

Textile Sound Structures

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ABSTRACT

In this paper we describe a set of sound sensitive structures based on piezoelectric technique. We have laminated piezoelectric polymer films between layers of different textile fabric structures. The initial results show that these structures register sound and the signal quality depends on the laminate set-up. Textile sound structures offer a variety of possible applications such as active sound absorbers and heart rate monitoring.

AUTHOR KEYWORDS

Smart textiles, microphone, piezoelectric, PVDF.

INTRODUCTION

Today humans are constantly surrounded by sounds, never before has the soundtrack of our lives been so cacophonous causing both psychical and physiological problems. Textile is often used as a passive sound absorber due to its inherent sound dampening qualities as a porous material. There are though possibilities to develop smart acoustic materials using smart materials and computing technology. Smart acoustic materials are useful in a wide range of application areas, such as active sound absorbing and medical textiles. The focus of this project is the development of textile microphone elements, like textile surfaces able to sense and transfer sound. Our motivation to look into this area is that active textile sound structures are rarely explored. Further our focus of interest lies in the microphone element itself, since it functions both as an active sensor and actuator, and the variety of application areas such structures offer. Sound is an element used in several

smart textile projects, in communication for example. In most projects the sound is recorded via miniaturised microphones and performed via loudspeakers integrated in the textile structures [1, 2]. Our ambition is to go one step further by integrating the recording of sound directly in the textile structure. To begin with we have integrated piezoelectric films in textile in order to investigate the possibilities to record sound in these structures.

Smart textiles represents the next generation of high tech innovations in textiles. The vision of smart textiles is to make textile products interactive by combining smart materials and integrated computing power into garments, interiors and technical textile applications. The term smart refers to materials that sense and respond in a pre-defined manner to environmental stimuli [3]. The degree of smartness varies; passive smart materials only sense the environmental conditions or stimuli, they are sensors. Active smart materials both sense and react to the conditions or stimuli, they are sensors and actuators. Further it is possible to enhance the intelligence by combining these materials with a controlling unit, for example a microprocessor, into a smart textile system (Figure 1). Such progress has become a reality due to the miniaturisation of computing technology, making it possible to combine and even integrate hardware, software and textiles in an unobtrusive way [4].

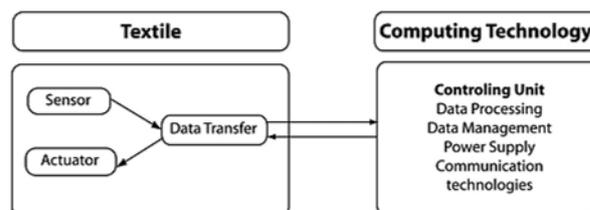


Figure 1. Smart Textile system.

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Sound is in many ways an interesting area for smart textile applications. First there are the two general applications; a textile microphone and a textile loudspeaker opening up for an alternative design and integration of these objects in our environment.

Two more specific applications are active sound absorbing materials and medical applications. In an active textile sound absorber active noise cancelling technique is used [5]. An active sound absorber performs best at lower frequencies while a passive absorber functions best at higher frequencies. The combination of a passive textile exhibiting sound absorbing qualities, at the same time working as a microphone connected with active loudspeakers, will provide sound affecting possibilities for a wide spectrum of frequencies. In medical applications, as we have seen in initial trials [6], sound recording can be an alternative measurement of heart rates. In that way we would be able to overcome some shortcomings with textile electrodes for heart rates measurements; intermittent disturbances, motion artefacts and high impedances in textile electrodes affect the signal quality [7].

TEXTILE MICROPHONE STRUCTURE

A conventional microphone uses a thin membrane, the microphone element, which vibrates in response to sound pressure and translate this movement into an electrical signal. The membrane or microphone elements are based on different types of functionality where capacitor, piezoelectric and dynamic membranes are the most frequently used techniques. Of these three options capacitive and piezoelectric seems to be the most suitable for integration in textile structures. We have earlier experienced capacitive and piezoelectric structures as textile press and stretch sensors [8] and due to a reliable interaction and function we choose to do further experiments with piezoelectric structures.

For textile use there is a polymer, PVDF (Polyvinylidene Difluoride). In piezoelectric PVDF the intertwined long-chain molecules attract and repel each other when an electrical field is applied or the material is mechanically distorted (Figure 2).

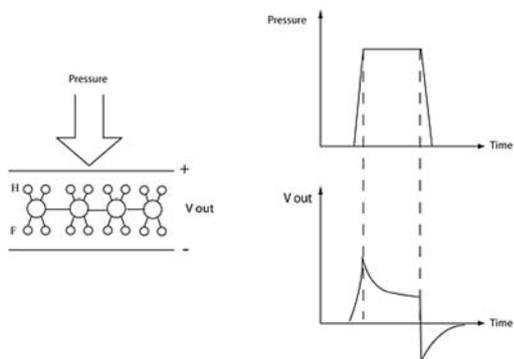


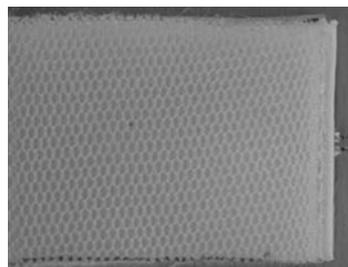
Figure 2. PVDF principle and electrical behaviour.

Piezoelectric PDVF materials are available as films suitable to laminate in different textile fabric struc-

tures [9]. Our tests aimed to evaluate how a textile structure affects the recording of sound. In order to explore that we choose textiles of different thicknesses, densities and manufacture techniques as woven, warp knitted and non woven textiles. The textile samples were made differently; either the piezoelectric film was laminated between two layers of the same material or between two textile layers of different qualities and structures.



Sample 1: The piezofilm (1x2 cm) laminated between two layers of woven thin (50 g/m²) polyamide fabric (11x15 cm).



Sample 2: The piezofilm (1x2 cm) laminated between one layer of polyamid warp-knitted spacer fabric (500 g/m²) and on layer of woven thin (50 g/m²) polyamide fabric (11x15 cm).



Sample 3: The piezofilm laminated between two layer of woven and heat calendered (350 g/m²) polypropylene fabric (11x15 cm).

These textiles were connected to a measurement set-up illustrated in figure 3.

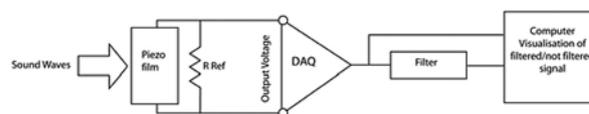


Figure 3. Measurement set-up.

Contact sound and air borne sound, were recorded via the textile into the computer for further analysis. We also made a reference test without any sound in order to measure each samples' passive condition. The contact sound was produced by scratching on the fabric sample while the airborne sound was produced by handclap. Each textile sample was investigated through identical audio tests in a vertical position allowing a free space around the sample and in a horizontal position on a contact surface.

RESULT AND DISCUSSION

The initial results in this projects show that the laminated piezoelectric film registers sound and the signal quality depends of the laminate set-up. Sample number 2 was the best performing sensor concerning both airborne and contact sound. Sample number 1 performs equal for airborne sound in a vertical position as sample 2. In a vertical position sample number 1 has the ability to sense contact sound as well as sample number 2. Sample 3 performs poorly in all positions and in relation to both types of sounds.

We expected the sample 1, the thinnest sample, to record sound better than the other samples. Instead the combination between a thin fabric and a spacer fabric showed to be most sensitive to both types of sound. A possible explanation could be the construction of the spacer fabric where the filaments are able to vibrate enhancing the sound signals. Concerning sample 3 the structure seems to be too stiff and compact for reinforcing sound signals. Thus it would be interesting to try out a combination between this fabric and a more thin and flexible fabric.

CONCLUDING REMARKS

Two directions are considered for the future work; systematic investigations of sound structures and applied design activities. An example of a further systematic investigation is to test the fabrics when they are exposed to a specific sine tone and in the same time record this tone with a conventional reference microphone. This procedure will make it possible to evaluate the quality of different frequencies in relation to each textile structure. The initial results show that sound is possible to record, but are the signals good enough to use in a sound application? In the applied design activities we will be able to test signal processing necessary for a certain application. This will probably also result in further adjustments of the piezoelectric structure. As described earlier the most interesting applications for us are active sound absorbing screens and medical application.

In active sound absorbing a microphone records a reference signal of the emitted sound and a loudspeaker sends out a sound with the same frequencies but in opposite face. This technique can be used in sound absorbing screens where both microphones and loudspeakers are integrated on the upper and lower parts of the screen (Figure 4). Passive screens are effective

sound absorbers of high and middle frequencies while active sounds absorbing technique make it possible to design screens also absorbing low frequencies. An additional positive aspect is that a small active screen performs as well as a bigger screen when this technique is used.



Figure 4. Prototype of an active sound absorbing screen.

The ability to record contact sound opens up for the recording of heart rate. In monitoring of heart rate using textile electrode it is necessary to have contact between the electrode and the skin. This has resulted in tight prototypes and poor comfort for the user. By measuring heart rate via piezoelectric structure it is not necessary to wear the prototype next to the skin which offers a more comfortable solution (Figure 5). A parallel measurement of breathing rate is also possible since piezoelectric structures are sensitive to stretch as well.

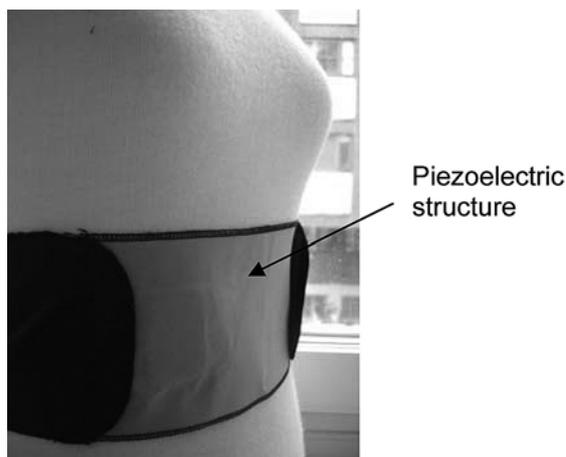


Figure 5. Prototype of a health monitoring belt.

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