

**An IoT based MEMS Sensor for The Detection of Biomarkers in Exhaled Breath**

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**Abstract:**

Internet of Things (IoT) and Micro Electro Mechanical System (MEMS) technology has played a major role in the advancement of smart health care and medical science. MEMS and microfluidics have provided the ability to integrate laboratory processes and biological analytes detection at micro scale. Micro sensors and actuators allow a MEMS device to sense, act and compute in a very short time. IoT enables to collect the information in real-time and send to the remote locations using IoT modules.

In this project, an IoT based MEMS sensor has been proposed to detect low concentration biomarkers from the exhaled breath. It is based on the Breath Analysis (BA) techniques used in medical science to detect infectious biomarkers exhaled in breath. An infected person exhales different kind of biomarkers which are sensitive to and detectable by biological analytes or polymers. This operation will be performed by MEMS device. IoT enables the data to be stored in cloud servers that can be securely accessed by the remote health care centers and received by doctors using IoT modules. The data is analyzed by doctors and based on their decision, a treatment regime could be advised.

**Introduction:**

*MEMS* is the abbreviation of *Micro Electro Mechanical System*. It is the integration of *Micro* *Electronics* and *Mechanics*. It can also be formed by integration of Micro *Optics* and *Magnetics* [1]. In its most general form, it is well defined as *miniaturization* of *electronic* and *mechanical* elements. It is manufactured by *microfabrication* technology. The length of typical MEMS device generally ranges from 1 micrometer to centimeter. It is consistent of *Micro sensors, actuators, electronics and structures* [4].

**History**

The term MEMS was introduced in 1986 by The Center of Engineering Design, University of Utah. The field of MEMS is evolved from Integrated Circuit (IC). IC Technology developed very fast and rarely matched in other fields. The density of transistor integration increases two-fold every 12 to 18 months as per Moore’s Law. *Microfabrication* and *Micromachining* is the engine behind functional integration and miniaturization of electronics and mechanics [4]. It promises to revolutionize nearly every field by bringing together silicon based micro-electronics with micro-machining [2].

In 1989, a *Polysilicon motor* of 120µm diameter and 1µm thickness was demonstrated by University of California. It was the first silicon surfaced *micro-machined micro-motor* driven by electrostatic forces. It was capable of rotating at a speed of 500 rpm under three-phase. 350 V driving voltage. This motor brought the excitement of MEMS to the community. By the time, MEMS became the internationally accepted name of the field [4].

By 1990s, the field of MEMS has grown rapidly. Government and private funding agencies funded and supported the research activities throughout the world. The early research turned out to be beneficial for some companies. From which, remarkable inventions include integrated Inertial Sensors by Analog Devices for automotive air-bag deployment, Digital Light Processing Chip by Texas Instruments [4].

In today’s market, there are numerous products based on MEMS technology. Such as: Ink Jet printing technology, accelerometers, smart writing instruments, electronic game controllers, biosensors, etc. The research areas include Optical MEMS, Bio MEMS, Microfluidics, Radio Frequency (RF) MEMS, Nano Electro-Mechanical System (NEMS) etc. [4].

**Idea of MEMS Sensor for detection of Biomarkers in Exhaled Breath**

According to the research, there have been enormous progress in the fields ranging from health to biosecurity for last two decades. It is due to the development of *lab-on-a-chip* or *micro Total Analysis System (µTAS) technology*. MEMS and microfluidics have provided the ability to integrate laboratory processes and biological analytes detection at micro scale. Its *advantages* of *portability, high sensitivity*, *low cost*, *less time consumption* and handling samples with small volumes have developed the interest of new methods for detection of biological analytes like bacteria, virus, etc. From which, detection of infectious diseases in a human body is a point of care [6].

Using MEMS technology, a Sensor can be manufactured with such a functionality to sense, analyze and identify the disease affected to a person. It is based on the logic that an infected person exhales different kind of gases/biomarkers when breathing out. By *using polymers, antibodies, micro sensors and actuators,* the device can sniff the odor and *catch the vapors or toxicity exhaled in our breath* using biotechnology. Which will then be *analyzed* and *identified* using different *bio MEMS* operations on micro level. Thus providing the result in a very short time.

**Materials and Methods:**

The required materials in the manufacturing of MEMS Sensor to detect biomarkers in exhaled breath:

* Silicon Substrate
* Polysilicon
* Aluminum
* Micro sensors
* Micro actuators
* Polymers

**Sensors and Actuators**

***Micro Sensors:*** Sensors are devices that transduce energy processes that result in perception. It detects and monitors physical or chemical parameter and converts in other form of measureable energy. Examples are: Inertia Sensor, Pressure Sensor, Thermal Sensor, etc. [4].

***Micro Actuators:*** Actuators are devices that transduce energy processes that produces actions. It detects measureable energy and produces mechanical motion, force or torque. Examples are: Thermal Actuators, Cantilevers, Magnetic Actuators, etc. [4].

**Working Principle**

The working principle of the device is based on the Parallel plate capacitors. These are applied in a variety of sensing and actuating applications. Such as inertia sensor, pressure sensor, etc. [4].

The parallel plate capacitors are also used for micro actuation to linearly displace the plate vertically or rotationally to the plane. The amount of displacement achieved is limited by the initial gap spacing. Increase in initial gap spacing allows longer range movement but limiting the magnitude of forces. [4].

**Design of MEMS:** *MEMS* is constituent of *two structures*:

* *The moveable structure (rotor plate)*
* *The static structure (stator plate)*

These plates are fabricated using *Complementary Metal Oxide Semiconductor* (*CMOS*) fabrication technology. It uses two *polysilicon layers*, three *aluminum metal layers* and two *Vertical Interconnect Accesses* (*VIAs*). Each structure is to be a constituent of three electrodes formed by three metal layers connected by VIAs. It forms *parallel plate capacitor* for *sensing* and *actuating* purpose. Two capacitors placed on the sides are used for electrostatic actuation while the capacitor in the center is used for sensing purpose. The rotor plate is suspended over the stator plate by four identical flexible beams to maintain initial gap [6].

The rotor plate is to be constituent of CMOS layers only. While stator plate will have a silicon substrate underneath CMOS layers [6]. Upon completion of fabrication, the reverse side of rotor plate is to be coated with *a sensitive polymer layer*. It will function as a *sensing element* for vapors and gases. Due to the vertical movement, the device will be dominantly affected by *squeeze film damping*. *bsq* Only the underdamped devices can be used as resonators for mass sensing applications. These resonators are based on *frequency shift sensing*. Which is considered high accuracy measurement technique [7].

By measuring the change in frequency and using other mathematical modeling techniques, we can calculate the ratio of disease a person is acquired with.

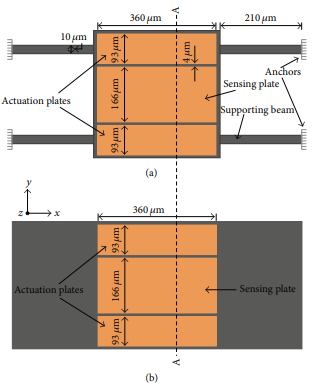
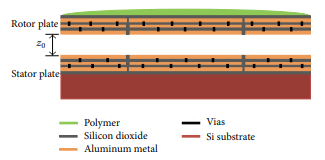


Figure 1: Cross section view of the plates showing CMOS layers, silicon substrate underneath stator plate and coated polymer on the top of rotor plate.

Figure 2: Schematic of proposed device. (a) The rotor plate.

(b) The stator plate with sensing and actuating parallel plates.

**MEMS Poster in National Project Competition (NPC)**

Our idea of MEMS based disease detector fits in the boundaries of NPC requirements. Luckily, it covers all the themes of NPC.

1. ***Creative:*** Idea of MEMS based disease detector is creative and revolutionary.
2. ***Innovative:*** It fulfils the promise of MEMS technology to modernize and simplify the world.
3. ***Socially Beneficial:*** It is for the benefit of people all around the globe. Success to this vision is the success of humanity.
4. ***Environment Friendly:*** Our idea is in no way harmful to the environment.
5. ***Feasible to Implement:*** The idea is feasible to implement technically. Easy to understand operationally and economically justifiable.

**Sustainable Development Goals (SDGs) focused in NPC**

Out of 4 selected SDGs of NPC, Our project covers 1 of them.

1. ***Goal 17: Partnerships for the goals:*** Our idea of MEMS sensor to detect biomarkers in exhaled breath can be a great initiative to the global partnership for the research and sustainable development. It will strengthen the means of implementation to this technology worldwide.

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[7].