BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
FIRST SEMESTER 2022-23

BITS F415: Introduction to MEMS
Mid-Semester Test (Open Book)

DATE: 11/01/2022 **Duration: 90 min** **Maximum Marks: 30**

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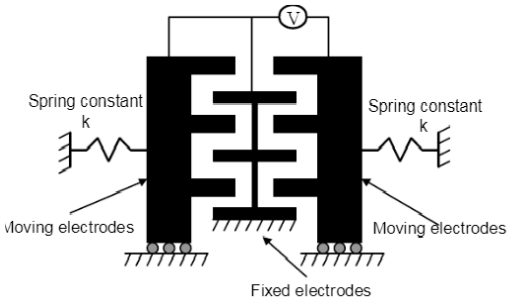
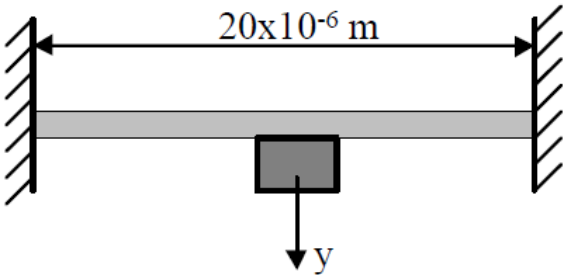
1. An n-type GaAs substrate with the background doping C_0=1X10^{17} cm^{-3} doped by the drive-in-diffusion process with a dose of beryllium atom Q of 1.5x 10^{15}cm^{-2}, located very close to the surface of the silicon. The wafer is annealed at 800°C for 10 min. a) what will be the junction depth? b) What surface concentration of beryllium will result? D_0= 7x10^{-6} cm^{2}sec^{-1} and E=1.2 eV. **[05M]**

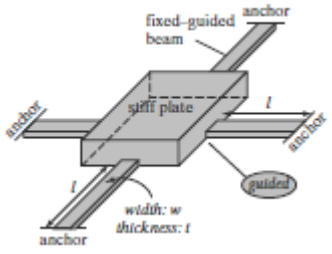
2. The configuration of the comb drive shown in the figure, is for the micro gripper mechanism. The electrodes need to move 5 µm each from both sides. Initially, the spring is in an unstretched position. The spring constant k is 0.1 N/m. The comb drive is operated in air. The gap d between the electrodes and the width W of the electrodes are 2 µm and 5 µm respectively. Determine the voltage applied for the movement of the electrode. **[05M]**



3. A micro device component, 10 g in mass, is attached to a fine strip made of silicon, as shown in Figure below. Both the mass and the strip-spring are made of silicon. The mass is pulled down by 5 µm initially and is released at rest. Determine (i) the natural frequency of the simulated mass-spring system. (ii) The displacement from its neutral equilibrium position at t= 1ms sec. For silicon modulus of elasticity = 190 GPa, Moment of area $I = 4 \times 10^{-24} m^4$. Assuming the supports are fixed. **[10M]**



4. A parallel-plate capacitor with four silicon support beams is shown in the figure. The movable plate is placed between two fixed electrode plates. The MEMS device has capacitors on both sides of the movable plate. Assume that equal voltage is applied over both plates. Note that the equilibrium point is always at x = 0. The movable plate has area of 1 mm x 1 mm. The thickness of the plate is 10 µm. The four support beams are each 500 µm long, 5 µm wide, and 0.3 µm in thickness. Young's modulus of silicon is 120 GPa. The density of silicon is 2.33 grams/cm^3. The original spacing between the two plates is 5 µm. (Data: Permittivity of free space ε_0=8.85 pF/m; Poisson's ratio v =0.25). Deflection in the fixed guided cantilever beam is $\delta = \frac{WL^3}{12EI}$



i. What is the percentage change in pull-in voltage if the support beam length becomes 0.25 mm.? **[03M]**

ii. According to the above conditions (in (i)), under a bias voltage of 0.3 volts, what is the distance between the two plates? The original spacing between the two plates is 5 μm. **[02M]**

iii. What is the maximum displacement possible without snapping the two plates? **[02M]**

iv. What is the relative change in the natural frequency of the system due to the decrease in length of the guided cantilever beam? **[02M]**
