Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2019/2020

COURSE NAME	:	MEMS AND NEMS DESIGN
COURSE CODE	:	BED 40503
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS. **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **FOUR (4)** PAGES

Q1 Micro-Electromechanical System or MEMS can be classified into three major groups; microstructures, microsensors and microactuators.

(a) List **TWO (2)** examples of MEMS microsensors and microactuators.

(4 marks)

(b) MEMS design process basically involves of modelling, simulation and experiment. Describe the importance of these processes.

(8 marks)

(c) A simple example of MEMS microstructure is a tip of an atomic force microscope (AFM) probe. Describe the tip's fabrication process by using an appropriate diagram.

(10 marks)

(d) Explain the reason silicon is an ideal substrate material for MEMS devices.

(6 marks)

Q2 Double-ended tuning forks (DETF) are potentially useful as frequency references for communication circuits. As the amplitude of vibration increases, the tuning fork's deflection is no longer proportional to the applied load.

(a) Given that the DETF is driven in the fundamental anti-symmetric mode and that the displacement at the center of the beam is y, use the principle of virtual work to estimate the dependence of the applied force F (concentrated in the beam's center) on y for large displacements. The answer should include a term proportional to y^3.

(10 marks)

(b) Then consider that the DETF is driven in its second mode by concentrated forces (each called F) applied at the locations of the peak displacement y. Elaborate the functional relationship between F and y.

(10 marks)

Q3 There are two principal signal transduction methods widely used in MEMS known as piezoresistive and capacitive.

(a) Compare the advantages and disadvantages of using capacitor and piezoresistor as transduction methods in MEMS.

(8 marks)

(b) Develop the main process flow to fabricate the MEMS capacitive microphone shown in **Figure Q3(b)**.

(10 marks)

(c) A fixed free cantilever is made of single crystal silicon with Young's modulus 150 GPa. The piezoresistive element is made by diffusion doping with a gauge factor of 100. The length, width and thickness of the cantilever are 200 μm, 20 μm and 5 μm, respectively.

(i) If a force F = 150 μN is applied in the longitudinal direction, calculate the magnitude of stress.

(5 marks)

(ii) By the aid of diagram, show the direction of force F that shows the tranverse piezoresistor configuration.

(7 marks)

Q4 A parallel plate capacitor is suspended by four cantilever beams, shown in **Figure Q4**. The lower electrode is connected to a voltage supply of value V = 5 V, while the suspended plate is grounded. The gap between the lower electrode and the plate is $g_0 = 2.0$ μm.

(a) The condition of pull-in or snap-in will occur due to the electrostatic actuation. By using an appropriate diagram, explain the pull-in effect of these parallel plate capacitive actuators.

(6 marks)

(b) Find the area A of the lower electrode in μm^2 such that the electrostatic force on the plate is 100 nN. Use $\varepsilon = 8 \times 10^{-12}$.

(6 marks)

(c) The four beams area each 200 μm long, 20 μm wide and 5 μm thickness. If the area, A of the lower electrode is equal to 1×1 mm^2, predict the distance between the two plates under the bias voltage of 0.5 V.

(10 marks)

-END OF QUESTIONS –

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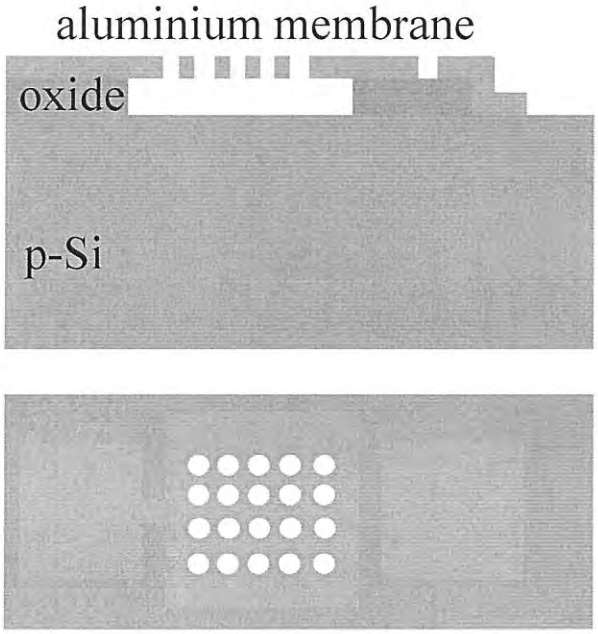

Figure Q3(b)

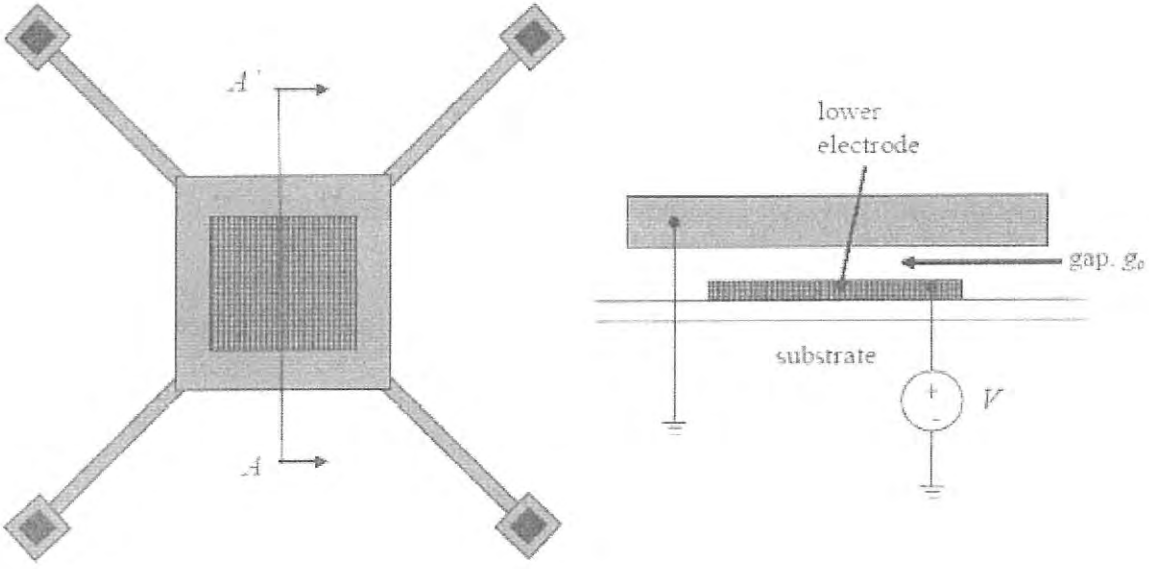

Figure Q4