Dr Mahesh Angira 23/11/2023

Roll No.: 18

(103)

National Institute of Technology, Hamirpur (HP)

Name of Examination: B.Tech., End Semester Examination, Dec. 2023

Branch: ECE **Semester:** 7th

Subject: MEMS and Sensor Design **(Professional Elective-1)** **Subject Code:** EC-433

Time: 3 Hours **Maximum Marks:** 50

Note: *Attempt all questions (There are 5 questions)*

Q-1 Figure 1(a) shows the cross-sectional view for a gap-closing electrostatic actuator. The plot of spring force (F_s) and electrostatic force (F_e) for 4 different applied voltages: 12 V, 16 V, 20 V, and 24 V is shown in the **Figure 1(b)**. The horizontal axis is in micro meter (µm), the vertical axis in micro Newton (µN). The initial gap between the bridge structure and electrode is 2um, and there are stoppers at 1um from bridge structure (Figure 1(a)). **[10M]**

(a) Estimate the pull-in voltage.

(b) Sketch the displacement of the actuator as the voltage is increased from 0 to 24V. (Plotdisplacement on vertical axis (y-axis) and voltage on horizontal axis (x-axis)).

(c) Estimate the contact force on stoppers if applied voltage is 24 V.

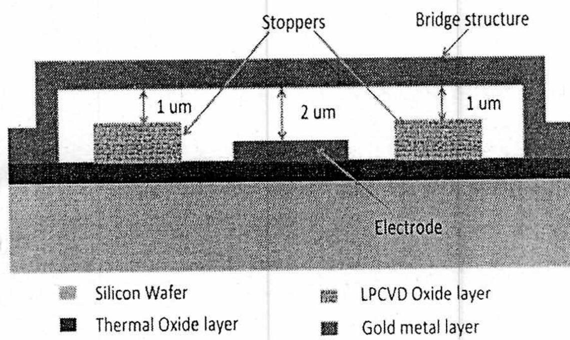

Figure 1(a)

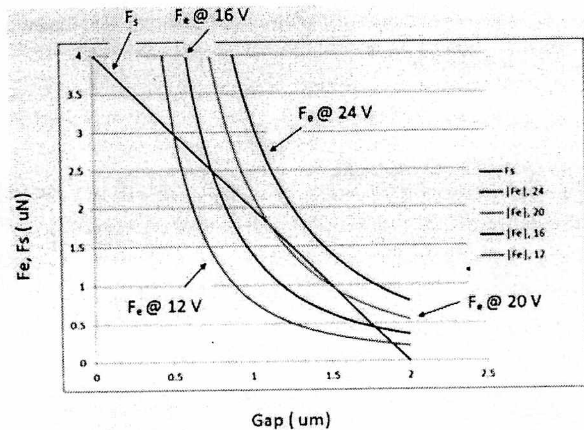

Figure 1(b)

Q-2 (i) Draw the diagram and explain the working of thermal bimorph actuator (bimetallic artificial ciliaactuator) for object transport in VLSI fabrication lab. **[5M]**

Q-2 (ii) Derive the relation given below:

$$GF = \frac{dR/R}{\varepsilon_l} = \frac{d\rho/\rho}{\varepsilon_l} + (1 + 2\nu)$$

Where GF = gauge factor, dR/R = relative change in resistance, dρ/ρ = relative change in resistivity, ν = Poisson's ratio, ε_l = strain (dl/l). **[5M]**

PTO

Q-3 (i) HF is used to etch SiO_2 isotropically at 100 nm/min. Further, assume that HF has infinite high selectivity against Si and photoresist (PR) such that it wouldn't etch them. **[Note PR stands for photoresist]**

(a) For the structure shown in the **figure Q-3(i)** below, how long should this wafer be placed in HF etchant to etch SiO_2 with 0% over-etch and 10% over-etch?

(b) What is the width of SiO_2 removed at the top of the resulting trench (at the Photoresist/SiO_2 interface), and what is the width of SiO_2 removed at the bottom of the trench (at the SiO_2/Si interface) at 0% over-etch and after the 10% over-etch? Also draw a schematic of the structure at 0% over-etch and after the 10% over-etch. **[5M]**

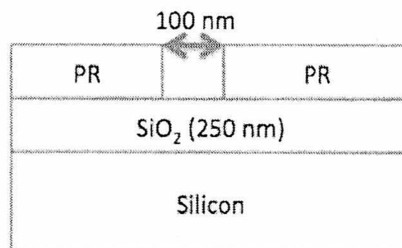

Figure –Q-3(i)

Q-3 (ii) Draw the cross-sectional and top views and explain the working of capacitive shunt RF-MEMS Switch. Also write some applications where this device can be used. **[5M]**

Q-4 (i) Explain the design cycle for MEMS Technology based devices. **[5M]**

Q-4 (ii) Figure 4 shows the cross-sectional view of a cantilever structure. The thickness of the cantilever structure is 20 µm and electroplating is used to realize this structure (Gold metal). Further, X-ray lithography is used for patterning of structural layer with PMMA as a photoresist. Furthermore, to make the air gap (2 µm), a sacrificial layer is deposited and patterned using UV light-based photolithography. The layer just above the Si Wafer is a seed layer (metal required for electroplating). Starting from the wafer, write all process steps required for the realization of the device depicted in Figure (4) along with cross-sectional after each process step. **[5M]**

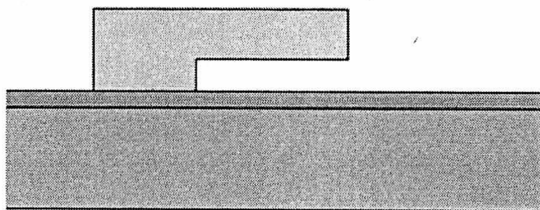

Figure-4

Q-5 (i) What is the direct and converse piezoelectric effect (write the equations). Discuss 1 application for direct and 1 application for converse piezoelectric effect. **[5M]**

Q-5(ii) What is an accelerometer. Draw the diagram and explain the working of accelerometer based on Capacitance change effect. **[5M]**

******End of Question Paper*****