BMEE315L	Micro-Electromechanical Systems	L	T	P	C
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Pre-requisite	**BMEE201L, BMEE209L, BMEE209P**	**Syllabus version**			
		1.0			

Course Objectives

1. To introduce the elements of MEMS and develop understanding on importance of scaling laws effect in phenomenon.
2. To introduce different materials, fabrication process and micro manufacturing techniques used in MEMs.
3. To outline the basic principles and operation of micro sensors and micro actuators, and introduce essential components of microfluidic components.
4. To highlight the application of MEMS devices in addressing social needs and integration with emerging technology areas.

Course Outcome

At the end of the course, the student will be able to

1. Comprehend the MEMS importance and diverse application, and related engineering concepts.
2. Understand the importance of scaling laws in MEMS, and predict the scaling effect in related phenomenon.
3. Evaluate and select appropriate material for MEMS devices and fabrication process.
4. Select appropriate fabrication and micro manufacturing process, and develop process sequence for building MEMS devices.
5. Grasp the functions of micro-sensors and actuators used in diverse applications.
6. Perceive the application of physical, chemical, biological and engineering principles in the design and operation of micro devices and roles of MEMS devices for addressing societal needs and emerging technology areas.

Module:1	**Introduction to MEMS**	**5 hours**

History of MEMS development; Components of MEMS; Intrinsic characteristics of MEMS; Interdisciplinary nature of MEMS; Overview of typical MEMS Products; Applications of MEMS in industries – Automotive, Healthcare, Aerospace, Telecommunications, Industrial products, Consumer Products; Review of essential concepts – Electrical and Mechanical; Trends in MEMS – Technology, application and market.

Module:2	**Scaling laws in miniaturization**	**3 hours**

Introduction to Scaling – Need for scaling laws, Types of scaling laws; Motivation for miniaturization; Scaling in-geometry, rigid body dynamics-Trimmers force scaling vector, electrostatic forces, electromagnetic forces, electricity, fluid mechanics, heat conduction, heat convection, etc., Overview of MEMS design process.

Module:3	**Materials for MEMS**	**5 hours**

Single crystal silicon – crystal structure and atomic arrangements, extraction process; Silicon compounds – Silicon Carbide, Silicon Nitride, polycrystalline silicon; Silicon piezo-resistors; Gallium Arsenide; Germanium; Metals-Gold, Silver, Copper, Aluminium; Polymer materials-SU-8, PDMS, Liquid crystal polymers, PMMA, Polyaimide, Parylene, conductive polymers; Other materials-Quartz; Ceramics. Glass.

Module:4	**MEMS fabrication process and micro manufacturing**	**10 hours**

Microfabrication processes-Photolithography, Ion implantation, Diffusion, Oxidation, Physical Vapour Deposition (PVD), Chemical Vapour Deposition (CVD), Deposition by epitaxy; Bulk micro manufacturing- Etching, Isotropic and Anisotropic etching, Wet etching, Etchants, Etch stop, Dry etching, Plasma etching, Deep reactive Ion Etching, Process steps with case studies; Surface micromachining- Process steps with examples, Mechanical issues, , LIGA: Advantages and limitation, Process steps with case studies, Materials, SLIGA; Soft lithography and its application; Wafer bonding; Microsystems packaging.

Module:5	**Micro sensors and Micro-actuators**	**6 hours**

. Micro sensors: Elements and characteristics; Basic principles and operation of different

types of micro sensors - surface acoustic wave micro sensors, bio-medical sensors, bio sensors, chemical sensors, optical Sensors, pressure sensors, thermal sensors, acceleration sensors. Micro actuators: Elements and characteristics; Basic principles and working of different types micro actuator-Electrostatic actuators, Piezoelectric actuators, Parallel plate capacitor actuator, Thermal actuators, Magnetic actuators. SMA actuators,		
Module:6	**Microfluidics**	**6 hours**
Introduction; Motivation for microfluidics; Overview of fluid mechanics – Viscosity, surface tension, capillary rise, flow types, Reynolds number; Components of a micro fluidic system – Channels, Mixers, Sensors, reservoir; Methods of fluid movement in channels; Fabrication process of microfluidics components with examples		
Module:7	**Case studies**	**8 hours**
Application of MEMS devices for – Smart home, visually impaired, surgery, Brain sensors, Self-driving car, Wearable sensors, pollution monitoring and other emerging areas/products; Modelling and analysis of MEMs devices.		
Module:8	**Contemporary Issues**	**2 hours**
	Total lecture hours:	**45 hours**

Text Books	
1.	Tai-Ran-Hsui, MEMS & Microsystems: Design and Manufacture, Wiley,Online,edition ,2020
2.	Chang Liu, Foundations of MEMS,Pearson,2012
Reference Books	
1.	Nadim Maluf and Kirt Williams (2004), An Introduction to Micro electro mechanical Systems Engineering, Second Edition, Artech House
2.	Stephen R.Santuria (2001), Microsystem Design, Springer Science-Business Media Inc.
3.	Minhang Bao (2005), Analysis and Design Principles of MEMS devices, Elsevier
4.	Marc J. Madou (2002), Fundamentals of Micro Fabrication: The Science of Miniaturization, Second Edition, CRC
5.	Gad-EL-Hak The MEMS Handbook CRC Press 2002-modified 2019
6.	V.K.Atre, Ananthasuresh, K.J.Vinoy. S.Gopalakrishnan,K.V.Bhat, Micro and Smart Systems,(WIND), 2010

Mode of Evaluation: CAT / Written assignment / Quiz / FAT / Seminar / Case studies			
Recommended by Board of Studies	09-03-2022		
Approved by Academic Council	No. 65	Date	17-03-2022