MANIPAL INSTITUTE OF TECHNOLOGY
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DEPARTMENT OF MECHATRONICS

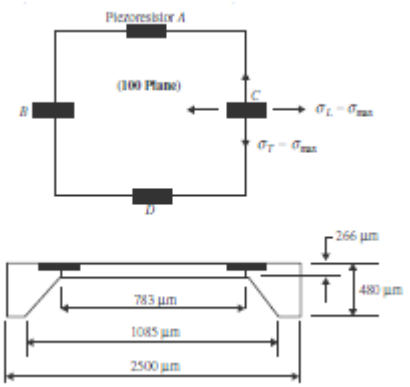
VII SEMESTER B. TECH

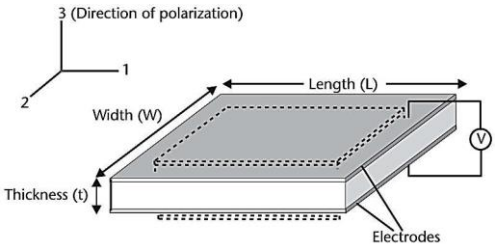
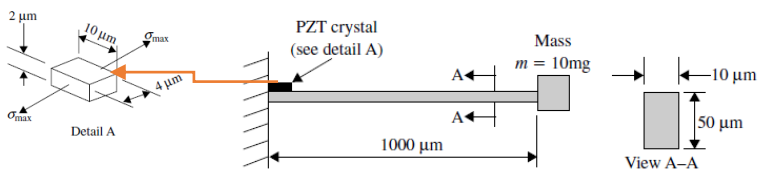
END SEM EXAM, JULY-NOV 2022

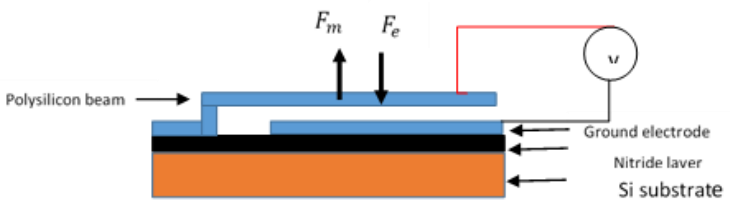
SUBJECT: Micro Electro Mechanical Systems Subject Code: MTE 4077

Date:21/11/2022 **Time: 2:00 PM TO 5:00 PM** **MAX. MARKS: 50**

- Answer **ALL** the questions.
- Missing data could be suitably assumed and justified.

Q. No.		M	CO	PO	BL
1A	Illustrate the working principle of chemical sensors, and mention the types of transduction principles used in the chemical sensor.	4	CO1	PO1,2,3	Apply
1B	Discuss the differences between microelectronics and microsystems concerning MEMS technology.	4	CO1	PO1,2,3	Understand
1C	Determine the voltage output of the four terminal micro thermopiles. The wire material (chrome /constantan) coefficient of 58.7 $\mu V/^0C$ can receive 500K radiation at a hot junction.	2	CO2	PO1,2,3,4,5	Analyze
2A	Investigate the change of resistance in the piezo resistor attached to the diaphragm of the pressure sensor. There are four identical piezo resistors, A, B, C, and D, diffused in the locations at the top face of the silicon die, as shown in Fig. 1. The square plane geometry of the diaphragm that is subjected to uniform pressure loading of 70MPa at the top surface, the bending moments normal to all edges are equal in magnitudes. Thus, $\sigma_L = \sigma_T = \sigma max$. Resistors A and D are subjected predominantly to the transverse stress component π_T, which is normal to the horizontal edges, whereas, resistors B and C are subjected to the longitudinal stress πL, which is normal to the vertical edges.  Fig. 1 Piezo resistors in a pressure sensor die	4	CO2	PO1,2,3,4,5	Creating

	Note: $\sigma_{max} = \frac{0.308 p a^2}{h^2}$ $\quad \frac{\Delta R}{R} = \pi_L \sigma_L + \pi_T \sigma_T$ $\pi_L = \pi_T = 0.02\pi_{44}$ Where, π_{44}=138.1x10^{11}Pa^{-1}				
2B	Explain the working principle of microactuators and name the major classes of MEMS actuators.	**3**	**CO1**	**PO1,2,3**	**Apply**
2C	Examine by considering a piezoelectric material 2 μm thick and 200 μm ×200 μm in area. A voltage of 10 V is applied across the film, which is made of ZnO material and its piezoelectric coefficient and compliance coefficient are d = 12 × 10^{-12} C/N and S = 7 × 10^{-12}.  $D = dT + \varepsilon E$ $\quad s = ST + d^T E$ Fig.2 Direction of the electric field applied on piezo material. a) Compute the total deformation in the direction of the electric field shown in Fig 2, when no force is applied. b) Calculate the magnitude of the maximum force that can be applied to prevent the deformation of the material.	**3**	**CO2**	**PO1,2,3 ,4,5**	**Analyze**
3A	A thin piezoelectric crystal film, PZT, is used to transduce the signal in a micro accelerometer involving a cantilever beam made of silicon. The accelerometer is designed for a maximum acceleration/deceleration of 10g. The PZT transducer is located at the support of the cantilever beam where the maximum strain exists (near the support) during the bending of the beam, as illustrated in Fig.3.  Fig.3 Piezoelectric transducer on a beam-accelerometer Determine the electrical voltage output from the PZT film at a maximum acceleration/deceleration of 10 g.	**5**	**CO2**	**PO1,2,3 ,4,5**	**Evaluate**

	Note: Young's Modulus of silicon beam E=1.9x 10^{11}Pa Piezoelectric coefficient d=480x10^{-12} m/V				
3B	What is pull-in voltage, and prove that deflection is less than or equal to d/3?	**3**	**CO2**	**PO1,2,3,4,5**	**Analyze**
3C	Find the reduction of electrostatic forces generated by a pair of parallel plate electrodes if the length and width of these plates are reduced by a factor of 10. **Note:** F=0.5 CV^2/d	**2**	**CO2**	**PO1,2,3,4,5**	**Analyze**
4A	Determine the pull-in voltage of the cantilever beam with a spring constant of 0.0567 N/m. The overlapping length and width beam is 300µm and 5µm. The gap between a parallel plate capacitor is 1µm, and the structure of the micro-actuated device is shown in Fig. 4. **Note:** Young's modulus of the beam material is 190 GPa, and the permittivity of air is 8.854x10^{-12} F/m.  Fig. 4 Structure of an actuated device	**4**	**CO2**	**PO1,2,3,4,5**	**Evaluate**
4B	Sketch and explain Czochralski's method for producing single-crystal silicon.	**3**	**CO3**	**PO1,2**	**Apply**
4C	Discuss the basic processes used in microfabrication and compare the difference between +ve and -ve resist.	**3**	**CO4**	**PO1,2,3,5,8**	**Analyze**
5A	Describe the physical vapor deposition method and list the types of PVD methods.	**4**	**CO4**	**PO1,2,3,5,8**	**Understand**
5B	Discuss the major steps and advantages of the LIGA process.	**3**	**CO4**	**PO1,2,3,5,8**	**Apply**
5C	Illustrate the three levels of microsystem packaging.	**3**	**CO4**	**PO1,2,3,5,8**	**Apply**