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DESIGN AND FABRICATION OF MEMS /NEMS BASED PIEZORESISTIVE CANTILEVER FOR IMPROVING SENSITIVITY AND SELECTIVITY OF THE DETECTION OF BIOMEDICAL SIGNALS

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ABSTRACT
This paper proposes to improve the selectivity and sensitivity of biomedical signals for the detection of biomedical signals EEG, ECG, EMG, based on the piezoresistive principleand MEMS/NEMS (Micro-Electro-Mechanical System) technology. Firstly, according to the characteristics of biomedical signals and detection, the U shaped micro and structure has been proposed, and the fabrication, characterization using SEM,LDV analysis have been carried out. Different designs of MEMS/NEMS cantilevers are fabricated and identified theresonance frequency response of the nano structure, its structure sizes have been determined.Secondly, the processing technology of the micronanostructure with the formation of material over the cantilever hasbeen observed for to increase the sensitivity and sensitivity and the detection of biomedical signals.The advantages of incorporating four cantilevers in the U shaped on the piezoresistive micro cantilever and its optimal position for maximum sensitivity is also studied in this paper. Different designs of cantilevers were modeled and it is found that U shaped cantilevers are found to be suitable structure showing maximum sensitivity for the detection of biomedical signals accurately.

Keywords: MEMS/NEMS Fabrication, Characterization, sensitivity and selectivity

1. Introduction

Auscultation is an important routine examination method in clinical diagnosis. Before thenineteenth century doctors could only put the ear on the patient's chest for "direct auscultation".

In 1816, French doctor Laennec invented the stethoscope; therefore, "indirect auscultation" becomespossible and the discipline of cardiac auscultation is formed, which has greatly promoted thedevelopment of medicine [1]. However, the traditional stethoscope has poor low-frequency response,and diagnosis highly depends on the subjective judgment of doctors. In addition, the human earis limited by the inherent limitation whose most sensitive frequency range is 1000~3000 Hz, whichis with poor sensitivity for low-frequency sounds [2]. However the clinically valuable heart soundfrequency range is often concentrated in the range of 20~600 Hz, so some important heart sounds withlow frequency and small intensity are difficult to capture [3,4].In 1999, the American 3M Littmann Company (São Paulo, MN, USA) developed and producedan electronic stethoscope, which was the first to apply electronic technology to auscultation [5]The traditional stethoscope has been replaced by the heart sound electronic auscultation system, which has the advantages of high accuracy, real-time waveform display, ease of use, low cost, andsmall volume. The common sound sensor used by electronic stethoscopes is the microphone [6].The microphone is divided into electret, coil, and capacitance, and electret is the most commonly used.The electronic stethoscope converts the heart sound signals to analog signals, which are amplified,and then the analog signals are converted to digital signals for further processing and transmission.The microphone-type electronic stethoscope receives the heart sound signals via the microphone inthe cavity, which is mounted behind the diaphragm. The vibration of the diaphragm causes soundpressure in the cavity, the microphone receives the sound pressure and converts it to an electricalsignal. Since the sound propagates through two layers of diaphragm and the internal cavity, namelya three-layer medium, the energy transfer is limited and the sensitivity of the stethoscope is low.MEMS technology has been applied to the detection, diagnosis, and therapy, which playsan important role in the improvement of medical devices and the prevention, diagnosis and treatmentof diseases [7,8]. The wireless endoscope technologies of M2A developed by Israeli Given ImagingCompany (Tel Aviv-Yafo, Israeli) and NORIKA3 developed by Japanese RF Company (Nagano-ken,Japan) have been applied to clinical practice [9–11]. Thousands of biomolecules can be integrated ina centimeter-scale chip by MEMS technology, which could be made into the bio-chip. The bio-chip canshow different allergic reactions for the various biochemical reactions to realize the test and analysis ofthe genes, antigens, ligands and other bioactive substances. MEMS technology can be also used ingenetic analysis and genetic diagnosis [12–14]. Therefore, MEMS piezoresistive pressure sensors, withthe advantages of good performance at low frequencies, comprised of mature and controllable MEMSpiezoresistive technology, with low cost, linear output, and simple circuitry, have been widely used inmedical diagnostic systems [15].This researches proposes an electronic heart sound sensor with a high signal-to-noise ratioand real-time waveform display based on MEMS technology and the piezoresistive principle.Combined with further clinical experience, preliminary diagnosis can be performed by the electronicheart sound sensor and the accuracy of heart attack diagnosis can be improved.

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2. Literature survey

An electric potential sensor (EPS) was developed at the University of Sussex in England. An electric Potential Integrated Circuit (EPIC), which is an advanced version of the previous studies and the main focus of this thesis, is developed by Plessey Semiconductors Ltd. The EPIC sensor has all electric potential sensor parts integrated to one component.The basic idea of capacitive electrodes to be used in electrocardiograph purposes is quite old, since the first working devices were introduced already in the year 1968 (Lopez, 1969). Even though many common problems associated with capacitive, non-contact electrodes have been solved during the last decades, any design has not really progressed beyond the lab prototype stage. EPIC sensors can be applied to a range of applications such as electrophysiology including monitoring the electrical activity of heart (ECG), -brain (an ElectroEncephaloGraph, an EEG), -muscles (an EMG) or eye movement (an ElectroOcularGraph, an EOG). EPIC sensors can also be applied to a proximity- and movement sensing, a non-destructive testing of composite materials and in nuclear magnetic resonance probes. Some microscopy applications have also been introduced (Plessey Semiconductors, 2013). The EPIC sensor can be used either in a contact or non-contact mode. The contact mode is used to measure for example bio-electric signals such as an ECG or an EEG from the human body, and the non-contact mode is used to measure the disruption of an electric field caused by a human body movement. For this purpose the EPIC sensor has very unique properties. The EPIC is a capacitive sensor that does not rely on a direct, ohmic contact to the body, so no gels or other contact-enhancing substances are needed. Since the EPIC sensors do not require a direct skin contact, they are capable of measuring an ECG or other bio-electrical signals through the clothing, too. (Plessey Semiconductors, 2013) EPIC sensors can be used for both simple heart rate analyses as well as making more exact clinical diagnostic measurements, such as a replacement of the traditional twelve-lead ECG. The twelve-lead ECG is used to measure the electrical activity of the heart from many, slightlydifferent perspectives to achieve a clearer picture of how the patient's heart is working. EPIC sensors can be used for recovering other physiological signals than the ECG, for example those signals that are caused by the electrical activity of an eye muscle when looking in different directions. Since different muscles are activated when looking up, down, left or right, each direction has its own unique signature on an EPIC sensor output signal. These sensors can also be used for an electroencephalography (an EEG), where the electrical activity of the brain is recorded (Harland, Clark & Prance, 2002). Since EEG signals can be recovered from near the proximity to the patient, EPIC sensors have a significant benefit compared to traditional sensors when there is no need to prepare a direct connection to the skin.

Drawbacks:

1. High cost
2. Detection is difficult
3. Analysis of biomedical signal is difficult

4. Diagnosis is limited
5. Suitable for only single ECG signal

3. Problem Definition

Today substance analytes are assuming extremely fundamental part in all applications,particularly biomedical, as in breath-gas monitoring where highly sensitive Volatile Organic Compounds (VOC) detection by chemical or gas sensorsenables new applications of human monitoring system, industrial chemical hazard prevention etc,.Hence it is important toDesigning a product based on MEMS/NEMS Piezoresistivecantilever for the detection and improving the sensitivity and selectivity for to identify the biomedical signal accuracy for the diagnosis result.

4. Objectives

The material coatings, with the blend of analytes for the cantilevers can be utilized for the identification of different types of biomedical signals.From the literature review the work carried out is very less in the use of sensor employing peizoresistivity nature of cantilever for identification of the biomedical signals. Keeping in perspective of the significance of building up a MEMS/NEMS Cantilever for the above applications there roused the present examination to build up a piezoresistive cantilever sensor for identification of signals and its characteristics. With this inspiration, the proposedresearch work hasthe following particular objectives.

1. To study about different design metrics of MEMS/NEMS based Piezoresistivecantilever with length, width and thickness.
2. To identify the different types of exclusive materials coatings on the cantilever with the combination ofanalytes and to study the response of the MEMS/NEMS based Piezoresistivecantilever.
3. To fabricate a suitable MEMS/NEMS based Piezoresistivecantileverwith different materials coatings for to build the overall system
4. To carry out the various experimental investigations, characterization and analysis for the fabricated Cantilever to investigate the resistance and time response for the detection.
5. To improve the sensitivity and selectivity of the cantilever and implementation for identification of the biomedical signals characteristics and detection for the diagnosis result
6. To compare the cantilever developed by the present investigation with commercially available sensor used for the detection of signals.
7. To develop a product based on the fabricated MEMS/NEMS Cantilever for the detection of biomedical signals.

Methodology

The following methodologies are used for the proposed research work.

STEP 1: Fabrication of array of MEMS cantilever with different metrics like length, width, thickness.

STEP 2: Different types of materials coatings on the fabricated cantilever.

STEP 3: Identifying the different types of analytes.

STEP 4: Verifying the functionality of the each coated material with analyte and observing the

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response and analysis for the biomedical application.

STEP 5: Based on response/function of cantilever, finding out the detection of biomedicalusing over system setup.

Omnicant is a piezoresistive MEMS/NEMS cantilever examination and experimentation stage proposed to becarried out in the research. The instrument shown in Figure 1 empowers the researchersto study MEMS/NEMS sensors, nano-cantilevers and their reaction to unpredictable natural mixes and gasses helpful for many applications.

Figure 1 OmniCant equipment a table top gadget

The OmniCant is a reduced table top gadget which serves as an arrangement with coordinated gas stream control, temperature control and sensor instrumentation alongside constant presentation and information logging of data. This instrument has been composed particularly to detect target analytes and for comprehending the reaction and nature of micro-cantilever and nano cantilever sensors affected by different physical and synthetic elements.

Microstructure Design

The design of the overall system is shown in Figure 1. The auscultation probe of the MEMSelectronic heart sound sensor is affixed to the registry and receives the faint heart sound signals.The heart sounds are transferred to the filter after the pre-amplifier to filter the high-frequency noise ofthe filter and environment and the high frequency components of the signals.MEMS technology has been applied to the detection, diagnosis, and therapy, which plays animportant role in the improvement of medical devices and the prevention, diagnosis and treatmentof diseases [7,8]. MEMS technology can be also used ingenetic analysis and genetic diagnosis [12–14]. Therefore, MEMS piezoresistive pressure sensors,with the advantages of good performance at low frequencies, comprised of mature and controllableMEMS piezoresistive technology, with low cost, linear output, and simple circuitry, have been widelyused in medical diagnostic systems [15]. This research proposes an electronic heart sound sensor with a high signal-to-noise ratio and realtimewaveform display based on MEMS technology and the piezoresistive principle. Combined withfurther clinical experience, preliminary diagnosis can be performed by the electronic heart soundsensor and the accuracy of heart attack diagnosis can be improve.

Figure 2: Fabricated cantilever with PVP material coating

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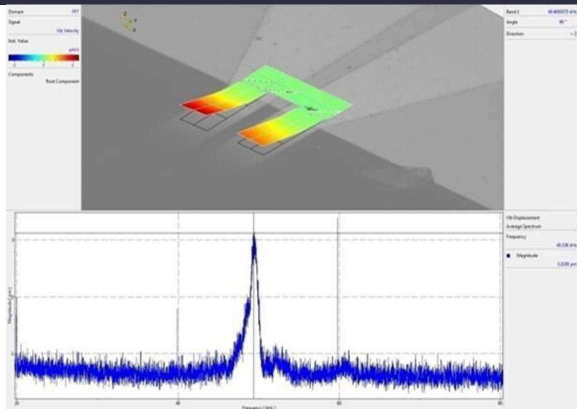

Figure 3: LDV Images of Micro and Nano MEMS/NEMS Cantilever Bending Movements

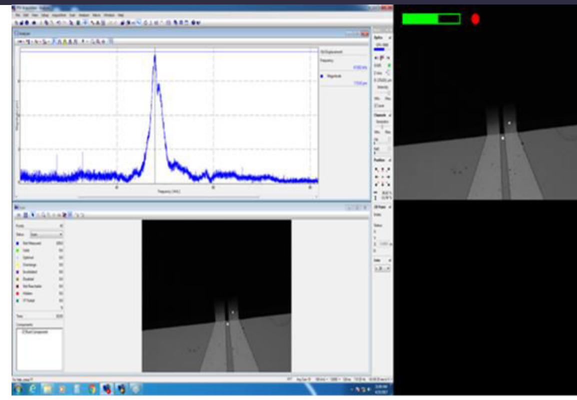

Figure 4: DV Images of Micro and NanoMEMS/NEMS Cantilever Resonance Frequency

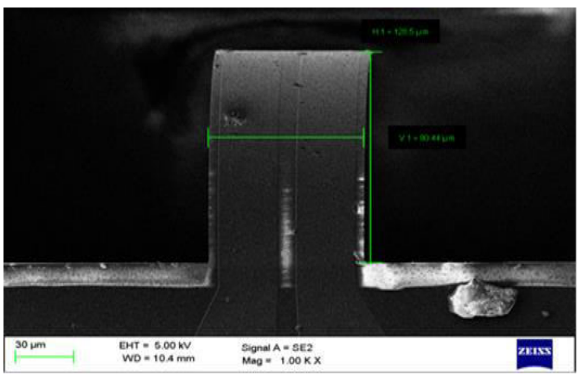

Figure 5: SEM Images MEMS/NEMS Cantilever Width and Height.

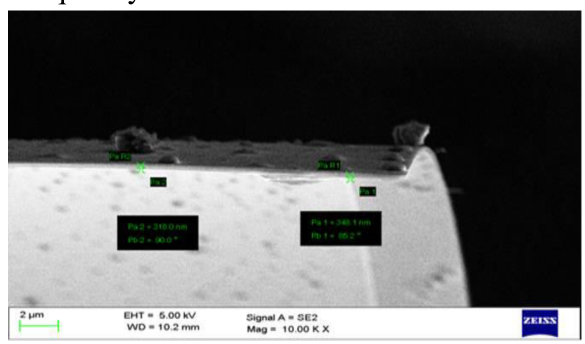

Figure 6:SEM Images of MEMS/NEMS Cantilever on PVP Material Thickness

Conclusion

The microcantilever is one of the popular MEMS structures available in market which is utilized as sensor for the detection of biomedical signals. It should be highly reliable and sensitive. The piezoresistive sensing mechanism is used to sense the stress change, which involves embedding of the piezoresistors on the top surface of the microcantilever to record the stress change occurring at the surface. The factors affecting the sensitivity aspect of microcantilever design include its shape and incorporation of stress concentrated region. There is a considerable increase in the sensitivity when U shaped were incorporated on the structure, different designs U shapeD of cantilevers are employed and analyzed for sensitivity. It was found that the U shaped Cantilevers gives better sensitivity if compared to any other shaped cantilevers.

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