REPLACEMENT FOR INHALERS

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Abstract: Asthma is an incurable disease and the effectiveness of its treatment is dependent upon how efficiently patients use their inhalers. Evidence shows that the level of nitrogen oxide in the exhaled breath can indicate signs of inflammation in the airways. An implantable MEMS device is designed to replace the inhalers and it will contain a breath sensor and a drug delivery system. The MEMS device contains an array of sensors which get activated by a hand held device .The device sets off an alarm if the level of nitrogen oxide is very high which indicates an impending asthma attack in the next twenty-four hours. Depending on the level of nitrogen oxide, the MEMS device will inject a corticosteroid (preventive drug) or a bronchodilator (rescuer drug) into the body. Precise drug delivery and zero drug wastage can be ensured. The device will have a programmed microprocessor, sensor feedback loop and wireless telemetry.

Keywords- Asthma, MEMS, drug delivery, breath sensor, implant.

INTRODUCTION

Asthma is a chronic lung disorder that causes airways to become inflamed, it is manifested by laboured breathing accompanied especially by wheezing and coughing that is triggered by hyper reactivity to various stimuli. Asthma cannot be cured but symptoms can be kept under control with the right treatment, which involves preventing the asthma symptoms and treating an asthma attack in progress. An inhaler is a medical device used for delivering medication into the body via the lungs, by breathing in (inhaling).It is mainly in the treatment of asthma and Chronic Obstructive Pulmonary Disease (COPD). Medications that are used to control the inflammation that causes asthma are long-term asthma control medications which include both inhaled and oral medicines. Preventer inhalers help protect airways. They make asthma symptoms less likely. Micro-Electro Mechanical systems (MEMS) have started to have a large impact on the drug delivery field**.** When electrical and mechanical components are combined together on a chip it is known as MEMS .Micro-fabrication technology is used to integrate the components on a single chip and the microsystem can sense as well as control the environment**.**

There are two types of drug delivery devices –active and passive. Active devices are those in which the drug can be delivered with an external trigger. Active drug delivery devices based on MEMS technology have been proven successful for in-vivo use in many applications. Wireless linking is used to provide power and communication to the device. The drug can be released by melting a membrane. It has the ability to deliver metered doses at the required site in a controlled manner.

Fig1: Asthma inhaler

Selection of biomarkers is key to illness management. Recent studies have shown that the level of nitrogen oxide in the exhaled breath can indicate signs of inflammation in the airways. To detect the level of nitrogen oxide a breath sensor is included in the MEMS device and is implanted within the trachea, bronchi or somewhere within the airway passage of the body. Electro-thermal actuation is the principle behind drug delivery. Motion is generated by thermal expansion amplification. A large amount of deflection of the overall device occurs due to a small amount of thermal expansion. It is fabricated out of doped single crystal silicon. An increase in temperature can be achieved internally by electrical resistive heating

CONVENTIONAL METHOD

A. Inhalers-

28 to 68% of the patients do not use the inhalers in the proper way, such as inhaling sharply at the wrong time, or not inhaling deeply enough. Toddlers and children might misuse the inhalers. Patients may also forget to use the inhaler twice a day, if they do not carry it with them always.

OBJECTIVE

The objective of the project is to design an implantable drug delivery device to enable precise drug delivery and to predict and prevent asthma attacks. A major challenge is to implement an active drug delivery device that is capable of storing large volumes with high delivery rates to achieve treatment in a few minutes as opposed to a few hours. Thus a device intended for long-term in-vivo application is designed to fulfill rigorous biocompatibility and bio-stability. The design should be such that it does not induce toxicity in the surrounding tissues and not damage the local tissue due to the induced mechanical stresses. Thus, the materials used are silicon nitride, silicon dioxide, titanium which are bio-compatible with the body.

MATERIALS AND METHODOLOGY

The initial stage of designing the MEMS device is a patterning technique by photolithographic process to design the desired patterns on the wafer surface. The wafer is photoresist and exposed to radiation through a mask which contains the pattern. Once the pattern is formed the photoresist is removed. The next step is deposition of thin film (silicon nitride) on the surface, followed by etching. The breath sensor is integrated with the MEMS device.

Breath Sensor

The levels of nitrogen oxide produced in exhaled breath can signal the levels of inflammation in the body. Nitrogen monoxide in the breath indicates that the bronchial tube is inflamed, which means that there is an impending asthma in the next 24 hours. Levels under about 20 parts per billion in children and under about 25 parts per billion in adults are considered normal. More than 35 parts per billion in children and 50 parts per billion in adults may signal airway inflammation caused by asthma. The higher the level of nitrogen oxide, the higher the inflammation level and also the voltage level is. The voltage level is transmitted to the hand held device, which sets off an alarm if the level is too high. Depending on the voltage level, it directs the MEMS device to inject a corticosteroid (preventive drug) or a bronchodilator (rescuer drug) into the body.

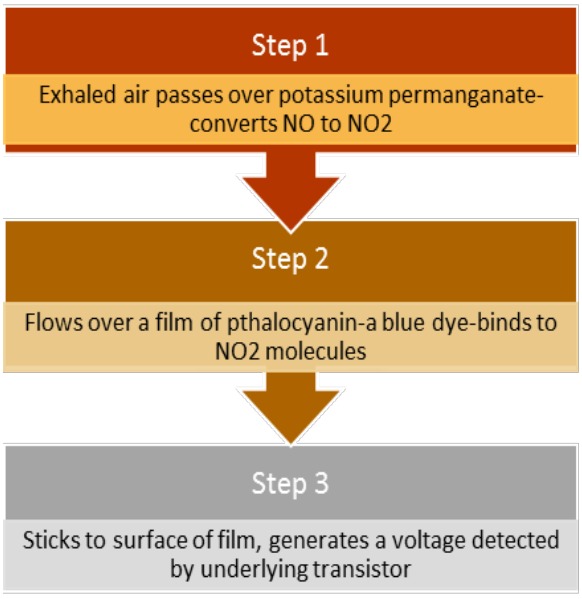

Fig. 2 .Working of breath sensor

B .Drug Delivery

The MEMS device has an array of sensors. Each sensor acts as a drug reservoir and is activated one at a time by the hand held device. The sensor has 3 layers-drug reservoir layer, membrane seal layer and activation layer. The MEMS device uses CMOS (complementary metal oxide semiconductor) circuitry for wireless transmission and collection. Micro valves control and regulate fluid motion during drug delivery. The drug is delivered at the rate of 25 micro litres in 45 seconds. For long term use the drugs can be refilled. Both corticosteroids and bronchodilators are stored in the reservoirs. Depending on the level of inflammation, the required drug is released into the body.

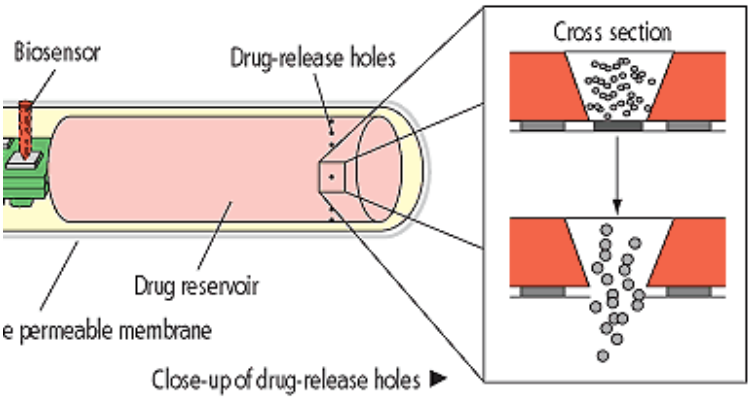

Fig. 3 .Sensor as a Drug reservoir

The activation layer consists of micro resistors, which on being activated generate heat locally.

This heat causes the fluid (drug) to generate bubbles. The increase in pressure caused by the bubbles ruptures the membrane (hermetic seal) and propels the solution out of the device and delivers the drug.

The hermetic seal membrane is made of silicon nitride which is biocompatible and prevents the drug from diffusing out and also from foreign substances entering inside. Electro thermal actuation is used. Titanium is used for the micro resistors to prevent drug degradation due to heating.

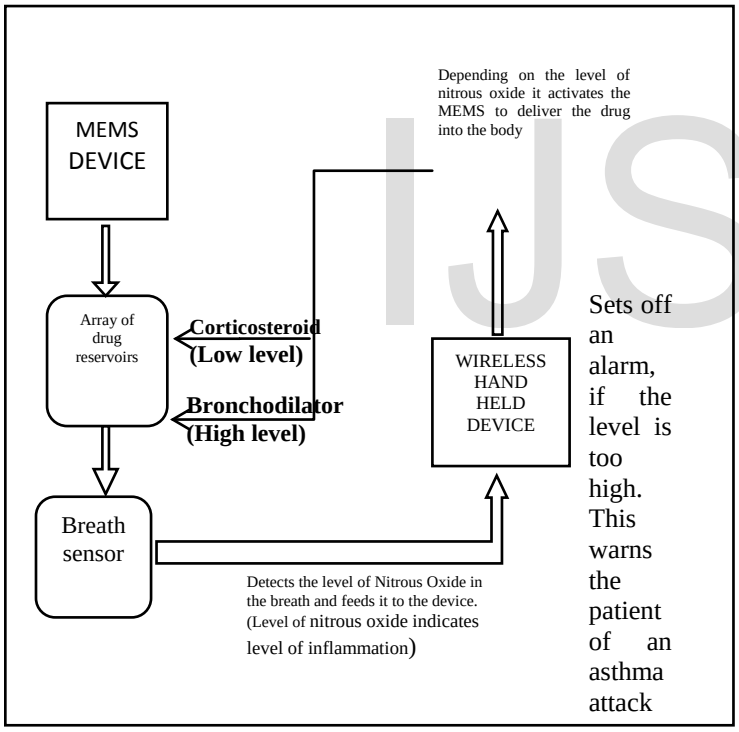

Fig. 4 Working of the device

The device is controlled by RF signals from the hand held device by using ASIC architecture (Application specific integrated circuit) which converts the RF signals into electrical signals.

C. Handheld Device-Wireless Transmission

Inductive coupling system is used, it consists of 2 coils, a transmitter and receiver coil. The receiver coil is placed inside the MEMS device. The U.S Federal Corporation for communication has allocated 14 MHz range for wireless medical telemetry service, which prevents interference of signals from other radio spectrum. The principle of inductive coupling- two magnetic coils made to resonate at same frequency is used for wireless data transfer. It has a pre-programmed microprocessor and an analog to digital convertor to convert the voltage level to digital data. It also contains bio sensor feedback loop.

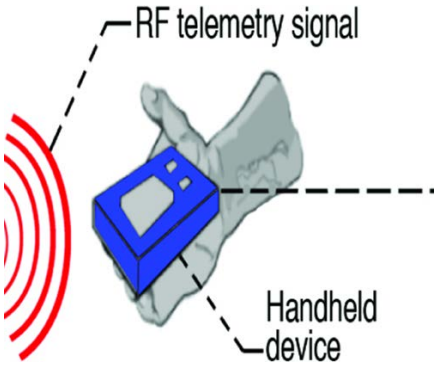

Fig. 5 Handheld device

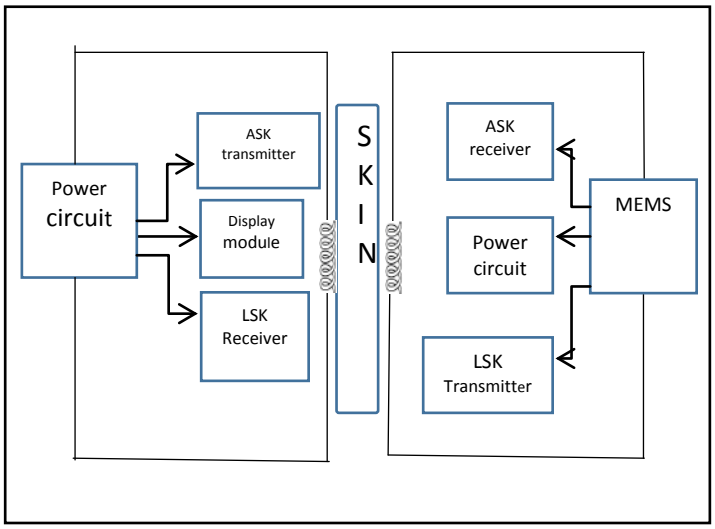

Fig. 6 Block diagram of wireless transmission

FUTURE WORK

Despite the many advantages of the drug delivery implants, many challenges still remain. As the implants are foreign materials implanted in the body they can be associated with toxic shock syndrome. Further research needs to be conducted on the efficacy of the implants.

RESULTS

Eliminating use of wires would lead to higher patient mobility range for drug administration to take place outside of clinical settings. Precise dose delivery and zero drug wastage are ensured. There is optimal usage of the drug by the lungs. (When the inhaler is used most of the medication remains in the mouth and throat). It reduces the side effects caused to the mouth and throat due to continuous use of steroid medication, such as oral candidiasis, thrush. It takes shorter duration of time for the drug to reach the lungs.Delivering the drug straight to the affected area increases the amount that gets taken up by tissues in the sinuses and reduces the chances of damage elsewhere in the body. Metered dose inhalers are inefficient with just 15% of the drug being delivered to the lungs in a best case scenario. This is caused by the difficulty to coordinate inhalation with actuation. One of the challenges with dry power inhalers is that they require peak inhalation but most patients do not have the ability to inhale deeply. Nebulizers also are enormously inefficient with only 1% of the drug being delivered. Hence the device can overcome all of these disadvantages.

ACKNOWLEDGMENT

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CONCLUSION

Asthma attacks can be predicted and preventive measures can be taken up with the device. Drug delivery biocompatible implants are promising next generation therapy techniques with its advantages. Additional research is required for sufficient data to prove their clinical efficacy and outcomes. By overcoming certain limitations and with more research it can become a treatment option for asthma patients in the near future.

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