GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering

Level: Diploma

Branch: Metallurgy Engineering

Subject Code: DI04021061

Subject Name: Material Characterization

W. E. F Academic Year:	2025-26
Semester:	4th
Category of the Course:	Professional Elective - I

Prerequisite:	Students need a foundational understanding of basic science, mathematics and engineering principles. Sometimes with specific requirements for subjects like Physics, Chemistry, Mathematics and Material Science.
Rationale:	Metallurgy engineers must possess a deep understanding of composition-structure-property relationship of materials. Therefore, it becomes essential for them to be familiar with various techniques to analyze the composition, properties as well as structure from atomic to macroscopic level. Material characterization includes study of techniques such as optical and electron microscopy, X-ray diffraction, thermal analysis, and mechanical testing. The subject will enable the students to get information on composition, crystal structure, defects, morphology, volume and orientation of phases, phase transformation, residual stress etc. This information can then be related to the physical, thermal and mechanical behavior of materials. Such knowledge is critical for selecting materials, developing new materials, improving existing ones in order to meet specific performance requirements as per the standards and specifications for various applications. Material characterization is also an essential aspect for quality control and troubleshooting problems during manufacturing. Since material characterization is a broad field, the present curriculum is designed to cater diploma engineering students.
Competency	Implement suitable technique for qualitative and quantitative analysis of composition, structure and properties of materials for material selection and quality control purposes.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
01	Classify various methods of material characterization	U
02	Understand Optical, Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) for qualitative and quantitative analysis of microstructure	A
03	Understand the use of X-ray Diffraction (XRD) technique for material characterization	A

04	Determine the chemical composition of materials using Energy Dispersive Spectroscopy (EDS), Spark Emission Spectroscopy and X-ray Fluorescence (XRF)	A

**Revised Bloom's Taxonomy (RBT)*

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE(V)	
2	0	4	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	**Introduction to Material Characterization** 1.1. Introduction and importance of material characterization 1.2. Classification of material characterization techniques	02	10%
2.	**Optical Microscopy** 2.1. Principle, construction and working of metallurgical microscope 2.2. Bright field and dark field illumination 2.3. Magnification, resolution and depth of focus and Numerical aperture 2.4. Polarized light microscopy 2.5. Color metallography	06	25%
3.	**Electron Microscopy** 3.1. Principle, construction and working of scanning electron microscope (SEM) 3.2. Interactions between electron beam and sample in SEM 3.3. Applications and limitations of SEM 3.4 Principle, construction and working of Transmission electron microscope (TEM) 3.5. Interactions between electron beam and sample in TEM 3.6. Applications and limitations of TEM	10	25%
4.	**X-ray Diffraction** 4.1X-ray generation, continuous and characteristic spectrum 4.2. Absorption of X-ray by matter and diffraction of X-ray – Bragg's	08	25%

	law 4.3 X-ray diffraction (XRD) methods 4.4 Application of X-ray diffraction (XRD) methods		
5.	**Chemical Composition Analysis** 4.1 Principle and working of Energy Dispersive Spectroscopy (EDS) 4.2. Applications and limitations of EDS 4.3.Principle and working of spark emission spectroscopy applications and limitations of spark emission spectroscopy 4.4. Application of Positive Material Identification (PMI) using XRF (X ray fluorescence)	06	20%
	Total	**30**	**100%**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
25	**28**	**17**	**0**	**0**	**0**

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

Unit No.	Unit Title	Teaching Hours	R Level	U Level	A Level	Total Marks
I	Introduction to Material Characterization	02	03	04	-	07
II	Optical Microscopy	06	07	07	06	20
III	Electron Microscopy	10	07	07	04	18
IV	X-ray Diffraction	08	04	06	04	14
V	Chemical composition analysis	06	04	04	03	11
Total		30	25	28	17	07

References/Suggested Learning Resources:
(a) Books:

Sr. No.	Title of Book	Author / Editor	Publication & Details
1	An Introduction to Material Characterization	P. R. Khangaonkar	Publisher: Penram International Publishing (India) Pvt. Ltd. Year: 2008 ISBN-10: 8187972807
2	A Guide to Materials Characterization and Chemical Analysis	John P. Sibilia	Publisher: Wiley-VCH Year: 1996 ISBN-13: 0471186333
3	Elements of X-Ray Diffraction	B.D. Cullity	Publisher: Addison – Wesley Publishing Company Inc. Year: 2001 ISBN-10: 0201011743
4	Materials Characterization: Introduction to Microscopic and Spectroscopic Methods	Yang Lang	Publisher: Wiley-VCH Year: 2013 ISBN-13: 9783527334636
5	ASM Handbook, Volume 10: Materials Characterization	ASM International	Publisher: ASM International Year: 2019 ISBN-13: 9781627082112

(b) Open source software and website:

- https:/www.doitpoms.ac.uk/miclib/index.php
- https://onlinecourses.nptel.ac.in/noc22_mm14/preview
- https://archive.nptel.ac.in/courses/112/106/112106227/
- https://archive.nptel.ac.in/courses/113/106/113106064/
- https://emb-iitk.vlabs.ac.in/exp/sem-basics/theory.html
- https://atelearning.com/XRLab/presentation_3/index.htm

Suggested Course Practical List:

Sr. No.	Practical Title	Unit No.	Approx. Hours
1.	Prepare a metallographic specimen and examine its microstructure using optical microscope	II	08
2.	Observe a metallographic specimen under bright field, dark field and polarized light microscopy	II	04
3.	Measurement of grain size and volume of phases in a metallic specimen using image analyzer as per ASTM E 1382, ASTM E 1245, ASTM B 487 and ASTM E 1077 standards	II	04
4.	Observe a metallic specimen using scanning electron microscope	III	06
5.	Observe a metallic specimen using transmission electron microscope	III	06
6.	Demonstrate the process of phase identification in metallic sample from its X-ray diffraction pattern	IV	06
7.	Determine the chemical composition of a metallic sample using SEM-EDS as per ASTM E 1508 standard	V	06
8.	Determine the chemical composition of a metallic sample using Positive Material Identification (PMI) (X-Ray Fluorescence) method and spark emission spectrometer as per ASTM E 1476 standard	V	04
9.	Preparation of a characterization report based on industrial or laboratory data.	-	08
10.	Case study of sample using different advance material characterization techniques	-	08
Total			**60 Hours**

List of Laboratory/Learning Resources Required:

Sr. No.	Equipment Name with Broad Specifications
1	**Metallurgical microscope** Magnification: 50X to 1000X Objective Lenses: 5x, 10x, 20x, 50x and 100x magnification Eyepiece: 10x magnification Calibration Standards (Calibration scale) **Image Analyzer with camera:** To capture and analyze digital images. The software should allow for measuring and analyzing features such as grain size, phase identification and length measurement. The microscope should have the capability to use a range of contrast methods, including bright field, dark field, and polarized light.
2	**Scanning Electron Microscope (SEM) with EDS probe:** Magnification range: up to 2,00,000 X Accelerating voltage range: 0.1 to 30 kV Imaging modes: SE, BSE, EDS
3	**Transmission Electron Microscope (TEM)** Type: Cold Field Emission Gun (FEG) or Schottky FEG (depending on model) Accelerating Voltage: 60 kV – 300 kV (variable) Energy Spread: ≤ 0.3 eV (for cold FEG) Beam Current: Typically 10–100 nA
4	**X-ray Diffraction (XRD) instrument:** Operating range: 2θ = 0 to 130 degrees
5	**PMI (Positive Material Identification) machine that uses the XRF (X-Ray Fluorescence) method** A standard calibration piece shall be available that have a known composition to ensure accurate and reliable results. Safety features to protect the operator from exposure to X-rays.
6	**Spark Emission Spectrometer:** Channels: For Ferrous and non-ferrous metals and alloys Sample holder: Solid samples Detector type: Photomultiplier tube or CCD

Additional suggested project list:

1. A literature review of various material characterization techniques including their advantages and limitations.
2. Analysis of microstructure and grain size of various alloys using image analysis software on pre-existing images available in databases or online resources.
3. Prepare a report on the information obtained from each type of interaction between electron beam and metallic sample in SEM.
4. Prepare a report on the information obtained from each type of interaction between electron beam and metallic sample in TEM.
5. Prepare a report on XRD testing of a powder and solid sample.
6. Compare EDS and spark emission spectrometry techniques for compositional analysis of a metallic specimen.

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