JSS MAHAVIDYAPEETHA
JSS SCIENCE AND TECHNOLOGY UNIVERSITY
SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING, MYSURU

DEPARTMENT OF POLYMER SCIENCE AND ENGINEERING

Domain Specific Courses for PhD course work

Sl No	Subject Code	Title of the course
1.	PSTD01	Advanced Rubber Technology
2.	PSTD02	Advanced Characterization Techniques
3.	PSTD03	Nanomaterials and Technology
4.	PSTD04	Biopolymers and Polymers from Renewable Resources
5.	PSTD05	Design of Polymer Nanocomposites

Advanced Rubber Technology

UNIT No.	Course Content
1	**Natural and synthetic rubbers:** Production, grades, properties, compounding principle and applications of general purpose and special purpose elastomers: Natural rubber, SBR, EPDM, PBR, NBR, IIR, polychloroprene rubber, fluoroelastomers, silicone rubber, chlorosulphonated polyethylene, chlorinated polyethylene, HNBR. Functionalized rubber.
2	**Compounding Ingredients:** Types, function, mechanism of the rubber additives used to modify mechanical properties, surface properties, optical properties. Other miscellaneous additives such as Flame retardants, blowing agents. Additives used for sustainability. **Design of compounds to meet –** (a) Product requirements, (b) Service requirements (c) Process requirements and (d) Statutory requirements.
3	**Fiber Reinforcement:** Textile terminologies; spinning process (synthetic fibers: melt spinning, solution spinning: wet and dry spinning), properties and applications of fibers such as cotton, rayon, polyamide, polyester, glass, aramid and steel wire for use in rubber products, pretreatment methods and rubberizing process.
4	**Advanced rubber processing techniques and troubleshooting:** Mastication, mixing process, Shaping process (extrusion and calendaring process), molding process (compression molding, transfer molding, injection molding), vulcanization techniques (batch and continuous techniques)
5	**Testing and characterization of raw materials, compounds and vulcanizates:** Principle, significance and application of following **-** ash content, aniline point, DBP number, solvent extraction, pH, Mooney viscosity, curing characteristics using ODR, MDR and RPA, Tensile properties, flex fatigue, heat build up, abrasion resistance, resilience, creep and stress relaxation, tear strength, peel adhesion, DSC, TGA, SEM

References:

1. Rodgers, B. Rubber compounding: chemistry and applications; Marcel Dekker: New York, 2004
2. Andreas Limper, Mixing of rubber compounds; Carl Hanser Verlag, Munich, 2012.
3. Roger Brown, Physical Testing of Rubber, Springer Science, US, 2006.
4. Gent, A. N. Engineering with rubber how to design rubber components; 2nd ed.; Hanser; Munich, 2001.
5. Morton, M., Rubber technology, 2d ed.; Van Nostrand Reinhold: New York, 1973.
6. Freakley, P. K., Rubber processing and production organization; Plenum Press: New York, 1985.
7. Brydson, J. A., Rubbery materials and their compounds; Elsevier Applied Science, London, 1988.

8. Barlow, F. W., Rubber compounding: principles, materials, and techniques; M. Dekker: New York, 1988.
9. J.E. Mark and Erman.F.R. Eirich, Science and Technology of Rubber, Elsevier Academic Press, UK, Third Edition, 2005.
10. N.R. Legge, G.Holden and H.E. Schroeder, Thermoplastic elastomers, 2nd edition, Hanser Verlag, Munich, 1996.
11. Blow, C. M.; Hepburn, C. Rubber technology and manufacture; 2nd ed.; Butterworth Scientific: London, 1982.
12. Alliger, G. and Sjothun, I.J., Vulcanization of elastomers: Principles and practice of vulcanization of commercial rubbers; Reinhold Pub. Corp.: New York, 1964.

Advanced Characterization Techniques

UNIT No.	Course Content
1	**Introduction to analytical instrumentation:** Calibration, accuracy, precision, reproducibility, standard deviation, electromagnetic spectra. **Spectroscopic Methods:** Introduction, classification**,** Ultraviolet-Visible spectroscopy- Introduction, principle, Lambert law, Beer's law, theory, instrumentation, procedure, advantages, disadvantages, interpretation of spectrogram, applications- qualitative analysis, quantitative analysis; purity, cis- and trans- conformation. Introduction to mass spectroscopy.
2	**Fourier transform infrared (FTIR) spectroscopy:** Introduction, principle, theory, instrumentation, procedure, sample preparation, advantages, disadvantages, interpretation of spectrogram, and applications- establishment of chemical structure of polymers, reaction kinetics, polymer linkage, hydrogen bond formation, purity, copolymerization, qualitative and quantitative results. **Chromatographic technique:** Principle of Gel permeation chromatography (GPC), mechanism of separation, theory / techniques, instrumentation, universal calibration, molecular weight determination and distribution (MWD), purity, composition and other applications.
3	**Nuclear Magnetic spectroscopy (NMR) - (^{1}H NMR and ^{13}C NMR):** Introduction, Principle, theory, spin-spin coupling, coupling constant, instrumentation, procedure, sample preparation, advantages, disadvantages, applications– chemical structures, purity, tacticity. **Microstructural analysis:** X-ray diffractometry (WAXS and SAXS): Principle, theory, instrumentation, applications-Chain conformations, chain packing, disorder in the crystal, degree of crystallinity, micro structural parameters, degree of orientations, crystallization behavior and other applications. XPS**:** Principle and applications.
4	**Thermal Methods:** Introduction, general classification, advantages of the TA methods; **Differential scanning calorimetry (DSC and MDSC)**- Introduction, theory, instrumentation, method of analysis, factors affecting on DSC results, advantage, disadvantage, interpretation of DSC thermograms, applications - T_g, T_m, determination of blends composition, purity, identification of unknown polymers, degree of crystallization, degree of cure and rate of cure studies / kinetics of curing, plasticizers effect. **Thermogravimetric analysis (TGA)**- Introduction Principle, theory, instrumentation, procedure for analysis of sample, factors influence on studies, advantages, disadvantages, applications – Purity, fiber content, composition of compounded rubbers, identification of polymers / rubbers, thermal stability, thermal degradation, kinetics of thermal degradation and IPDT. **Dynamic mechanical analysis (DMA)**- Introduction, principle, instrumentation, and its applications.
5	**Morphological analysis:** Polarizing microscope, SEM, TEM and AFM- Introduction, Principle, theory, instrumentation, procedure, sample preparation,

	advantages, disadvantages, applications– Morphology of polymers, phase separation, particle size analysis, fracture study and other applications.

References:

1. D.Campbell and J.R. White – Polymer Characterization – Physical Techniques (Chapman and Hall), 1989
2. F.W.Billmeyer - Text book of Polymer Science - 3rd ed. Wiley Interscience,1984.
3. K.J.Saunders-The Identification of Plastics and Rubber , Chapman and Hall, London 1970.
4. William C. Wake - Analysis of Rubber and Rubber like Polymers – Rev. ed. Wiley Interscience, New York 1969.
5. E.Turi - Thermal Characterization of Polymeric materials - Academic Press,New York 1981.

Nano Materials

UNIT No.	Course Content
1	**Introduction:** Introduction to nanotechnology, difference between micro and nanostructured materials, basic of Nanoparticles, Nanowires, Nanorods, Nanoplatelets, Nanoclusters. **Classification:** based on origin, dimensions – 0-D, 1-D, 2-D, 3D, Chemical composition, phase composition and manufacturing process, Nano material synthesis and processing, Bottom up and top down approaches, Mechanical grinding, Wet Chemical Synthesis of Nanomaterials, Sol-gel process, Methods Based on Evaporation - Physical Vapor Deposition, Ionized Cluster Beam Deposition, Gas Phase synthesis, Flame assisted ultrasonic spray pyrolysis, Gas Condensation Processing (GPC), Chemical Vapour Deposition (CVD), Electric Arc Deposition, Sputtered Plasma Processing, Microwave Plasma Processing, Particle precipitation aided CVD, Laser ablation. Properties of Nanomaterials, Advantages and disadvantages of nanomaterials, Applications of nanomaterials and technology.
2	**Nanoclay:** Introduction, chemistry, types, properties and uses of nanoclay, surface modification of nanoclay with different organic compounds, characterization and their properties, reason for modification of nanoclay. **Nanocellulose:** Structure and Source of Cellulose, Nomenclature and Types of Nanocellulose, Nomenclature and types of nanocellulose properties and applications**.** **Carbon nanotubes:** Structural aspects, single walled and multi walled nanotubes, preparation of CNTs carbon arc process, catalytic assisted pyrolysis, laser technique, electro chemical method, purification, properties, and surface modification of CNTs, **Fullerenes:** Structure, properties and applications. **Graphene:** Structure, properties, modifications and applications.
3	**Introduction to nanocomposites:** Classification of nanocomposites. Preparation of Polymer - clay nanocomposites - solution, In-situ intercalative polymerization method and melt intercalation; types of nanoclay composites – Intercalation and exfoliation. Application of nanoclay filled polymer nanocomposites. **Nanocellulose based green composites**: fabrication and applications. **CNT - Polymer composites:** Methods of fabrication -In situ polymerization, Solution processing and Melt processing, properties of CNTs composites, Application of CNT-polymer composites.
4	**Characterization of nanocomposites:** Mechanical properties – tensile properties, flexural properties, impact properties, thermal characterization - TGA and DSC (crystallization behavior, melt characteristics), dynamic mechanical analysis, heat distortion temperature, fire retardant properties, barrier properties – GTR and WVTR, conductivity, optical properties, rheology, biodegradability, morphology.
5	**Application of Nanotechnology:** Nanotechnology for waste reduction and improved energy efficiency, nanotechnology based water treatment strategies. Nanotechnology in biomedical applications. Polymeric nanoparticles for drug and gene delivery.
Reference Books:	

1. Nalwa, H. S. (Ed.). (2004). Encyclopedia of nanoscience and nanotechnology Stevenson Ranch, CA: Vols- 1-10,American scientific publishers.
2. Schwarz, J. A., Contescu, C. I., & Putyera, K. (Eds.). (2004). Dekker encyclopedia of nanoscience and nanotechnology (Vol. 5). CRC press.
1. Ke, Y. C., & Stroeve, P. (2005). Polymer-layered silicate and silica nanocomposites. Elsevier.
2. Joong Hee Lee, Siddaramaiah, and Nithin Kundachira Subramani. (2020) Polymer – Based Smart Composites for Optoelectronic and Energy Application. Elsevier
3. Theng, B. K. G. (2012). Formation and properties of clay-polymer complexes. Elsevier.
4. Theng, B. K. G. (1974). The Chemistry of Clay-Organic Reactions. The Chemistry of Clay-Organic Reactions. Wiley, New York.
5. Chirala, V., Marginean, G., Brandl, W., & Iclanzan, T. (2006). Vapour grown carbon nanofibres-polypropylene composites and their properties in Carbon nanotubes edited by VN Popov and P. Lambin. Springer, Netherlands.
6. Thomas, S., Zaikov, G. E., & Valsaraj, S. V. (Eds.). (2009). Recent advances in polymer nanocomposites. Bonston: VSP. CRC Press
7. Thomas, S., & Zaikov, G. E. (2008). Progress in polymer nanocomposite research. Nova Science Publishers.

Biopolymers and Polymers from Renewable Resources

UNIT NO.	Course Content
1.	**Natural and Biodegradable polymers:** Introduction, classification of biodegradable polymers (based on source; natural origin and synthetic/mineral origin based biodegradable polymers) classification of natural polymers based on source (animal, plant, microbes), based on chemical nature **(**Polysaccharide polypeptides/proteins, polyesters and polynucleotides**),** advantages and disadvantages, general applications.
2.	Biodegradability: Natural biodegradable polymer, synthetic and modified biodegradable polymers. **Mechanism of biodegradation:** Biological and nonbiological degradation, factors affecting polymer degradation (Structure, morphology, Molecular Weight, Physical Properties)
3.	**Biopolymers in the medical field:** tissue engineering, wound healing, controlled release of drugs, post-surgical treatments, etc.
4.	**Biopolymer Applications in Agriculture**: Biopolymer Films – Biodegradable mulching – Advantages and Disadvantages – Chemical sensors – Biosensors – Functionalized Biopolymer Coatings and Films – Applications of biopolymers in horticulture.
5.	Use of biomaterials for manufacture of plastic films, blends, various types of films and their applications. **Testing methods of biodegradability of biopolymers: Monitoring biodegradation processes:** Enzyme Assays, Plate Tests, Respiration Tests, Gas (CO_2 or CH_4) Evolution Tests, Natural Environments and Field Trials, Spectroscopy, microscopy etc., **Standards and norms:** International and National norms on biodegradability and certification procedures

References:

1. Katiyar, V., Kumar, A., & Mulchandani, N. (Eds.). (2020). Advances in Sustainable Polymers: Synthesis, Fabrication and Characterization. Springer Nature.
2. Lendlein, A., & Sisson, A. (Eds.). (2011). Handbook of biodegradable polymers: isolation, synthesis, characterization and applications. John Wiley & Sons.
1. Bastioli, C. (Ed.). (2020). Handbook of biodegradable polymers. Walter de Gruyter GmbH & Co KG.
2. Thakur, V. K., & Thakur, M. K. (Eds.). (2015). Handbook of Polymers for Pharmaceutical Technologies, Biodegradable Polymers (Vol. 3). John Wiley & Sons.
3. Thakur, V. K., & Thakur, M. K. (Eds.). (2015). Handbook of polymers for pharmaceutical technologies, processing and applications (Vol. 2). John Wiley & Sons.
4. Smith, R. (Ed.). (2005). Biodegradable polymers for industrial applications. CRC

press.
5. Olatunji, O. (Ed.). (2015). Natural polymers: industry techniques and applications. Springer.

Design of Polymer Nanocomposites

UNIT NO.	Course Content
Unit 1	**Introduction:** Definition, need for polymer nanocomposites, classifications of composites, advantages of PMC over other composites, functions/role of matrix, fillers, reinforcements and coupling agents. Physical, chemical, thermal and mechanical properties of selected thermoset and thermoplastic matrix systems.
Unit 2	**Nano fillers and reinforcements:** Introduction, types (both natural and synthetic should be considered), properties, chemistry and applications of nanofillers. Short and long fibers, general purpose and high performance fibers, whiskers, organic and inorganic fibers, properties, structure and uses. Structured reinforcements. **Coupling agents:** Function, chemistry, methods of applications, examples, advantages and limitations.
Unit 3	**Composite raw materials**: prepregs, preforms and compounds (SMC, DMC, BMC, LPMC, XMC), preparation, properties and uses. **Processing of thermoplastic nanocomposites:** Types of processing methods and conditions, matched die moulding, solution, film, lamination, sandwich. **Fabrications of thermoset nanocomposites:** layup methods, match die molding, compression and transfer molding, pressure and vacuum bag process, filament winding, pultrusion, RIM, RRIM, VARTM and VERTM, Injection moulding of thermosets, Advantages and limitations of each method.
Unit 4	Prediction of composite properties based on constituent materials. Mathematical models for composite properties estimation. **Factors influencing on performance of the nanocomposites:** Aspect ratio, void content, nature of the fiber/filler, structure property relationship between fiber and matrix, modifications of the fiber surface, degree of interaction between and fiber and matrix, wetting behavior, surface functionalization. **Testing of nanocomposites:** Destructive and non-destructive tests; Destructive-tensile, compression, flexural, ILSS, impact strength and HDT.
Unit 5	**Nanocomposite design:** Introductions, Design fundamentals, structure-material-design relationships, design values and design constraints, uncertainty in product design, design process, decision making in design, design methodologies, material considerations in composite design, prediction tools. **The basic concepts of composite fracture mechanism. Advanced applications of nanocomposites.**

References:

1. V. Arumugaprabu, R. D. Joel Johnson, M. Uthayakumar, P. Sivaranjana (2021). Polymer-Based Composites: Design, Manufacturing and Applications. CRC Press.
2. Md Rezaur Rahman (2020). Advances in Sustainable Polymer Composites. Woodhead Publishing.
3. Peters, S. T. (Ed.). (2013). Handbook of composites. Springer Science & Business Media.
4. Chawla, K. K. (2012). Composite materials: science and engineering. Springer Science & Business Media.
5. Rosato, D. V., & Rosato, D. V. (2004). Reinforced plastics handbook. Elsevier.
6. Mazumdar, S. (2001). Composites manufacturing: materials, product, and process engineering. CRC press.

7. Hollaway, L. C. (Ed.). (1994). Handbook of polymer composites for engineers. Woodhead publishing.