Journal of Advanced Research in Microelectronics and VLSI
Volume 6, Print Issue 1 - 2023, Pg. No. 1-4
Peer Reviewed Journal

Research Article

Eyes on the Future: Noninvasive Micro-Electromechanical Systems Revolutionizing

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How to cite this article:
Singh S. Eyes on the Future: Noninvasive Micro-Electromechanical Systems Revolutionizing. *J Adv Res Microelec VLSI* 2023; 6(1): 1-4.

Date of Submission: 2023-05-15
Date of Acceptance: 2023-06-20

ABSTRACT

This study evaluates the prevalence of glaucoma in the developing world and explores the potential of microelectromechanical systems (MEMS) to treat the disease. Glaucoma's main cause, intraocular pressure (IOP), is brought on by the aqueous humour fluid's improper outflow. As a result, the lens and retina sustain irreversible damage that renders a person permanently blind. It is common in places where access to and penetration of high-income communities are beyond the scope of standard medicine and ophthalmology care. To assess the pressure, techniques including palpitations, manometry, and telemetry have been employed. They need a personal commitment to routine checkups and are obtrusive. MEMS, however, have a chance to provide less obtrusive and extremely effective IOP measurement and reporting systems. The use of contact lenses with on-chip sensors devices makes it simple to measure IOP and to continuously update an external device on changes. Since the instrument enables self-reporting of the state, the patient can simply monitor this gadget. As a result, it can be employed in places where ophthalmologic care is urgently needed yet poor on accessibility and penetration. Additionally, it uses current mobile and internet connection technology directly, which makes it practical for use.

Keywords: Microelectromechanical Systems (MEMS), Intraocular Pressure (IOP), Glaucoma, Measurement, and Reporting

Introduction

After cataracts, glaucoma is the second most common reason for blindness in developing nations. 30% of all occurrences of blindness are caused by it.[3-5] However, the lack of knowledge and the condition's growth pose the biggest obstacles to its resolution. Glaucoma is brought on by an imbalance in the aqueous humor's inflow and outflow, which raises intraocular pressure.[6] This can then cause irreparable harm to the lens or the optic nerve, which would cause blindness. This illness has mild symptoms that take time to manifest, delaying treatment. Numerous individuals visit eye clinics when their condition has advanced to the point where it cannot be helped.[7] Little steps are taken to prevent the pressure from building up to dangerous levels since it is painless. According to reports, many patients in these nations attend when their intraocular pressure is reaching 45 mmHg, which is far higher than the recommended 25 mmHg.[8] The lack of resources in eye clinics that prioritise treatment over prevention is another barrier. Surgery is a surgical option to relieve the pressure accumulation. This is done to collect the draining mechanism's build-up of pressure and reroute the extra fluid.[20] Many patients, however, are hesitant to undergo this procedure, especially if it does not cure their partial blindness.

Proposed System

Many conventional medical innovations are not as accessible or as skilled in developing nations. Traditional methods of iop measurement have been in use for a very long period. Their ability to reach a large number of individuals who are suffering in developing nations, however, leaves a vacuum in their effectiveness. Manometry and tonometry are two of them. Another approach that is rudimentary for determining IOP is palpation. It entails pressing a finger against the cornea of a closed eye. Practise can lead to adequate learning, making it feasible to properly assess the buildup of eye pressure.[11] Due to the fact that it does not differentiate between different pressure sources, this technique has numerous disadvantages. However, the other two are much more developed and out of reach for many of the world's poorer countries.

Manometry

Consistently measuring the IOP in the lab requires an invasive method. The figures acquired are utilised to determine the IOP's level, which guides the ensuing steps. Therefore, it is challenging to carry out the experimental pharmacological experiments on a large scale.[2,8]

Tonometry

The two methods appear to exhibit significant restriction in terms of general use in regions with limited access to ophthalmology and a culture of preventative medication, according to a review of the simplicity of use and the participation levels required. The syndrome is fatal to many people due to the unmonitored IOP's sneaky progression and irreparable harm. The two approaches are therefore restricted in the following areas: they are too invasive for the patient and demand more attention to one's medicine than is discreetly required. Hours of laboratory observation are needed when using manometry in order to obtain a useful result that can be used as a benchmark for calculating IOP pressure.[13] In terms of limiting the effectiveness of the medicinal strategy in taming the prevalence of glaucoma, this produces a demanding investment on the patient's part.[17] Since the illness is painless, there are expenses associated with receiving monitoring for a condition that doesn't currently restrict one's ability to go about their regular lives. Tonometry serves as a less invasive alternative to manometry but still involves frequent visits and intrusive measurements of the cornea. Additionally discrete, the methods make measuring IOP difficult.

They need to be measured on a regular basis, which depends on the patient's trips to the local opticians. This tradition of financial support for non-immediately life-limiting medical illnesses is lacking in developing nations. IOP is the most likely culprit, yet the true causes of glaucoma are still unknown.IOP varies widely, making it difficult for ophthalmologists to make meaningful decisions.[23-25] Finally, the approach is ineffective in nations with limited access to healthcare and widespread self-ignorance. Developing nations lack the professional capacity to provide sophisticated management of complex illnesses like glaucoma.[1,13,22] Due to this, the delivery of services is constrained to the most populated parts of these countries. The lack of knowledge and hostility to the frequently used invasive treatments only serve to exacerbate the ignorance. Technology has shown to be a powerful tool for enhancing service delivery in underdeveloped nations. By utilising reporting and monitoring technologies through shared interfaces with the medical providers, it makes for easy penetration and, in contrast to other active monitoring technology now available, it is inexpensive.[12,18,19,21] The intervention in the measurement of IOP using MEMS in underdeveloped nations is referred to as the noninvasive MEMS leverage. These advances are brought about by the growth of VLSI in the digital system. As an advancement of present practises, the technologies discussed have the potential to create significant advancements in the field of ophthalmology. Therefore, the evaluation should be seen in the context of technological advancements in the application of MEMS in medical solutions, as well as the integration of the technology with current infrastructures. The latter concentrates more on reporting methods, offering a platform for patient and physician self-medication and enabling evasive scaling of therapy in widely prevalent medical disorders like glaucoma.[14–16]

This results from the realisation that some disorders are more opaque than others, allowing for accurate diagnosis and effective treatment. MEMS provide an excellent starting point for interacting with such illnesses and enabling accuracy in diagnosis and prevention.

Experimental Results and Discussions

Contact Lens Sensors

The meridional angle, which is the angle between the cornea and the sclera, is where the lenses are positioned. It is non-invasive, and its positioning ensures the least chance of eye damage and occlusion. Due to the widespread use of lenses to correct visual impairments, it is also quite progressive in terms of design and application. The lens sensors pick up changes in the IOP-related angle between the sclera and cornea. The theory underlying this is that variations in IOP pressure can impact variations in corneal curvature. The variations are gathered by a strain gauge and sent to a detecting device. The gauge is arranged like a whetstone bridge. While the latter is better suited for thermal correction, the former offers double sensitivity. The most pressure from IOP is intended to be provided by the detecting resistive gauges' critical form.The soft lens may deform, enabling changes that can be seen and communicated to readers.A microprocessor and an Application Specific Integrated Circuit (ASIC) that control the wireless interaction of IOP measurement with an external receiver are integrated inside the lens.A voltage that is directly proportionate to the strain felt by the lens is transmitted by the ASIC, which is implanted in the lens. This is comparable to the changes in IOP that the eye can detect.These modifications are sent to a portable device that the patient can access and maintain.

On-Chip Sensor Device

They are in the eye-implanted implants. They operate internally, with possibilities altering depending on the patient's state and their power requirements. They are less invasive because all that is required to coordinate their operation is a straightforward surgery. Similar measurement techniques are used, with the only differences being in the reporting and power sources. The basic mechanism is explained further down. The apparatus includes an array of micromechanical pressure sensors. An RF transponder, an antenna, a calibration electronic, a digital control unit, and a temperature sensor are also included. These components can now be incorporated in the system thanks to the development of micromachining, which has allowed for their miniaturisation. References, voltage regulators, a radio frequency rectifier, and a sensor make up the device's ASIC component. Two capacitors are needed to measure IOP. The first type is made up of MEMS capacitors, whose capacitance changes when IOP changes. This alters the MEMS device's charge and discharge levels, enabling discernible alterations.

The base charge needed to measure changes in the other capacitor is stored in the other capacitance. The digital logic circuit can produce a pulse thanks to the two capacitors' different capacitance and charge-time characteristics. The MEMS capacitance is proportional to the period between initial charge up and threshold, which correlates to variations in the IOP. The generated pulse is digitally transmitted to a memory module. The data is stored in a nonvolatile ferroelectric random access memory (FeRAM). Through the RF module, the antennae serve as the transmission and charging source. As a result, the sensor can operate without internal power and is instead powered by the RF signal.

This module can be modified to use solar energy that is captured from light energy that reaches the eye. This increases independence by reducing dependency on foreign energy sources. When the energy reaches the cornea of the eye, a 0.7mm2 solar cell is used to collect it. The energy is then stored and used to power the implanted device by a thin film lithium battery.Since this gadget is implanted in the eye, it enables self-monitoring.The patient is also able to keep track of variations in IOP thanks to communication between the device and an external device. This is crucial because it enables a Glaucoma management system with low operating expenses.In order to coordinate and offer services to common devices like smartphones, the device can also transmit to an external device that amplifies the signal. Since their adoption of Smartphone technology has boosted several industries, this is crucial for emerging nations. The delivery of this technology relies heavily on the device's miniaturisation. The chip's adaptation can be seen in its little intrusion and effective operation in determining the patient's IOP level. As a result, it gains more acceptance in the regions where it is put into practise and offers a strong possibility for furthering the decrease of glaucoma-inhibiting circumstances.

Conclusion

In conclusion, these technologies will probably result in greater adoption rates and hence offer a platform for combating glaucoma. Self-monitoring enables the shift from the painless condition to visible signals that may be correctly evaluated and remedial actions implemented. The ease of reporting and ongoing monitoring of the IOP provide leverage. It enables patients to control the illness, which, in contrast to other conditions, has few internal mechanisms in the form of pain or an outward discharge to call for ophthalmological assistance. Since most disorders have limiting symptoms like pain, nausea, or other physical manifestations, they necessitate medical attention and ongoing monitoring. As a result, it is certain that the patient would ignore the symptoms and seek quick medical attention. IOP, on the other hand, is sneaky and is not accompanied by any prior patient suffering. However, the problem gets worse the longer it is neglected, which could lead to long-term and severe repercussions including blindness.

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