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Review of MEMS Based Application in Medical Industries

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Abstract: MEMS or Micro-Electro-Mechanical Systems are chips that are made in semiconductor material that combine electronic functions with mechanical actions in micro level. MEMS devices are capable of sensing and controlling numerous applications that include ink jet printers, automotive motion sensors and even digital projectors. MEMS are used in the medical field to reduce pain and increase the efficiency of the patient. This paper will describe the rapidly emerging field of MEMS based instruments used in medical field and discuss its present and future applications.

Keywords: MEMS, Bio-sensors, Bio-MEMS, Surgery and surgical instruments.

1. Introduction

MEMS (Micro electro mechanical systems) are a part of semiconductor electronics-VLSI (very large scale integrated) technologies that was developed in the 1980s. MEMS has wide spread applications from mechanical, electrical to microsurgery, diagnostics. MEMS has mechanical parts, which are movable whereas VLSI has no mechanical parts. MEMS have a complex fabrication processes which are used in manufacturing of very high precision devices. In VLSI devices are mainly circuits of commercial purpose manufactured in large scale and have applications in day-to-day life. MEMS devices are made in clean room facilities available in many places across the world. The principle of MEMS is based on silicon as the main component used in manufacturing and they are used for making Biosensors. These silicones wafer are bio compactable with the human body. And some of the MEMS devices used in medical field are discussed in this paper.

2. MEMS in Surgical Fields

Today MEMS is widely used in the field of surgery and it has given the surgery as risk less and successful process. Due to MEMS technology miniaturization, today the cost of surgerical process is very much reduced. In the early days the surgery was done with cutting and sewing of the body tissues. This process of surgery was called open surgery which is painful and takes a lot of time to recover. In present, these methods are replaced by minimally invasive surgery procedures. It helps the patient to recover quickly and pain is reduced. So cost of operation and short hospital stays helps to reduce the total cost for surgery. But main disadvantage is surgeon has very limited view on the surgical area. Here comes the importance of MEMS technology, it helps to give better view and control over surgical procedures. Since MEMS devices are very small and have better performance than any other devices, it helps the surgeon to be precise and accurate during minimally invasive surgerical procedures [1].

Fig. 1. MEMS based Intuitive Surgical da Vinci Robot [2].

2.1. MEMS Based Micro-Machined Cutting Tools

The making of cutting tool which is miniatured helped to make incision precise and accurate even for small one. It also helps to reduce the bleeding caused by these incisions. Previously we use diamond and stainless steel blades for the incision but it is replaced by using silicon as scalpels. The main advantage is that we can make it shaper to atomic level of their crystalline structure. And also we can integrate sensors and their electronic circuit parts to silicon scalpels to increase precision and accuracy in the surgery (See Fig. 2) [2].

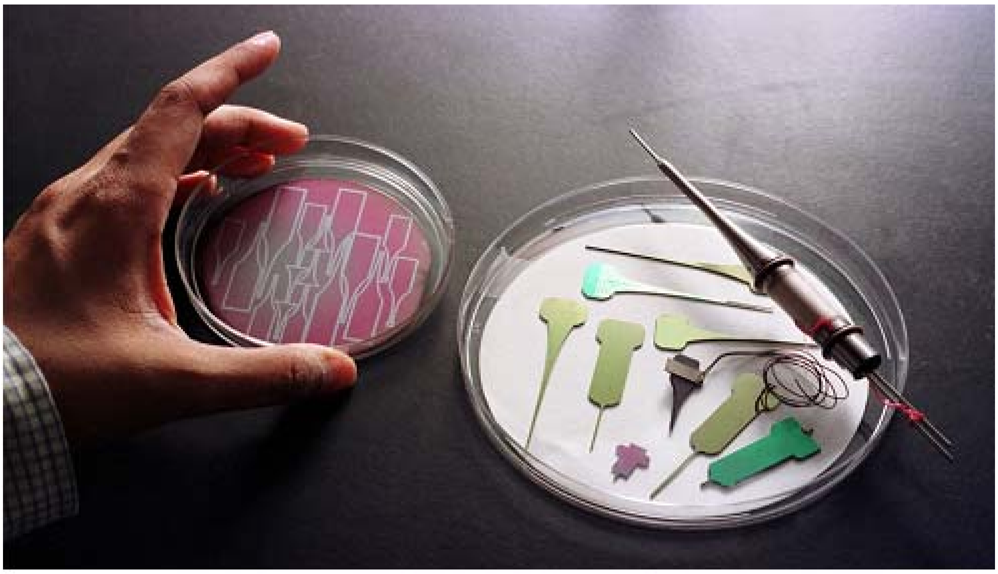

Fig. 2. MEMS based micro machine cutting tools [3].

2.2 MEMS Based Eye-Surgery (Minimally Invasive Type)

MEMS based ultrasonic cutting tool is commonly used in cataract removing process in modern world now. The cutter is connected with a piezoelectric material and when the tip which is in contact with piezoelectric material resonates at ultrasonic frequencies it cut very easily through larger tissues like cataract affected Len of the patient. Today piezoelectric sensor is connected with cataract removing hand pieces to ease the process of cataract removal and thus gives a general feed back to surgeon about thickness of tissues in different area.

Other important part of MEMS in eye surgery is the retinal implant. Retina is the part of eye which converts light into neural impulse and transmit those into brain. It contains many photoreceptive cells which are in surface of the retina. These cells are work with photo transduction. In some case retina of eye will damaged and optic nerves remain undamaged, here we use retinal implant. Retinal implant copies the function of retina by exciting photo restive cell. Recently MIT Researchers have created implants which consist of electrodes that can stimulate correct ganglion cells by making current pulses which is controlled by a chip attached to the white part of the eye (Fig. 3) [4, 5]. The microprocessor in the video camera fixed with spectacles make light wave to radio signals.

2.3. MEMS Based Catheters

Today MEMS based catheters are very much in small and have multifunctional properties and also displays high performance. Pressure sensors designed using MEMS are used in catheters and for ultrasonic intravascular imaging, MEMS based transducer are used. MEMS based sensors placed in catheters for diagnostics purposes like to measure the pressures, oxygen level, blood flow rate, temperature and chemical compositions. Conventional type catheters cannot move actively and often causes the patient more pain and damage. Today MEMS based catheters are made up of shape memory alloy and gel type actuators which reduces pain and increase the comfort for the patients [1].

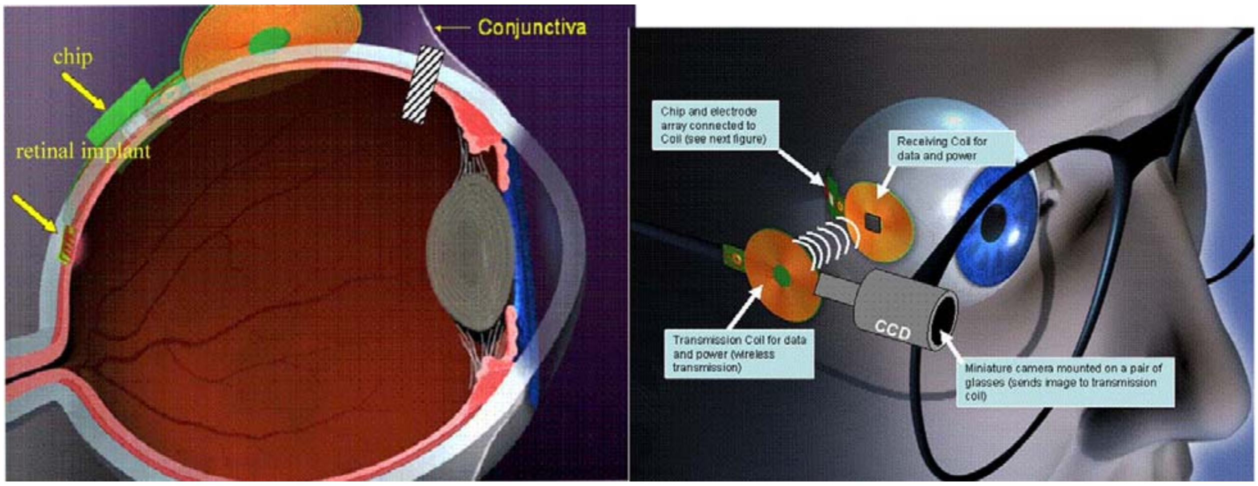

Fig. 3. Retinal implant on the eye during surgery [5].

2.4. MEMS Based Endoscopy

Here a fiber optic tube is inserted and passed through the patient's gastrointestinal tract and is able to view the condition of each parts and perform procedures like biopsies to rectify the problems. The important part of endoscope is its end. It consists of an objective Len piece and with camera on one end and on other end is having light source. In conventional type MEMS used in mirror technology. Mirrors are integrated to endoscope and it reduced the size of the end of endoscope inserted into gastrointestinal tract. The new model of endoscope is similar to that of a capsule. This type contains one optical fiber for illumination and six for receiving the light back. The four LED light are used. The three LED (red, green, blue) are used to color output and one (IR) to give thermal imaging of the area. The fiber inside endoscope spins and bounces according to electric impulses given through a wireless radio wave transmitter. The video camera integrated to endoscope records the images and transmits the data to image processor which convert data to 2-D pictures. The capsules are made up of bio-compatible materials which don't digest in stomach [4, 6, 7].

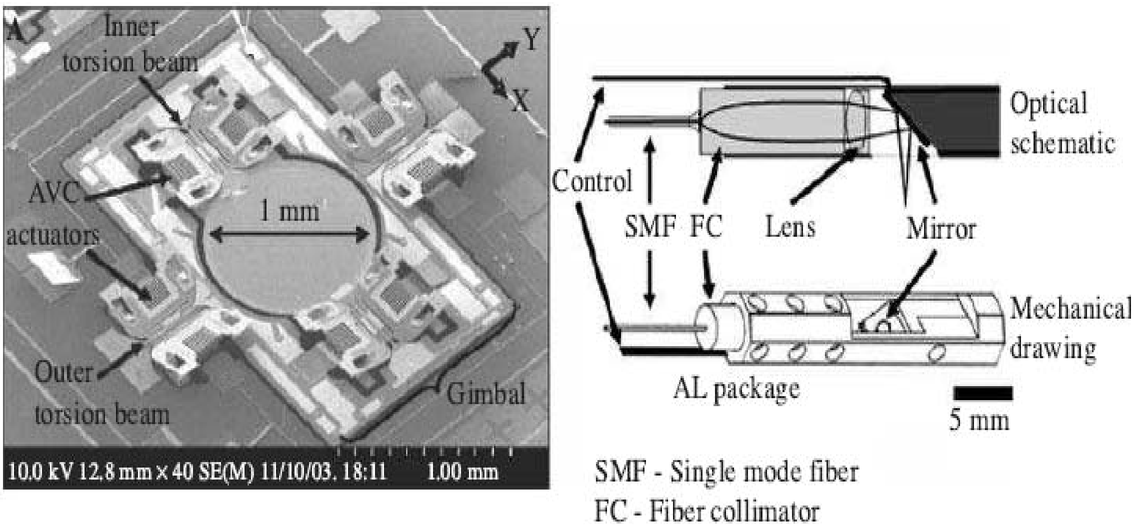

Fig. 4. Mirror technology used in endoscope [6].

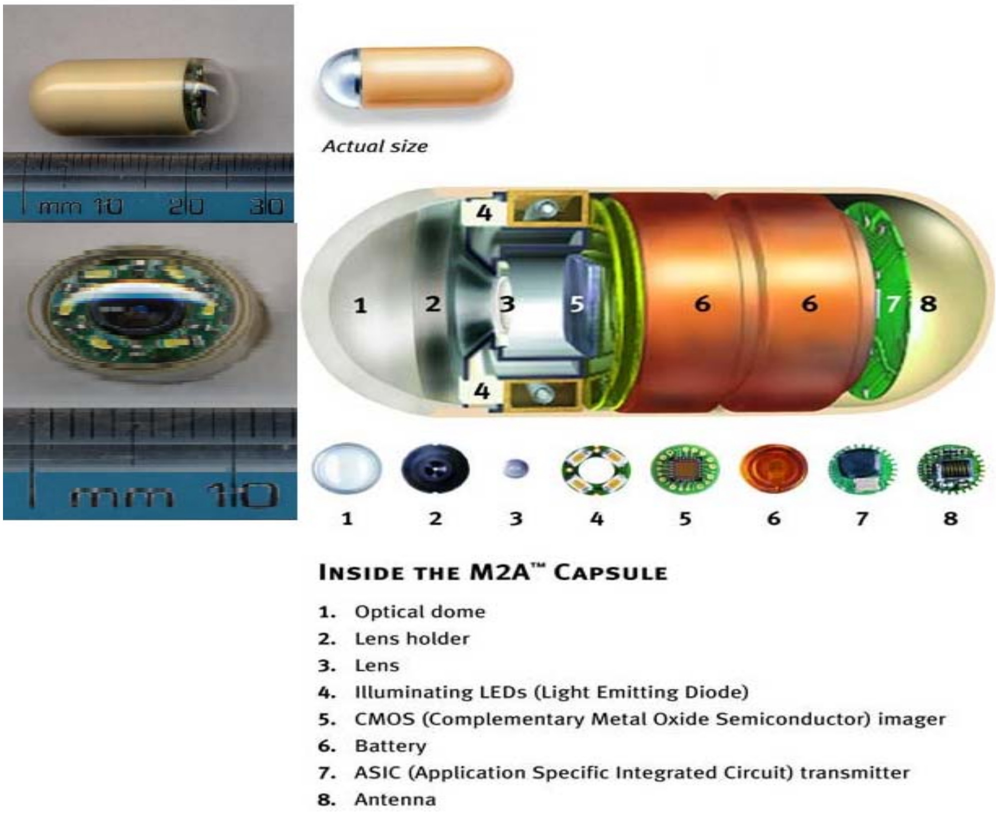

Fig. 5. Capsule type endoscope [8, 9].

2.5. MEMS Based Tactile Sensing

For a minimally invasive procedure, determining the force used on tissue is very important. So the tactile sensing is used for this purpose. It gives the feedback to the surgeon about firmness and elasticity of the tissue and this achieved through force feedback devices. This type sensor contain a sensing layer made up of piezoelectric, capacitive, piezoresistive, mechanical and optical elements and also have an electronic layer with a protective layer and supportive layer. A tactile sensor can measure the magnitude and the direction of force applied, softness of the tissue and slippage of the device. Tactile sensor is integrated with many minimally invasive surgery tools using MEMS technology. Piezoelectric films (sensory layer) like PVDF produce electrical output when the beam bends inward due to tissues and electrical output produce is directly proportional to the bending stress [8].

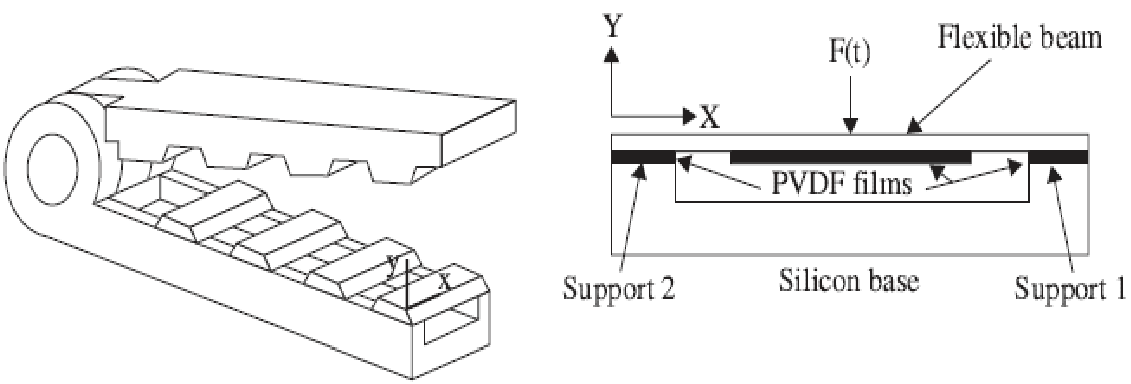

Fig. 6. An example of MEMS based tactile sensor [10].

3. Drug Delivery Systems Based on MEMS

The drug's effect and its efficiency depend on the method of delivery of the drugs to the body. MEMS based delivery system increases parameters like controlling, targeting and gives us a precise delivery of the drugs with automated feedback. So MEMS based drug delivery system emerging high potential platform for delivery system of high precision. Now new ways to improve timed delivery are mircoencapsulation, implants and transdermal patches. Any delivery system based on MEMS consists of micro pumps, micro needles, valves and micro reservoirs components.

3.1. MEMS Based Micro Reservoirs

We know that drug supply or depot is needed for drug delivery systems. The silicon micro particles are used for drug reservoir in oral type and the surface of these micro devices is designed to attach to specific tissues or cells in the digestive system to deliver therapeutic agents. If it is injected type, the surface is made from starch or gelatin which is used deliver drug for cancer treatment. The supply of anodic voltage in the presence of chloride ion induces the electrochemical dissolution of the cell tissue causing tissue to be weak. Since the tissue is weaken, it is easy to dissolve drugs within the reservoir and thus it diffuse into the surrounding cells .the MEMS based reservoir is digitalized so that release of drug can be chosen in complex profile. One of the problems raised was sealing of components like electronics, reservoir, etc. This was rectified by Santini et al [11] by using cold compression technique.

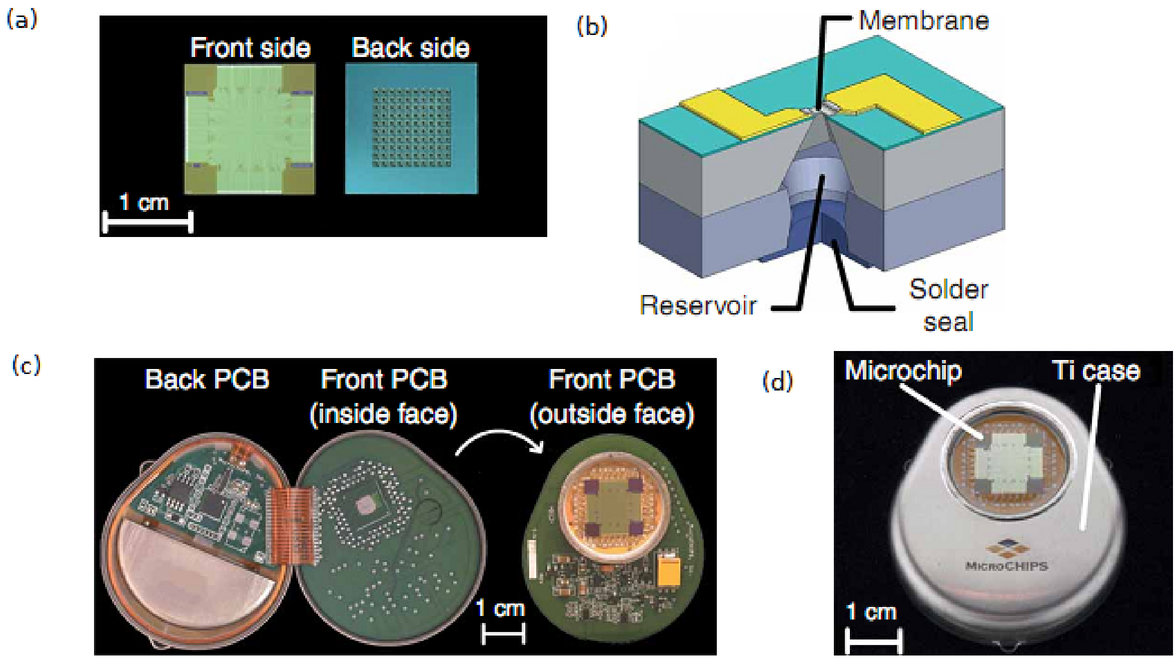

Fig. 7. MEMS based microchips [11].

3.2. MEMS Based Micro Needles

Micro needles are very important and considered to primarily developed technique for transdermal drug delivery. Recently HP (Hewlett-Packard) Co. has integrated with their inkjet technology in printer with transdermal patch to reduce pain because of low penetration (below 0.75 mm) and increases the absorption of bigger molecules which cannot pass through the skin directly. This patch has about 400 micro reservoir and 150 micro needles [12].

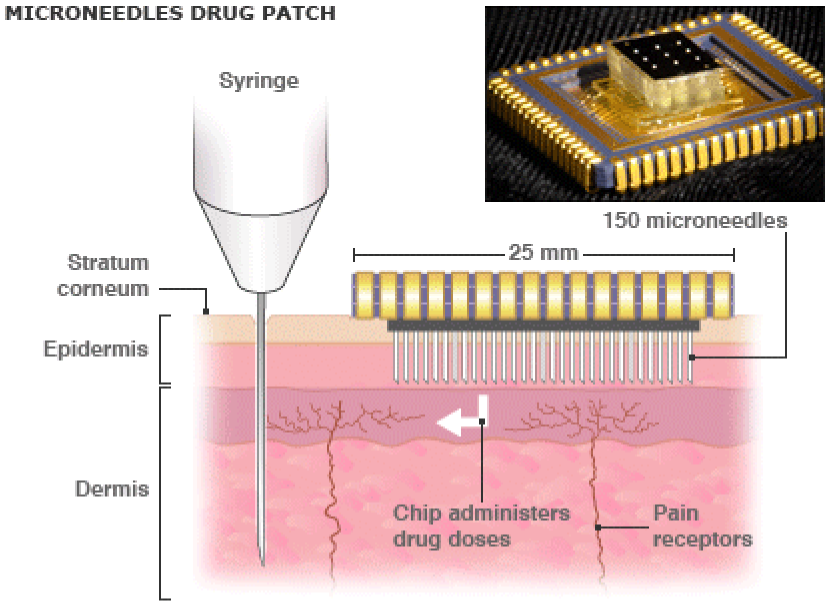

Fig. 8. HP micro needles [13].

3.3. MEMS Based Micro Pumps and Values

The controlling fluids flow and precise measurement of the fluids are very importance in drug delivery systems. For these purpose we use MEMS based micro pumps. Here major designs are based on size, pressure and biocompatibility. Micro pumps are of two types-mechanical type and non mechanical type. The electrostatic, piezoelectric, bimetallic, thermo-pneumatic and shape memory alloy (SMA) are examples of MEMS based micro pumps [14].

In electrostatic type when the voltage is applied across pump diaphragm and the electrode, the diaphragm of the pump will go either up or down based on applied voltage. But in piezoelectric type, this applied voltage will cause deformation on the surface of membrane where piezoelectric materials are deposited. And this will act as push mechanism to throw fluid out of the micro pump. In case of thermo pneumatic type of micro pumps, the chamber under the diaphragm will get expanded and compressed using a pair of cooler and heater. The change in volume will cause momentum for fluid flow by membrane. In SMA type, the shape of deformation is used as force to actuate the diaphragm of micro pump. Here SMA can retain their shape after a cycle of heating/cooling. In bimetallic type, the deformation cause by two different metals is the cause for actuating force in the diaphragm of the micro pump [15].

MEMS based micro valves are used for switching flow control, sealing of liquids, gas and vacuum. The mechanism of actuation in micro valves is electric, magnetic, thermal, piezoelectric are as described in the case of the MEMS based micro pumps.

4. MEMS in Diagnostics

It is very important to detect the diseases in early manner and give proper treatment to the patient in medical field. Biological testing for knowing disease and certain substances are made quicker, flexible and sensitive by combination of MEMS to the diagnostic field of medicine. A biosensor made using MEMS technology consists of a sensing part, transducer part and electronics circuit to process the data and generate the signals. MEMS based biosensors had made the high end platform for commercial applications like drug discovery, genomics, biomedical research and medical diagnostics.

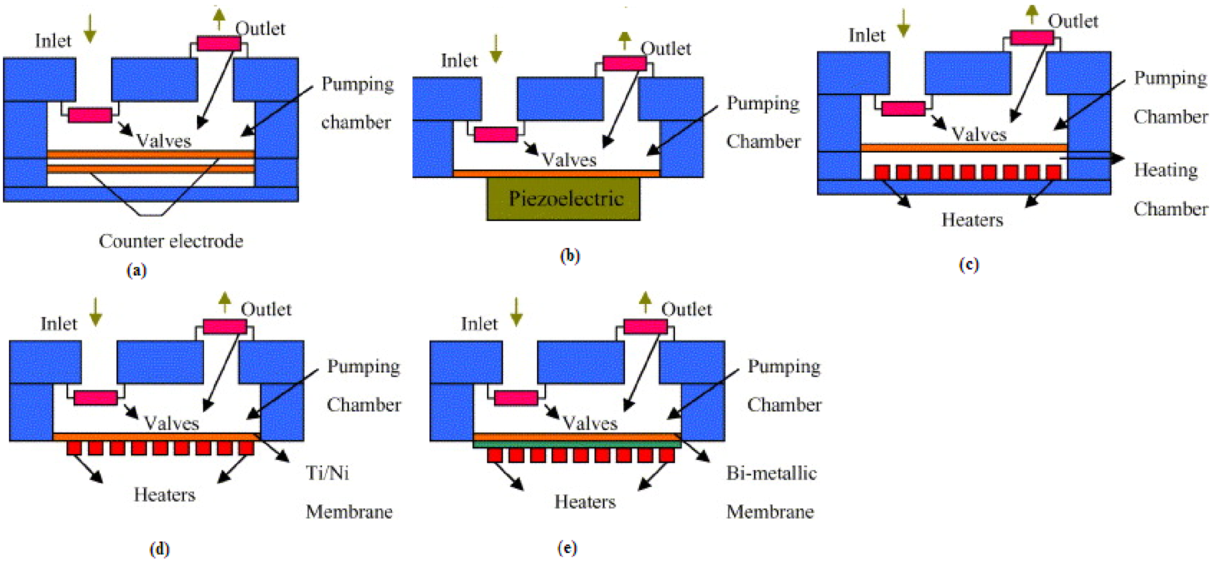

Fig. 9. Actuating mechanism in micropumps [15].

4.1. MEMS Based Optical Sensing

Optical sensing based BioMEMS devices use light as a source of excitation. It has photosensitive layer used in detection of various samples in the field of medicine. The techniques used in manufacturing these optically sensitive devices are based on photolithography. The optical device consists of layer which is exposed using photo-mask by UV light. The active regions are denoted by the antibody bindings. And the grating produces a diffraction pattern with laser as its source [16]. The example for these types of BioMEMS sensors is gene chip made by affymetrix.

Fig. 10. Gene chip made by affymetrix [17].

4.2. MEMS based Micro-cantilever Beam Sensor

Micro-cantilever works on the principle of mechanical deflection of the beam. The cantilever beam is coated with bio-molecules like antibodies. The materials used in making the beam are mostly gold. There are two modes of operation. One is static mode and another one is dynamic mode. In static mode the deflection of the cantilever beam signifies the presence of analyte molecules. In the dynamic mode, the principle of detection of analyte molecules depends on the change in resonance frequency of cantilever beam [18].

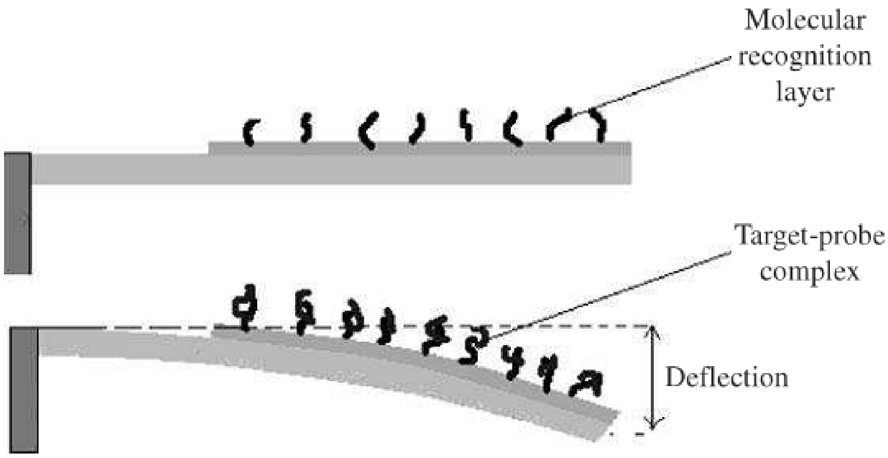

Fig. 11. Working of MEMS based Micro-cantilever beam sensor [18].

5. Conclusions

MEMS discussed in this paper have very high end applications in everyday life. And they play a major role in shaping the role of MEMS in medical field related application in the future as well. There are lots of challenges to faced in developing multifunctional devices in surgery. Also the integration of nanotechnology into MEMS will play an important role in miniaturization of these devices. This can in turn result in smart surgical devices that can communicate with surgeons. All these advancements can be achieved with proper funding, collaboration between surgeons and MEMS engineers. These MEMS device are of fourth generation type and they posses fusion of the sensor element with analog amplification, analog-to-digital Converter and digital intelligence for linearization and compensation on the same chip. As well as Memory for storing data related to analysis of biological systems.

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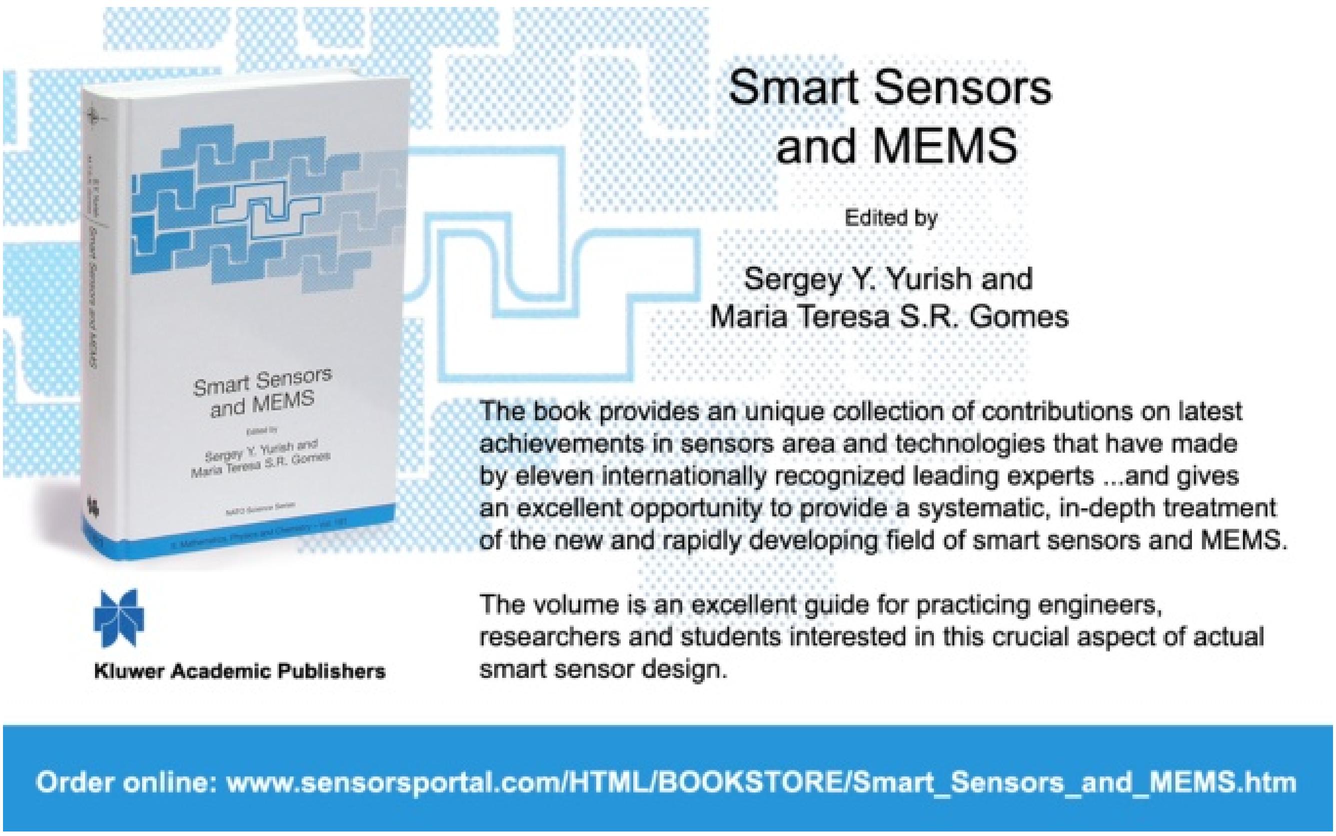

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
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- Technologies and materials;
- Nanosensors;
- Microsystems;
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