



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Branch: Biomedical Engineering

Subject Code : ME02031091

Subject Name : BioMEMS

| | |
|-------------------------|------------------------------|
| w. e. f. Academic Year: | 2024 – 25 |
| Semester: | 2 |
| Category of the Course: | Professional Elective Course |

| | |
|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Prerequisite: | Basics of Biology and Chemistry, Mathematics, |
| Rationale: | This course explores the principles, fabrication techniques, and applications of BioMEMS in medicine and biology. Topics include microfabrication, bio-sensing, lab-on-a-chip systems, and implantable devices. |

Course Outcome:

After Completion of the Course, Student will able to:

| No | Course Outcomes | RBT Level |
|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 01 | Understand the fundamentals, historical development, benefits, and materials of BioMEMS for biomedical applications. | U/A |
| 02 | Understand microfabrication techniques, including photolithography, micromachining, etching, deposition, and molding methods, for BioMEMS applications. | U/A |
| 03 | Explain advanced microfabrication and nanofabrication techniques, including soft lithography, microfluidic patterning, and self-assembly methods. | U/A |
| 04 | Explain advanced microfabrication and nanofabrication techniques, including soft lithography, microfluidic patterning, and self-assembly methods. | U/A |
| 05 | Understand the mechanics, design considerations, and applications of BioMEMS, including fluid dynamics, biomaterials, device simulation, and case studies in healthcare. | U/A/E |

**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 |
|----------------------------|---|----|---------------------------------|------------------------------|-------------|----------------------|---------|-------------|
| L | T | PR | C | Theory | | Tutorial / Practical | | |
| | | | | ESE (E) | PA / CA (M) | PA/CA (I) | ESE (V) | |
| 3 | 0 | 2 | 4 | 70 | 30 | 20 | 30 | 150 |



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Course Content:

| Unit No. | Content | No. of Hours | % of Weightage |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|----------------|
| 1. | Introduction to BioMEMS: Definition and scope of MEMS and BioMEMS, Historical development of MEMS in biomedical applications. The Small-Scale Benefit, The High-Throughput Benefit, The Quantitative Benefit, Properties of materials used in BioMEMS (biocompatibility, durability), Common materials: Silicon, SU-8, PDMS, and hydrogels. | 8 | 18% |
| 2. | Microfabrication Techniques- 1 : Photolithography, Basics: Photoresist and Photomask, Black or White versus Gray Scale, Resolution, The SU-8 Era: High Aspect Ratios, Biocompatible Photoresists, Mask-less Photolithography, Micromachining, Etching: Wet versus Dry, Isotropic versus Anisotropic, Deposition and “Lift-Off”, Nontraditional Substrates, Laser Cutting, Multiphoton Lithography, Micro-molding, Injection Molding, Hot Embossing, Curable Polymers | 7 | 15% |
| 3. | Microfabrication Techniques – 2 Soft Lithography, Basics of Soft Lithography, PDMS, Microstamping, Microfluidic Patterning, Stencil Patterning, Dynamic Substrates, Tunable Molds, Microfluidic Photomasks for Grayscale Photolithography, Hydrogel Devices, Nanofabrication Techniques, Electron Beam Lithography, Scanning Probe Lithography, Fabrication Based on Self-Assembly. | 7 | 15% |
| 4 | Microfluidics and Lab-on-a-Chip Systems : Microscale Behavior of Fluids, Viscosity, Non-dimensional Analysis: Reynolds Number and Peclet Number, Laminar Flow, Parabolic Flow Profile, Circular Cross-Section, Rectangular Cross-Section, Triangular (Isosceles) Cross-Section, Microchannel Resistance, Shear Stress, Capillary Flow, Flow through Porous Media, Diffusion, Surface Tension, Contact Angles, and Wetting, The Surface-to-Volume Problem. Fluids in Electrical Fields, Fluids in Acoustic Fields, Fabrication of Microfluidic Channels, The Building Materials, 3-D Stacking and Bonding, Inlets: the “Macro-to-Micro Interface” Problem, Microchannel Wall Coatings, Operation of Microfluidic Channels: Practical Concerns, Microfluidic Resistors, Multiplexers, Micro pumps, | 8 | 18% |
| 5 | Mechanics and Design Considerations: Biomechanics in BioMEMS: Fluid dynamics in micro-channels: Hagen-Poiseuille flow, capillary action. Mechanical properties of biomaterials and their impact on device design, Design and Simulation Tools: Finite element analysis (FEA) for | 8 | 18% |



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| | stress and fluidic simulations. Practical Design Challenges: Scaling effects and system integration. Packaging, power supply, and wireless communication for implantable devices. | | |
| 6 | Applications and Case Studies: BioMEMS for drug delivery applications, Applications of MEMS technologies for minimally invasive medical procedures, MEMS as implantable neuro-probes, MEMS as ocular implants, MEMS for in vivo sensing. Point-of-Care Diagnostics Using BioMEMS | 7 | 16% |
| | Total | 45 | 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 | 25 | 20 | 10 | 10 | 10 |

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

References/Suggested Learning Resources:

(a) Books:

1. Introduction to BioMEMS by Albert Folch, CRC Press Inc; 1st edition, ISBN-10 : 9781439818398, ISBN-13 : 978-1439818398
2. MEMS for biomedical applications, Shekhar Bhansali and Abhay Vasudev, Woodhead Publishing Series in Biomaterials: Number 43, Woodhead Publishing Limited, ISBN 978-0-85709-129-1 (print).
3. BioMEMS, Biosensing Applications, Samira Hosseini, Michelle Alejandra Espinosa-Hernandez, Ricardo Garcia-Ramirez, Ana Sofia Cerda-Kipper, Sofia Reveles-Huizar, Luis Acosta-Soto, <https://doi.org/10.1007/978-981-15-6382-9>, 978-981-15-6382-9, Published: 13 August 2020
4. BioMEMS and Biomedical Nanotechnology, Volume I, Biological and Biomedical Nanotechnology, Mauro Ferrari, Volume I, ISBN-10: 0-387-25563-X, Springer Science+Business Media, LLC.
5. Fundamentals of microfabrication and nanotechnology, Volumes I, II and III, Marc J. Madau, CRC Press; 3rd edition, ISBN-10 : 0849331803

(b) Open source software and website:

1. Journals and Articles, Lab on a Chip (Royal Society of Chemistry), Biomedical Microdevices (Springer), Sensors and Actuators B: Chemical (Elsevier).
2. <https://www.biomemsrc.org/>
3. <https://ocw.mit.edu/courses/3-051j-materials-for-biomedical-applications-spring-2006/pages/lecture-notes/>



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4. https://onlinecourses.nptel.ac.in/noc20_me93/preview
5. <https://moodle.taltech.ee/course/view.php?id=32189>
6. <https://www.udemy.com/course/future-science-microfluidic-lab-on-a-chips-and-biomems/>

Suggested Course Practical List:

1. Study of photolithography and microfabrication techniques.
2. Study of soft lithography and microfabrication techniques.
3. Study of the process of creating microfluidic devices using PDMS casting.
4. Study of surface modification of a BioMEMS device to enhance biocompatibility.
5. Simulate laminar flow and pressure distribution in a T-junction microchannel.
6. Study of mechanical properties of biomaterials and their impact on device design.
7. Study of mechanics and design considerations of BioMEMS.
8. Study the applications of BioMEMS in drug delivery systems.
9. Study the applications of BioMEMS in minimally invasive medical procedures.
10. Study the applications of BioMEMS in Neuro and Ocular specialty.
11. Study the applications of BioMEMS in Point-of-care devices.

List of Laboratory/Learning Resources Required:

Computer system, PDMS, COMSOL, CoventorWare, Ansys, SIMULIA, Intellisense, MEMS Plus, AutoCAD,

Suggested Project List:

1. Design the micro-channels and micro-reservoirs in computational tools.

Suggested Activities for Students:

1. Students should be encouraged to participate in state and national level workshops in microfabrication technology.
2. Students must visit microfabrication work station in industry or institute of national repute to understand the need of technology in biomedical specialization and research opportunities.

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