VDPE3010 MEMS (3-0-0)

Course Objectives:

1. To introduce the fundamental principles, history, and intrinsic characteristics of MEMS, including materials and fabrication technologies.
2. To familiarize students with bulk and surface micromachining processes, as well as various MEMS foundry technologies.
3. To develop an understanding of different MEMS sensors and actuators such as electrostatic, thermal, piezoresistive, and piezoelectric mechanisms.
4. To provide knowledge of magnetic actuation and scaling laws essential for analyzing and designing micro-scale systems.
5. To expose students to real-world MEMS applications in mechanical, optical, and microfluidic systems, enabling practical understanding of MEMS design and usage.

Module 1: Introduction-History of MEMS, Intrinsic Characteristics of MEMS- Miniaturization, and Silicon based MEMS processes, New Materials properties, Silicon as a MEMS material mechanical properties of silicon. Mechanical components in MEMS, basics of micro technology-definitions and terminology. Fabrication technologies Photolithography Ion implantation - diffusion- oxidation - CVD - Physical Vapor Deposition - Etching. (7 hrs)

Module 2: Micro manufacturing - Bulk and surface micro machining, LIGA. MEMS foundries: MUMPs, CMOS MEMS. (5 hrs)

Module 3: Electrostatic actuators: cantilevers, comb drives. Thermal sensing and actuation: chevron actuator, heat actuator, biomimetic cilia. Piezoresistive Sensors: Piezoresistive Sensor Materials, Stress Analysis of Mechanical Elements, Applications of Piezoresistive Sensors. Piezoelectric Sensing and Actuation: Introduction, Properties of Piezoelectric Materials, Applications. (8 hrs)

Module 4: Magnetic actuation: magnetic fields, Lorentz force, micro-coils, magnetic actuators. Scaling laws Scaling in geometry, rigid body dynamics, electrostatic forces, electromagnetic forces, electricity-fluid mechanics and heat transfer. (5 hrs)

Module 5: MEMS Applications: Mechanical sensors and actuators: Piezoresistive pressure sensors, MEMS capacitive accelerometer, Optical Gyroscopes: Micro-lens, Micro-mirror, Microfluidics: Capillary action, Micro pumping, Electro wetting, Lab-on-a-chip. (5 hrs)

Textbooks:

1. G.K. Ananthasuresh, K.J. Vinoy, S. Gopalakrishnan, K.N. Bhat and V.K. Atre, Micro and Smart Systems, Wiley India, New Delhi, 2010.
2. N.P. Mahalik: MEMS, Tata McGraw-Hill, New Delhi, 2007.
3. T. Hsu: MEMS and Microsystems: Design and Manufacture, Tata McGraw-Hill, New Delhi, 2002.
4. Gabriel M. Rebeiz: RF MEMS Theory, design & Technology, Wiley India Education, 2010.

Course Outcome:

CO1 Realize the operation of micro devices, micro systems and their applications.
CO2 Able to decide which micromachining technique, such as bulk micromachining and surface micromachining, can be used for a specific MEMS fabrication process.
CO3 Able to design the micro devices, micro systems using the MEMS fabrication process.
CO4 Able to analyze the MEMS devices and to develop suitable mathematical models.
CO5 Able to apply scaling laws that are used extensively in the conceptual design of micro devices and systems.