Role of Mecroelectromechanical Devices in Improving Human Health

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Abstract: ***Microelectromechanical system (MEMS) devices are dominant creative devices used nowadays in our health care system. The researcher examined the roles of microelectromechanical devices and their applications in investigation, treatment, monitoring and improvement of various human health conditions. The microelectromechanical (MEMS) is the technology of very small devices, it mages at the nano-scale in to nanoelectromechanical system and are made between 1 to 100 micrometers in size (0.001 to 0.1mm). And the devices are generally range in size from 20 micrometers (20 millionth of meter). The health is the level of functional or metabolic efficiency of a living organism. In humans, it is the general condition of a person's mind and body, being free from illness, injury or pain. The description of Basic materials being used in fabrication and manufacturing of biomedical instruments and they function with the basic principles of biosensors whose application are geared towards improvement, investigation and monitoring of human biological system. Despite the great achievements recorded through the use of these devices, many of them are not free from certain complications such as device failure, attraction of harmful microorganisms, rejection etc.***

Keywords: Biomedical sensors; MEMS devices; smart pills

1. Introduction

The word MEMS stand for Micro- Electro- Mechanical System. Micro means small, Electro means controllable by electrical signals such as computers, Mechanical means moveable for sensing and actuation, System means integration of many devices. Micro-Electro-Mechanical Systems (MEMS) is defined as devices made up of miniaturized mechanical and electromechanical elements using micro fabrication techniques [1]. The device sizes are very small, usually in the range from 10µm to 1mm. To compare, a typical MEMS gear is about the size of a red blood cell. An optical mirror is about the size of the diameter of a human hair. The thickness of moveable parts in the chips are usually in the order of microns, therefore, the mass of moveable parts are very small which require very small force to move. The miniature feature reduces the size and weight of the integrated components, which further reduces power consumptions. MEMS devices can also be divided into two categories:

A. Sensors

Sensor are to sense the environmental changes such as pressure, temperature, humidity, vibration, speed, acceleration, force ,motion, shock, rotation, orientation, magnetic field, electrical field, chemicals ($co_{2,}$ No, co. E.t.c), biological agents (anthrax, virus, bacteria…), and strain….etc.

B .Actuators

Actuators are to provide motions and changes to the environments such as acoustic wave generation and processing, electromagnetic wave generation and processing, optical signal processing, mechanical manipulation, fluidic management, pumping, picking, cutting, shuttering, scanning, and imaging …etc.

The miniaturized structures such as sensors, actuators and microelectronics are also called transducers which help in conversion of one form of the energy into another. Technological advances have led to development of a synergistic relation between the unrelated fields such as biology and microelectronics. MEMS finds its application in medical sector especially diagnosis and biotechnology. There has been a paradigm shift of patient taking treatment from hospital to home care.

C. Factuality of MEMS Devices

MEMS devices can be utilized in many ways. Roughly speaking, they can be applied in a conventional application but with much smaller sizes and power requirement or in a novel way to enable a new application. Both are finding in many application of our life.

D. Advantages of MEMS Devices

MEMS devices have been attracting a lot of attention due to their unique features – small sizes and low power requirement. They have proven to be a key enabling technology of developments in sectors such as transportation, telecommunications, and healthcare, but the range of MEMS applications covers nearly every sector. The most significant advantage of MEMS is their ability to communicate easily with semiconductor chips. Other advantages include MEMS' compact size, reduced power consumption, lower cost, and increased reliability. The growth in the use of MEMS has also led to the creation of supporting industries in areas such as MEMS design software, design services, specialty fabrication equipment, and fabrication facilities.

E. How to make a MEMS Devices?

There are many ways to make MEMS devices. Conventional silicon micromachining technique is a popular approach. It allows monolithic fabrication using the existing semiconductor such as VLSI or CMOS processes, which reduce manual labor and fabrication costs. The monolithic feature also allows precise positioning for components on the chips. The accuracy of alignment can be in submicrons. The mechanical characteristics of silicon have been well studied and show great promise for robust and reliable devices. Surface micromachining build 3-dimensioanl structures by depositing multiple poly-silicon and sacrificial layers such as SiO2 and releasing the sacrificial layers in the final step. Other approaches use the similar philosophy – multiple layers of deposition and etching but different materials. Electroplating of metals, polymer coating, evaporation of materials, physical embossing and molding are also parts of the fabrication techniques.[6]

2. So why are we applied the mems technologies to medical field?

2.1 Portability

Rise in healthcare expenditure compounded by geriatric population is driving the demand for portable medical diagnostic devices. In addition, need for rapid diagnosis coupled with minimum turnaround time has compelled medical device manufacturers to focus on providing a single platform for multiple diagnostic tests. By leveraging MEMS, manufacturers can produce significantly smaller, low-power consumption connectors that deliver high performance than larger components used in devices. Governments across the globe have realized the potential of nanotechnology and MEMS in healthcare and are supporting the growth of this industry through significant funding. This has overall boosted the confidence of the entire value chain of MEMS industry right from foundries to the final product.

The technology of microelectromechanical systems (MEMS) is impacting the biomedical industry, leading to a new generation of tools with sophisticated functionality. Some of these miniature instruments used for biomedical applications (BioMEMS) are appearing as medical devices, as well as playing a role in drug delivery.

2.2 Miniaturization

Much medical instrumentation is expensive, bulky, and heavy and require experienced technicians to operate. This is partially due to the component sizes and the analysis methodology. MEMS can reduce the component sizes significantly and enable new analysis methods so portable, highly-sensitive diagnosis tools would become possible.

3. Classification of Biomems

3.1 Biomedical Instrument

Biomedical Instrumentation involves devices designed and connected together in a scientifically appropriate manner to sense (or capture) signals (e.g.: electromagnetic, mechanical, thermal, acoustic) and process them for human display and/or further processing for control, therapy etc. A simple and widely known example would be a digital thermometer which senses the temperature using a electronic sensor (one example of which is a device called 'thermistors').

BioMEMS can be classified functionally in to the following categories [2]:

3.2 Biomedical MEMS

The biomedical MEMS is usually deals with 'in vivo' within the host body and they are classified as listed below.
- Precision surgery
- Biotelemetry
- Drug delivery
- Biosensors and other physical sensors

3.3 Biotechnology MEMS

This is also classified according to there are of application and they are dealing with 'in vitro', with the biological sample obtained from the host body, and they are also classified below.
- Diagnostics
- gene sequencing
- Drug discover
- pathogen detection and elimination

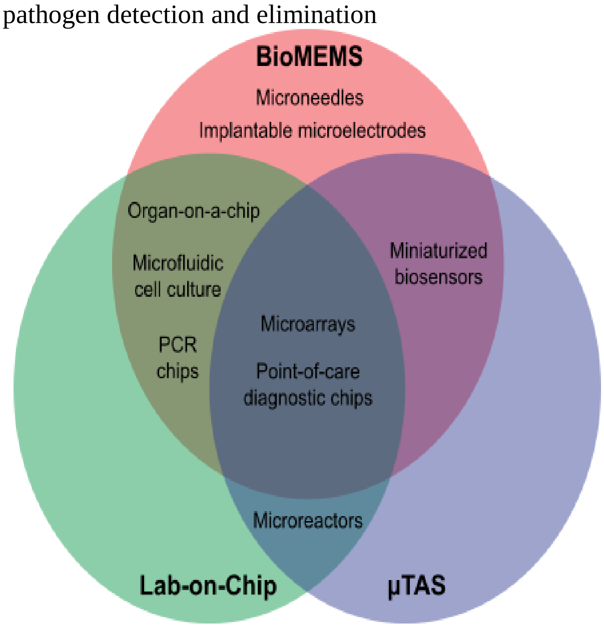

Figure 1: A Venn diagram outlining and contrasting some aspects of the fields of bio-MEMS, lab-on-a-chip, µTAS

MEMS sensors in the biomedical field maybe used as:
- Critical sensors, used during operations.
- Long term sensors for prosthetic devices.
- Sensor arrays for rapid monitoring and diagnosis at home.

4. Precision Surgery

4.1 Endoscopy

Endoscopy is a diagnostic procedure which involves the introduction of a flexible device into the lower or upper gastrointestinal tract for diagnostic or therapeutic purposes. It is an uncomfortable procedure so it requires sedating the patients.

4.2 Conventional endoscopes

In conventional endoscopes which was use in before the modified MEMS endoscopy it can be used to view only the first-third of the small intestine.

4.3 MEMS modified endoscopy ("Lab on a Pill")

This modified MEMS endoscopy is very small in nature of size (35mm) and it comprises the following components:

- Digital camera (CMOS Technology)
- Light source
- Battery
- Radio transmitter
- Sensors (MEMS Technology)

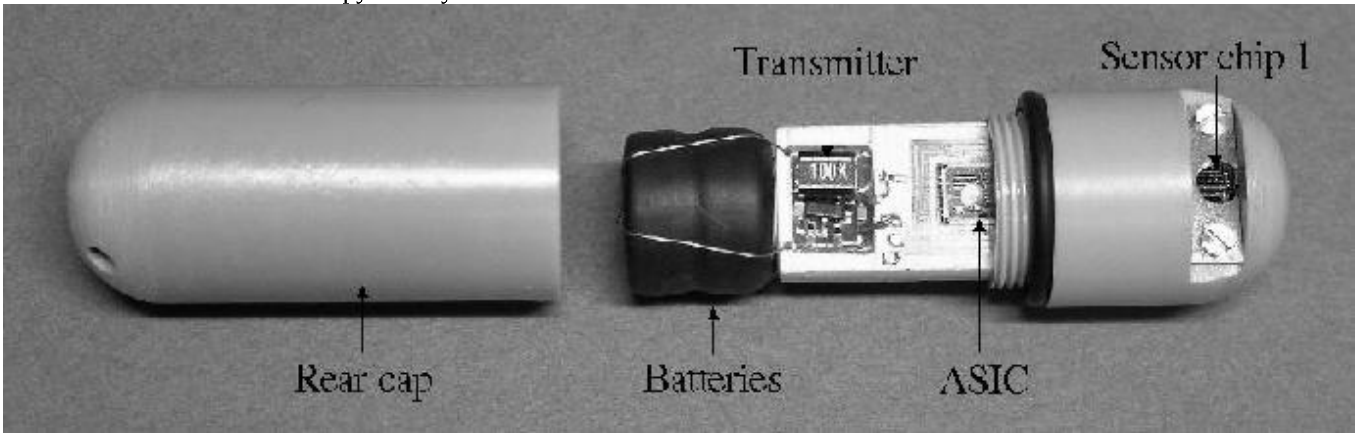

Figure 2: Lab on a pill

4.4 Characteristic functions

- Can show a view of the entire small intestine
- Can aid in early detection of colon cancer
- Requires no sedation

4.5 Working principle

- The pill is intended to be swallowed like any normal pill.
- Once within the body, the pill's sensors sample body fluids and pick up "meaningful patient data" such as temperature, dissolved oxygen levels and pH.
- The pill is expected to retrieve all data over a 12-hour period and disposed off, once excreted.
- This data is transmitted wirelessly to a card attached to the wrist of the individual.

4.6 Micro-surgical tools

- Present day surgeons operate within a domain restricted by the mobility and control of the surgical tools at hand.
- MEMS surgical tools provide the flexibility and accuracy to perform precision surgery.
- Examples of microsurgical tools include:

i. MEMS driven scalpel

- Precise control of the scalpel is an important requirement in any surgery.
- MEMS piezoelectric motor helps to accurately position the scalpel.
- MEMS pressure sensors incorporated on the scalpel, so that it can help to measure the force exerted on the area operated upon. Accordingly, the scalpel can he handled.

ii .Ultrasonic MEMS cutting tool

- These tools make use of piezoelectric materials attached to the cutter.
- It consists of micro channels to flush out the fluid and debris while cutting.
- Can be used to cut tough tissues, like the hardened lenses of patients with cataract

4.7 MEMS Skin surfacing tools

- Skin resurfacing is a form of cosmetic surgery that is often used to aesthetically enhance the appearance of wrinkles, skin lesions, pigmentation irregularities, moles, roughness, and scars.

Conventional resurfacing techniques involve the use of :

- Dermabraders – devices or tools used in plastic surgery.
- Chemical peels – chemicals such as glycolic acid.

These may be associated with excessive bleeding, time-consuming, require multiple sessions and chemical peels cannot be used for removal of lesions with significant depth. However, MEMS tools have been found to overcome many drawbacks present in the conventional techniques. For example:

- They can be used to remove raised skin lesions as well as lesions up to certain depths.
- These MEMS structures are packaged onto rotary elements and used over the affected areas.
- The debris can then be suctioned-out using a suction pump.

5. MEMS and Drug Delivery

5.1 MEMS enable hundreds of hollow microneedles to be fabricated on a single patch of area, say a square centimeter.

- This patch is applied to the skin and drug is delivered to the body using micropumps.
- These micropumps can be electronically controlled to allow specific amounts of the drug and also deliver them at specific intervals.
- Microneedles are too small to reach and stimulate the nerve endings, and hence cause no pain to the body.

5.2 Drug delivery on command

Moving from ailment diagnosis to treatment leads to Microchips, Inc., Bedford, Mass., where the development of BioMEMS for drug delivery is underway. Using micro fabrication technology, the company is producing implantable tools that store, then release specific doses of medication to the body. With the help of microprocessors, wireless telemetry, or biosensors, this technology enables doctors, as well as patients, to administer drugs on command. This is in sharp contrast to today's implantable technology, which uses polymeric depots to deliver drugs. Once embedded, these depots cannot be regulated and will only stop releasing medication upon depletion of the drug or extraction of the device--which is often not a simple process. Microchip's implantable device consists of a silicon chip that holds an array of individually addressable reservoirs where the medication is stored. This medication is shielded from the surrounding tissue by a noble metal membrane that hermetically seals the reservoirs. Such a barrier is important because "it enhances drug stability by protecting the drug from the body until it is needed," says John Santini, founder, president and CSO of Micro-CHIPS, Inc. The issue of stability is especially crucial when dealing with peptide and protein drugs because of these drugs' limited stability. Moreover, this issue is not addressed by existing implantable pumps, which deliver drugs only in a liquid state, exacerbating the stability problem of peptide and protein medications.

The protection provided by the protective membrane remains intact until an electric current is aimed at one of the reservoirs. Once this occurs, the sealed membrane breaks, releasing the drug into the surrounding tissue. And repeating the procedure for each of the reservoirs in the array allows the frequency of drug release to be controlled. Finally, with wireless telemetry, biosensors, or pre-programmed microprocessors, the timing of drug administration can be regulated.

Benefiting from Microchip's technology are people with multiple sclerosis, congestive heart failure, ophthalmology, and osteoporosis, where the devices are currently being applied. The company also recently formed an alliance with Micralyne, Edmonton, Alberta, Canada, to expand its work in drug delivery and biosensing instruments. This parallels Microchip's view of the future, one that will include tools that incorporate both drugs and biosensors, allowing the automatic administration of medication based on conditions spotted by the biosensor. "Such closed-loop systems will allow patients to receive the right amount of drug at the right time without having to think about it," says Santini.

5.3 Smart pill

A MEMS device that can be implanted in the human body and consist of

- Biosensors
- Battery
- Control circuitry
- Drug reservoirs

The biosensors sense the substance to be measured, say insulin, once this quantity falls below a certain amount required by the body, the pill releases the drug.

5.5 Pathogen detection and elimination (MEMS /nano robot)

These are micro/nano scale devices capable of detecting and eliminating medical problems. Such problems may arise due to the accumulation of unwanted organic substances, which interfere with the normal body functions, such as:

- Tumours
- Life threatening blood clots
- Accumulation of scar tissue
- Arterial blockage
- Plaque detection
- Localized sites of infection

5.7 Considerations before introducing the robots in to the body

- The robot size should be smaller than the diameter of the artery.
- The robot should not damage the arterial walls as it traverses through it.
- The robot can be introduced into the body through the circulatory system of the body.
- The femoral artery in the leg would be the most suited, because it is a large diameter artery and is traditionally used to introduce catheters in the body.

5.8 Detecting hidden plaque

Vulnerable plaque--unlike "standard" plaque, which leads to a gradual narrowing of the artery that can be observed in an angiogram--often, does not exhibit any suspicious arterial narrowing. This plaque is problematic because it is discovered only when it becomes inflamed and ruptures, causing a blood clot that can result in death [3].

The danger is compounded by current methods' inability to detect these plaques, since today's IVUS results are restricted to gray-scale images with a coarse resolution. Although such images display the overall composition of major homogenous areas, which are characteristic of largely calcified areas, they do not distinguish between adjacent smaller heterogeneous regions, where vulnerable plaque resides.

Thus, to detect vulnerable plaque and improve early diagnosis and treatment of coronary artery disease, a better quality IVUS image with high resolution is needed [5]. To enhance the axial resolution, which resolves objects that lie above each other, a large signal bandwidth is required. For lateral resolution, which resolves objects that lie side by side and is dependent on a transducer's radiation pattern, improvement is accomplished by working at a higher frequency and focusing the transducer to specific imaging area [3].

This focusing is achieved by micromachining the transducer into a hemispherical shape, thus aiming the ultrasonic radiation to a focal point. However, such hemispherical shaping is not possible with today's ceramic-based transducers, due to the material's brittleness. As a result, the LRI researchers used polymer piezoelectric materials, like polyvinylidene fluoride (PVDF), and its copolymer PVDF-trifluoroethylene (PVDF-TrFE), to easily create hemispherical-shaped, focused radiators. With better focused radiators, the axial resolution of 158-µm and lateral resolution of 309- to 649-µm exhibited by today's state-of-the-art transducers were enhanced to <50 µm, and <100 µm, respectively.

In the future, Fleischman and his colleagues plan to concentrate their efforts on creating a microelectronics-integrated, high-resolution micro transducer. Such an integration "will allow for improved resolutions of <30 µm and will enable an integratable platform for use in development of intelligent, multifunctional surgical microinstruments,"

6. Conclusion

As MEMS technology reaches the biomedical field, complex, implantable, tiny devices are emerging; whose goal is improved healthcare. Life of the device, retrieving data out of the device and drift resistance along with the body fluids remain the challenges to the technology. Despite the great achievements recorded through the use of these devices, many of them are not free from certain complications such as device failure, attraction of harmful microorganisms, rejection etc. Biocompatibility remains one of the biggest hurdles for MEMS medical devices. But still now Size of MEMS is getting smaller, frequency response and sense range are getting wider. MEMS are more and more reliable and their sensitivity better every day.

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