MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)

Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

DESIGNING YOUR FUTURE Estd. 2000

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MUST KNOW CONCEPTS

MKC

ECE

2021-2022

Course Code & Course Name : 19ECC16 - NEMS and MEMS Technology

Year/ Sem/Sec : III / VI / A, B & C

Subject		**19ECC16 - NEMS and MEMS Technology**		
S. No.	**Term**	**Notation (Symbol)**	**Concept/Definition/Meaning/Units/Equation/Expression**	**Units**
UNIT I - INTRODUCTION TO MEMS AND NEMS				
1	MEMS		Micro Electro Mechanical System	
2	NEMS		Nano Electro Mechanical System	
3	Definition of MEMS		The MEMS is the batch-fabricated integrated microscale system that: 1. Converts physical stimuli, events, and parameters to electrical, mechanical, and optical signals and vice versa; 2. Performs actuation, sensing, and other functions; 3. Comprises control, diagnostics, signal processing, and data acquisition features,	
4	Basics of the MEMS operation		Microscale features of electromechanical, electronic, optical, and biological components (structures, devices, and subsystems), architectures, and operating principles are basics of the MEMS operation	
5	Microdevice		The microdevice is the batch-fabricated integrated microscale motion, electromagnetic, radiating energy, or optical microscale device that 1.Converts physical stimuli, events, and parameters to electrical, mechanical, and optical signals and vice versa; 2.Performs actuation, sensing, and other functions,	
6	Basics of the microdevice operation		Microscale features of electromechanical, electronic, optical, and biological structures, topologies, and operating principles are basics of the microdevice operation.	

7	Microstructure		The microstructure is the batch-fabricated microscale electromechanical, electromagnetic, mechanical, or optical composite microstructure that is a functional component of the microdevice and serve to attain the desired microdevice's operating features.	
8	Biological nanomotors		Biological (bacterial) nanomotors convert chemical energy into electrical energy, and electrical energy into mechanical energy	
9	Biomimetic systems		Biomimetic systems are the man-made systems which are based on biological principles, or on biologically inspired building blocks integrated as the systems structures, devices, and subsystems.	
10	Electromagnetic and mechanical laws used in MEMS		Barrier Potential in a PN junction refers to the potential required to overcome the barrier at the PN junction.	
11	Issues which must be addressed in view of evolving nature of the MEMS and NEMS		Synthesis, analysis, design, modeling, simulation, optimization, complexity, intelligence, decision making, diagnostics, fabrication and packaging.	
12	Most challenging problems in systems design		The topology– architecture–configuration synthesis, system integration, optimization, as well as selection of hardware and software	
13	Design of systems		The design of systems is a process that starts from the specification of requirements and progressively proceeds to perform a functional design and optimization.	
14	Types of approaches to design		Top-down and Bottom-up	
15	Need to augment interdisciplinary areas		To acquire and expand the engineering-science-technology core	

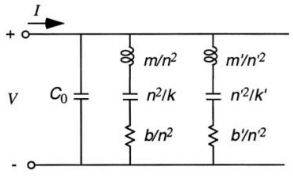
16	Design of high-performance MEMS and NEMS		The design of high-performance MEMS and NEMS implies the subsystems, components, devices and structures synthesis, design, and developments.	
17	Sequential activities		Synthesis, modeling, analysis and simulation are the sequential activities	
18	important aspects for developing and prototyping advanced MEMS and NEMS		Modeling, simulation, analysis, virtual prototyping, and visualization.	
19	Software tools to design		MATLAB, VHDL, SPICE	
20	Quantum dots		Quantum dots are metal "boxes" that hold the discrete number of electrons which is changed applying the electromagnetic field.	
21	Classification of electromechanical systems		1. Conventional electromechanical systems, 2. Microelectromechanical systems (MEMS) 3. Nanoelectromechanical systems (NEMS)	
22	Flip-chip technique		Flip-chip MEMS assembly replaces wire banding to connect ICs with micro- and nanoscale actuators and sensors.	
23	Large-scale MEMS and NEMS		Large-scale MEMS and NEMS, which can integrate processor (multiprocessor) and memories, high-performance networks and input-output (IO) subsystems.	
24	Types of microsensors		Position, displacement, velocity, torque, force, current and voltage.	
25	Micro- and nanoscale sensors used in aircraft		Load, vibrations, temperature, pressure, velocity, acceleration, noise and radiation sensors are used in aircraft.	

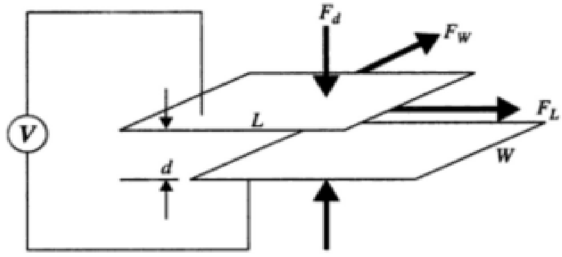
UNIT II-MEMS FABRICATION TECHNOLOGIES				
26	Silicon direct bonding		Silicon direct bonding is used to bond a pair of silicon wafers together directly (face to face).	
27	Anodic bonding		Anodic bonding is used to bond silicon to glass	
28	Assembling and packaging of MEMS		Assembling and packaging of MEMS includes microstructure and die inspection, separation, attachment, wire bonding, and packaging or encapsulation.	
29	Technologies of MEMS fabrication		Bulk micromachining, surface micromachining and LIGA technologies	
30	Etching techniques used in bulk micromachining		The anisotropic and isotropic wet etching processes, as well as concentration dependent etching techniques, are widely used in bulk micromachining.	
31	Etchants used in anisotropic etching		Potassium hydroxide KOH, sodium hydroxide NaOH, H2N4 and ethylene-diamine-pyrocatecol EDP	
32	Three-dimensional structures formed using anisotropic etching		Through anisotropic etching cons, pyramids, cubes and channels into the surface of the silicon wafer are fabricated	
33	Wet etching		Wet etching is the process of removing material by immersing the wafer in a liquid bath of the chemical etchant.	
34	Isotropic etchants		Isotropic etchants attack the material being etched at the same rate in all directions.	
35	Anisotropic etchants		Anisotropic etchants attack the material or silicon wafer at different rates in different directions, and therefore, shapes/geometry can be precisely controlled.	
36	Example for Anisotropic etchants		Ethylene-diamine- pyrocatecol, potassium hydroxide, and hydrazine	

37	Etchants for isotropic etching of silicon		Mixtures of hydrofluoric (HF) and nitric (HNO3) acids in water or acetic acid (CH3COOH	
38	Surface micromachining		It is an additive fabrication technique which uses modified CMOS technology, materials and involves the building of a microstructure or microdevice on top the surface of a supporting substrate.	
39	Advantage of Surface micromachining technology		This technology is used to fabricate the structure as layers of thin films. This technology guarantees the fabrication of three-dimensional microdevices with high accuracy	
40	Key challenges in fabrication of microstructures using surface micromachining		Control and minimization of stress and stress gradient in the structural layer. High selectivity of the sacrificial layer etchant to structural layers and silicon substrate Avoidance of stiction of the released (suspended) microstructure to the substrate	
41	Microtransducers		Microtransducers have stationary and rotating members (stator and rotor) and radiating energy microdevices	
42	LIGA		LIGA process denotes Lithography–Galvanoforming–Molding (in German Lithografie–Galvanik–Abformung).	
43	Capability of LIGA process		LIGA is capable of producing three-dimensional microstructures of a few centimeters high with the aspect ratio (depth versus lateral dimension) of more than 100.	
44	Metal evaporation		To deposit a thin film of metal on a wafer by heating a metal source in a crucible until it boils, and hence transfer metal from the crucible to the wafer through evaporated metal particles	
45	Thermal oxidation		To grow a thin film of silicon dioxide by reacting the substrate with oxygen at very high temperature (e.g., >900°C)	

46	Photolithography		To pattern the photoresist thin film by exposing the film through a patterned mask, thus transferring the patterns on the mask to the photoresist layer.	
47	Ion implantation		To inject high-kinetic-energy dopant atoms into the substrate matrix to change electrical or chemical characteristics of the material.	
48	Deposition of photoresist		To coat a wafer with a uniform and thin layer of photoresist, typically with the spin coating method.	
49	Metal sputtering		To deposit a thin film of metal on a wafer by bombarding a metal source with highenergy particles. The particles sputter the metal off the source and on to the wafer	
50	Plasma etching		To etch a material by reacting it with chemically active species produced in a high-energy plasma, while the wafer is placed on a ground electrode.	
UNIT III - MICRO SENSORS				
51	Major Classes of MEMS Actuators		Electrostatic, Thermal, Piezoelectric Magnetic	
52	Acoustic wave sensor		It is does not related to the sensing of acoustic waves transmitted in solids or other media, as the name implies	
53	Application of Acoustic wave sensor		Sensors is to act like "band filters" in mobile telephones Sensing of torques and tire pressures Sensing biological and chemical substances Sensing vapors, humidity and temperature Monitor fluid flow in microfluidics	
54	MEMS switches		It is consume less power and better isolation and insertion loss	
55	Basic actuation for MEMS switches		There are four basic actuation principles, electrostatic actuation, electromagnetic actuation, piezoelectric actuation , and electrothermal actuation	

56	Energy-conserving transducers		It is depend only on the state variables that control energy storage	
57	Gyroscope		It is the sensor aiming at measuring the angular variance or angular rate based on the Coriolis force	
58	Vibratory gyroscope		Drive frame, a Coriolis frame, and a detection frame	
59	Dissipative transducers		It is depend, in addition, on state variables that determine the rate of energy dissipation	
60	Electrostatic Actuators		Attraction between oppositely charged conductors	
61	Thermal Actuators		Displacement due to thermal expansion	
62	Piezoelectric Actuators		Displacement due to strain induced by an electric field	
63	Magnetic Actuators		Displacement due to interaction among various magnetic elements: permanent magnets, external magneticfields, magnetizable material, and current-carrying conduct	
64	Suspended structure		A sandwich of piezoelectric material between electrodes	
65	Materials challenges in Acoustic		Repeatability of piezoelectric's properties (choose AlN and work the process until it is repeatable) Low acoustic losses and low electrical losses	
66	Fabrication challenges in Acoustic		Precise control of layer thickness • Process compatibility (with IC and piezoelectric) • Structure built over an oxide-filled cavity in the substrate; oxide removed at end to release • Packaging in the fab, by wafer bonding	
67	Capacitive pressure sensors		This sensor conducting layers are deposited on the diaphragm and the bottom of a cavity to create a capacitor.	
68	Principle of Capacitive pressure sensors		Measure changes in electrical capacitance caused by the movement of a diaphragm	

69	Piezoelectric		Apply an electric field across a piezoelectric material; deformation (strain) results, along with actuator deflection and force	
70	Piezoelectric harvesting		An attractive technology for harvesting small magnitudes of energy from ambient vibrations	
71	Piezoelectric effects		The coupling between internal dielectric polarization and strain, an effect called piezoelectricity.	
72	Piezoelectric features		High force High switching speeds Low power dissipation	
73	Ppiezoelectric materials		Quartz, lithium niobate, and gallium arsenide	
74	Piezoelectric substrates		It can also set up traveling acoustic waves.	
75	Electrical Equivalent circuit for Piezoelectric			
UNIT IV - MICRO ACTUATORS				
76	Actuator functions		Converting rotary motion into linear motion to execute movement.	
77	Thermal Actuators		It is a direct result of incorporating tiny heaters, or resistors. These resistors can be controlled to locally heat specific areas or layers as in the case of a bilayer actuator.	
78	SMAs		Shape memory alloy actuation	
79	SMAs function		Exhibit considerable changes in their length (contraction) when heated. These include titanium/nickel alloys, of which some, once mechanically deformed, would return to their original unreformed state when heated.	
80	Magnetic Actuators		It is based on the fact that a current-carrying conductor generates a magnetic field. If this conductor is a wire (or coil) and interacts with another external magnetic field a mechanical force is produced.	

81	Magnetostrictive Actuators		These rely on the magnetostrictive effect, which is the change of shape or size of a ferromagnetic material induced by a magnetic field	
82	Chemical Actuators		Electrochemical electrode concept in which current is transducer from the circuit domain into the chemical domain through oxidation or reduction of chemical species at the electrode surface.	
83	The additive approach in piezoelectric		The piezoelectric thin films are deposited on silicon substrates with layers of insulating and conducting material followed by surface or silicon bulk micromachining.	
84	The subtractive approach in piezoelectric		Single crystal polycrystalline piezoelectrics and piezoceramics are subjected to direct bulk micromachining and then electroded	
85	The integrative approach in piezoelectric		Micromachined structures are integrated in silicon or piezoelectrics by using bonding techniques on bulk piezoelectric or silicon substrates.	
86	Actuation Using Electrostatic Forces		Coulomb's Law- Electrostatic force F is defined as the electrical force of repulsion or attraction induced by an electric field E	
87	Electrostatic forces on parallel plates		Two charged plates separated by a dielectric material (i.e. an electric insulating material) with a gap d. The plates become electrically charged when an electromotive force (emf), of voltage, is applied to the plates	
88	Electrostatic forces on parallel plates diagram			
89	Electrostatic forces on parallel plates		There are two forces in the two directions	

90	Electrostatic forces in width direction		$F_W = \frac{1}{2}\frac{\varepsilon_r \varepsilon_0 L V^2}{d}$	
91	Electrostatic forces in Length direction		$F_L = \frac{1}{2}\frac{\varepsilon_r \varepsilon_0 W V^2}{d}$	
92	EDA		Electronic Design Automation	
93	RF MEMS switches		Small, micromechanical switches that have low power consumption and can be produced using conventional MEMS fabrication technology	
94	RF MEMS switches Application		Wireless communication applications in smartphones, mobile infrastructure, IoT and defense.	
95	RF MEMS switches are classification		Actuation method (electrostatic, electro thermal, magnetic, piezoelectric), axis of deflection (lateral, vertical), circuit configuration (series, shunt), clamp configuration (cantilever, fixed-fixed beam), or contact interface (capacitive, ohmic).	
96	RF MEMS switches forces		Electromagnetic and Electrostatic	
97	Electromagnetic force		It is low actuation voltage, but a high current consumption	
98	Electrostatic force		It is no current consumption, but has a high actuation voltage.	
99	Electrostatic switches use		The microwave and mm-wave regions. Electro statically actuated RF MEMS components offer low insertion loss and high isolation, linearity, power handling, and Q factor	
100	Electrostatic switches mode		There are two kinds of electrostatic switches: series and shunt. Both ohmic and capacitive coupling switches can be used either as a serial or a shunt switch, generally ohmic switches are used in serial mode	

UNIT V - NANO DEVICES				
101	Atom		An atom is a complex arrangement of negatively charged electrons arranged in defined shells about a positively charged nucleus.	
102	Atomic structure		The structure of an atom comprising a nucleus (centre) in which the protons (positively charged) and neutrons (neutral) are present.	
103	Quantum mechanics		Quantum mechanics is a fundamental branch of physics concerned with processes involving small particles (e.g, atoms and photons)	
104	Quantum theory		Describes matter as acting both as a particle and as a wave.	
105	Difference between atom and quantum		Atomic physics studies the electrons orbiting atomic nuclei, nuclear physics studies the nuclei of atoms, while quantum mechanics (today most of us call it "quantum physics" because this theory is far from "mechanical") studies all "microscopic" objects including electrons in any situation	
106	Father of atomic theory		John Dalton, (born September 5 or 6, 1766, Eaglesfield, Cumberland, England—died July 27, 1844, Manchester), English meteorologist and chemist, a pioneer in the development of modern atomic theory.	
107	Atoms made of quantum		Atoms are made of smaller ingredients: protons, neutrons and electrons.	
108	Photon		Elementary particle that serves as the quantum of the electromagnetic field, including electromagnetic radiation such as light and radio waves	
109	Schrödinger equation		The Schrödinger equation is a linear partial differential equation that governs the wave function of a quantum-mechanical system.	
110	Schrodinger's law		The Schrodinger equation plays the function of Newton's laws and energy conservation – i.e., it forecasts a complex system's potential conduct.	
111	Schrodinger's model		Schrödinger used mathematical equations to describe the likelihood of finding an electron in a certain position. This atomic model is known as the quantum mechanical model of the atom.	

112	Schrodinger discover		Assuming that matter (e.g., electrons) could be regarded as both particles and waves, in 1926 Erwin Schrödinger formulated a wave equation that accurately calculated the energy levels of electrons in atoms.	
113	ZnO used for		ZnO is used as an additive in numerous materials and products including cosmetics, food supplements, rubbers, plastics, ceramics, glass, cement, lubricants, paints, ointments, adhesives, sealants, pigments, foods, batteries, ferrites, fire retardants, and first-aid tapes.	
114	ZnO		Crude zinc oxide is a yellow-gray granular solid with no odor. It is insoluble in water.	
115	Applications of zinc oxide		Zinc oxide nanoparticles (ZnO NPs) are used in an increasing number of industrial products such as rubber, paint, coating, and cosmetics.	
116	Elements are in ZnO		Zinc, oxygen.	
117	Gas sensors		Gas sensors (also known as gas detectors) are electronic devices that detect and identify different types of gasses. They are commonly used to detect toxic or explosive gasses and measure gas concentration.	
118	Gas sensors uses		Gas sensor converts the components and concentrations of various gases into standard electrical signals by using specific physical and chemical effects.	
119	NEMS resonator		MEMS/NEMS resonators have various structures, which can be used as mass sensing, oscillators, quantum spin coupling, filters, and gyroscopes	
120	Types of gas sensors		Electrochemical sensors, catalytic sensors, infrared sensors and photoionization sensors	
121	Nanodevice		A nanodevice is a device with at least one overall dimension in the nanoscale, or comprising one or more nanoscale components essential to its operation.	
122	Color sensor		A color sensor is a type of "photoelectric sensor" which emits light from a transmitter, and then detects the light reflected back from the detection object with a receiver.	
123	Benefits of NEMS		NEMS leads to smaller and more efficient sensors to detect stresses, vibrations, forces at the atomic level, and chemical signals.	

124	Types of Sensors		• Temperature Sensor. • Proximity Sensor. • Accelerometer. • IR Sensor (Infrared Sensor) • Pressure Sensor. • Light Sensor. • Ultrasonic Sensor.	
125	NEMS sensors		Nanoelectromechanical System (NEMS) Chemical Sensors are devices that combine electrical and mechanical functionalities at the nanoscale for the detection of minute concentrations of target gaseous compounds in the environment.	
PLACEMENT QUESTIONS				
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25	Applications of zinc oxide		Zinc oxide nanoparticles (ZnO NPs) are used in an increasing number of industrial products such as rubber, paint, coating, and cosmetics.	

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