

**INTRODUCTION TO MEMS
(AEIE 4244)**

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

*Candidates are required to answer Group A and
any 4 (four) from Group B to E, taking one from each group.*

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) The sensors preferably use as “band filters” in mobile telephones and base stations are
 - (a) Chemical sensors
 - (b) SAW sensors
 - (c) Optical sensors
 - (d) Proximity sensors
- (ii) For a 10 times reduction in electrode linear dimensions, the drop in the magnitude of the electrostatic forces is
 - (a) 10 times
 - (b) 50 times
 - (c) 100 times
 - (d) 1000times
- (iii) In smart phone, the sensor that primarily measures displacement is
 - (a) MEMS gyroscope
 - (b) MEMS capacitive sensor
 - (c) MEMS accelerometer
 - (d) MEMS inductive sensor
- (iv) The process of diffusion analysis is based on
 - (a) Fourier’s Law
 - (b) Fick’s law
 - (c) Hooke’s Law
 - (d) Coulomb’s Law
- (v) The dry etching process is:
 - (a) Isotropic
 - (b) Anisotropic
 - (c) Conformal
 - (d) Planarization
- (vi) Van der Waal’s force is also referred to as
 - (a) Inter molecular force
 - (b) Nuclear force
 - (c) Intra molecular force
 - (d) Electromagnetic force
- (vii) The process used to bond silicon to glass is
 - (a) Anodic
 - (b) fusion
 - (c) Eutectic
 - (d) Glass frit
- (viii) If the selectivity ratio of a material is very high, as a mask material, it will be
 - (a) very bad
 - (b) highly conductive
 - (c) very good
 - (d) cannot be used

- (ix) The shape of the diaphragm that can handle highest induced stress is
 (a) Circular (b) Rectangular
 (c) Triangular (d) Square
- (x) In micro/robotic surgery, linear motion of the actuator is achieved based on which operating principle of
 (a) electrostatic effect (b) electromagnetic effect
 (c) electro-mechanical effect (d) chemical effect

Fill in the blanks with the correct word

- (xi) The etching process having highest aspect ratio is ____ etching.
- (xii) The concept used in “air bag” deployment system in automobile is ____.
- (xiii) Smart sensors typically include ____ conditioning circuitry inside the sensor module.
- (xiv) The physical process to dope silicon substrate is ____.
- (xv) Doping of impurities induces lattice mismatch and change of ____ sizes.

Group - B

2. (a) Why are the scaling laws required in MEMS design? [[CO1](Understand/LOCQ)]
 (b) Justify the use of GaAs as a candidate material for MOEMS. [[CO4](Evaluate/HOCQ)]
 (c) Determine the surface to volume ratio in case of basic scaling Law. [[CO2](Apply/IOCQ)]
4 + 3 + 5 = 12
3. (a) Classify micro pressure sensors according to their transduction effect. [[CO3](Analyze/HOCQ)]
 (b) What are the applications of micro-grippers? [[CO4](Remember/LOCQ)]
 (c) Explain the operation of micro-motor. [[CO2](Apply/IOCQ)]
4 + 4 + 4 = 12

Group - C

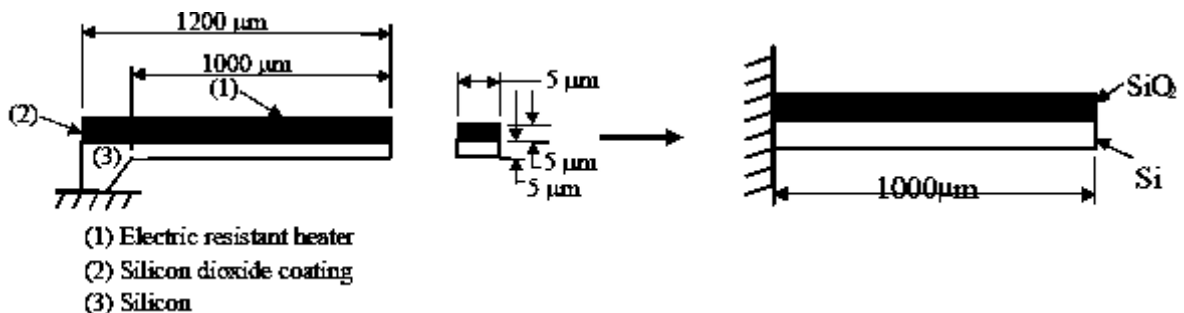
4. (a) Classify different types of Physical vapour deposition techniques. [[CO3](Analyze/HOCQ)]
 (b) How does metal vapour form in sputtering? What is used as carrier gas in sputtering? [[CO4](Remember/LOCQ)]
 (c) What do you mean by epitaxial growth? State any one type of reactors for epitaxy. [[CO2](Apply/IOCQ)]
4 + (2 + 2) + 4 = 12
5. (a) Explain the process of oxidation. [[CO2](Analyze/IOCQ)]
 (b) How to prepare SiO₂ in the laboratory? [[CO4](Remember/LOCQ)]
 (c) State the major applications of SiO₂ in micro-fabrication process. [[CO2](Apply/IOCQ)]
 (d) Why do you prefer positive photoresist over negative one? [[CO4](Remember/LOCQ)]
3 + 4 + 3 + 2 = 12

Group - D

6. (a) Define the micro manufacturing technique in MEMS. State different types of micro-manufacturing techniques with examples from application point of view. [[CO3](Analyse/HOCQ)]
- (b) In this technique, which plane of the Si crystal will be considered and why? [[CO4](Remember/LOCQ)]
- (c) Why the 111 plane of the single crystal Silicon is treated as the hardest? [[CO2](Apply/IOCQ)]
- (3 + 3) + 4 + 2 = 12**
7. (a) Define the term LIGA. What are the advantages of LIGA compared to other micro-manufacturing processes? [[CO6](Understand/LOCQ)]
- (b) Identify the basic requirements of photo-resist materials in LIGA process. [[CO6](Remember/LOCQ)]
- (c) Describe briefly the process of fabrication of a square tube using LIGA. [[CO5](Apply/IOCQ)]
- (2 + 3) + 2 + 5 = 12**

Group - E

8. (a) Show the basic input information required for Finite element method based analysis. [[CO5](Analyse/HOCQ)]
- (b) List the Possible sources for intrinsic stresses in Thermomechanical stress analysis. [[CO4](Remember/LOCQ)]
- (c) A micro actuator made up by a bi-layered strip using oxidized silicon beam is illustrated below in Fig. 1. A resistant heating film is deposited on the top of the oxide layer. Estimate the interfacial force and the movement of the free-end of the strip with a temperature rise, $\Delta T = 100^\circ\text{C}$. Use the following material properties: Young's modulus: $E_{\text{SiO}_2} = E_1 = 385000 \text{ MPa}$; $E_{\text{Si}} = E_2 = 190000 \text{ MPa}$; Coefficients of thermal expansion: $\alpha_{\text{SiO}_2} = \alpha_1 = 0.5 \times 10^{-6}/^\circ\text{C}$; $\alpha_{\text{Si}} = \alpha_2 = 2.33 \times 10^{-6}/^\circ\text{C}$. [[CO2](Apply/IOCQ)]



4 + 5 + 3 = 12

9. (a) What are pseudo elements in FEM based simulation analysis? [[CO4](Remember/LOCQ)]
- (b) Choose the reasons behind the dynamic analysis in MEMS actuators. [[CO3](Analyse/HOCQ)]

- (c) Determine the minimum thickness of the circular diaphragm of a micro pressure sensor made of Silicon with conditions: Diameter $d = 600 \mu\text{m}$; Applied pressure $p = 20 \text{ MPa}$; Yield strength of silicon $\sigma_y = 7000 \text{ MPa}$; $E = 190,000 \text{ MPa}$ and $\nu = 0.25$.

[[CO2](Apply/IOCQ)]

3 + 4 + 5 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	38.54	35.42	26.04