BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
HYDERABAD CAMPUS
FIRST SEMESTER 2022-23
Course Handout (Part II)

Date: 29/08/2022

In addition to part -I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

Course No.	**: MST F331**
Course Title	**: Materials Characterization**
Instructor-in-charge	**:** Karthik Chethan V.
Lab Instructors	**:** Karthik Chethan V.

1. **Scope and Objective of the Course:** The course scope is to introduce various materials characterization techniques (mechanical, thermal, analytical, structural, physical, microscopy, surface, rheological and electrical) in the most hands-on manner possible. Typically, for a well-defined industry wish list and applications, product development involves the sequence of material selection, materials design and materials processing steps. During product development, these major steps go back and forth in an iterative manner prior to obtaining an acceptable product. The role of materials characterization is to provide clear goals for iterations (what and why a certain property of the product has to be characterized and the usefulness of the same) and also to eventually reduce the number of iterations. In summary, materials characterization is the crucial link for the three previously mentioned steps, it not only acts as a liaison but is also the train engine that drives these product development coaches.

   For ex: product development of textile apparel with a wish list such as, particular hygroscopicity, weaving requirements, anti-microbial, self cleaning, fiber diameter, fiber performance etc., materials characterization answers with quantitative evidence to questions such as, what is this material, it's composition, it's response to environmental factors, can it be modified and if so the evidence of fruitful modification, can it be designed to fiber like aspect ratios, can it be woven, can it be coloured and mixed with relevant additives, can it be processed using melt spinning with certain speed, solvent, temperature, spinneret diameter etc. The point is without these quantitative answers to all the pertinent questions of the three steps, the link and feedback loop between the steps and the progress or going forward of product development will cease to happen. It's an understatement if we said materials characterization is central and indispensable to research and development in both academic and industry domains. That also means, the career and personnel who are involved in materials characterization are equally invaluable.

   The course is primarily aimed at understanding a variety of materials characterization techniques that are commonly utilized in the product development scenario. In general, learning of these techniques would follow the sequence of principles and theory of the experimental technique, mathematical formalisms, hands-on instrumentation and operating procedure, case studies with data analysis and interpretation and troubleshooting. In conclusion, the main thing is to develop a habit to learn to identify the nine yards of product development in terms of various requirements/wish list and associated properties and relevant characterization involved.

Course Outcomes (CO):

CO1. To conduct materials characterization hands on for composition, performance and structural requirements on a variety of materials in regards to mechanical, thermal, microscopy, compositional, structural, physical, surface, rheological and electrical properties in solving product development related issues.

CO2. To conduct data analysis and interpretation of results in either oral or written form for composition, performance and structural requirements on a variety of materials in regards to mechanical, thermal, microscopy, compositional, structural, physical, surface, rheological and electrical properties in solving product development related issues.

CO3. To identify characterization artifacts and to prevent the same in addition to modifying existing test protocols (basically to conduct troubleshooting) for composition, performance and structural requirements on a variety of materials in regards to mechanical, thermal, microscopy, compositional, structural, physical, surface, rheological and electrical properties in solving product development related issues.

Student Learning Outcomes (SLO): SLOs are outcomes (a) through (k) plus any additional outcomes that may be articulated during the course.

(a) an ability to apply knowledge of science and engineering.
(b) an ability to design and conduct characterization experiments, as well as to analyze and interpret results.
(c) an ability to select and apply relevant characterization techniques to meet specific desired needs within realistic constraints such as availability, expertise and economics.
(d) an ability to function on teams.
(e) an ability to identify, formulate, and solve engineering problems.
(f) an understanding of professional and ethical responsibility.
(g) an ability to communicate effectively.
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

2. **Textbooks:**

TB 1. Mary Ann White, “Physical Properties of Materials”, CRC Press, 2nd edition, 2011.
TB 2. Callister William D & R. Balasubramaniam, Materials Science and Engineering, Wiley Student Edition, 7th Edition, 2007.

Reference books

1. R.E. Newnham, “Properties of Materials: Anisotropy, Symmetry, Structure”, Oxford University Press.

3. Course Plan:

Lect. No.	Topics to be covered	Learning objectives	Chapter in the Text Book
1-2	Introduction	Intro to Materials Science and Materials Characterization and its role and a case study discussion	TB 1: 1
3-6	Mechanical Characterization	Fundamentals of stimulus and response. The different mechanical properties will be discussed and conceptualized. Various tests such as, short-term static tests (tension, compression, shear, bending, impact, hardness and abrasion), long-term static tests (mechanical creep and stress relaxation) and dynamic tests (fatigue and dynamic mechanical relaxation) will be discussed. Specific focus on mechanical properties of plastics, rubber and composites,	TB 1: 14 and TB 2: 9 Classroom and experiential learning activities such as learning to read plots, interpret and analyse and discuss.
7-10	Mechanical Characterization - Instrumentation	Universal testing machine, Fatigue machine, Izod and charpy impact testers, Hardness indentors, Abrasion tester, Mechanical creep and stress relaxation instruments, Dynamic mechanical analyser and single fibre tester.	TB 2: 11 Lab visit and activities such as learning to read and understand testing protocols in addition to lab activities during lab hour
11-14	Thermal Characterization	Fundamentals of stimulus and response. Properties such as heat capacity, thermal expansion coefficient, thermal conductivity, thermal diffusivity and thermal emissivity will be discussed. Further, physical and chemical processes due to temperature changes: glass transition, melting and crystallization, thermal degradation, phase separation and chemical reactions will be discussed.	TB 1: 6-8 Classroom and experiential learning activities such as learning to read plots, interpret and analyse and discuss with respect to DSC, TGA and thermal conductivity results for

			biological, polymeric and composite materials.
15-18	Thermal Characterization-Instrumentation	Differential scanning calorimetry, Thermo-gravimetric analysis, Thermal conductivity and Differential Thermal Analyzer instruments.	TB 1: 6-8 Lab visit and activities such as learning to read and understand testing protocols in addition to lab activities during lab hour
19-22	Physical, analytical and surface Characterization	Microstructure Characterization: qualitative and quantitative phase analysis, size and shape determination of phases, surface morphology, interfacial characterization, crystalline morphology and fractography/failure analysis, particle size determination and surface charge (zeta potential), elemental analysis, and surface topography measurements.	TB 1: 10 Classroom and experiential learning activities such as learning to read micrographs and plots, interpret and analyse and discuss with respect to OM, SEM, LSM, DLS, FTIR, UV-Vis and AFM for biological, polymeric and composite materials.
23-26	Physical, analytical and surface Characterization - Instrumentation	Optical Microscopy (OM), .Laser Scanning Microscopy (LSM), Scanning Electron Microscopy (SEM), UV-Vis, FTIR, AFM and nanoparticle size analyser (DLS).	TB 1: 5 Lab visit and activities such as learning to read and understand testing protocols in addition to lab activities

			during lab hour
27-29	Rheological Characterization	Fundamentals of stimulus and response: Basics of viscoelasticity, viscoelastic models, types of fluids (both newtonian and non-newtonian) and electro-rheological fluids. Properties: viscosity and frequency dependent shear modulus and relaxational behavior. Characterization instruments: Viscometer and Rheometer	TB 1: 10 Classroom and experiential learning activities such as learning to read viscosity profiles and dynamic rheometry plots, interpret and analyse and discuss with respect to viscometer and rheometer for biological, polymeric and composite materials.
30-31	Rheological Characterization Instrumentation	Viscometer and Rheometer	TB 2:14 Lab visit and activities such as learning to read and understand testing protocols in addition to lab activities during lab hour
32-35	Compositional and Structural Characterization	Elemental composition, surface charge, % crystallinity and d-spacing and nanocrystal size.	TB 1: 10 Classroom and experiential learning activities such as learning to read XRD plots and XRF data, interpret and analyse and discuss for biological, polymeric and

			composite materials.
36-42	Compositional and Structural Instrumentation	XRF and XRD	TB 1: 5 Lab visit and activities such as learning to read and understand testing protocols in addition to lab activities during lab hour

4. Plan for Lab Experiments (work includes case studies and problem solving):

Expt. No.	Lab name	Experiment and learning objective
1	Materials Science Lab (Chemical Eng)	Introduction to Materials Science and Materials Characterization. Reverse engineering of a commercial product will be discussed extensively
2-3	Materials Testing Lab (Mechanical), Characterization Lab (Pharmacy) and Physics Testing Lab (Physics)	Mechanical Characterization – Instrumentation: Universal testing machine, Fatigue machine, Izod and charpy impact testers, Hardness indentors, Abrasion tester, Mechanical creep and stress relaxation instruments, Dynamic mechanical analyser and single fibre testing
4-5	Central Analytical Lab - 1 (Chemistry) and Materials Testing Lab (Mechanical)	Thermal Characterization-Instrumentation: Differential scanning calorimetry, Thermo-gravimetric analysis, Thermal conductivity, Thermo-mechanical analyzer and thermal conductivity instruments.
6-10	Central Analytical Lab – 1 and 2 (Chemistry), Characterization Lab (Pharmacy) and Physics Testing Lab (Physics)	Physical, analytical and surface Characterization – Instrumentation: OM, LSM, SEM, OM, UV-Vis, FTIR, DLS and AFM..
11	Central Analytical Lab -2 (Chemistry) and Highway Construction Lab (Civil)	Rheological Characterization – Viscometer and Rheometer
12-14	Central Analytical Lab – 1 and 2 (Chemistry)	XRF, EDX and XRD

5. **Evaluation Scheme:**

Component	Duration	Weightage	Date & Time	Nature of Component
Mid-Sem	90 mins	20%	03/11 1.30 - 3.00PM	Open Book
Lab work*	Continual Evaluation	45 %		NA
Comprehensive Exam	3 hours	35 %	26/12 AN	Open Book

*lab work will involve hands-on experimental work, data analysis and troubleshooting, video presentations and discussions, reading and presenting test protocols and standards and publications.

Chamber Consultation Hour: Time will be announced later.
Notices: All notices related to the course will be uploaded in CMS.
Make-up Policy: Make-up will be granted for genuine cases with prior approval.
Academic Honesty and Integrity Policy:
Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

Karthik Chethan V.
INSTRUCTOR-IN-CHARGE