MSA PROJECT REPORT

Design of MEMS based biosensor with cantilever for detection of Covid-19 Virus.

Group-6:

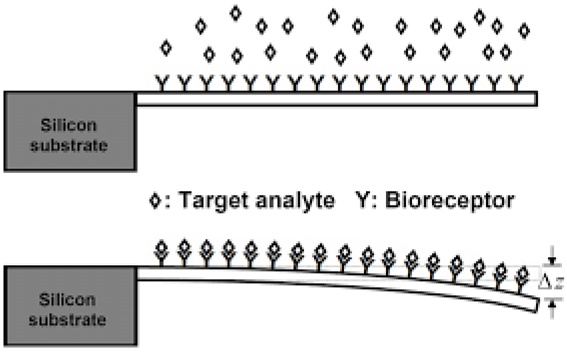
D Vishal	(S20190020210)
K V S S Pavan Teja	(S20190020216)
K Sreenivasulu Reddy	(S20190020217)
K Litheesh Kumar	(S20190020218)

About Project:

Aim of the project is to design a cantilever-based biosensor which helps in detecting SARS –CoV19 virus. Piezoelectric material is used because **change in stress generates a voltage** across the electrodes of piezoelectric material. Piezoelectric MEMS detection method for the virus, which is fast, portable, cost-effective, requires less samples, is reliable, and can diagnose the stage for SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) from the first day of virus infection. The piezoelectric material is **sandwiched between upper and lower aluminum layers**; they act as electrodes for measuring voltage. The design and analysis of cantilever-based MEMS biosensors is done by COMSOL Multiphysics. Three cantilevers are used in the design, one each for **viral load, IgM,** and **IgG**. The bio-molecular reaction on the cantilever increases the mass at the end, changing the electrical and mechanical properties in the cantilever. Piezoelectric material generates the voltage proportional to the mass applied. From the values of voltage obtained from three cantilevers, the infection stage for symptomatic and asymptomatic can be diagnosed.

Principle:

The principle involves **bio-sensing**, change in mechanical properties of the cantilever due to force/mass applied, and generation of electric energy via piezoelectric material. The pits of the cantilevers are functionalized by applying the bio-receptor, and then the analyte is deposited. The bioreceptor and analyte form the bio-complex. The combination of analyte and bio-receptors is unique, as shown



Some governing equations used for calculation are

$$F = m_{bio} g \tag{1}$$

$$\sigma = \frac{Fa}{Z} \tag{2}$$

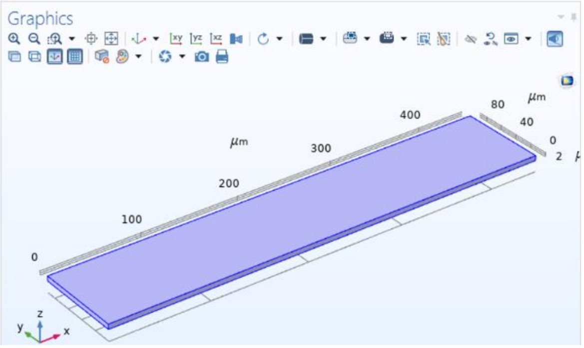
$$V = \frac{d_{33} t_p \sigma A}{\varepsilon_0 \varepsilon_r w_p l_p} \tag{3}$$

$$\delta \max = \frac{Fa^2 (2a + 3b)}{6EI} \tag{4}$$

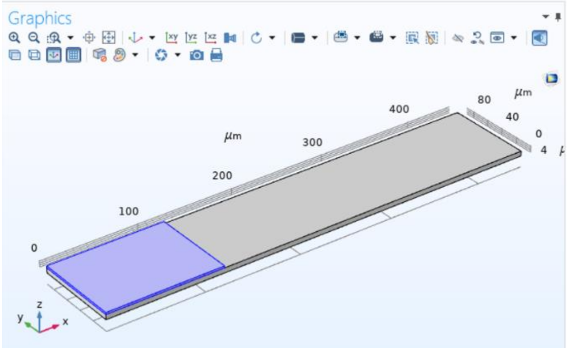
$$f = \frac{1.8752}{2\pi} \sqrt{\frac{EI}{meff \ I_c^3}} \tag{5}$$

Where F = force, V = voltage,
d33 = piezoelectric coefficient of PZT-5A = 3.7e-10,
E = Young's Modulus of Silicon,
I = moment of inertia,
A = cross-section area of cantilever,
σ = stress near PZT-5A,
Z = section modulus of the crosssection of the beam,
δmax = maximum displacement of cantilever,
f = frequency,
lc, lp, wp, and tp are cantilever length, piezoelectric material Length, width, and height,
a and b are distance from fixed end to pit middle point and from pit middle point to free end,
Meff = effective mass of the sensor and
mbio = mass of the analyte and bio-receptor.

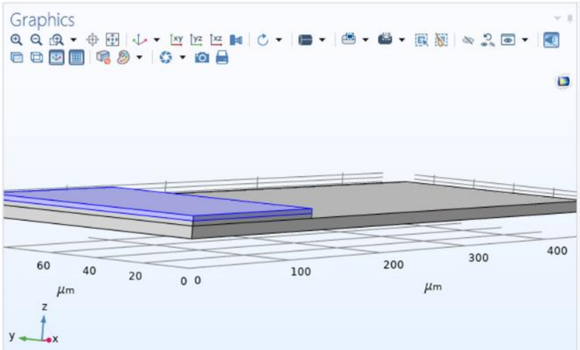
Design of BioMEMS Sensor:



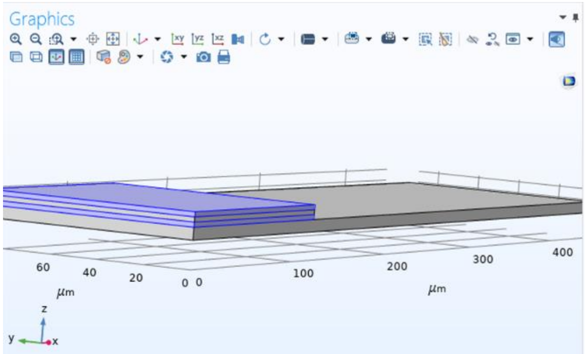
Step-1: Silicon cantilever (450μm*90μm*5μm)



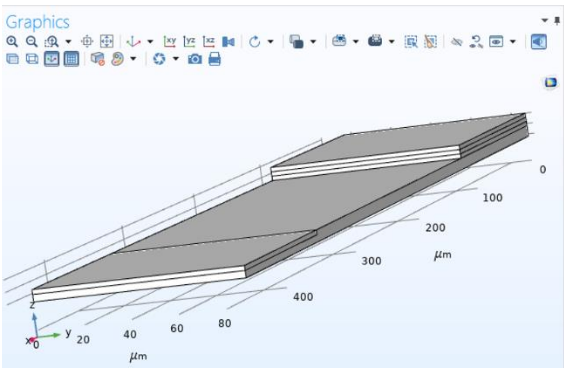
Step-2: Aluminum Block (120μm*90μm*2μm) at fixed end on top of cantilever



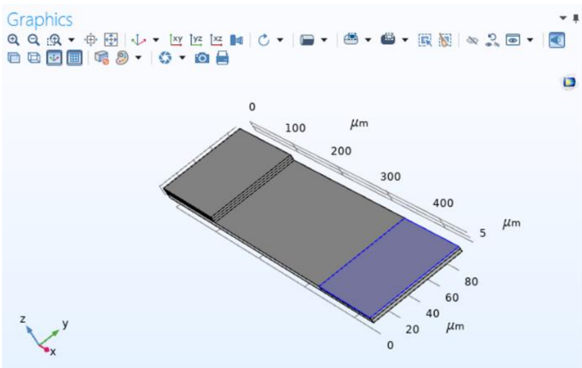
Step-3: PZT-5A Block (120μm*90μm*2μm) at fixed end on top of aluminum block



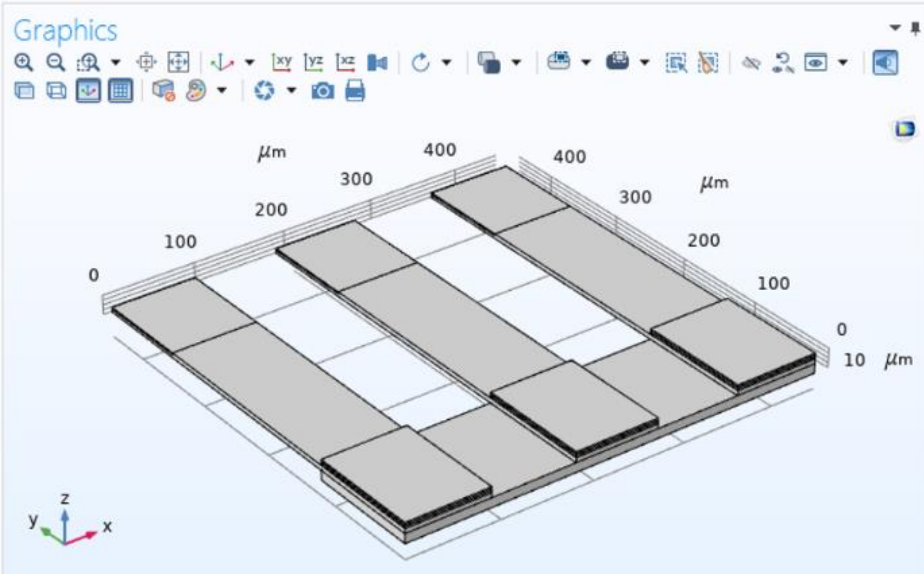
Step-4: Aluminum Block at fixed end on top of PZT-5A block(120μm*90μm*2μm)



Step-5: Pit is placed at free end (100μm*90μm*2μm)



Step-6: load applied on pit



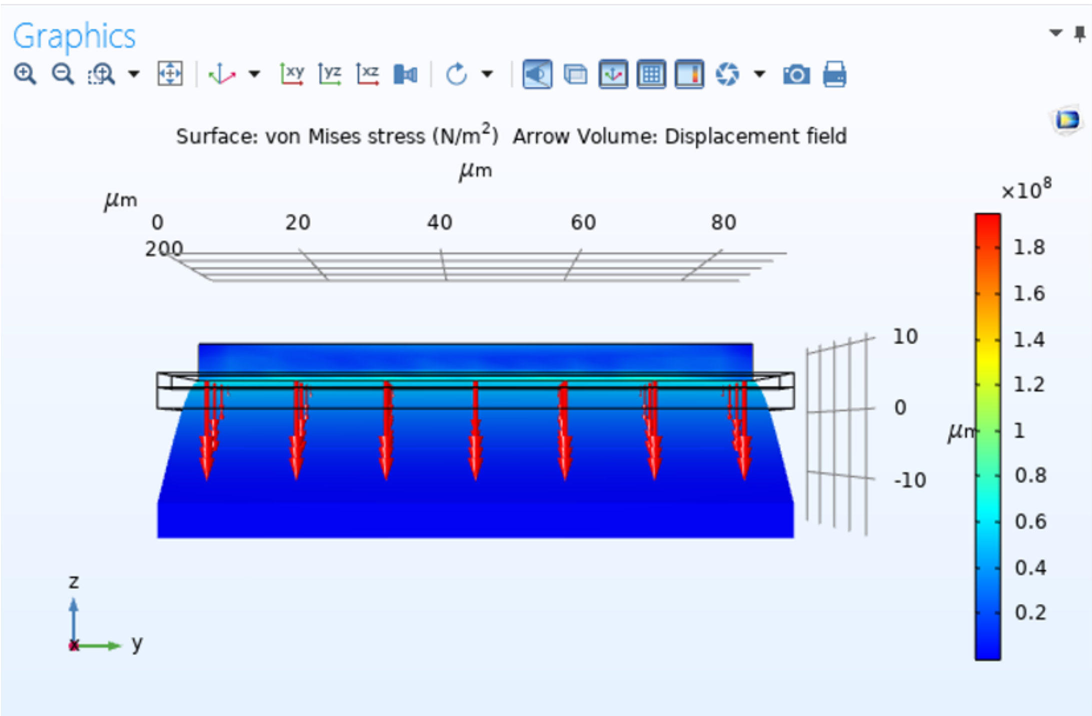
Step-7: three cantilevers placed on Silicon Block(450μm*90μm*10μm)

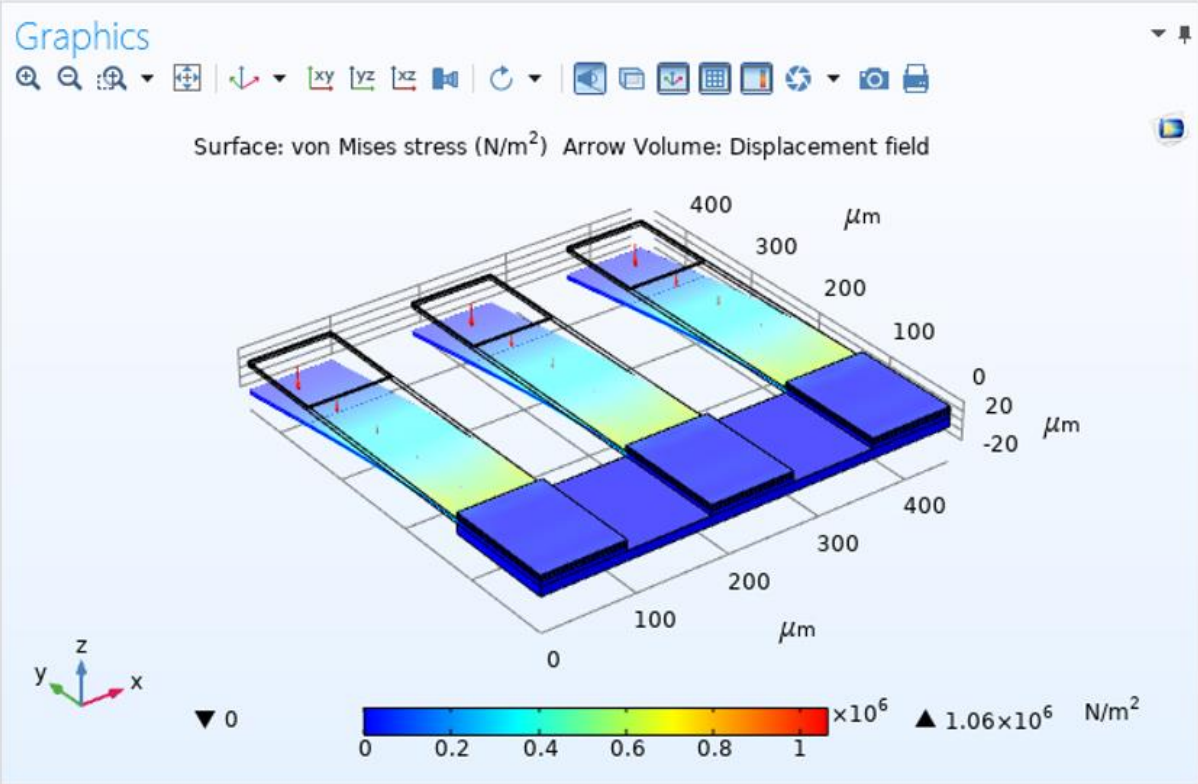
Properties of materials:

	Silicon	Aluminum	Piezoelectric material
Young's Modulus (psi)	169x10^9	68x10^9	210x10^9
Poisson's Ratio	0.3	0.31	0.31

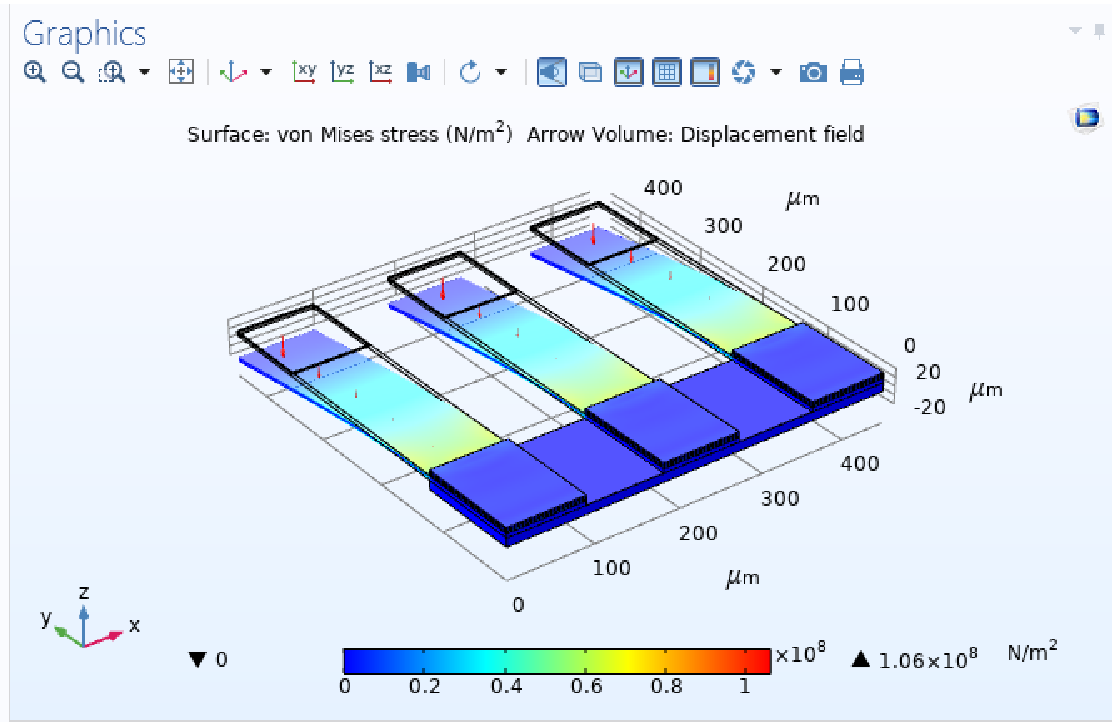
Simulation Results:

Stress vs deformation: (Arrow Volume: displacement field)

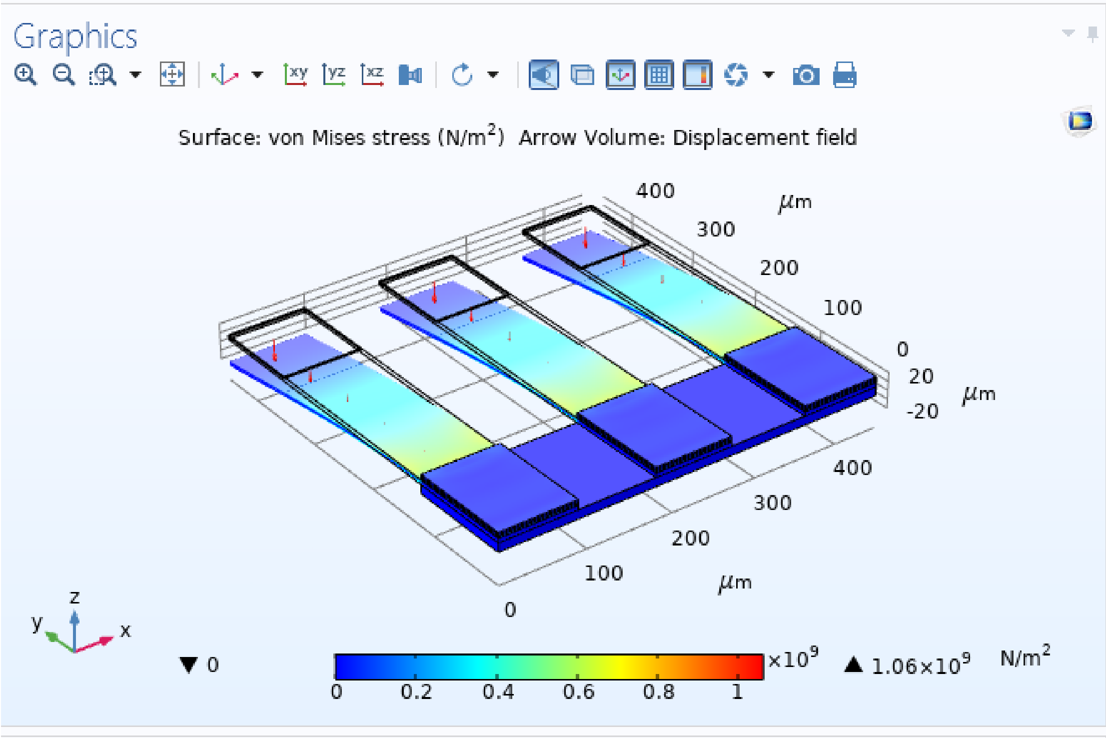




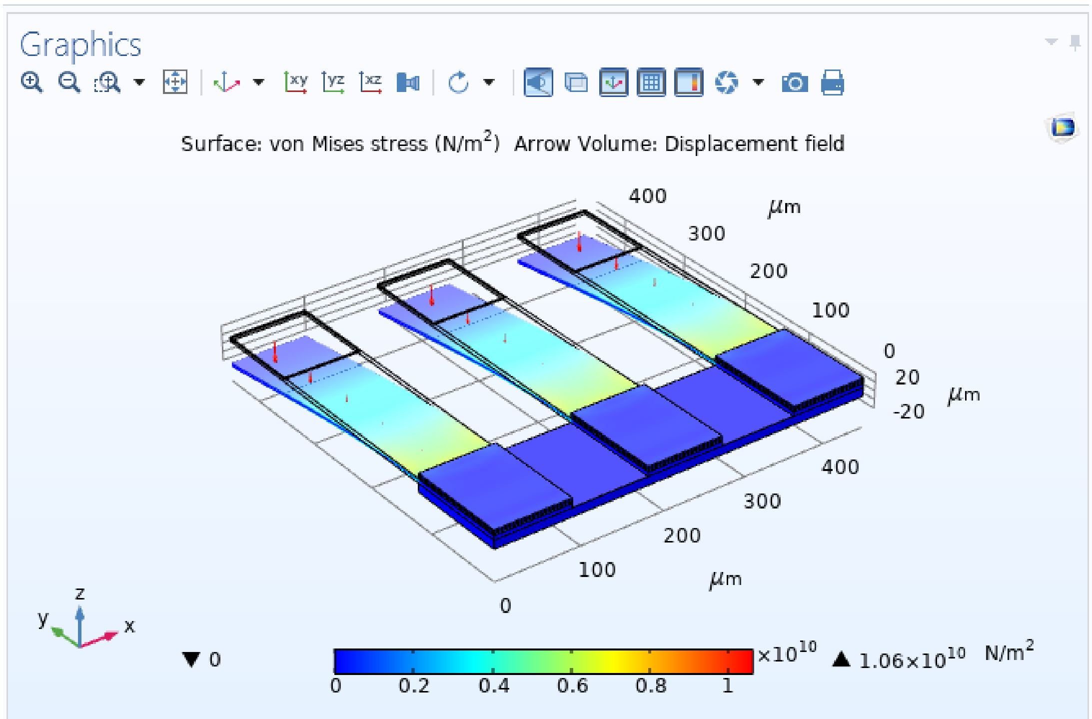
Case-1: Pressure = 10KPA



Case-2: Pressure = 100KPa



Case-3: Pressure = 1000KPa



Conclusions:

Designed piezoelectric MEMS Cantilever based Biosensor detects Viral Load, IgM, and IgG values for SARS-CoV-2. Its main advantage is that it can determine infection from the first day to months afterward, relative to RT-PCR, which provides positive results only till 25 days of illness. The design gives results in 5 to 10 minutes, which is quicker than RT-PCR, and also has a reusability advantage. The proposed sensor offers good mass sensitivity of almost 20 copies/ml. Also, this is reliable, cost-effective, easy to use, portable, requires less amount of sample and may diagnose analytes in low concentration. Some of the severe and critical cases can be handled within the first week of infection.

Contribution:

- K Litheesh Kumar (S20190020218) - Cantilever for IgM (COMSOL).
- D Vishal (S20190020210) - Cantilever for IgG (COMSOL).
- K V S S Pavan Teja (S20190020216) - Cantilever for viral load (COMSOL).
- K Sreenivasulu Reddy (S20190020217) - Testing, Analysis, report, ppt.

References:

1. M.G.G. Jithendra Prasad, Shameem Syed, "Design and analysis of micro-cantilever based biosensor for swine flu detection", International Journal of Electrical and Computer Engineering, vol. 6, issue 3, June 2016, pp. 1190-1196.

2. Wan Y. Shih, Wei-Heng Shih, Zuyan Shen, "Piezoelectric cantilever sensors", issued Dec. 2,2008, U.S. Patent 7,458,265 B2.

3. Arpana Niranjan, Pallavi Gupta, Manisha Rajoriya, "Piezoelectric MEMS Microcantilever Biosensor for Detection of SARS –CoV2", Sharda University, Greater Noida, India, IEEE 20 July 2021, **DOI:** 10.1109/ICCISc52257.2021.9484976.

4. https://www.coventor.com/blog/overview-piezoelectric-mems-principles-applications/