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REVIEW OF MEMS PRESSURE SENSOR

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Abstract: The world is getting digitalized, demands for new and emerging technologies have reached its peak, and customer demands have taken a U-turn. To cope with such unique requirements many systems and system devices are into the market and one of such enhancing technology is Microelectromechanical System(MEMS). MEMStechnologies that are in the most common form that can be defined as miniature mechanical and electro-mechanical elements (i.e. devices and structures)integrated on the same chip using microfabrication techniques.It possess various merits, such as low power consumption, being light weight, having small volume, accurate measurement in space-limited region, low cost.

Key Words: Diaphragm, COMSOL multiphysicssoftware, Pressure sensor,Sensitivity

1. INTRODUCTION

Pressure acts as an essential parameter in many real life applications. The pressure always be monitored and maintained at appropriate and constant level to prevent overpressure the device or system, which may cause severe damages. With this requirement, the pressure measurement becomes a critical issue and this can be done by using a pressure sensor. Generally, the pressure is defined as applied force per unit area. The mathematical expression of pressure, P is given by:

$$P = \frac{F}{A} \text{ -------- } (1)$$

Where F is applied force and A is the area of element.This applied force resulting mechanical movement in the elements, which is proportional to the applied pressure. This applied force can be used to determine the magnitude of the pressure. Basically, a pressure sensor is an electronic device used to detect the pressure of an element. When a pressure is applied to the sensor, the elements inside the sensor, for example a diaphragm, undergo a deformation. As a result, this mechanical movement produces an output signal that can be easily recognized, detected and measured by other devices. This output signal can either be current, resistance, capacitance or voltage. The block diagram shown in Fig. 1 summarizes this process.

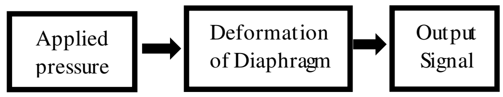

Fig. 1: Basic operating principle of pressure sensor

MEMS have been studied since the 1960's. The first devices appeared in the 70's and the public interest gave MEMS a boost in the 80's. During the last decade, the research has grown through funding from governmental agencies, involving researchers from universities and industries all over the world (MEMS Exchange, 2003). Most of this research and development has beendirected toward the replacement of conventional technologies to increase functionality, reduce cost, and improve reliability.

The strong demand of these systems in different fields of work makes the study and general understanding of MEMS required for any engineer. This paper introduces the general concepts of this technology, by summarizing the materials and processes involved in fabrication, and provides a closer look at applications where MEMS have been successfully implemented.

Micro electromechanical systems (MEMS) is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometres to millimetres. These deviceshave the ability to sense, control and actuate on the micro scale, and generate effects on the macro scale.

MEMS consist of mechanical microstructures, microsensors, microactuators and microelectronics, all integrated onto the same silicon chip. This is shown schematically in Figure 1.

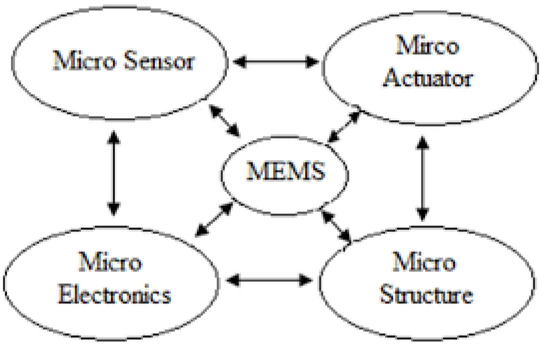

Fig. 2: Schematic illustration of MEMS components.

The MEMS pressure sensor is a MEMS sensing device that can detect and measure the external stimuli such as pressure, and then it can response to the measured pressure by having some mechanical movements. The simulation done using COMSOL multiphysics, where is a simulation platform where it encompasses all the steps in modeling workflow that is from defining geometry, material properties, physics to produce accurate and trustworthy result.

In this Paper, types of MEMS pressure sensor has been introduced and presented.

2.TYPES OF PRESSURE SENSOR

There are many different types of pressure sensor have been implemented today. They can be classified according to their applications such as high pressure and low pressure, type of measurements such as absolute pressure and differential pressure or their sensing element such as piezo resistive, piezoelectric and capacitive.

A. Classification Based on Type of Pressure Measurement

The pressure sensor can be classified according to the targeted type of pressure measurement, for example absolute pressure measurement, differential pressure measurement and gauge pressure measurement.

Absolute pressure: an absolute pressure sensor measures the pressure relative to zero absolute pressure or a perfect vacuum. A gage pressure sensor measures the pressure relative to the normal atmospheric pressure. Absolute pressure is hard to achieve, absolute pressure sensors are harder to make which increases their cost and lead time.

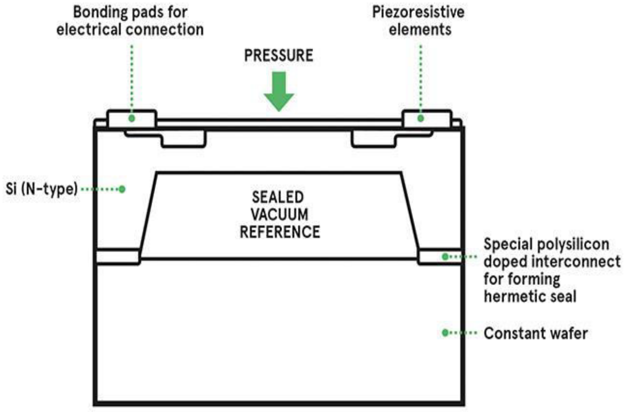

Fig.3: An absolute pressure sensor measures pressure relative to a sealed vacuum reference in a hermetically seal chamber

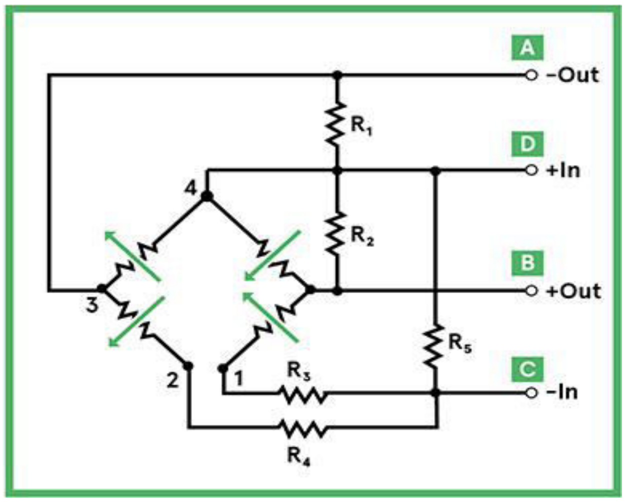

Fig.4: Wheatstone bridge structure of an absolute pressure sensor

Gauge pressure: Measures pressure relative to a reference pressure, which is usually the local

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atmospheric pressure. The sensor has two ports, allowing entry of the fluid at the reference pressure, and at the pressure to be measured.

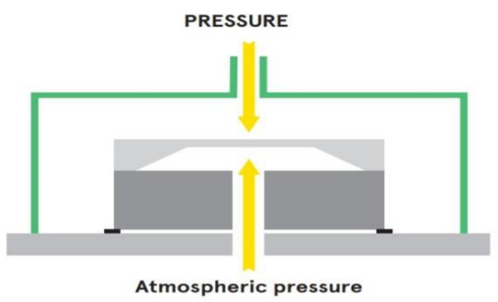

Fig.5: Gauge pressure measurement principle

Differential pressure: Differential pressure is the pressure difference measured between two pressure sources. This is usually expressed in pounds per square inch differential (psid). When one source is the ambient pressure, this is then called gage or relative pressure and is typically expressed in pounds per square inch gage (psig). Therefore, gage pressure is simply a special case of differential pressure with pressures measured differentially but always relative to the local ambient pressure. Similar to gauge pressure – although in this case, the reference pressure is the pressure experienced at a different point in the system, as determined by the system designer. The change in differential output is positive or negative, depending on which is greater. The magnitude of the change is proportional to the pressure difference between the two domains.

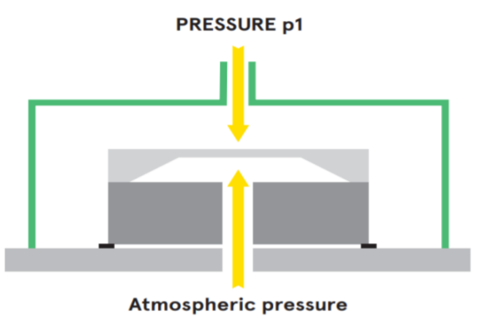

Fig.6: Differential pressure measurement

B.Classification Based on Sensing Element

Piezoresistive pressure sensors: The piezoresistive pressure sensors are those which detect the change of external pressure by changing its resistance. The piezoresistive pressure sensor consists of a semiconductor material (silicon) mounted on the elastic diaphragm. This semiconductor material acts as piezoresistive sensing element in the pressure sensor. When pressure is applied then the diaphragm is stretched and deformed, the piezoresistive element will change its resistance.

The mathematical expression of the resistance, R is given by:

$$R = \frac{\rho L}{A} \text{------------(2)}$$

Where, ρ is the resistivity of the material, L is the length of the piezoresistive material and A denotes the cross-sectional area of the piezoresistive material.

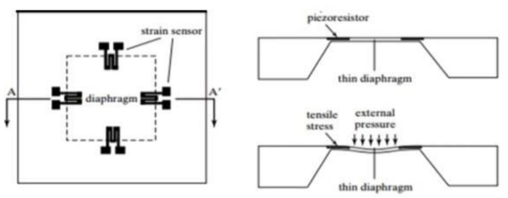

Fig. 7: Basic operating principle of pressure sensor

The surface is usually connected to a Wheatstone bridge to convert the resistance changes into the change in electrical potential. The Wheatstone bridge runs a small amount of current through thesensor. When the resistance changes, less current passes through the pressure sensor. The Wheatstone bridge detects this change and reports a change in pressure.

Piezoelectric pressure sensors: A piezoelectric pressure sensors are detecting the applied external pressure by changing its electrical potential as the output of sensor. When a pressure is applied, the diaphragm of piezoelectric pressure sensor is deformed, and then electrical voltage is generated. When a pressure is applied, the diaphragm of piezoelectric pressure sensor is deformed, and then electrical voltage is generated.

The relationship between generated potential, V and the charge, Q is given by:

$$V = \frac{Q}{C} \text{------------(3)}$$

This eq.3 says that the generated voltage is directly proportional to the generated charge from the crystal.

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Potential difference between the crystal and the base, the value indicates the pressure that is applied to the pressure sensor.

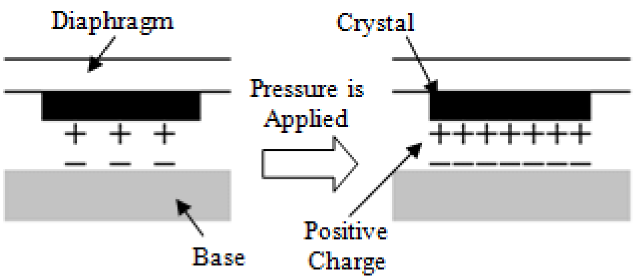

Fig.8: Basic operating principle of Piezoelectric pressure sensor

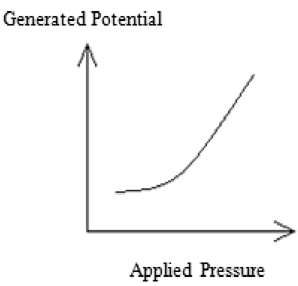

Fig.9: The relationship of applied pressure and generated potential

Capacitive pressure sensor: Capacitive pressure sensor makes parallel plate capacitive transduction principle usage. The applied pressure creates capacitance change between two plates. This uses diaphragm as one movable electrode with respect to fixed electrode. The charge produces a potential difference which may be sustained using external voltage. A capacitive pressure sensor measures pressure by noticing an electrostatic capacitance change. The deflection of the diaphragm results to the change in capacitance.

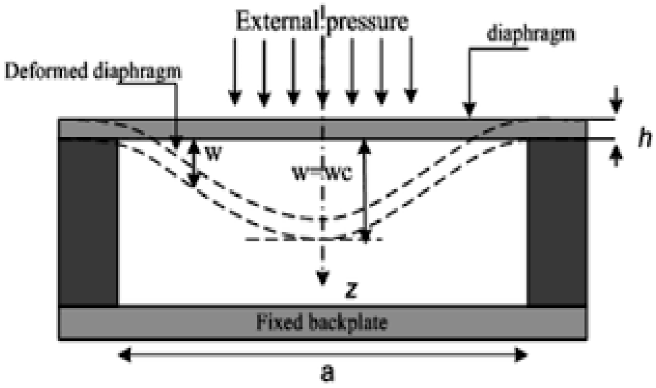

Fig. 10: Basic operating principle of Capacitive pressure sensor

The equation of capacitance which can be given by:

$$C=\frac{A}{d}\varepsilon_o\varepsilon_r \text{ -------------(4)}$$

Where

- εr is the dielectric constant of the material between the plates (this is 1 for a vacuum)
- ε0 is the electric constant (equal to 8.854x1012 F/m)
- A is the area of the plates
- dis the distance between the plates

3. APPLICATION OF MEMS PRESSURE SENSORS

Pressure sensors are used for many automotive, medical, industrial, consumer and building devices, which depend on accurate and stable pressure measurements in order to operate reliably. As more industries rely on pressure sensors to monitor and control their applications, demand for these technologies has greatly increased, putting estimations of the worldwide pressure sensor market at $11.4 billion by 2024.

Automotive Applications:
In automobiles, hydraulic brakes are a crucial component in passenger safety. The ability to control a vehicle using brakes is down to a complex blend of components, including pressure sensors. These can be used to monitor pressure within the chambers of

the braking system, alerting drivers and engine management systems alike if pressures are too low to be effective. If pressure inside chambers is not measured, systems can fail without the driver knowing and lead to a sudden loss of braking efficacy and accidents. Until recently, airbags were solely designed to inflate inside of vehicles for the front two passenger seats in the event of a collision. Now, car manufacturers have created airbag innovations inside and outside of vehicles that release faster, resulting in safer outcomes for passengers in any seat and pedestrians too. They have also found ways of making the driving experience safer for the planet; bringing down engine emissions, by recirculating exhaust gases. Learn more about the life-altering and ecofriendly applications of pressure sensors for automotives.

Life-Saving Medical Applications:
Raising the air pressure in a sealed chamber containing a patient is known as hyperbaric therapy. It can be effective for treating a number of medical conditions, from skin grafts, burn injuries, and carbon monoxide poisoning to decompression sickness experienced by divers. Measuring blood pressure correctly is crucial to patient care, as errors in readings can lead to a misdiagnosis. Thanks to recent innovations, tiny pressure sensors can even be implanted into the body, known as In Vivo Blood Pressure Sensing for more accurate monitoring. Learn more about the medical advances being made with pressure sensors.

Industrial Applications:
Submersible pressure sensors can be used to measure liquid pressures (up to 30 PSI) with either a voltage or current (4-20mA) output in liquid tanks. By positioning these sensors at the bottom of a tank, you can get an accurate reading of the contents in order to alert workers or the process control system when levels in the tank fall below safe limits.

Automated Building Applications:
As building and home automation technologies become increasingly popular, pressure sensors continue to play a central role in controlling the environments we live in. Refrigeration systems are one such example. Common coolants in HVACs like ammonia can cause significant danger to people in the event of a leak. Using relative pressure sensors to monitor the pressure of the ammonia as it passes through the system ensures it stays within safe limits. Controlling large building environments is a challenge for designers and operations staff alike.

Life-Enhancing Consumer Applications:
The things we use, carry and wear on a daily basis are growing in intelligence. Adding a pressure sensor to a consumer device can provide new information for an improved user experience. Take vacuum cleaners, or example. By measuring suction changes, they can detect what kind of flooring is being cleaned and adjust settings accordingly, or notify their owners when a filter needs replacing.

4. CONCLUSION

The origins of what we call nowadays "MEMS technologies" can be traced back to 1954. Interest in silicon sensor technologies grew dramatically, and by the late 1960s a number of US companies, pioneers and leaders in this field, this laid the foundations for the miniaturisation of mechanical systems, with the development of micromachining technology based on silicon semiconductor technology, as engineers began realizing that silicon chips and MOSFETs could interact and communicate with the surroundings and process things as chemicals, motions and light. One of the first silicon pressure sensors was isotropicallymicromachine in 1962.
Nowadays MEMS are made up of components between 1 and 100 micrometers in size (i.e., 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micrometres to a millimetre (i.e., 0.02 to 1.0 mm), although components arranged in arrays can be more than 1000 mm^2.
MEMS pressure sensor can be classified based on the measurement of pressure,sensing element and MEMS application is wide,currently it is used in every field. Some examples of current MEMS devices include accelerometers for airbag sensors, inkjet printer heads, computer disk drive heads, projection display chips, blood pressure sensors, optical switches, microvalves, biosensors and many other products that are all manufactured in high commercial volumes.

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