

List of PhD Courses with its credit structure detail for the Dept. of MME

Sl. No.	Subject Code	Course Name	L	T	P	C
1.	MM7101/MM7201	Rubber Science and Technology	3	0	0	3
2.	MM7102/MM7202	Flash Sintering of Ceramics	3	0	0	3
3.	MM7103/MM7203	Advanced Topics in Ceramic Processing	3	0	0	3

Course Number	MM7101 / MM7201
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Rubber Science and Technology
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To know about the properties, structure-property relationship, and application of different rubbers. To understand the importance of compounding/shaping/vulcanization techniques of rubbers. To understand the recent developments in rubber science and technology.
Course Description	This course covers the fundamental to advanced aspects of rubber science and technology from materials selection, compounding, reinforcement, vulcanization, processing (conversion of raw materials into finished products) and testing/characterization of rubbers and rubber composites. This course will provide a sound introduction to different rubber materials and their properties.
Course Content	Syllabus Rubbers and rubber blends: Natural rubber, polymerization: synthesis of synthetic rubbers, different synthetic rubbers: polybutadiene rubber, styrene-butadiene rubber, acrylonitrile butadiene rubber, chloroprene rubber, polyisoprene rubber, butyl rubber, halogenated copolymers of butyl rubber, ethylene propylene rubber (EPM and EPDM), ethylene vinylacetate copolymers, chlorinated polyethylene, chlorosulfonated polyethylene, acrylic rubbers and ethylene acrylate copolymers, epichlorohydrin rubber, polypropylene oxide rubber, fluoroelastomer, polynorbornene, polysiloxane and silicone rubber, polysulfide rubber, polyester and polyether rubber, polyurethane elastomer and chemical modification of rubbers. Rubber blends: rubber-rubber blends, rubber-plastic blends, thermoplastic elastomers, thermoplastic vulcanizates and structure property relationship in different rubbers and rubber based blends. Rubber compounding: Rubber chemicals and additives: Mastication and peptizers, vulcanizing agents, accelerators, activators, retarders, aging, fatigue and ozone protective agents, antioxidants, reinforcing fillers and non-reinforcing fillers, pigments, plasticizers, processing aids and factice, blowing agents and adhesion promoters. Developing formulations for rubber compounding. Processing of rubbers: Compound preparation using internal mixers and two-roll mixing mill, processing to sheets, manufacturing of extruded products and manufacturing of molded rubber goods. Rubber testing and analysis: Mechanical testing, rheological studies, viscoelastic studies, adhesion testing, electrical testing, chemical testing, thermal testing and morphological analysis Rubber latices: Natural rubber latex and modified natural rubber latices, synthetic rubber latices: styrene butadiene rubber latex, nitrile rubber latex, polychloroprene latex, isobutylene isoprene rubber latex and modified synthetic rubber latices, latex compounding, latex processing and testing. Recent developments in rubber science and technology: Nanofillers and application of nano-fillers in rubbers, alternative

	vulcanization systems, advancements in rubber processing techniques, sustainable elastomers, smart elastomers, self-healing elastomers, recent advances in the devulcanization technologies and rubber recycling.
Learning Outcome	Upon completing this course, the student will be able to Will be able to summarize the chemical structure, molecular properties, physical/chemical properties, and areas of application of major types of rubbers. Will be familiar with the role of compounding ingredients, vulcanization process, and appropriate processing techniques at a basic and advanced level. Will be able to clearly decipher the advancements in rubber science and technology from research and industrial perspectives.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Textbooks:

1. Rubber Technology, Maurice Morton; Kluwer Academic Publishers, 1999.
2. Rubber chemistry, JA Brydson (ed), Applied Science Publishers Limited, 1978.
3. Current Topics in Elastomers Research, Anil K. Bhowmick (ed); CRC Press, 2008.

Reference books:

1. Rubber Products Manufacturing Technology, Anil K. Bhowmick, M. M. Hall, H. Benary, (Eds); Marcel Dekker Inc, 1994.
2. Rubber Compounding-Principles: Materials and Techniques, Fred W. Barlow (ed), Marcel Dekker Inc, 1996.
3. Physical Testing of Rubber, Roger Brown (ed); Chapman and Hall, 1996.
4. Handbook of Elastomers, AK Bhowmick, Howard L. Stephens (eds); Marcel Dekker Inc, 2001.

	CLO1	CLO2
PLO1		
PLO2		
PLO3	X	X
PLO4	X	

Course Number	MM7102 / MM7202
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Flash sintering of ceramics
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand how flash sintering can be used in various technological applications. To learn how the structure of dense samples can be modified through flash phenomena to create new states of matter. To learn how flash sintering can be used for phase reaction and sintering, together.
Course Description	The course explores the scientific underpinnings of flash sintering, including microstructure evolution, thermal runaway, electrochemical reactions and its applications.
Course Content	Introduction: Two-electrode method of sintering. Flash sintering phenomena, onset criteria, conductivity at the flash onset, and different stages of flash sintering. Process parameters, atmosphere, and equipment. Temperature measurement: temperature evolution, Modelling temperature evolution, <i>in-situ</i> and <i>ex-situ</i> temperature measurement, measurements at synchrotrons. Mechanism: Microstructure evolution. Thermal runaway of Joule heating, grain boundary overheating, electrochemical reaction, and avalanche of Frenkel pairs. Science to technology: Flash sintering of multi-layered materials, continuous flash sintering, flash joining, Contactless flash sintering, the influence of imposed magnetic field. Sintering maps, constrained sintering. Reactive flash sintering: Resolving the issue of phase reaction and sintering. Influence of volume change on sintering. <i>In-situ</i> measurements of phase reaction. Synthesis of materials for battery and fuel cells. Flash phenomena on dense samples: Flash experiments on single crystals, bicrystals and dense polycrystals. Materials development through repetitive flash experiments. Quenching experiments to freeze structure. Case studies: ○ Flash assisted synthesis of materials for lithium-ion battery ○ Development of solid oxide fuel cell in one step ○ Superplastic elongation of ceramics through flash phenomena
Learning Outcome	Upon completion of this course the student will be able to: Understand the fundamental principle, hardware and applications of flash sintering technique. Understand the novelty of flash sintering technique. Understand how flash sintering can be used as a generic tool for materials development.

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.
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Textbook:

1. Field-Assisted Sintering: Science and Applications, Eugene A. Olevsky and Dina V. Dudina, Springer, 2018.

Reference papers:

1. C.E.J. Dancer. Flash sintering of ceramic materials. Materials Research Express. 2016;3(10):102001.
2. M. Yu, S. Grasso, R. Mckinnon, T. Saunders, M.J. Reece. Review of flash sintering: materials, mechanisms and modelling. Advances in Applied Ceramics. 2017;116(1):24–60.
3. M. Biesuz, V.M. Sglavo. Flash sintering of ceramics. Journal of the European Ceramic Society. 2019;39(2):115–143.
4. R.I. Todd. Flash Sintering of Ceramics: A Short Review. In: B. Lee, R. Gadow, V. Mitic, eds. Proceedings of the IV Advanced Ceramics and Applications Conference. Paris: Atlantis Press; 2017:1–12.
5. E. Gil-González, L.A. Pérez-Maqueda, P.E. Sánchez-Jiménez, A. Perejón. Flash Sintering Research Perspective: A Bibliometric Analysis. Materials. 2022;15(2):416.

	CLO1	CLO2
PLO1	X	X
PLO2		
PLO3		
PLO4	X	

Course Number	MM7103 / MM7203
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Advanced Topics in Ceramic Processing
Learning Mode	Lecture
Prerequisite	
Learning Objectives	To understand the influence of various parameters like temperature, pressure, and electric field on the sintering of ceramic. To understand the theoretical concepts of different sintering methods.
Course Description	The course covers advanced topics related to sintering driving force, diffusional pathways and grain growth, and the effect of sintering on mechanical properties, density, and microstructure evolution of the ceramic material.
Course Content	Syllabus Historical overview of the processing of ceramic materials, different ceramic processing techniques, powder processing routes, techniques of powder production Kröger-Vink notation, defects in ceramic, defect equilibria, Brouwer diagram. Diffusion in ceramics, theory of diffusion, the diffusion equation and Fick's laws, atomistic mechanism of sintering, lattice, grain boundary and surface diffusion, ambipolar diffusion Thermodynamics of surfaces and interfaces, interfacial free energy, role of surfaces and interfaces on sintering, the change of pressure and chemical potential under a curved surface, Gibbs-Thomson equation Definitions, stages, and driving force for sintering, geometric model of sintering Intermediate and final stage theory, the models of Coble, grain growth, grain boundary-pore interaction, two-step sintering, reactive sintering Liquid phase sintering, transient and persistent liquid phase sintering, microstructural evolution Effect of pressure on sintering, Plastic Yielding Mechanisms, creep Mechanisms, hot pressing, cold sintering, the effect of electric field on sintering, FAST, and Flash sintering, Numerical Simulation of Sintering, sintering maps, and case studies, Properties of sintered ceramics
Learning Outcome	Upon completion of this course, the student will be able to: Understand how different process parameters influence the sintering. Understand the fundamental of sintering including newer sintering technologies like FAST.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books

1. Ceramic Processing and Sintering, Mohamed N. Rahaman,, 2nd Edition, CRC Press, 2003

2. Fundamentals of Ceramics, M.W Barsoum; McGraw Hill, 1997.
3. Introduction to Ceramics, 2nd Ed, W. David Kingery, H. K. Bowen, Donald R. Uhlmann, Wiley,1976.

Reference Books

1. Ceramic Materials: Science and Engineering, C. Barry Carter, M. Grant Norton; Springer, 2nd ed. 2013.
2. A. Upadhyaya, G.S. Upadhyaya, Powder Metallurgy: Science, Technology and Materials, 2011.

	CLO1	CLO2
PLO1	X	X
PLO2		
PLO3	X	