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Intracranial Monitoring Pressure Sensor using MEMS

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Abstract: A completely integrated numerous devices for the measurement of Intracranial Pressure (ICP) have been defined, Intracranial Pressure (ICP) sensor is associated with the brain of the body for monitoring the ICP. It includes both wired and wireless systems. It is having a major role in different diagnostic procedure patients with head injuries and trauma. Conventionally, invasive methods are used for ICP controlling which involve surgical procedures. This method is low infection, biocompatibility, small size, accurate and easy to use. With this knowledge of requirements in mind we define an implantable ICP sensor based on Micro Electro Mechanical Systems (MEMS) from the comsol multi physics tool CMUT (Capacitive Micro machined Ultrasonic Transducer) is chosen as the biocompatible and flexible architecture. Sterilization and dynamic element matching tactics are applied in sensor interface circuits to reduce circuit noise and offset .On-chip sequencing is implemented for each sensor to satisfy the process variation. This paper describes various work which are done with respect to proposed characteristics of CMUT that make it well suited for biomedical applications and comparisons are made with other polymers in terms of biocompatibility and certification.

***Keyword**: Intracranial Pressure sensor, MEMS(Micro Electro Mechanical Systems),CMUT(Capacitive Micro machined Ultrasonic Transducer)*.

I. INTRODUCTION

Intracranial Pressure (ICP) is the pressure inside the skull, brain tissue and within the ventricles containing the cerebrospinal fluid (CSF). ICP increases in cases of TBI, head injuries and other neurological disorders. Increased ICP is one of the major cause of intracranial haemorrhages, neurological problems, coma, visual impairment, and stroke. Raised ICP increases the volume of the brain, the cranial diameter and the cerebral blood flow towards the brain. On the other hand raised ICP reduces respiration rate and pulse rate. Hence monitoring of ICP in patients with head injury is necessary in the field of neurosurgery. Monitoring is one of the standard operating procedures that have to be performed on the patient, this is because ICP monitoring helps the doctor to find out whether the patient sustained any severe head trauma ,if the ICP is too low or too high it can cause a damage to the brain ICP is measured in millimeters of mercury (mmHg) and normally its value ranges from 7 - 15mmHg for adult. However ICP ranges above 20 mmHg is considered dangerous to one's life and has to be treated seriously. The brain is a highly sensitive part of the body so even just the smallest change in its immediate environment may cause complications. An injury due to traffic accidents, blasts, sport injuries or physical assaults exert strong external forces on the brain and damages the brain. Such damages are called Traumatic Brain Injuries (TBI) and are a major cause of death and disability for patients subjected to closed head injuries. Traumatic brain injury (TBI) is a worldwide phenomenon that has highly destructive consequences for both the patient and society. The key to TBI management is the control of intracranial pressure to prevent secondary brain injury. In the case of severe neurological diseases and injuries the brain is able to swell which causes to an

increase in pressure called intracranial pressure (ICP). It is necessary to measure monitor, and maintain ICP.As per the centres for disease control and prevention, it has been stated that the deaths related to TBI is more than 50000 annually . Apart from the primary injuries caused at the time of accidents, a severe secondary damage due to lack of oxygen supply to the brain, herniation, swelling etc, is encountered due to excess of Cerebrospinal Fluid (CSF) flowing into the brain. Traditional methods for measuring ICP require drilling the skull and inserting the catheter (thin, flexible, hallow tube) into a specific position depending on the type of device. In general there are two effective methods in terms of reliability. They are 1] The ventricular catheter, this 'gold standard' technique using a fluid-coupled concept, relies on inserting the catheter to the lateral ventricle. The system not only monitors ICP but is also useful for Cerebral Spinal Fluid (CSF) drainage. Even though the "gold standard" method gives most accurate results by calculating the difference between cerebral pressure and standard atmospheric pressure, it is having a high risk of infections as these catheters are manually inserted into the cranium(skull), which is usually needed to derive cerebrospinal fluid by specific surgical methods. However, a non-invasive technique overcomes this issue but compromising accuracy. Some common non-invasive

methods are described in Micro Electro Mechanical Systems (MEMS) is a trending area of research. Several MEMS based ICP monitoring techniques exist. Some of these techniques are minimally invasive. Existing non-invasive techniques are less accurate and rarely used. The potential complications associated with existing ICP monitors are that they are minimally invasive, there is a risk for infection, recalibration is required if patient moves the head, they are less accurate, large in size and expensive. Thus there is a need for a completely non invasive,accurate, small and inexpensive ICP monitor.
It can be made more suitable for implanting with lowest infection risks by using Capacitive Micro machined Ultrasonic Transducer (CMUT), being an enlightening area under research is chosen to develop the non-invasive ICP sensor.
2].Intra parenchymal systems are a second method of measuring ICP, these systems may rely on fiber-optics, strain gauge catheter tips, or pneumatic devices. These systems are designed based on the concept of a catheter tip transducer, which is placed on the brain parenchyma. The advantages of intraparenchymal systems include: low chance of infection, small drift, and one time calibration; the disadvantages include: the inability to drain CSF, fragility and expense. However this measurement method suffers from relatively large error rate because of the derived fluid With the development of Microelectro Mechanical Systems (MEMS) technology a new pressure sensor which is small enough to be implemented close to the tip of a needle can be developed and hence ICP can be directly detected by this acupuncture(thin needle).

II. LITERATURE SURVEY

Intracranial pressure monitoring is widely used in neurointensive care, especially for the management of patients with traumatic brain injury. ICP levels are used to decide and verify the efficiency of therapeutic maneuvers. In real life, however, ICP measurement is challenging work. The MEMS pressure sensor is represented by a variable capacitor whose capacitance varies in response to the pressure change. The ICP sensor is equivalent to a variable current source producing the output current proportional to the dissolved oxygen concentration. Accuracy was defined as the degree of correspondence between the pressure read by the catheter and a reference real ICP measurement. Drift was defined as the loss of accuracy over the monitoring period. The MEMS pressure sensor is represented by a variable capacitor whose capacitance varies in response to the pressure change. The ICP sensor is equivalent to a variable current source producing the output current proportional to the dissolved oxygen concentration.

A. *Steps to evaluate sensitivity of the pressure sensor*

1) *Wheatstone bridge:* It is traditionally applied to the network of pressure sensors. When the pressure is loaded, the output voltage can be obtained

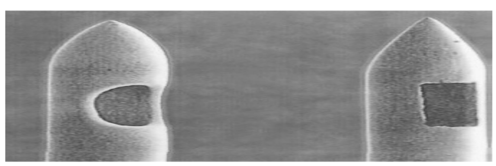

Fig 1. The micrograph of the lumbar puncture needle.

The MEMS sensor is installed at the very top, protected under the conical tip The piezoresistive pressure sensor is designed using nonlinear programming which is a mathematic tool to find the minimum value of the objective function. The schematic view of the piezoresistive pressure sensor is

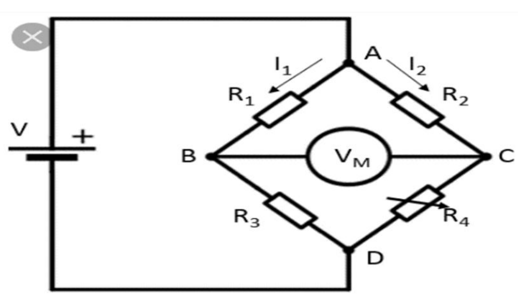

Fig 2.Wheat stone bridge.

$$V=\frac{(R2+\Delta R2)(R4+\Delta R4)-(R1+\Delta R1)(R3+\Delta R3)Vm}{(R1+\Delta R1+R2+\Delta R2)X(R3+\Delta R3+R4+\Delta R4)} \quad \text{-------(1)}$$

Where R1 = R2 = R3 = R4 = R. R is the original
Piezo resistance which can be expressed by Eq. (2),
where L and W are the length and the width of
piezoresitors and R is the sheet resistance

R =R▼L/W------(2)

where _l and _t are the longitudinal and transverse stress, respectively

$\Delta R/R = \pi t \sigma t + \pi i \sigma i = \pi 44/2(\sigma t - \sigma i)$--------(3)

Based on Eqs. (2) and (3), Eq. (4) is obtained, where A is the integration of stress difference with respect to the path along R1,. It will change when different pressures are applied on the surface of the diaphragm

$\nabla R1 = \frac{R\nabla\pi 44}{2W\int(\sigma x1 - \sigma y1)dx} = R\nabla\pi 44\, A/2\, W$----- (4)

There will be similar format with respect to R2, R3, and R4. We name the corresponding integrals B, C, and D, respectively. When there is neither translation deviation nor rotation deviation, then A equals C and B equals D. Combine all the formula above, V can be modified as

$V = \frac{\pi 44(B-A)}{4L+\pi 44A+\pi 44B}$ Vm ------ (5)

With output voltage values for each pressure (from zero to full-scale pressure) applied, it is easy to calculate the sensitivity. The result will be achieved conveniently together with the Finite Element Analysis (FEA) software.These are the few equations how the pressure is calculated using the wheat stone bridge.

III. DESIGN OF DIAPHRAGM

A. *Square Diaphram*

The square diaphragm is preferred because it produce the highest induced stress for a given pressure which mean it can provide a pressure sensor with better sensitivity. Also it is easy to dice the diaphragm from standard wafers. There were also a few mask design techniques available to avoid convex corner undercutting phenomenon that always occur in realizing a perfect square diaphragm. To obtain the maximum sensitivity, resistors should be placed near the edges of the silicon diaphragm, which are the high stress regions when there is a pressure load. FEA analysis of piezoresistive pressure sensor with square diaphragm is investigated and proposed by ‘Zanhang’ and coworkers.

B. *Slotted Diaphragm*

For achieving more sensitive device and reducing the effect of residual stress and stiffness of the diaphragm, slotted diaphragm is proposed. Eight slots with the same dimension and geotmetry was formed on the square diaphragm.

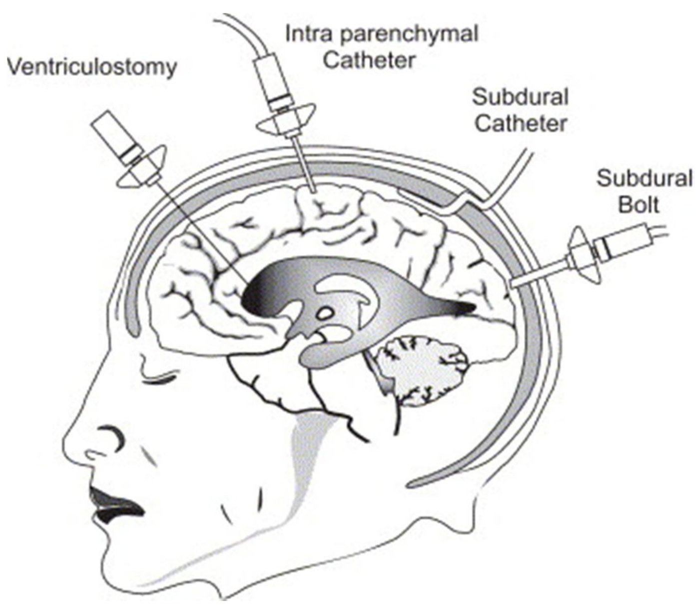

Fig3:Intracranial pressure measuring techniques and positioning

IV. COMPARISION CHARACTERISTIC RESULT

Sr no	Elements	Properties	Medical	Remarks
1	LCP	-Higher mechanic Al strength at higher temperature -High chemical resistance -Low moisture absorption and permeability	USP CLASS VI	-Specially designed types per medical application -Newly developped material inneurological field -Lower processing cost and easier bonding thankapton.
2	POLYIMIDE (KAPTON)	-Thermoxidative stability -High modulus -High insulator -High chemical resistance	NC	-Still in study of biocompatibility , Cytotoxicity ,Hemolytic capability
3	PDMS	Physiological in difference. Biodegradable resistance. -high biocompatibility -high gases and permeability	USP CLASS VI	-most widely used polymer in biomedical application. -no photo definable for implantable grade.
4	SU-8	-high optical transparency -chemicaland mechanical stability.	NC	- Still in study of biocompatibility Cytoxicity.-Hemolytic capability. -low processing cost than silicon micromachining -unable to integrate with microelectronic circuits

V. CONCLUSION

A fully integrated multimodal sensing CMUT for intracranial pressure monitoring has been presented. High-sensitivity low-noise sensor interface circuits and calibration circuits are implemented to provide accurate sensor readouts. Sensitivity and properties behavior showed that the ICP sensor is suitable for biochemical use .Measurement results verify the system functionality and performance. In practical, this sensor is shown with the changes of resistivity with respect to applied pressure is plotted. The experiment will be conducted in air and water to find the drift of the sensor. Sensitivity and properties behavior showed that the ICP sensor is suitable for biomedical use. Test results confirmed the simulation method, which is significant in improving the product consistency for pressure sensor designers. It can be concluded that the response of the pressure sensor proposed in this work is linear and possess good sensitivity .The sensor is very small, its sensitivity is not much affected by environmental parameters like temperature. The results also show that the sensors meet the demand of ICP measurement. As the sensor size reduces, the effect of noise on the output signal becomes the limiting factor in the sensor design, and future work needed is the noise factor optimization.

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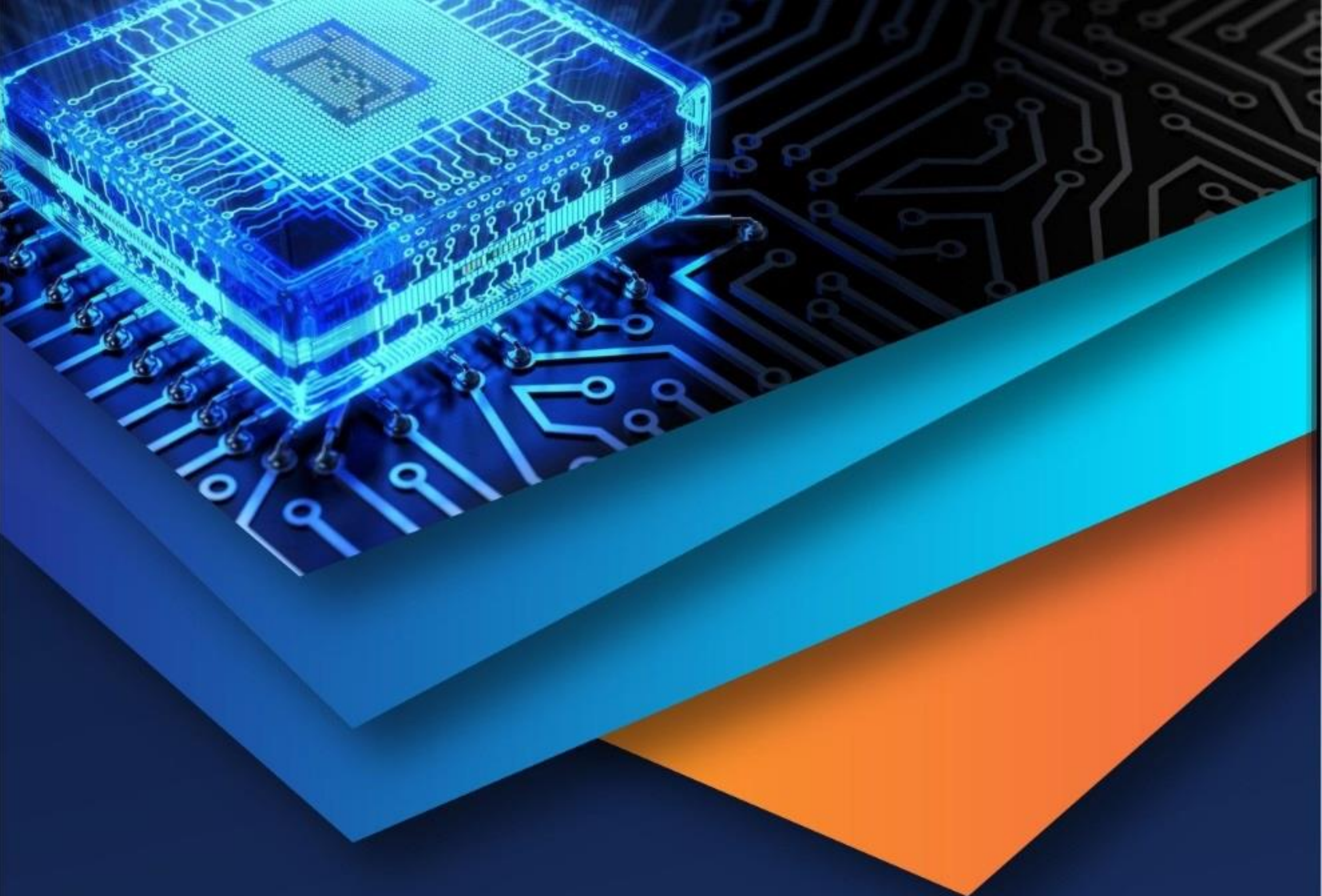

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