

FOLDABLE POLYMER STENT INTEGRATED WITH WIRELESS PRESSURE SENSOR FOR BLOOD PRESSURE MONITORING

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ABSTRACT

Cardiovascular disease (CVD) is the leading cause of death in worldwide. One of the main diseases is atherosclerosis, in which plaques build up in the walls of the arteries, causing them to narrow gradually. This narrowing effect of the arteries blocks blood flow and interrupts oxygen supply. One of the most common treatments utilized in the narrowed vessel is the insertion of a stent into the blood vessel. However, despite various stents decreasing the risk of recurrence, in-stent restenosis keeps the possibility of late thrombosis and subsequent heart attack. Therefore, to reveal restenosis at an early stage, non-invasive and accessible methods are required. The proposed new fabrication method for integrating wireless pressure sensor and foldable polymer stent is based on MEMS processes. Photosensitive polymer SU-8 was utilized as a body of mesh stent structure and LC wireless pressure sensor. Wireless pressure sensor connection and working principle was evaluated based on inductance and capacitance coupling circuit.

KEYWORDS

Polymer stent, wireless sensor, LC type pressure sensor

INTRODUCTION

Cardiovascular disease (CVD) is one of the leading factors of fatalities in the world. In 2019, over 850,000 deaths were attributed to CVD in the United States and 17.9 million worldwide. Heart attacks and strokes are the cause of nearly 85% of all deaths worldwide [1]. Atherosclerosis is a major CVD causing heart attacks by the buildup of plaques (fats, cholesterol, calcium etc.) in and on the arterial walls that causes them to thicken. The continuing thickening or narrowing of the arteries can impede the blood supply to and from the heart, eventually leading to a heart attack. In such a situation, an angioplasty followed by stenting is a common treatment option to open the blood vessels and resume the blood flow. A stent is a small and expandable mesh tube placed inside the constricted artery to keep it open for a long term. The stent usually made from metal has been in use over the last 20 years [3-6]. A limitation of these stents is that they cannot prevent the further accumulation of plaque, that can cause inflammation and the resultant re-narrowing of the stent portion, known as in-stent restenosis. Over time, this situation can cause an abrupt thrombotic occlusion of the artery (stent thrombosis) leading to a myocardial infarction or death. Drug eluting stents (DES) are more commonly used now, as the drug coated on the stent is released

gradually [7-10]. DES can prevent the occurrence of a thrombus and lower the plaque build-up. However, it cannot fully stop this continues growing tissue, resulting in in-stent restenosis, and the patients may suffer from late thrombosis in the long run leading to a heart attack. Nearly 50% of the stented patient can suffer from this restenosis [11].

To prevent restenosis at the early stage, it is desirable to monitor its onset by the use of "intelligent/smart" stents that can sense the pressure change and transmit the information wirelessly in real time. Tiny pressure sensors made by the micromachining process can be integrated with the metallic stent and implanted into the artery, where the stent acts as an antenna for wireless communication. This integration was first attempted by Takahata et al. with a silicon based capacitive pressure sensor and dual inductor stentenna [12]. Park et al. then demonstrated the use of biocompatible polymer stents with the incorporation of miniature MEMS based wireless pressure sensors and data sensing [13]. The proposed approaches offered increasing the inductance value and quality factors as well as promoting the sensing distance. The use of MEMS-based pressure sensor in this application was also introduced by Chen et al. with its integration with an antenna stent, thereby enhanced the electromechanical performance in-vivo [14]. Their team further developed a new chip made of pure steel (316LSS) with an encompassing pressure sensor that was connected by laser micro-welding [15]. In addition, the use of 3D printing technology is advanced way of fabricating biodegradable stent [16], however the combination of the pressure sensor and stent still questionable, and the integration process was proceeding with the help of the various biocompatible glue. Till now, the integration of the sensor with the stent was achieved by mechanical assembly like bonding, gluing and conventional soldering, which is low-throughput and time-consuming process. More reliable integration techniques were needed to mass-produce a combination of stents and pressure sensors.

In this work, we developed a new process method to fabricate integrated stents and pressure sensors using the standard MEMS fabrication process. Both the stent and the pressure sensor were patterned using biocompatible photosensitive SU-8 polymer on a silicon wafer. The pressure sensor is combined with an inductor coil built on the top of the stent strut, which increases the inductor size and improves the output performance of the wireless sensor. The proposed smart stent is designed to follow standard catheter insertion procedures with required mechanical strength and compact footprints. The sensor main concept is shown in Figure 1.

was 1.28 kHz/mmHg. It was found that the working distance was greatly improved as the entire stent structure was employed as an inductor, differentiating from the smart stents proposed in the previous study.

CONCLUSION

This paper demonstrated smart stent integrated with LC type wireless pressure sensor. The proposed fabrication technique allows for solving the challenges of integrating stent and wireless LC pressure sensors. The unique design enables mass production based on MEMS techniques in 2D planners. After that, it exhibits a folding effect to make a 3D structure without changing the performance of the smart stent by using heat treatment that induces permanent deformation of the polymer stents. The sensitivity of the proposed sensor was evaluated in a various pressure range, and the improved sensitivity of the smart sensor was experimentally confirmed through various experiments.

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