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Packaging of Polyvinylidene fluoride nasal sensor for biomedical applications

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ABSTRACT

This paper presents the design technique that has been adopted for packaging of Polyvinylidene fluoride (PVDF) nasal sensor for biomedical applications. The PVDF film with the dimension of length 10mm, width 5mm and thickness 28µm was firmly adhered on one end of plastic base (8mm×5mm×30µm) in such a way that it forms a cantilever configuration leaving the other end free for deflection. Now with the leads attached on the surface of the PVDF film, the cantilever configuration becomes the PVDF nasal sensor. For mounting a PVDF nasal sensor, a special headphone was designed, that can fit most of the human head sizes. Two flexible strings are soldered on either side of the headphone. Two identical PVDF nasal sensors were then connected to either side of flexible string of the headphone in such a way that they are placed below the right and left nostrils respectively without disturbing the normal breathing. When a subject wares headphone along with PVDF nasal sensors, two voltage signals due to the piezoelectric property of the PVDF film were generated corresponding to his/her nasal airflow from right and left nostril. The entire design was made compact, so that PVDF nasal sensors along with headphone can be made portable. No special equipment or machines are needed for mounting the PVDF nasal sensors. The time required for packaging of PVDF nasal sensors was less and the approximate cost of the entire assembly (PVDF nasal sensors + headphone) was very nominal.

1. INTRODUCTION

Polyvinylidenefluoride (PVDF) is a synthetic fluropolymer. It is a flexible, light-weight, thin and tough engineering plastic, available in a wide variety of thickness. It does not require external power in order to function as it is both piezoelectric and pyroelectric in nature [1]. When a mechanical force is applied on a PVDF polymer film, it generates an electrical signal (charge or voltage) between upper and lower electrode surfaces, proportional to the amount of applied mechanical force due to its piezoelectric property, also, when PVDF film are subjected to temperature changes, it generates an electrical signal due to its pyroelectric property [2]. These unique combinations of properties enable PVDF polymer film to be used in a wide range of medical applications where very low-level mechanical signals must be detected. It is also extremely durable, capable of with-standing hundreds of flexing cycles (1 GHz) to as low as 0.1Hz and also chemical resistant.

Earlier, PVDF films have been used in recording various biomedical signals such as respiratory signal, cardio signals, pulse signal, body movements etc. Huang et al. [3] and Kulkarni et al. [4] have used pyroelectric property of the PVDF film to monitor respiration by placing them inside the oxygen mask. Choi and Jiang [5] have developed a wearable device consisting a PVDF films incorporated in a belt for measuring cardio and respiratory signals. An array of PVDF films was placed under the bed to monitor body movements and cardiorespiratory activities by Siivola [6].

In the present study, a suitable packaging method for PVDF film to use it as nasal sensor for biomedical application has been described. The aim here was to evaluate a new packaged PVDF nasal sensor to monitor human respiration.

2. EXPERIMENTAL

2.1 Initial design

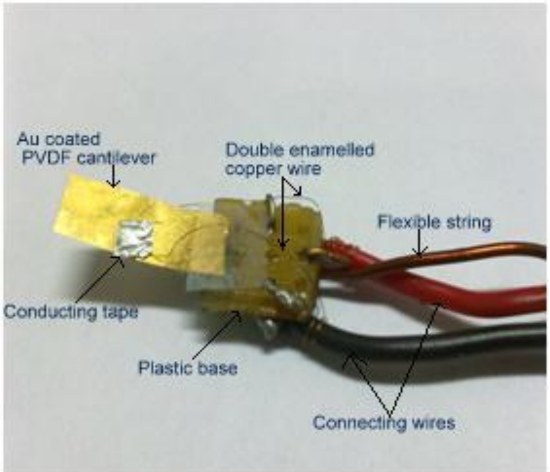

FIGURE 1: PVDF film adhered on a thick PCB

The PVDF film (obtained from Precision Acoustics, UK) used in the present study is poled and gold coated on both sides. The optimized dimensions of the PVDF film was: length 10mm, width 5mm and thickness 28µm [7]. One end of the PVDF film was firmly adhered to a thick PCB (Printed circuit board) with the thickness ~ 800µ, in such a way that it forms a cantilever configuration leaving the other end free for deflection as shown in Figure 1. The double enameled copper wires (diameter ~ 0.07mm) whose ends were tinned about 3mm length are attached on top and bottom surfaces of the PVDF thin film using aluminum conducting tape for measurement of voltage output. Initially, a conducting silver paste was used to glue copper wires on PVDF surface. But, the silver paste had poor

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adhesion with the PVDF film and it was peeling off often. Now with the leads attached on the surface of the PVDF thin film, the cantilever configuration becomes the PVDF nasal senor. The PCB of the PVDF nasal sensor was soldered to a flexible copper string (diameter ~ 1.5mm) so that the PVDF nasal sensor can be adjusted using copper flexible string as per the requirement. Thus, the two identical PVDF nasal sensors with flexible copper strings were mounted on an ordinary spectacle frame as shown in Figure 2 in such a way that it is placed about 4mm below the nostrils without disturbing the normal breathing. The pulsating air flow due to the inspired and expired air impinge on these two identical PVDF nasal sensors at the respective nostril leading to bending strain that generates voltage signal corresponding to respiration pattern of the respective nostrils.

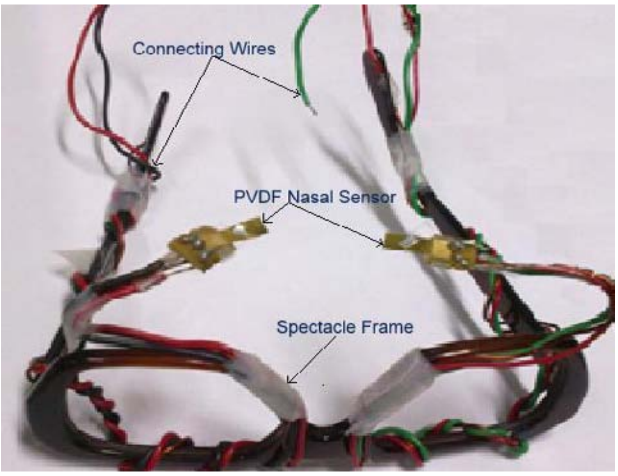


FIGURE 2: PVDF film mounted on an ordinary spectacle frame

2.2 Disadvantages with the initial design

After mounting PVDF film on an ordinary spectacle frame as explained in section 2.1, there were some disadvantages as given below while using this assembly during data collection (monitoring human respiration) at the hospital,

1. The spectacles must be carefully handled while wearing and taking off, so as not to make damage to the sensor part.
2. It was intolerable for a person to sleep with wearing a spectacle as it may be dislodged during sleep.
3. There was a problem in infection control as the PVDF nasal sensors cannot be detached/ disposed once they are mounted on spectacles.
4. Once the PVDF nasal sensor were damaged, than an entire spectacle should be replaced and this would increase the cost.
4. The copper wires used for mounting of PVDF nasal sensor on the spectacles were not strong and every time the sensors were getting dislocated.
5. The PVDF cantilever was bending due to the mass of conducting tape which was adhered in the middle of the PVDF cantilever (as shown in figure 1).
6. The entire assembly (as shown in figure 2) was not visually appealing.

3. RESULTS

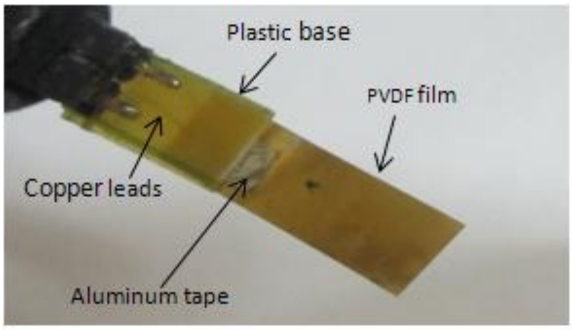


FIGURE 3: Newly packed PVDF nasal sensor

In order to overcome the disadvantages of the initial designs, an entire assembly was redesigned with some major modifications. First, at one end of PVDF film (10mm×5mm×28µ), double enameled copper wires (diameter 0.07mm) whose ends were tinned about 3mm length were attached on top and bottom surfaces using aluminum conducting tape for measurement of voltage output. After attaching copper wire, one end of the PVDF film was firmly sandwiched between two thin copper etched FR4 PCB (thickness ~ 250µ) in such a way that it forms cantilever configuration leaving the other end free to deflect. After attaching the copper leads, 2 pin berg sticks (male connector) were glued on the top side of the PCB. The copper wires were soldered to the 2 pin berg sticks. Now with the leads attached on the surface of the PVDF film, the cantilever configuration becomes the PVDF nasal sensor as shown in figure 3. For mounting a PVDF nasal sensor, a special headphone was designed, that can fit most of the human head sizes. Two flexible strings (diameter ~ 3mm) are soldered on either side of the headphone. At the end of the each flexible string, 2 female connectors were soldered so that the PVDF nasal sensor can be attached and detached to the flexible strings of the headphone. Two identical PVDF nasal sensors were then connected to either side of flexible string of the headphone as shown in figure 4 in such a way that they are placed below the right and left nostrils respectively without disturbing the normal breathing. When a subject wares headphone along with PVDF nasal sensors, two voltage signals due to the piezoelectric property of the PVDF film were generated corresponding to his/her nasal airflow from right and left nostril.

The advantages of this new packaging method of PVDF nasal sensor was,

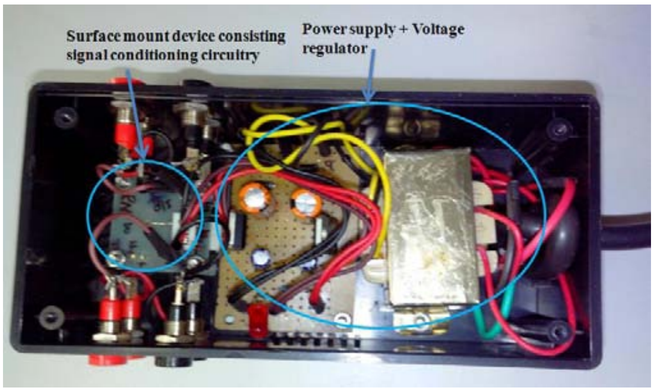
1. As the flexible strings were firmly soldered to the headphone, one can adjust the PVDF nasal sensor position with respect to different nostril size of subjects.
2. The entire design was done in a simple way that PVDF nasal sensor can be detached and disposed for avoiding infection, during using this for different subjects.
3. During data recording, subject can wear headphone first and then one can attach PVDF nasal sensors. By this we can ensure no damage was made to the nasal sensors while using PVDF nasal sensors for different subjects.
4. The entire design was made compact, so that PVDF nasal sensors along with headphone can be made portable.
5. During idle time, the PVDF nasal sensors can be detached and kept safely.
6. Also, due to simplicity of design there is no need of special training for a technician/nurse in hospitals to operate the PVDF nasal sensors.

The entire assembly of PVDF nasal sensor was made easy so that the patients should be comfortable during nasal test.

FIGURE 4: PVDF nasal sensor mounted on specially designed head phone

3.1 SIGNAL CONDITIONING CIRCUIT PACKAGAING

The output signals from the two PVDF nasal sensors corresponding to Right nostril (RN) and Left nostril (LN) were given to signal conditioning circuitry for pre-amplification, filtering (low pass filter) and further amplification (with a gain of 10). The final amplified signal was given to analog-to-digital converter for recording and storing in the computer. Figure 5 (a) and (b) shows the top and front view respectively of the packaging of the signal conditioning box. The entire signal conditioning circuitry was designed using surface mount technology (SMT) on a small 25.17mm×25.07mm PCB. Then components like resistors, capacitors, IC's etc of 0805 and 0603 package sizes were soldered on designed PCB to form a surface mount device (SMD). A voltage regulator of ± 5V was designed to supply power for SMD. The signal conditioning box was small, compactable and hence can be easily portable.



5(a)

5(b)

FIGURE 5: Packaged signal conditioning box (a) Top view (b) Front view

One can easily assemble the entire PVDF nasal sensor device (PVDF nasal sensors + headphone + signal conditioning box) in house. No special equipment or machines are needed for mounting the PVDF nasal sensors. This makes the packaging of the PVDF nasal sensor device cost effective. Also, the time required for packaging of PVDF nasal sensors was less.

4. CONCLUSIONS

The modified design technique used for package of PVDF nasal sensors had many advantages. The PVDF nasal sensors can be attached/ detached easily. Thus, PVDF nasal sensors can be disposed that make infection control for technicians/nurse easier and safer at hospitals. The entire assembly of PVDF nasal sensors (PVDF nasal sensors + headphone + signal conditioning box) was easy, cost effective, compact and portable.

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