MEMS AND NEMS

Course Objectives

After completing this course, students will be able to:

1. Understand the fundamentals, materials, and operating principles of Micro-Electro-Mechanical Systems (MEMS) and Nano-Electro-Mechanical Systems (NEMS).
2. Acquire knowledge of microfabrication technologies including photolithography, thin-film deposition, etching, micromachining, and packaging processes.
3. Analyze the design and working principles of MEMS-based sensors and actuators used in engineering applications.
4. Understand nanoscale phenomena, quantum mechanical concepts, and molecular dynamics relevant to NEMS.
5. Apply MEMS/NEMS concepts for solving practical problems in sensing, actuation, biomedical, optical, and microfluidic applications.

Module 1: Overview and Introduction (7 hours)

New trends in Engineering and Science: Micro and Nano scale systems Introduction to Design of MEMS and NEMS, Overview of Nano and Micro electromechanical Systems, Applications of Micro and Nano electro mechanical systems, Micro electromechanical systems, devices and structures Definitions, Materials for MEMS: Silicon, silicon compounds, polymers, metals.

Module 2: MEMS Fabrication Technologies (8 hours)

Microsystem fabrication processes: Photolithography, Ion Implantation, Diffusion, Oxidation.Thin film depositions: LPCVD, Sputtering, Evaporation, Electroplating; Etching techniques: Dry and wet etching, electrochemical etching; Micromachining: Bulk Micromachining, Surface Micromachining, High Aspect-Ratio (LIGA and LIGA-like) Technology;

Module 3: Micro Sensors (5 hours)

MEMS Sensors: Design of Acoustic wave sensors, resonant sensor, Vibratory gyroscope, Capacitive and Piezo Resistive Pressure sensors- engineering mechanics behind these Microsensors.

Module 4: Micro Actuators (5 hours)

Design of Actuators: Actuation using thermal forces, Actuation using shape memory Alloys, Actuation using piezoelectric crystals, Actuation using Electrostatic forces (Parallel plate, Torsion bar, Comb drive actuators), Micromechanical Motors and pumps.

Module 5: Nano-systems and Quantum Mechanics (5 hours)

Atomic Structures and Quantum Mechanics, Molecular and Nanostructure Dynamics: Shrodinger Equation and Wavefunction Theory, Density Functional Theory, Nanostructures and Molecular Dynamics, Electromagnetic Fields and their quantization, Molecular Wires and Molecular Circuits.

Course Outcome:

Upon successful completion of the course, students will be able to:

CO1 Explain the fundamentals of MEMS and NEMS, including their materials, structures, fabrication requirements, and engineering applications.

CO2 Analyze and compare various MEMS fabrication techniques such as photolithography, deposition, etching, bulk micromachining, and surface micromachining processes.

CO3 Design and evaluate MEMS-based sensors including pressure sensors, acoustic wave sensors, resonant sensors, and vibratory gyroscopes for specific applications.

CO4 Investigate the operating principles and performance characteristics of MEMS actuators based on electrostatic, thermal, piezoelectric, and shape memory alloy actuation mechanisms.

CO5 Apply concepts of nanotechnology, quantum mechanics, molecular dynamics, and nanosystems to understand and develop emerging NEMS devices and applications.

TEXT BOOKS:

1. Marc Madou, “Fundamentals of Micro fabrication”, CRC press 1997.
2. Stephen D. Senturia,” Micro system Design”, Kluwer Academic Publishers,2001
3. N.P. Mahalik: MEMS, Tata McGraw-Hill, New Delhi, 2007.
4. Gabriel M. Rebeiz: RF MEMS Theory, design & Technology, Wiley India Education, 2010.

REFERENCES:

1. Tai Ran Hsu ,”MEMS and Microsystems Design and Manufacture” ,Tata Mcraw Hill, 2002.
2. Chang Liu, “Foundations of MEMS”, Pearson education India limited, 2006
3. G.K. Ananthasuresh, K.J. Vinoy, S. Gopalakrishnan, K.N. Bhat and V.K. Atre, Micro and Smart Systems, Wiley India, New Delhi, 2010.