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- Impart basic knowledge about the classification of abrasives
- Gain knowledge on the importance of grinding/polishing and selection of abrasives for a given application

UNIT I RAW MATERIALS FOR ABRAASIVES 9

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

UNIT II DESIGN OF COATED ABRASIVES 9

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

UNIT III DESIGN OF COATED ABRASIVE BACKUPS 9

Contact wheels - cloth contact wheels, rubber contact wheels, hardness, face serrations, shape, wheel diameter, speed, belt tension, dressing and protection of contact wheels, their characteristics; Other backups – drums, rolls, pads, and platens – types, characteristics, choice and uses.

UNIT IV DESIGN OF BONDED ABRASIVES 9

Bonded wheel manufacture with different bonds and their characteristics. Shapes and sizes of wheels. Factors determining grinding action – characteristics of abrasive grain, bond type, structure. Other types of wheels – Diamond wheels, reinforced wheels, mounted wheels.

UNIT V SELECTION OF GRINDING MACHINE AND ABRASIVES 9

Types of grinding – cylindrical grinding, centre less grinding, surface grinding, internal grinding.

Grinding fluids – properties, types and purpose. Material, surface finish and process considerations for selection of grinding method, selection of abrasive type, and selection of coolant.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Understand the basic principles of material removal by use of abrasive materials
CO2 Understand the mechanism of the different abrasive processes
CO3 Identify the different raw materials and its properties for a specific application
CO4 Design and execute the process of material removal for traditional and advanced applications
CO5 Interpret the root causes for material failure and report the causes and rectification mechanisms

REFERENCES

1. Coes L Jr., Abrasive, Springer Verlag, New York, 1971.
2. Metzger J.L, Super Abrasive Grinding, Butterworths, UK, 1986.
3. Francis T.Farago, Abrasive Methods Engineering, Vol.2, Industrial Press Inc., NY, 1980.
4. Coated Abrasives – Modern Tool of Industry, Coated Abrasive Manufacturer's Institute, Cleaveland, Ohio, 1982.
5. Kenneth B.Lewis, William F.Schleicher, The Grinding Wheel, The Grinding Wheel Institute, Cleaveland, Ohio, 1976.
6. Stephen Malkin & Changsheng Guo, Grinding Technology, 2nd Edn., American Society of Civil Engineers, 2008.
7. Edwards R, Cutting Tools, The Institute of Materials, Cambridge, 1993.
8. Brian Rowe W, Principles of Modern Grinding Technology, William Andrew Publications, 2009.

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3009 GLASS SCIENCE AND TECHNOLOGY

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- Introduce the theoretical foundations of the glass raw materials and the glass melting processes
- Gain knowledge on the properties and applications of glass in various sectors.

UNIT I CONCEPTS OF GLASS FORMATION 9

Glassy state, Glass formation – structural concepts, kinetic considerations, ranges of glass formation; Microstructure of glass – phase separation and liquid immiscibility; Atomic arrangements in glass – silica glass, alkali silicate glass, alkali – alkaline earth silicate glass, boric oxide, borate and borosilicate glasses, alkali aluminosilicate glass, phosphate glass, lead and zinc silicate glass,

UNIT II COMPOSITION – STRUCTURE - PROPERTY OF GLASS 9

Composition – structure – property relationship – glass formula and interdependence, Measurement and composition dependence - Density and molar volume , elastic properties, microhardness, viscosity; surface energy, heat capacity, heat transfer, thermal expansion, glass transformation range behaviour, diffusion and permeation, electrical conduction, dielectric properties, chemical durability, mechanical strength, optical properties.

UNIT III GLASS MAKING 9

Glass melting – steps and types of melters; Glass forming – blowing, pressing, casting, centrifugal forming, rod and tube drawing, sheet drawing, rolling, float glass, fritting, spheres, marbles and microspheres.

UNIT IV ANNEALING AND TEMPERING 9

Introduction, Development of permanent stress in glass, Stress profiles during annealing and tempering, Standards of annealing, Annealing practices, Standards of temper, Commercial tempering practices, Limitations of thermal tempering, Chemical strengthening of glass, Examination of stresses in glass

UNIT V GLASS TYPES AND GLASS FIBERS 9

Commercial glasses – soft glass, hard glass, fused silica and high silica glasses, borate, phosphate, aluminate and germanate glasses, non oxide glasses; Special glasses – sealing and solder glasses, colored and opal glasses, optical glasses, photochromic and polarizing glasses, photosensitive glass, glass ceramics, strengthened glass, high silica glasses; Glass fibers – discontinuous fiberglass, continuous fiberglass, traditional fiber optics; Optical communication fiber – materials, types of optical fiber design and manufacturing process.

TOTAL :45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Identify and classify the raw materials and its properties used in glass manufacture for a particular application

CO2 Understand the process of glass formation and its structure-property relationship

CO3 Understand the various glass manufacturing process and technologies

CO4 Design and develop new compositions for specialized applications

CO5 Apply the skill to identify problems when converting the raw material to glass.

REFERENCES

1. Tooley F.V, Handbook of Glass Manufacture, Vol I&II, Ogden Publishing Co., NY, 1960.

2. James E.Shelby, Introduction to Glass Science & Technology, The Royal Society of Chemistry, 1997. 3
3. Glass Furnaces-Design, Construction & Operation, Wolfgang Trier, Society of Glass Technology, 2000.
4. Paul, Chemistry of Glasses, 2nd Edn, Chapman & Hall, 1990.
5. Fundamentals of Glass Manufacturing Process 1991, Proceedings of the First Conference of the European Society of Glass Science and Technology, Society of Glass Technology, 1991.
6. Charles A Harper, Handbook of Ceramic Glasses & Diamonds, McGraw Hill, 2001.
7. Volf V.B, Technical Approach to Glass, Elsevier, 1990.
8. Adalbert Feltz, Amorphous Inorganic Materials and Glasses, VCH Verlagsgesellschaft mbH, 1993
9. B O Mysen and P.Richet, Silicate Glasses & Melts, Properties and Structure, Elsevier, 1986.
10. Narottan P.Bansal & R.H. Doremus, Handbook of Glass Properties, Elsevier, 1986.
11. Glass & Ceramic Technology, NIIR Board of Consultants & Engineers, Asia Pacific Business Press Inc.
12. James F.Shackelford, Ceramic & Glass Materials, Springer, 2008.
13. M.Cable and J.M. Parker, High Performance Glasses, Blackie, Glasglow & London published by Chapman and Hall, New York 1992

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3010 RARE EARTH CERAMICS **L T P C**
3 0 0 3

COURSE OBJECTIVES

1. To impart fundamental knowledge on rare earth materials
2. To familiarize with the use of rare earth materials in various applications.

UNIT I RARE EARTH ELEMENTS 9

Periodic Table, Rare earth resources and optimization strategies, physical properties of rare earth elements, chemical properties of rare earth metals, reactions of rare earth metals with non metals, complexes of rare earth elements; Rare earth nanomaterials – basic features and characteristics of nanoparticles, structure of nanoparticles, nanoblock materials, nanocomposites; Preparation of rare earth nano oxide materials, multidimensional rare earth material; Composites and assembly of rare earth nanomaterials.

UNIT II SOLID ELECTROLYTES AND HIGH TEMPERATURE PROTON CONDUCTORS 9

Introduction, YSZ stable solid electrolyte, Bi_2O_3-Y_2O_3 solid electrolyte, rare earth fluoride ion conductors, Rare earth solid electrolytes at high temperatures, Interaction between element atoms in metal melts; Preparation of high temperatures proton conductors, Causes of proton conduction in perovskite materials, applications of perovskite proton conductors

UNIT III CATAYLSTS AND HYDROGEN STORAGE 9

Introduction, Characteristics of catalytic activity, basic features of catalytic activity, composition and function of catalysts, adsorption and multiphase catalytic reactions, metal oxide catalysts and their catalytic activity, molecular sieve catalysts and their catalytic activity, preparation and application of industrial catalysts, application of rare earth catalysts; Introduction to hydrogen storage, structure of rare earth hydrides, characteristics of hydrogen storage materials, preparation of rare earth hydrogen storage materials, storage and application of hydrogen storage materials.

UNIT IV MAGNETIC AND SUPERCONDUCTING APPLICATIONS 9

Magnetic properties of substances, Magnetic origin of rare earth elements, magnetic properties of rare earth metals and 3d transition metal compounds, types of rare earth permanent magnetic materials, phase diagrams of rare earth permanent magnet materials, application of alloy phase transition, preparation and application of rare earth permanent magnets, rare earth super magneto strictive materials, magnetic refrigeration and magnetic storage materials; Superconducting materials – properties, types, oxide superconductors, preparation of RE123 oxide superconductors, second generation high temperature superconducting wires, applications.

UNIT V FUNCTIONAL CERAMICS 9

Introduction, Piezoelectric ceramics, Rare earth transparent electrooptical ferroelectric ceramics, dielectric ceramics, semiconductor ceramics, rare earth polishing materials, rare earth ceramic color glazes, rare earth heating materials.

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

- **CO1** Identify the various rare earth materials along with its structure and properties
- **CO2** Describe the structure property relationship of the rare earth materials
- **CO3** Understand the concepts for use of rare earth in specific applications
- **CO4** Apply the concepts in developing new rare earth compositions for advanced applications
- **CO5** Interpret the properties of the developed rare earth material compositions

REFERENCES

1. Frank R Spellman, “The Science of Rare Earth Elements”, CRC Press, 2023
2. Changzhen Wang, “Theory and Application of Rare Earth Materials”, Springer, 2023

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3011 REFRACTORY ENGINEERING

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1. To gain deep knowledge on the raw materials, properties and applications of refractories
2. To understand the process of designing and installation of refractories
3. To gain knowledge on the thermal calculations and ways to improve the efficiency of the furnace

UNIT I SELECTION OF MATERIALS 9

Materials - Shaped dense materials, Basic refractory bricks, Sintered special refractory bricks, Carbon and graphite bricks, Silicon carbide bricks, Fused cast products; Shaped heat insulating materials, Unshaped refractory materials, ceramic fibers; Types of loading – stress controlled and strain controlled loads; Design philosophy of structures based on load types, Materials properties required for structural analysis.

UNIT II CRITERIA FOR SELECTION OF REFRACTORY MATERIALS 9

ASTM Strength tests, Choosing best refractory for thermos-mechanical application – verification from field test study, Static compressive stress strain data, Creep data, Influence of stress state on the strength of refractories, thermal expansion data

UNIT III DESIGN 9

Selection criteria for refractory and heat insulating materials, Design with shaped dense materials – standard shapes, standard bricks, anchoring with holding bricks, joints; Design with shaped heat insulating materials – standard shapes, shaped bricks, anchoring, joints; Design with unshaped refractory materials – anchoring, joints lining of cylindrical vessels; Design with ceramic fibre materials – forms of delivery, attachment, and fixation.

UNIT IV THERMAL CALCULATIONS 9

Temperature, Heat, Heat amount, Heat capacity, Heat flow, Heat flow density, storage heat, Heat transfer via thermal conduction, convection, radiation and transmission, Heat flux, discussion of wall design, Nonstationary calculations, multidimensional problems, static calculations of load bearing parts taking the temperature influence into consideration, expansion calculations.

UNIT V REFRACTORY LINING JOINTS 9

Joints – refractory mortar joint fundamentals, Finite elemental analysis of a mortar joint – behaviour of structural masonry mortar joint – influence of mortar joint thickness on mortar joint behaviour – mechanical behaviour of dry joint – fundamental of refractory hinges – aspects of hinge behaviour – analytical study of hinge joint; Basics of refractory brick arch behaviour – fundamentals of brick lined cylindrical shells- brick dome behaviour – fundamentals of flat brick linings – cylindrical refractory – lined vessel analysis -refractory sprung arch – spherical refractory silica brick dome; dos and don’ts in refractory lining design.

TOTAL : 45 PERIODS

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Explain the classification and properties of refractories

CO2 Understand the production methods of the refractories, shaping and selection based on the various refractory materials

CO3 Understand and evaluate the properties of the refractories and the testing procedures of the refractories

CO4 Interpret the insulation and thermal conductivity based on the field of use and evaluate the design of refractories for industrial applications

CO5 Interpret the location and design of refractory materials used for industrial applications

REFERENCES

1. C. A. Schacht, Refractory Linings: Thermo-mechanical Design and Applications, CRC Press, 1995.
2. S. C. Caniglia and G. L. Barna, Handbook of Industrial Refractories Technology, William Andrews Publishing, NY, 1992.
3. C. A. Schacht, Refractories Handbook, CRC Press. , NY, 2004
4. S. Banerjee, The Changing Refractories Industry: New Technologies, Materials and Markets, Business Communication Co, 1999.
5. Norton F.H, Refractories, 4thEdn., McGraw Hill Book Co.,1968.
6. Nandi D.N, Handbook of Refractories, Tata McGraw-Hill Publishing Co., New Delhi,1991.
7. Akira Nishikawa, Technology of Monolithic Refractories, Plibrico, Japan Co. Ltd., Tokyo,1984

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**

CR3012 TRIBOLOGY IN CERAMICS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

1 To provide the knowledge and importance of tribology in design, friction, wear and lubrication aspects of machine components

2 To introduce the concepts of surface engineering and its importance in the behaviour of tribological components

UNIT I INTRODUCTION 9

Surface interactions, Mechanical properties that influence surface interactions – elastic properties, plastic deformation properties of materials, relation between strength and other properties of solids, chemical reactivity of surfaces, adsorbed surface layers, surface energy, relationship between surface energy and hardness, surface energies of solids under engineering conditions, energies of adhesion values using compatibilities, computing energies of adhesion values of clean metal pairs, non-metals, other properties influencing tribological behavior.

UNIT II FRICTION 9

Introduction, Solid – solid contact – rules of sliding friction, basic mechanism of sliding friction, other mechanisms of sliding friction, friction transitions during sliding, static friction, stick slip, rolling friction; Liquid mediated contact, Friction of materials – friction of metals and alloys, ceramics, polymers, solid lubricants; interface temperature of sliding surfaces – introduction, thermal analysis, interface temperature measurements – thermocouple and thin film temperature sensors, radiation detection techniques, metallographic techniques, liquid crystals.

UNIT III WEAR 9

Introduction, Types of wear – adhesive, abrasive, fatigue, impact, corrosive, electrical arc induced, fretting and fretting corrosion; Types of particles present in wear debris – plate shaped particles, ribbon shaped particles, spherical particles, irregularly shaped particles; Wear of materials – metals and alloys, ceramics and polymers

UNIT IV LUBRICATION 9

Introduction, Regimes of fluid film lubrication – hydrostatic lubrication, hydrodynamic lubrication, elastohydrodynamic lubrication, mixed lubrication, boundary lubrication; Viscous Flow and Reynolds Equation – viscosity and Newtonian fluids, fluid flow; Hydrostatic lubrication, Hydrodynamic lubrication – thrust bearings, journal bearings, squeeze film bearings, gas lubricated bearings; Elastohydrodynamic lubrication – forms of contact, line contact, point contact, thermal correction, lubricant rheology.

UNIT V SURFACE CHARACTERIZATION 9

Nature of surfaces, Physico-chemical characteristics of surface layers – deformed layer, chemically reacted layer, physiosorbed layer, chemisorbed layer, methods of characterization of surface layers; Analysis of surface roughness – average roughness parameters, statistical analysis, fractal characterization, practical considerations in measurement of roughness parameters; Measurement of surface roughness – mechanical stylus methods, optical method, SPM Methods, Fluid methods, Electrical method, Electron microscopy methods, analysis of measured height distribution, comparison of measurement methods

TOTAL : 45 PERIOD

COURSE OUTCOMES

After the completion of the course, the students will be able to

CO1 Understand the different techniques used to solve engineering problems
CO2 Understand the principles and importance of tribology in design
CO3 Understand the concepts surface engineering and its importance in tribology
CO4 Apply mechanics of materials and machine design concepts to provide preliminary results used for testing
CO5 Analyze tribological systems in terms of structure and material properties

REFERENCES

1. Prasanta Sahoo, "Engineering Triboloby" PHI learning private limited, New Delhi, 2011
2. Bikramjit Basu, Mitjan Kalin, Tribology of Ceramics and Composites: Materials Science Perspective, Wiley-American Ceramic Society, 2011.
3. Said Jahanmir, Friction and Wear of Ceramics, CRC Press, 1993
4. Jitendra Kumar Katiyar, P. Ramkumar, T. V. V. L. N. Rao, J. Paulo Davim, Tribology in Materials and Applications, Springer International Publishing, 2020
5. Ahmed Abdelbary, Li Chang, Principles of Engineering Tribology Fundamentals and Applications, Elsevier, 2023

COURSE ARTICULATION MATRIX

CO	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	2	2	2
CO2	2	-	2	2	2	2
CO3	2	-	2	2	2	2
CO4	3	-	3	3	3	2

CO5	3	-	3	3	3	2
AVG	**2.4**	**-**	**2.4**	**2.4**	**2.4**	**2**