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Biomedical Applications Of Mems & Nems Pressure Transducers/ Sensors

Dr. Prasanna Kumar S.C
HOD & Professor, Dept., of Instrumentation, RVCE, Bangalore, India
Jyothsna.D
BMSP&I, Second year MTech, Dept., of Instrumentation, RVCE, Bangalore, India

Abstract:
The paper discusses about the medical applications of MEMS (Micro- Electro-Mechanical-Systems) microsensors have been introduced. MEMS based sensors such as pressure sensors. Small size, low price, high functionality, high precision, fast response time and so on are some of MEMS sensors benefits. This paper discusses some recent advances in the biomedical applications of MEMS and NEMS technology.

Keywords: *MEMS, NEMS, Biomedical, Transducers, sensors.*

1.Introduction

Micro-Electro-Mechanical Systems, or MEMS, is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of micro fabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. The one main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move. The term used to define MEMS varies in different parts of the world. In the United States they are predominantly called MEMS; while in some other parts of the world they are called "Microsystems Technology" or "micro machined devices".Figure 1 shows the components of MEMS. While the functional elements of MEMS are miniaturized structures, sensors, actuators, and microelectronics, the most notable (and perhaps most interesting) elements are the microsensors and microactuators. Microsensors and microactuators are appropriately categorized as "transducers", which are defined as devices that convert energy from one form to another. In the case of microsensors, the device typically converts a measured mechanical signal into an electrical signal. [1]

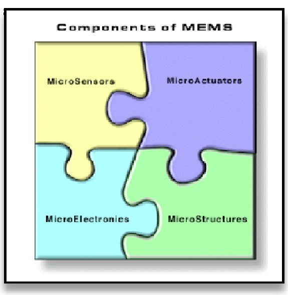

Figure 1: components of MEMS [1]

Nanoelectromechanical systems (NEMS) are devices integrating electrical and mechanical functionality on the nanoscale. NEMS form the logical next miniaturization step from so-called microelectromechanical systems, or MEMS devices. NEMS typically integrate transistor-like nanoelectronics with mechanical actuators, pumps, or motors, and may thereby form physical, biological, and chemical sensors. The name derives from typical device dimensions in the nanometer range, leading to low mass, high mechanical resonance frequencies, potentially large quantum mechanical effects such as zero point motion, and a high surface-to-volume ratio useful for surface-based sensing mechanisms.[2] Uses include accelerometers, or detectors of chemical substances in the air.

2.Fabricating MEMS And Nanotechnology

MEMS pressure sensors market is growing fast with many different potential applications. On cell phone where they can be used as an altimeter or to measure the barometric pressure , on car navigation system to allow them to discriminate between multi plan motorways (common in Japan), on disk drives to compensate for the altitude pressure variation to optimize the head height, on medical device to measure blood pressure. If on some applications the driver are the packaging dimensions (mainly the thickness if we mind the cell phone) , on other one it is the need of dedicated interfaces with piping system to be the decisive factor to enter the market.

MEMS-based sensors are a crucial component in automotive electronics, medical equipment, smart portable electronics such as cell phones, PDAs, and hard disk drives, computer peripherals, and wireless devices. These sensors began in the automotive industry especially for crash detection in airbag systems. Throughout the 1990s to today, the airbag sensor market has proved to be a huge success using MEMS technology. MEMS-based sensors are now becoming pervasive in everything from inkjet cartridges to cell phones. Every major market has now embraced the technology.

MEMS fabrication uses many of the same techniques that are used in the integrated circuit domain such as oxidation, diffusion, ion implantation, LPCVD, sputtering, etc., and combines these capabilities with highly specialized micromachining processes. They are as mentioned below:

- Bulk Micromachining
- Surface Micromachining
- Wafer Bonding

2.1.High-Aspect Ratio MEMS Fabrication Technologies

- Deep Reactive Ion Etching of Silicon

An already developed packaging for pressure devices is based on the so-called HLGA (holed LGA) The MEMS sensor device is based on a thin silicon membrane with a Wheatstone bridge, protected by a silicon cap with a small pass thru hole. The silicon wafer cap is attached to the sensor wafer by means of a material “glass frit”, which is applied with a stencil screening process. The capped pressure device is glued to the LGA strip BT substrate and then wire bonded with gold wire. On the Altimeter-barometer version a Custom ASIC die is bonded by the side of the pressure sensor. The open packaging is realized by means of a film assisted molding which leaves the pressure port hole exposed around the molded case There are different packaging dimensions measures , the smallest stand alone sensor packaging is 3x3x1 mm.

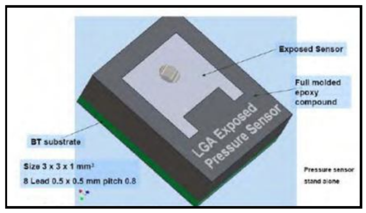

Figure 2: HLGA packaging

3.Mems Medical Application

Pressure sensors and accelerometers remain the largest two market segments for MEMS technology and products. With a few exceptions [3,4], most current MEMS products are fabricated using bulk micromachining techniques. These utilize anisotropic etching solutions (e.g., potassium hydroxide) along with various etch-stop methods to form silicon diaphragms, beams, springs, and other micromechanical structures. The sensing elements are most often implanted piezoresistive resistors, though capacitive based sensing is also common among a few manufacturers. Disposable blood pressure sensors represent today a significant market. Early strain gauge sensors, achieved using external silicon beams or quartz-capacitive type pressure sensors, were expensive. Sterilization for reuse resulted in additional costs. Disposable micromachined blood pressure sensors provided smaller size at substantially lower costs. Smaller sensors were also fabricated for other medical applications, including intrauterine pressure for measuring the pressure around a baby's head during delivery, and disposable angioplasty devices for monitoring the pressure in a balloon catheter. One such small sensor, measuring 400 pm by 900 pm is illustrated in Fig. 1.

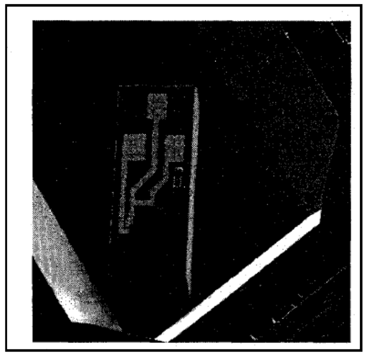

Figure 2: A pressure sensor (400 pm x 900 pm) designed for catheter tips inside the back-etched cavity of conventional silicon pressure sensor

The following are the recent developments in the field of medical regarding MEMS. Developments in genetic analysis, DNA amplification by means of pcr, DNA detection. There are a wide variety of applications for MEMS in medicine. MEMS pressure sensors, which have been in use for several decades. Some of the applications of MEMS pressure sensors in medicine include:

- MEMS pressure sensors in the medical sector is the disposable sensor used to monitor blood pressure in IV lines of patients in intensive care. These devices were first introduced in the early 1980's.
- MEMS pressure sensors are used to measure intrauterine pressure during birth.
- MEMS pressure sensors are used in hospitals and ambulances as monitors of a patient's vital signs, specifically the patient's blood pressure and respiration.
- The MEMS pressure sensors in respiratory monitoring are used in ventilators to monitor the patient's breathing.
- MEMS pressure sensors are used in inhalers to monitor the patient's breathing cycle and release the medication at the proper time in the breathing cycle for optimal effect.
- MEMS pressure sensors are used in drug infusion pumps of many types to monitor the flow rate and detect for obstructions and blockages that indicate that the drug is not being properly delivered to the patient.

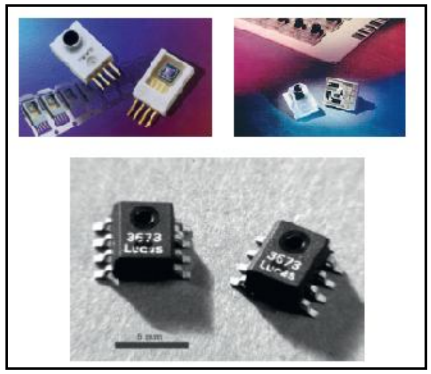

Figure 4: The medical pressure sensors

(Left: Motorola corp., Right:Eurosensor Corp. Centered: Lucas Novasensor)

3.1.Pressure Sensors

The medical applications of MEMS (Micro- Electro-Mechanical-Systems) microsensors have been introduced. MEMS based sensors such as pressure sensors, accelerometers, Glucose sensors, chemical gas sensors and etc. and its advantages with respect to the other sensors in medical applications are explained. Small size, low price, high functionality, high precision, fast response time and so on are some of MEMS sensors benefits. Also, some special applications of these sensors such as blood pressure Measurement, pacemaker acceleration measurement, blood Glucose measurement and etc. are evaluated.

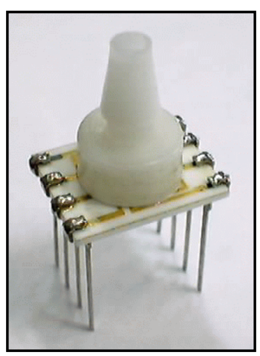

Figure 5: piezoresistive pressure & temperature sensor

Pressure sensor is the first high volume MEMS production that is opened new thrusts into the medical instruments market. This sensor is extremely employed for blood pressure management. Various type of this sensor is used such as disposable pressure sensor and manifold absolute pressure sensor [5]. The majority of the pressure sensors use piezoresistive sense elements to detect stress on diaphragm in response to a pressure load. Also a few designs used the capacitive methods to this purpose. Medical applications of pressure sensors have extremely grown, so that many companies produce these sensors. Some fabricated pressure sensors by sensor companies are shown in fig4. Pressure sensors not only are used for blood pressure but also for the other applications such as: kidney dialysis, respirators, pacemakers, intracranial pressure inside the eyeball and etc. Fig4. The medical pressure sensors (Left: Motorola corp., Right: Eurosensor Corp. Centered: Lucas Novasensor) Pressure sensors have been designed based on application issues and its packaging is one of the major challenges, because it must have biocompatibility. Hence, the materials, fabrication techniques and packaging type are the main important challenges. The packaging of a sensor (e.g. pressure sensor) should, on one hand, protect the implanted devices and ensure their proper operation and on the other hand, prevent or minimize tissue reactions. In addition, all materials that are contact with human body must be benign. In other words, these materials must not have toxicity and carcinogenicity [6, 7].

Wireless blood pressure sensors are especially suitable for surgery rooms, intensive care or post-anesthetic recovery units, even small laboratory animals. Low power consumption is a critical point to improve the distance between the wireless sensor and monitoring equipments and improve the battery life of the sensors, reducing at the same time the power radiated to establish the wireless communication. State of-the-art blood pressure transducers, based on four resistors in a full Wheatstone bridge configuration, are usually optimized for sensitivity [8]-[10] and linearity. Temperature effect on sensitivity in silicon piezoresistive transducer has been studied in detail in [10]-[12]. Analysis of the noise in piezoresistive transducer has been presented in [5]. Most of the piezoresistive transducer are ion-implanted into a thin Silicon monocrystalline membrane. Typical values are in the range between 100 fl and 3 kfl, powered between 3 V and 5 V. This means power consumption between 3 m W and 250 m W, typically 20 mW, only for the full Wheatstone bridge without the required signal conditioning circuit -a signal conditioning Circuit with at least one operational amplifier is required. [13]

4.Conclusion

Techniques borrowed from the integrated circuit industry have allowed the development and production of MEM devices and transducers in ever smaller size, and consequently larger volumes and lower costs. Such micromachined devices found immediate acceptance among the manufacturers of biomedical instrumentation. For example, disposable blood pressure silicon sensors successfully replaced older, strain gauge based transducers. The same microfabrication techniques also allowed the development of novel devices and microinstruments. the paper discusses the MEMS pressure sensors and the development of them till date. It also states the applications of the sensors in the medical field and also contains a few examples of the sensors used in the present time.

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