Name: Enrolment No:	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination (ONLINE), May 2020

Course: MEMS (MEEL 441) **Semester: VIII**
Program: B.Tech. Mechatronics Engineering
Time: 03 hrs. **Max. Marks: 100**

Instructions:
(1) There are total 41 questions in this question paper. All the questions are compulsory.
(2) Section A contains 30 multiple-choice type questions. Only one answer is correct. Total marks is 30.
(3) Section B contains 10 questions which are to be answered in not more than 20 words. You can answer in phrases. Total marks is 50.
(4) Section C contains 1 question only. There are seven sub-parts: (i) to (vii). The sub-parts: (i) and (ii) are of 5 marks each while sub-parts: (iii) to (vii) are of 2 marks each. The sub-parts: (iii) to (v) are to be answered in paragraphs. Avoid using phrases while answering. Total marks is 20.
(5) Assume any missing data.

SECTION A

S. No.		Marks	CO
Q 1	A substrate is: (a) a sublayer in MEMS, (b) a flat microscopic object, (c) a flat macroscopic object in microelectronics.	1	CO3
Q 2	A semiconducting material can be made to become an electrically conducting material by: (a) applying high electric voltage, (b) applying high current, (c) introducing the right kind of foreign atoms into the semiconducting material.	1	CO3
Q 3	Silicon has a Young's modulus similar to that of: (a) aluminium, (b) stainless steel, (c) copper.	1	CO3
Q 4	Silicon has a mass density similar to that of: (a) aluminium, (b) stainless steel, (c) copper.	1	CO3
Q 5	The principal reason why silicon is an ideal material for MEMS is: (a) its dimensional stability over a wide range of temperatures, (b) it is light and strong, (c) it is readily available.	1	CO3
Q 6	The 300-mm wafers offer: (a) 2, (b) 2.25, (c) 2.5 times more area for substrates than that by 200-mm wafers.	1	CO3
Q 7	Pure and single-crystal silicon: (a) exists in nature, (b) is grown from special processes, (c) is made by electrolysis.	1	CO3
Q 8	Wafers used in MEMS and microelectronics are: (a) the products of a single-crystal silicon boule, (b) are synthesized from silicon compounds, (c) exist in nature	1	CO3
Q 9	MEMS design engineers are advised to adopt: (a) any size, (b) a custom-specified size, (c) an industrial standard size of wafer.	1	CO3

Q 10	The total number of atoms in a silicon unit crystal is: (a) 18, (b) 16, (c) 14.	**1**	**CO3**
Q 11	The toughest plane for processing in a single silicon crystal is: (a) (100), (b) (110), (111).	**1**	**CO3**
Q 12	Gallium arsenide is chosen over silicon for the use in micro-optical devices because of its: (a) optical reflectivity, (b) dimensional stability, (c) high electron mobility.	**1**	**CO3**
Q 13	It is customary to relate the voltage produced by a piezoelectric crystal to the: (a) deformations, (b) temperature, (c) stresses induced in the crystal.	**1**	**CO3**
Q 14	The LB process is used to produce: (a) thin films, (b) dies, (c) piezoelectric polymers in MEMS and microsystems.	**1**	**CO3**
Q 15	MEMS and microsystem packaging materials are: (a) restricted to microelectronics packaging materials, (b) just about all engineering materials, (c) semiconducting materials.	**1**	**CO3**
Q 16	*Micromanufacturing* is: (a) synonymous to, (b) antonymous to, (c) unrelated to *microfabrication*	**1**	**CO4**
Q 17	In general there are: (a) two, (b) three, (c) four distinct micromanufacturing techniques.	**1**	**CO4**
Q 18	Bulk manufacturing involves primarily: (a) adding, (b) subtracting, (c) both adding and subtracting portions of material from the substrate.	**1**	**CO4**
Q 19	The principal microfabrication process used in bulk manufacturing is: (a) etching, (b) deposition, (c) diffusion.	**1**	**CO4**
Q 20	Isotropic etching is hardly desirable in micromanufacturing because: (a) the etching rate is too low, (b) the cost is too high, (c) it is hard to control the direction of etching.	**1**	**CO4**
Q 21	The most favoured orientation for micromanufacturing is the: (a) <100>, (b) <110>, (c) <111> orientation.	**1**	**CO4**
Q 22	The higher the selectivity ratio of a material, (a) the better, (b) the worse, (c) neither better nor worse is the material as an etching mask.	**1**	**CO4**
Q 23	PSG stands for: (a) polysilicon glass, (b) phosphosilicate glass, (c) phosphorus silicon glass.	**1**	**CO4**
Q 24	Sacrificial layers in surface micromachining are used to: (a) strengthen the microstructure, (b) create necessary geometric voids in the microstructure, (c) be part of the structure.	**1**	**CO4**
Q 25	Stiction in finished microstructures is a result of: (a) layers of dissimilar materials, (b) thin films, (c) atomic forces between layers.	**1**	**CO4**
Q 26	The geometric aspect ratio in MEMS structures is defined as the ratio of dimensions in: (a) depth to surface, (b) surface to depth, (c) width to length.	**1**	**CO4**
Q 27	Synchrotron X-rays are used in photolithography in the LIGA process because: (a) they are more effective with the photoresist, (b) they are a cheaper source of light, (c) they can penetrate deep into the photoresist material.	**1**	**CO4**
Q 28	One of the principal advantages of the LIGA process is its ability to produce: (a) microstructures with high aspect ratio, (b) microstructures with low cost, (c) microstructures with precise dimensions.	**1**	**CO4**
Q 29	An electrically conductive base plate must be used in a LIGA process because of the need for: (a) signal transduction, (b) electroplating of metals, (c) required electric heating of the mold.	**1**	**CO4**

Q 30	SLIGA is an improvement of the LIGA process with the provision of: (a) slicing the base plate from the finished product, (b) a sacrificial layer for ready separation of the base plate from the product, (c) a clean product.	**1**	**CO4**
	SECTION B (Answer in not more than 20 words. Use phrases while answering.)		
Q 31	Recognize your major criterion in selecting materials for the masks used in etching, e.g., in etching silicon substrate with moderate depth and also for deeper etching?	**5**	**CO4**
Q 32	Differentiate between bulk manufacturing and surface micromachining.	**5**	**CO4**
Q 33	Differentiate between wet etching and dry etching.	**5**	**CO4**
Q 34	List the principal advantage and disadvantage of the LIGA process.	**5**	**CO4**
Q 35	Name the procedure for production of pure silicon crystals. Give very brief description.	**5**	**CO3**
Q 36	Give atleast one use of four different types of silicon compounds.	**5**	**CO3**
Q 37	Provide the principal applications of microsensors, actuators and fluidics.	**5**	**CO2**
Q 38	Differentiate between MEMS and microsystems.	**5**	**CO1**
Q 39	Describe the various types of microactuation processes.	**5**	**CO2**
Q 40	Discuss the methods of producing conductive polymers. Give applications of LB film.	**5**	**CO3**
	SECTION C		
Q 41	A microdevice component, 4 gram in mass, is attached to a fine strip made of silicon, as illustrated in the Figure 1. Both the mass and the strip-spring are made of silicon. The arrangement is to be used in a microaccelerometer deployed in airbags of a car which comes to rest from its initial velocity of 50 km/h. Take Young's modulus of Si, E = 190,000MPa. Length of strip-spring, L = 1000 µm, width of strip-spring, b = 50 µm and thickness of strip-spring, d = 10 µm.	**20**	**CO5**

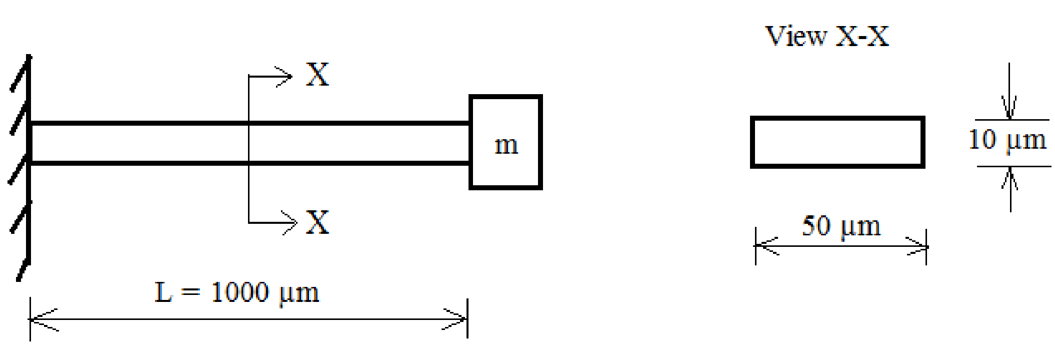

Figure 1: Figure for Q 41

	Consider the following. i. The equation of motion of the mass in Fig. 1 can be written as: $$m\frac{d^2x(t)}{dt^2} + k_{eq}x(t) = 0$$ where, *m* = mass attached at the end of microdevice, k_{eq} = equivalent stiffness of the strip-spring, *x(t)* = displacement of mass 'm' at any time 't' from its mean position. Find the value of k_{eq} and natural angular frequency, ω. Mention the formulae used by you in evaluating these two values. ii. If the solution for the differential equation described in part a) is given as: $$x(t) = C_1\cos(\omega t) + C_2\sin(\omega t)$$ Determine the values of coefficients: C_1 and C_2 and hence find out the displacement of mass 'm' from its neutral equilibrium position. Mention the boundary conditions used by you for finding out the values of C_1 and C_2. iii. Name the method that can be used for manufacturing the microdevice with the least amount of scrap. Discuss the significant aspects of this method. iv. Discuss the various stages of micromanufacturing method mentioned by you in part c). v. Which material can be used as a mask for the manufacturing process. How can this mask be produced? vi. Is there any requirement of sacrificial layer? If yes, then how this layer can be removed. vii. Mention the various mechanical problems associated with this type of micromanufacturing method.		