ME 553 Final Project

University of Michigan College of Engineering

Piezoresistive Sensor Design for Single Layer PDMS on Silicon Hybrid Micro Actuator with Multi Axis Out of Plane Motion Capabilities

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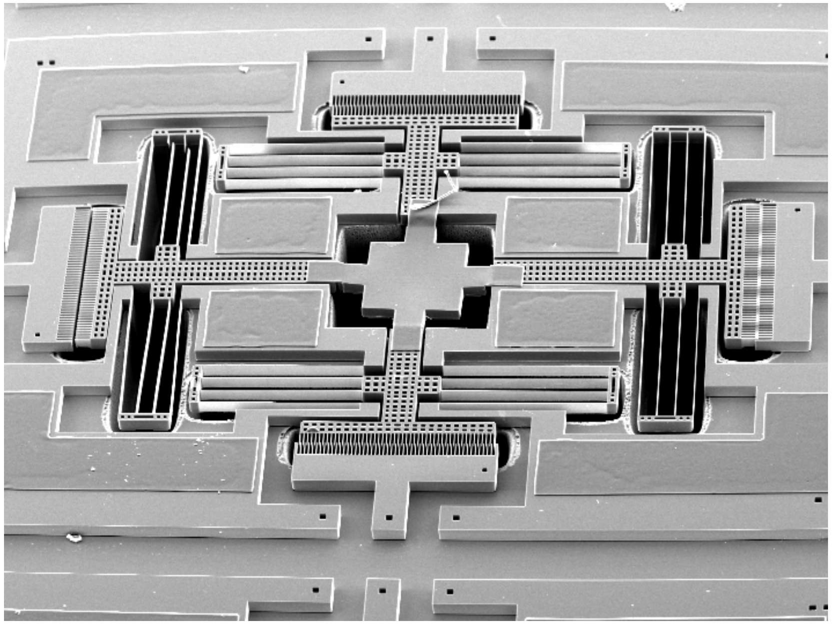
Motivation

- Use of PDMS in Mems.
- Out of plane actuation.
- Useful applications.
- High Bandwidth.



Project Goal

Precise control of hybrid Actuator.

Objectives:

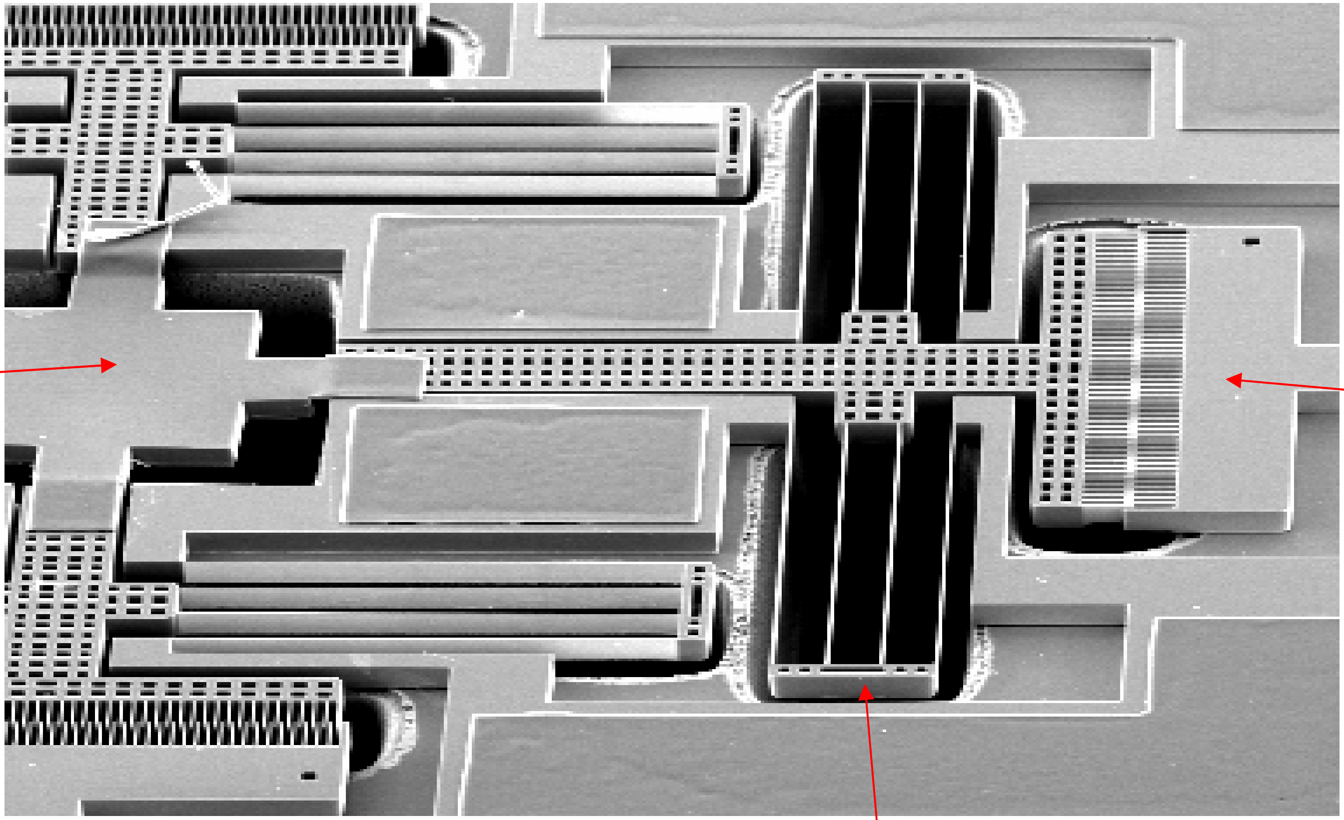
- Design a sensor using the existing structure.
- Propose fabrication strategy.
- Parametric study of sensor.
- Design optimization.

Problem Setup

- Manufacturability.
- Structural compatibility of sensor to the platform.
- Capacitive / Resistive Sensor. Pros & Cons.
- Analysis of the sensor characteristics e.g. sensitivity, Bandwidth

Proposed Solution

Platform



Comb Drive Actuator

Folded Flexure Beam

Cantilever Fabrication

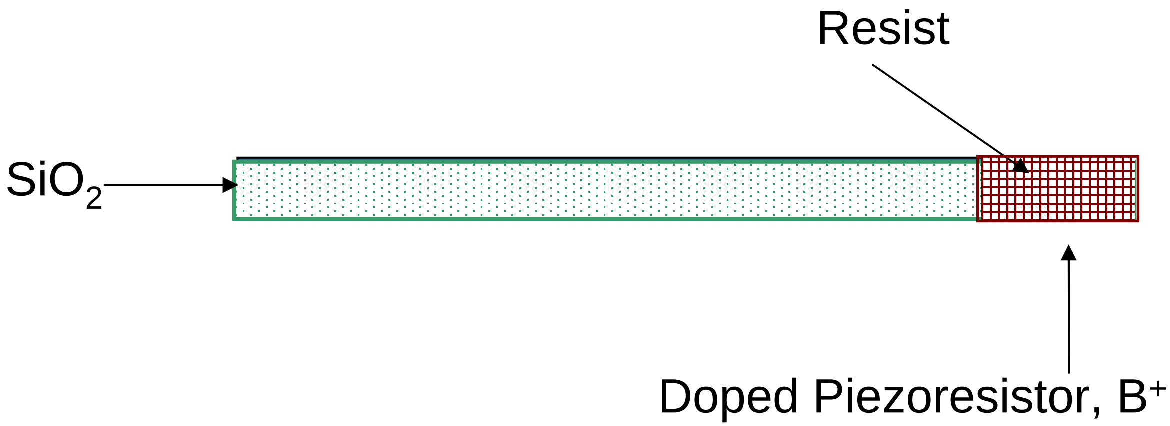
Silicon Cantilever beam ready to be fabricated into Piezoresistive sensor.

KEY:

Processing: Piezoresistor B+

Cantilever beam is lightly doped by Piezoresistor, B+ Using oblique ion doping.

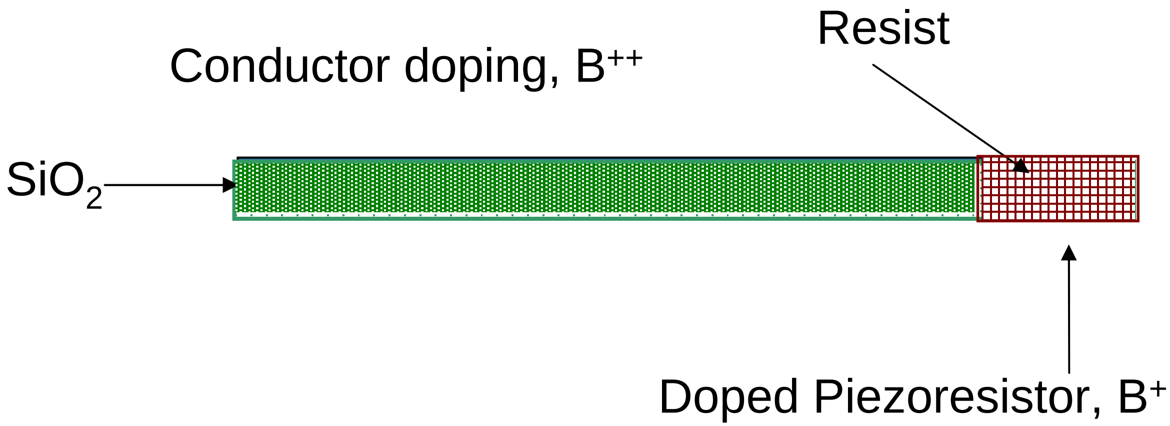
Processing: Resist



Resist is applied to heavily dope the beam.

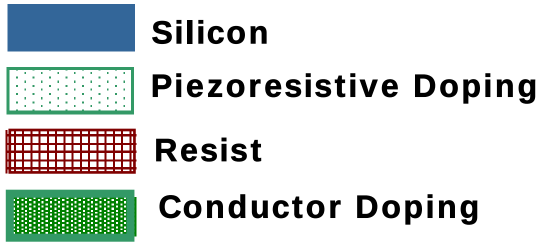
KEY:

Processing: Conductor B++

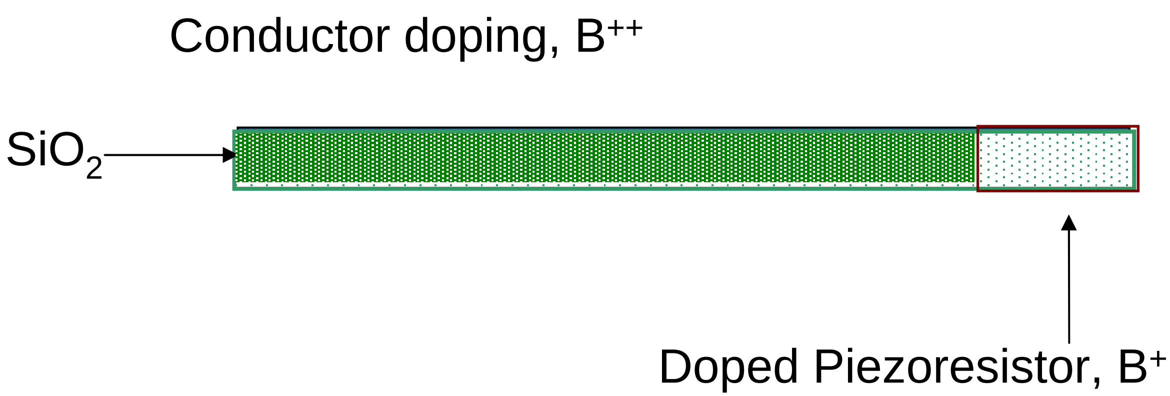


Oblique ion doping is applied again to heavily dope the desired portion.

KEY:

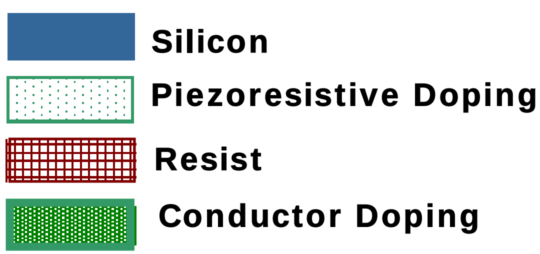


Cantilever Fabrication



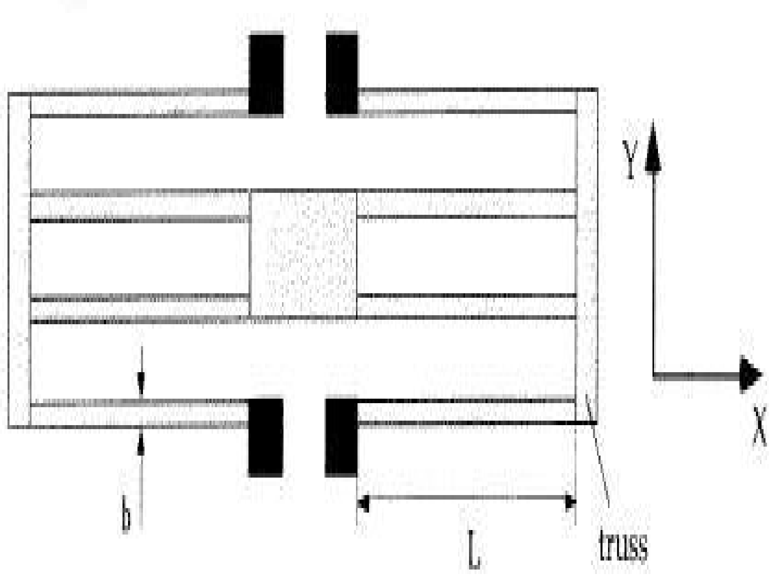
Final structure with Piezoresistor B+ and conductive B++.

KEY:



Sensor Design

- Folded Flexural Beams Modeling.
- Piezoresistive Expression.
- Wheatstone bridge Analysis.



Flexure Beam Modeling

- Actuating force

$$Fe = \frac{n \varepsilon h V^2}{g}$$

- Deflection

$$u(x) = \frac{Fe}{8EI}\left(\frac{L}{2}x^2 - \frac{1}{3}x^3\right)$$

- Stress

$$\sigma(x) = \frac{10^8}{3.6}\left(\frac{L}{2} - x\right)V^2$$

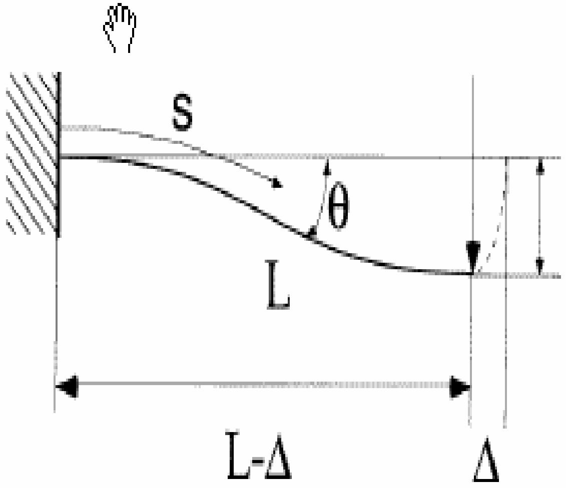
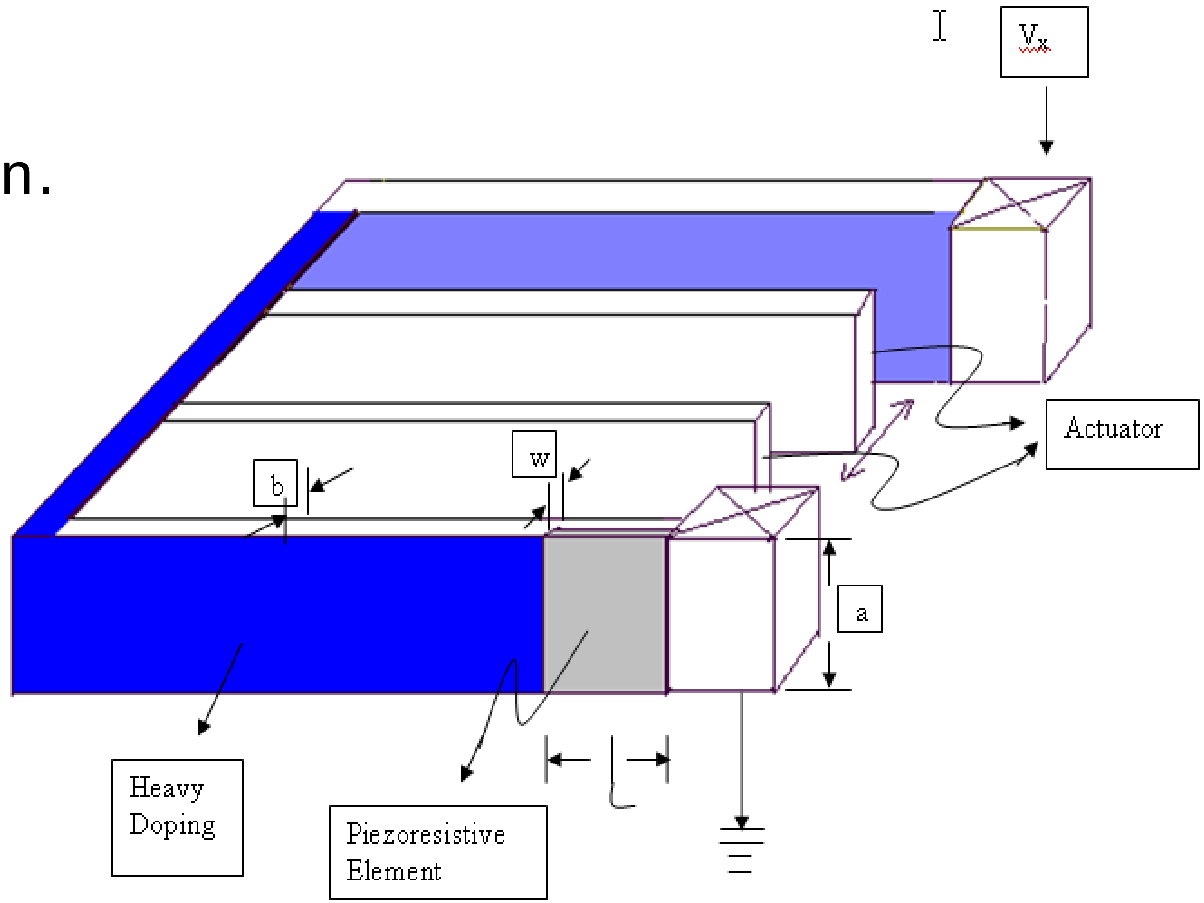


Figure A1. Sketch of clamped–guided beam including parameters.

Piezoresistive Expression

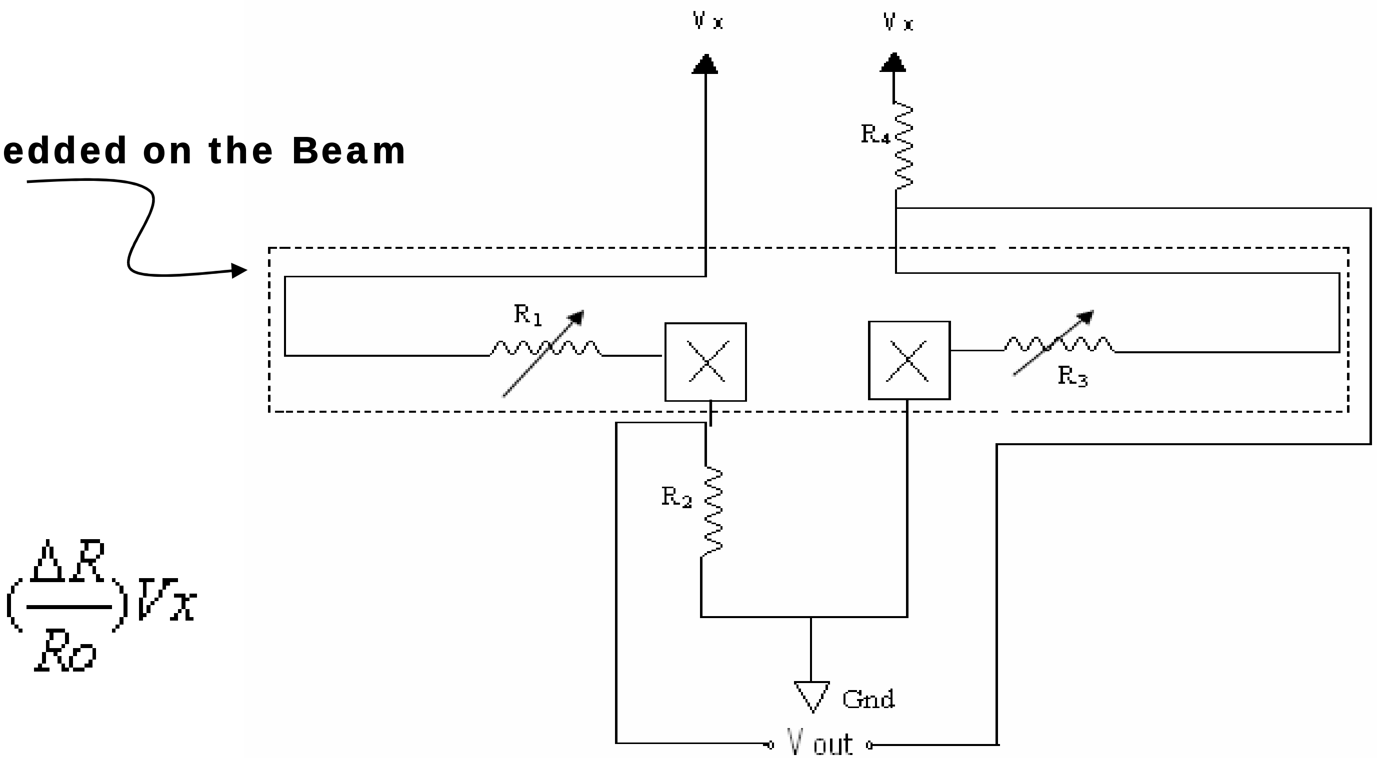
- Assuming:
  - [110] direction.

$$\frac{d\Delta R(V,x)}{dRo} = \frac{\pi_{[100]}\gamma V^2}{3.6}\left(\frac{L}{2} - x\right)$$



Electrical Circuit Analysis

Circuit Embedded on the Beam

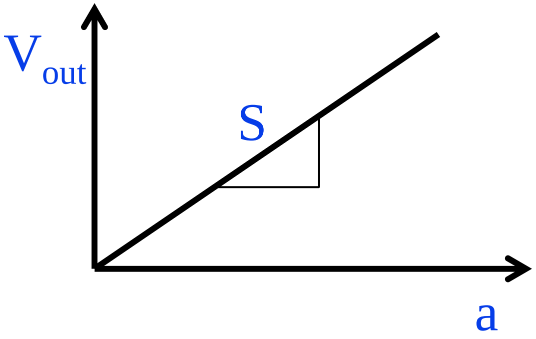


$$Vout = \frac{1}{2}\left(\frac{\Delta R}{Ro}\right)Vx$$

$$Vout(u) = \frac{1.258x\,\pi_{11}\rho_o E}{\omega}(5x10^{-4}\,l - l^2)u$$

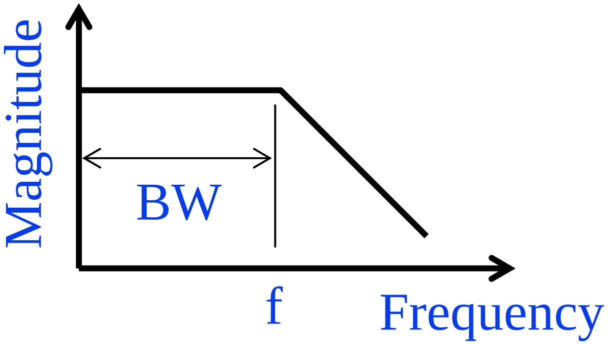
Optimization

- Sensitivity Analysis
  - Actuator voltage
  - Displacement



- SCR optimization
  - Piezoresistors geometry

- Bandwidth Sensitivity Tradeoff
  - First natural frequency
  - Overall system bandwidth



- Effect of Noise and MDD
  - Johnson's noise

Results

- Tradeoff between Bandwidth and Sensitivity
  - We require sensitivity optimization
  - Inherent need due to high bandwidth actuation.

- Different Design Parameters effect Different Sensor Characteristics:
  - Cross-sectional Parameter (a,w): affects Sensitivity
  - Longitudinal Length Ratio (L): affects Bandwidth
  - SCR affects sensitivity

Future Work

- Transfer Function or State space Relationships for the System.
- Control Algorithm for Nano-positioning of the platform.
- Use of the platform in exciting Applications like the scanning probe microscope.

Questions?