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DESIGN AND SIMULATION OF MEMS PIEZOELECTRIC ACTUATOR FOR DRUG DELIVERY SYSTEM

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Abstract: Piezoelectric principle based an actuator is design for a micropump, which is suitable for drug delivery systems. The natural frequency and stress analysis have been performed to determine the reliability of the device in terms of minimum safety factor. We have observed the uniform deflections of the actuators by varying the thicknesses of the piezoelectric layer of the actuator. The design of the actuators is considered in circular and rectangular geometry. The materials are selected appropriately such that the component is biocompatible and can be used in biomedical applications. Among the various considerations made on dimensions and geometry, it is observed that the circular piezoelectric actuator undergoes a high displacement at an infinitesimal thickness of 20 µm. At minimum safety factor of one, the maximum stress and voltage the actuator respectively

***Keywords*: actuator,Membrane,MEMS,PZT,Si etc.**

I. Introduction

MEMS, an abbreviation of “Micro Electro Mechanical Systems”, are the innovations of very small devices. MEMS are minor integrated frameworks or a system that associates electrical and mechanical components which are made using the methods of micro fabrication. They sort in dimension from the micro-meter level to milli-meter level. Smaller scale electromechanical structures (MEMS) are a method advancement which is used to make minimal consolidated contraptions or systems that joins both electrical and mechanical parameters. The extent of the MEMS gadgets extending from couple of micrometers to a few millimeters and they are created utilizing incorporated circuit cluster preparing systems. MEMS gadgets can control detect and incite on smaller scale and produce impacts on the large scale. A piezoelectric actuator is a transducer, used to change an electrical signal into an accurately controlled physical displacement or stroke by using piezoelectric effect based on electromechanical coupling rather than electromagnetic induction. If the stroke is avoided, then useable energy will develop. The exact movement control afforded by these actuators is mainly used to change machining tools, mirrors, lenses, or other apparatus finely. The working principle of a piezoelectric actuator is, once the voltage is applied to piezoelectric actuators then they generate a small displacement through a high force capacity, so these are used in many applications like ultra-precise positioning, in high forces handling & generation in stationary or dynamic conditions. The configuration of the piezoelectric actuator can change greatly based on application. These devices are Ultrasonic actuators which are designed specifically to generate strokes of numerous micrometers at ultrasonic frequencies above 20 kHz. They are particularly used for positioning, controlling vibration & quick switching applications. The important specifications of piezoelectric actuators mainly include force, displacement, & operating voltage. The factors that need to consider while using these actuators are capacitance, stiffness & resonant frequency

II. LITERATURE SURVEY

1.Revathi S, Padmapriya N, Padmanabhan R A design analysis of piezoelectric-polymer composite-based valveless micropump. This paper presents the three-dimensional numerical simulation of a micropump, including diffuser and analytical modelling of the micropump flow rate. The numerical simulation of the diffuser is performed in all possible flow regimes to optimize its geometry for maximum efficiency.

2. Dhananchezhiyana P, Hiremath Soma Shekhar S Optimization of multiple micro pumps to maximize the flow rate and minimize the flow pulsation in recent years, micro pump plays a significant role in many fields, specifically in chemical, medical, and thermal managements. Since there are distinct requirements in each field, several types of micro pumps have been designed to meet those requirements. Fluid flow from these micro-pumps is delivered in a series of small discrete volumes, which make up a pulsating flow. In order to reduce the pulsating flow, the multiple micro-pumps should be actuated in parallel.

3 Karman S, Ibrahim F, Soin N (2007) A review of MEMS drug delivery in medical application. MEMS drug delivery devices in medical application such as micropumps, microvalves, micro actuator and microneedles, using biocompatible material such as silicon. The review will focus on micropumps structures in different actuators. The electrostatic actuated micropumps and circular bossed membrane were found out to be the most suitable device for medical application.

2.1 Outcome of Literature Survey

After evaluation of different research papers, we came to know that piezoelectric actuator and its mechanical behavior as well as changing properties by changing in few parameters it has been observed that sensitivity and its deflection in frequency can be utilized to a drug delivery system

III. PROBLEM STATEMENT

To design and simulate MEMS Piezoelectric actuator for drug delivery system medical application drug delivery is one of the processes in this process patient should be given proper amount of drug/medicine in proper time. For this concern piezoelectric actuator is designed and implemented in drug delivery system.

IV. OBJECTIVES

- **Design of MEMS piezoelectric actuator using COMSOL Multiphysics tool.**
- **Modal and parametric analysis of MEMS Piezoelectric actuator for different values of dimensions and boundary conditions (like force/pressure).**
- **Total displacement and capacitance to be obtained and both are compared.**

V. METHODOLOGY

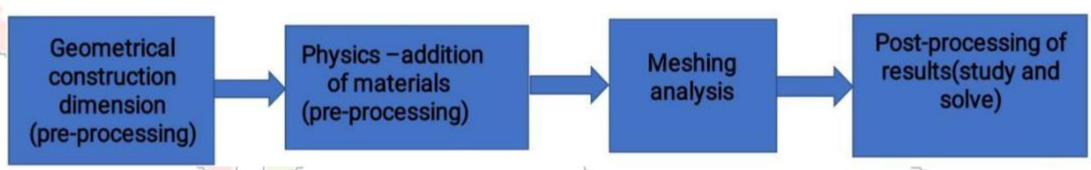


Figure.1: Block Diagram

Figure 1 shows architecture for designing a MEMS piezoelectric actuator.

- The MEMS piezoelectric actautor structure is designed by using COMSOL Multiphysics analysis tools to compute the result parameters such as frequency and displacement and vary the same for obtaining the required results.
- Figure 1 shows architecture for designing a MEMS based piezoelectric actuator
- MEMS piezoelectric actuator structures will be designed by using COMSOL Multi physics using comb drive structure.
- The designed structures will be computed to get results like displacement, stress and deflection of actuators on COMSOL Multi physics
- At last frequency analysis will improve the situation of every single composed model and will be able to think about consequence of all models like displacement, capacitance.

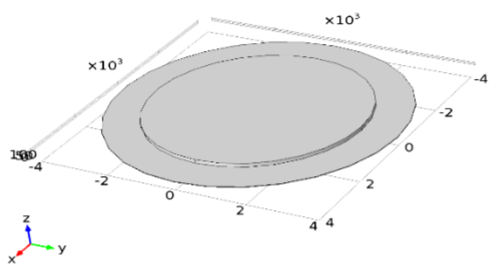
The actuator is laid over both the chamber. It consists of a diaphragm and a piezoelectric layer. A thin layer of piezoelectric material is laid over a diaphragm constituting a piezoelectric actuator. When electric potential is applied over the upper surface of piezoelectric layer of diaphragm which causes the bonded layer of diaphragm to deflect down wards. This creates the pressure inside the chamber containing the drug. The developed pressure makes the drug to flow from chamber 1 to chamber 2 through the diffuser. Another piezoelectric actuator is placed over the chamber 2. The application of voltage makes the drug to flow through the micro needle.

Initial design of Piezoelectric actuator Design specifications for initial design of MEMS piezoelectric actuator using COMSOL Multiphysics as shown in the Table

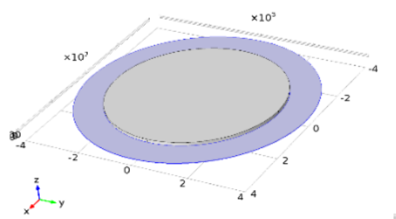
Components	Dimension(µm)
Radius of circle 1	5
Radius of circle 2	4
Thickness of circle 1	20
Thickness of circle 2	20

Design specification of piezoelectric actuator

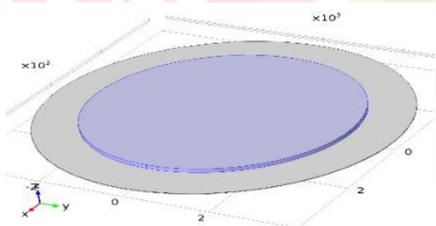
The designed MEMS based actuator in circular bonded with a circular shaped PZT makes a circular piezoelectric actuator. Having diameter of 5µm with the thickness of 20µm and it is clamped or fixed with its boundary. Above that membrane a piezoelectric actuator is attached of diameter 4µm with the thickness of 20µm.The material used here is silicon for a substrate fixed with boundary load and another with PZT material with the elctropotential of 5V.



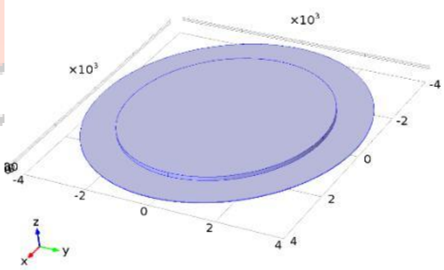
Step 1 : Initial design of MEMS piezoelectric actuator,.



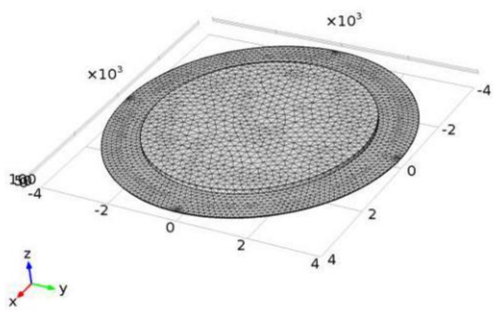
Step 2: Adding material



Step 3: Adding material to the Structure



Step 4: Representation of fixed constraints



Step 5 : Meshing

ADVANTAGES/DISADVANTAGES/APPLICATIONS

- Simple design
- Least moving parts,
- High-reliability characteristics
- These are simply optimized for particular applications like a non-magnetic, cryogenic, ultra-high vacuum & high stiffness.
- High force for each unit area Resolution is unlimited
- Vacuum &Clean Room Compatible
- Generation of High Force

Disadvantages

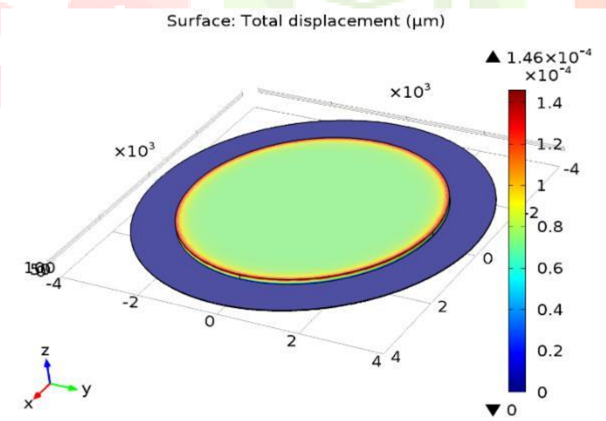
- Non-explosion proof.
- Sensitive to vibration.
- More complex technology.
- High speeds, less thrust.
- High thrust, less speed.

Application

- A piezoelectric actuator is used to adjust different types of equipment like lenses, machining tools, mirrors, etc.
- These are used in various precision motion control-based applications.
- These actuators are also used to control hydraulic valves which work like a special-purpose motor or a small-volume pump
- These are used in applications where force or movement is required.
- These are used in different industries like aviation, automotive, consumer electronics, medical, aerospace due to many benefits.
- Piezo actuators are used in braille & precision knitting machines.

VI. RESULTS AND DISCUSSIONS

Displacement: The Figure 5.5 shows the 3D image of total displacement in Model On theapplication of 1m pa pressure on the piezoelectric actuator the total displacement obtained 1 . 4 6 x 1 0 ^ - 4 .



Capacitance: The total capacitance obtained by the result is as shown in the figure. The capacitance obtained is 1.48x10^-10.

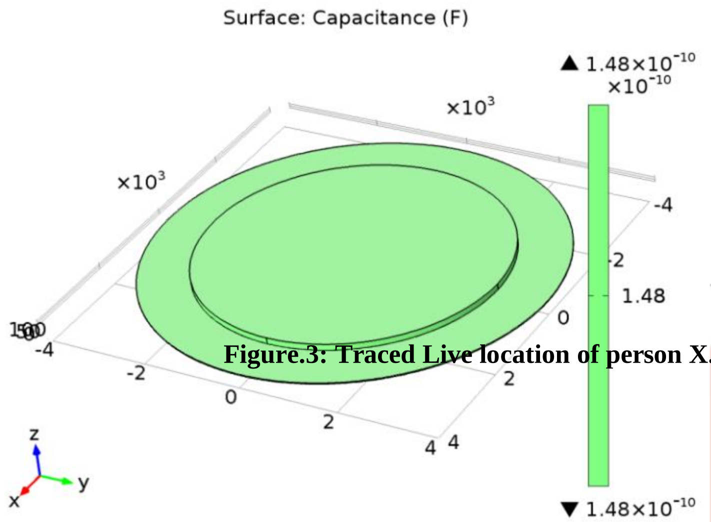


Figure.3: Traced Live location of person X.

Geometry	Total displacement	Capacitance
Circle (PZT)	1.46x10^-4	1.48x10^10
Rectangle (PZT)	2.9 x10^-3	5.22x10^10
Square (PZT)	2.9 x 10^-3	7.73x10^-10

Comparison table for a three designed parameters

On Comparing all the parameters above shown in table the results of circular, rectangular and square PZT actuator, square is more advantageous then other two designs, square PZT fits to all parameters and it has proper dimension like length and width are same as compare to other two parameters.

- Stress of the Membrane is Proportional to length diameter is inversely proportion to the thickness
- On comparing Square and circular membrane base on the edge length/ diameter is increased
- Here same voltage and boundary conditions are applied in both the cases.
- The displacement of the circular plate because surface area of the square is always greater than the circular plate.
- The thinner membrane will be the more deformation occurs

VII.CONCLUSION

In this work, the piezoelectric actuator of different shapes of the same foot print is compared, one the shapes are rectangular, circular and square. Hence with the same boundary and load conditions are applied in the both the cases. The actuator is considered in circular, square and rectangular shapes. The thickness of the piezoelectric layered are varied and observed. As it is analyzed that the greater deflection and more amount of volume and displaced for a certain electric field in case of piezoelectric actuator this is consider better than a circular and rectangular.

The square plate dimension is always greater than that of circular and rectangle and the surface plate is also greater than that of other two parameters. Hence drug can be delivered to the target site can be flow in at the better rate of the micropump when PZT actuation mechanism is used and the shape of the actuator is square. This actuator is utilized in micropump for easy delivery of drug into patients' body.

VII. REFERENCE

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