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A STUDY ON DEVELOPMENT OF MEMS IN THE FIELD OF MEDICINE

Engineering

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ABSTRACT

MEMS are miniaturized electro-mechanical elements that are made using the technique of micro-fabrication. They physical dimension of MEMS devices can vary from a few millimeters to just one micrometer. They are used as sensors and actuators and hence have a wide spectrum of applications like ink jet printers, automotive motion, digital projectors etc. But MEMS have a huge scope in the field of medicine and biomedical applications. MEMS analyzers can be used to perform biological tests and even sequence DNA. This paper will describe the rapidly emerging field of BioMEMS and discuss present and future applications.

KEYWORDS

MEMS, BioMEMS, medicine, DNA

INTRODUCTION

There has been a remarkable advancement in the field of medicine which is accomplished through the innovative applications of electronics and related advanced technologies. Medicine, these days is not just confined to diagnosis but early pre-emption and cost-effective prevention is equally important as well. Irrespective of any disease the quality of post-curative measures is important and thus all the new venturing into latest technology for the treatments is getting importance.

Early medicine mainly focused on external examination of the patient. Later, x-ray permitted internal examination from the outside. With the advent of new technology called MEMS the diagnostic techniques are taking a new look, that the new devices and extreme miniaturization now permit examination, sensing, and monitoring from inside the patient. MEMS devices help better understanding of coding and functions of DNA, thus building up knowledge that will make diagnostics even more powerful and allow deployment of preventive and interceptive medical techniques much earlier for greater success. Molecular based medicine is the ultimate frontier. Today, MEMS devices, electromechanical chip technology, is steadily being adopted and adapted by the biomedical field to bring the significant benefits of micromechanics.

MEMS are tiny chips that can be produced microfabrication processes to combine mechanical sensing, control and motion to solid state electronics to deliver extraordinary functionality and versatility. Anything that we see as a sensor and actuator in macro world can exactly be depicted in miniatures through this technology called MEMS. MEMS can sense pressure, measure forces, identify bio-agents, measure displacements, detect the motions, pump and control fluids, and perform lot of other actions that can be of use in the field of biomedicine.

Bio-MEMS is the term very specific to applications related to this field of biomedicine. These Bio-MEMS chips can used as biochemical analyzers, micro-valves, micro-pumps, hearing aid components and tiny sensors for pressure detection and many more.

MEMS is that technology which is capable of integrating almost all the physical, chemical, biological phenomena involving the motion of light, sound or any other particle for that matter, on to a single chip. Thereby, with one single chip any task can be accomplished pertaining to physics or chemistry or biology or even a combination of these. The beauty about these micrometer sized chips is that they can replicate the sensing actions performed by human nerves and hence such tiny chips can replace the damaged tissues in human bodies and this is the most sought-after research area now. For now, accomplishments have already been done in handling surgeries with almost zero pain using micro-scalpels with less blood loss, extending hearing aid, vision impairments, treating cardiac blocks, treatment of glaucoma etc. MEMS is also about technology convergence where miniature devices including gears, propellers, turbines, pumps, mirrors, motors, radio elements, radiation sensors, and many types of detectors and other assemblages are synergistically united in a new micro- and even a nano-world. MEMS are already being used in detecting the defective DNAs and helping in studying the pattern of DNA changes that takes place during viral infection in particular diseases. There is larger scope in the years to come.

HOW DOES A MEMS WORK

Typically MEMS are mass produced with the process of micro-fabrication using bulk micromaching or surface micromachining [1]. The miniature 3D structures are created using Sio2 just like the way it is done in IC fabrication. These miniature devices will have electronic as well as mechanical parts which are responsible for actions and sensing. The energy source is typically the electricity which gets converted to thermal, mechanical or photonic energy. The change in motion, or displacement can also be found by these devices by gathering the information from external environment. The sensor basically works with capacitor plate principle or the piezoelectric effect. The actuators are based on mechanical movement that is caused due to application of force. The other types of actions involved in actuators are production of magnetic field, light or even heat. Based on the requirement different sensors and actuators can be used.

TYPES OF MEMS USED IN BIOMEDICAL APPLICATIONS

Basically MEMS can be categorized as Sensors and Actuators.

- Sensors
- Actuators

There are many MEMS devices which act as sensors are used for biomedical applications. Since the human body is made up of blood vessels, pumps and interconnects, this complex system needs the measurement of pressure like blood pressure, spinal fluid pressure, bladder pressure, retinal fluid pressure etc. In such cases MEMS based pressure sensors are used. The field of neuroscience has got revolutionized largely with the advent of MEMS technology in hand. Array of sensors can be designed and developed on a microscale that give the real-time measurements and that too on a cellular level which has a deep implication in the process of treatment and healing. There are sensors that can process the signals from brain to stimulate and control prosthetic limbs. Microactuators are gaining tremendous importance due to their ability to control and manipulate biological objects at a microscopic level.

MICROMANIPULATORS

Micromanipulator, as the name goes, manipulates cells, tissues and other biological objects for that matter, at microscopic level. A surgical microgripper actuated by shape-memory alloy forces is shown in the figure below [2]. It is capable of grasping tissues during endoscopic surgical procedures

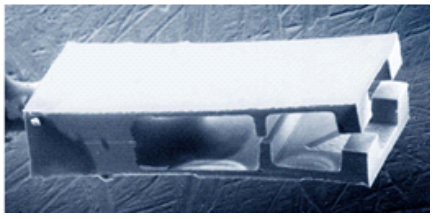

Fig.1: Surgical Microgripper [2]

MICROINSTRUMENTS

At microscopic level the surface force parameter becomes very important. The surgical instruments should be capable enough to handle the force applied. MEMS technology helped in dealing with this. A piezoelectric microactuator drives a scalpel used in surgery [3]. The piezoelectric stepper motor precisely controls the movement and apt positioning of the scalpel. The actual cutting force can be quantified and controlled by integrating an ability to measure the stresses experienced by the scalpel during cutting. Fig. 2 shows the piezoelectrically driven Scalpel that helps in controlled cutting and hence there would be minimal bleeding and eventually faster healing.

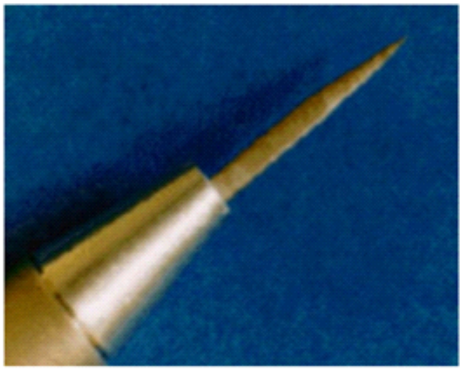

Fig. 2 Piezoelectrically driven Scalpel [3]

Microneedles are very thin needles that are manufactured by micromachining. They were conceptualized long ago but started gaining importance only from last two decades. The microneedles are basically fabricated to deliver drugs. They are almost painless. They are used for

- Solid microneedles for skin pretreatment to increase skin permeability
- Microneedles coated with drug that dissolves off in the skin
- Polymer microneedles that encapsulate drug and fully dissolve in the skin
- Hollow microneedles for drug infusion into the skin [4]

These microneedles are extremely small and hence they are almost painless.

MICROVALVES

Microvalves are the microscopic devices that control, routing, timing and separation of fluid in a microfluidic device. They are similar to macrovalves in action but they have longer operational lifetime, they pass the fluid when open. Microvalves allow user to control the flow of fluids in a microchannel by varying a macroscopic parameter. These valves can be actuated by introduction of external force [5, 6] by changing the phase [7, 8, 9-13], electrokinetically [14-17], mechanically [18-21], or even pneumatically [22-27].

MICROPUMPS

Micropumps are devices that can control and manipulate small fluid volumes. As the name says, they are small pumps operating on the scale of micrometer. On micrometer scale the physical parameters behave differently, in here, surface forces dominate and volume forces are almost negligible. In the field of biomedicine they are extremely useful in the drug delivery system.

Micropumps can be grouped into mechanical and non-mechanical devices [28]. Mechanical systems contain moving parts, which are usually actuation and microvalve membranes or flaps. The driving force can be generated by utilizing piezoelectric, electrostatic, thermo-pneumatic, pneumatic or magnetic effects. Non-mechanical pumps function with electro-hydrodynamic, electro-osmotic, electrochemical [29] or ultrasonic flow generation, just to name a few of the actuation mechanisms that are currently studied.

MICRO TOTAL ANALYSIS SYSTEMS (μTAS)

The controlled flow of fluids in the micromachined channels without any moving parts has led to the realization of complex micro total analysis systems [30]. Parallely many independent flow channels can be controlled, complex sample preparation can be done, various mixing, and testing procedures can be established. Basically the electrically controlled pumping and valving mechanism is either electroosmotic flow or electrophoretic flow [31]. The method of separating liquids based on their different mobility in a long flow channel is termed as Liquid chromatography and this can be used to perform a precise chemical analysis in microfabricated flow channels. Sensors integrated at the end of the flow channel will reveal a time-domain spectrum of the fluid composition. Micromachined electrophoretic devices have been used to separate ions and DNA molecules from 70 to 1000 bases in under 2 minutes – much faster than conventional capillary electrophoresis systems [32]. The detection of each ion or molecule species can be accomplished with electrochemical measurements, fluorescence, or optical absorption. Thus with the advent of MEMS technology the fluid mechanics has apparently got quite complex and quite easier as well.

CONCLUSION

MEMS technology over the years has come up with lot of devices that have proven to be boon to the field of biomedicine. With the micromachining tools the development of sensors and actuators for biomedical applications has improved tremendously. It is anticipated that in the future the microfluidic systems will grow to much heights and thereby the drug delivery, the treatment procedures for various diseases and the survival rates in the field of medicine are going to be much more successful.

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