Sharon Jebet
EN201/0241/2019
EES 409
CAT II

29/30

a) Using diagrams explain the working principle of:

i) Microvalves

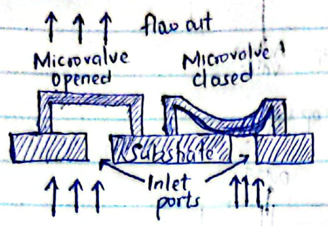


Fig 1. Microvalve array conceptual design.

To modulate flow, a voltage is applied between the diaphragm and substrate causing the diaphragm to collapse unstably, into contact with the substrate, closing the inlet port and restricting flow.

The microvalve operates as a parallel plate electrostatic actuator with the diaphragm functioning as the moving electrode & Si substrate as ground electrode. If voltage is applied between them, an electrostatic force develops, causing the diaphragm to deflect toward the substrate. As the voltage increases, the diaphragm experiences electromechanical instability and collapses toward the substrate, closing the inlet port and restricting flow.

4

The critical voltage at which electromechanical instability occurs depend on the fluidic pressure created by the flow and the mechanical compliance of the microvalve diaphragm. In normal operation, all microvalves are open, allowing flow. Upon closing, the flow rate across is proportional to the number of microvalves that remain open.

ii) Micropumps

It consists of 3 layers: glass, Si substrate and membrane part. The membrane part includes 3 active valves on top of the membranes, microchannels, 3 electrostatic chamber (air gap), input and output.

Its working principle is based on the peristalic motion

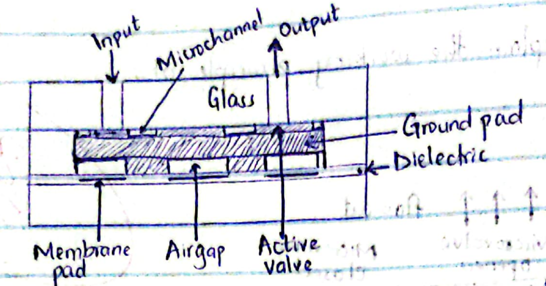


Fig: Electrostatic micropump

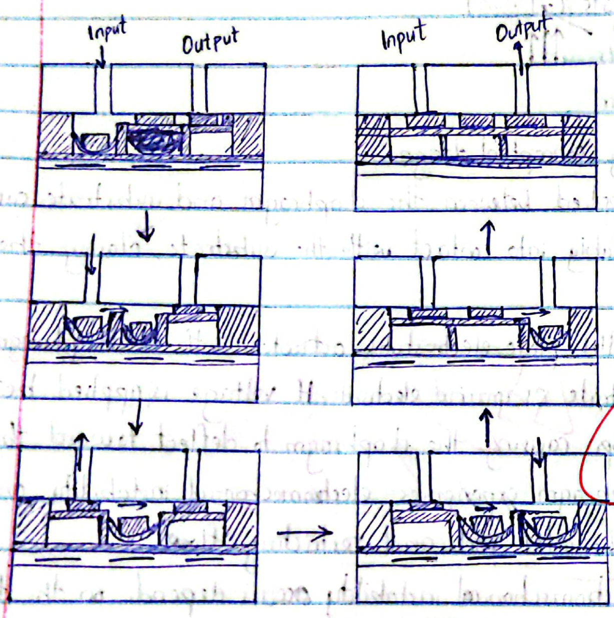
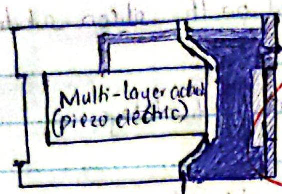


Fig 2: Working principle of the micropump.

b) Mechanical sensor in automotive applications:

Pressure and acceleration sensors have already been implemented in automobiles. The excellent features of micromachined accelerometers enabled a tremendous impact in improvement of car dynamics. The low mass and reduced power consumption associated with a reduced cost, facilitating implementation in various vehicles applications, including air bag deployment systems.

ii) 

iii) Piezo-electric effect principle on inkjet printer operation.

The inkjet printhead contains a piezoelectric crystal that is used to create an electric charge. When this charge is applied to the inkjet printhead, it causes the ink to be ejected from the printhead onto the paper.

Most inkjet printers use electrical charge to induce the shape of the piezoelectric crystal, causing it to change & move ink out of the nozzle. This results from applying voltage to a crystal, causing it to expand and deform slightly at high speeds, resulting in the removal of ink from the nozzle.

Piezo printer are reliable and are less likely to clog or jam, and they are very fast.

iii) Micromirror technology in micrograph scanning

There are different types of micromirror technologies, electrostatic actuation, magnetic actuations, electromagnetic actuations, piezo electric actuation and thermal biomorph actuation.

Electrostatic actuators → they are further classified into four groups, linear comb-drives, vertical comb-drives, rotary comb-drives and surface electrostatic actuators.

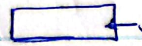
Piezoelectric actuators → they are governed by the principle that stress in the material are caused by a change in the electrical field applied to the actuators. They have fast response, low driving voltage and low power consumption

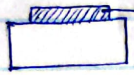
Electrothermal actuators → they generate motion by ~~extension~~ expansion of materials due to different thermal expansion coefficients of two materials. ($\Delta L = L \cdot \Delta\alpha \cdot \Delta T$)

They are classified into two cantilever micromirror and parallel-connected micromirror.

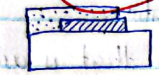
ii) Surface micromachining technique in fabrication of MEMS.

First, polyimide is selectively deposited on the silicon substrate.

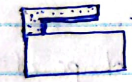

← Silicon wafer


→ Polyimide deposited as sacrificial layer.

Then aluminium film is deposited via physical vapor deposition (PVD) on the sacrificial layer.


← Aluminium deposited.

The polyimide is then removed in a process called release.


→ sacrificial layer removed, realising cantilever.

2a) List at least 4 materials employed in fabrication of MEMS.

Single-crystal cubic silicon carbide.

Germanium-based materials for example polycrystalline germanium and polycrystalline silicon germanium.

Metals and metal nanocomposites (gold, aluminum, nickel-iron, titanium-nickel)

Ceramics (aluminium nitride, gallium ~~nitred~~ nitride).

Piezoelectric materials.

b) Explain MUMPs processing sequence and design rules.

Design rules are supposed to ensure the greatest possibility of successful fabrication. They define the minimum feature sizes and spaces for all levels and minimum overlap and spacing between relevant levels.

Hole layers (HOLE 0, HOLE 1, HOLE 2 and HOLEM) for POLY 0, POLY 1, POLY 2 and METAL respectively are shown as separate levels in order to make layout of POLY 0, POLY 1, POLY 2 and METAL easier. These holes (except HOLE 0) provide shorter release etch paths under large polysilicon features, and a way to 'extract' holes from a light field level.

Mnemonic level name	CIF level name	GDS level name	Nominal line/space	Minimum feature	Minimum space
* POLY0	CPZ	13	3.0	2.0	2.0
* ANCHOR1	COF	43	3.0	3.0	2.0
* DIMPLE	COS	50	3.0	2.0	3.0
* POLY1	CPS	45	3.0	2.0	2.0
* POLY1-POLY2-VIA	COT	47	3.0	2.0	2.0
* ANCHOR 2	COL	52	3.0	3.0	2.0
* POLY 2	CPT	49	3.0	2.0	2.0
* METAL	CCM	51	3.0	3.0	3.0
* HOLE 0	CHZ	41	3.0	2.0	2.0
* HOLE 1	CHO	0	4.0	3.0	3.0
* HOLE 2	CHT	1	4.0	3.0	3.0
* HOLEM	CHM	48	5.0	4.0	4.0

3