# TRIBOELECTRIC SENSING SYSTEMS

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**Abstract**: Triboelectric phenomenon, historically, is one of many problems which engineers wanted to be avoid. However nowadays this phenomenon seems to be useful source of electrical signal for displacement measurement. In this work all sensing elements are made from pure PVDF by electrospinning manufacturing method. Nano fibres, which are result of the process are placed to aluminium foil naturally without mechanical rectifying. Used material was tested only for triboelectric charge generation, although piezoelectric phenomenon was expected. We were not able to quantify it by standard methods, probably due to chaotic structure and fabric behaviour of the final product. Triboelectric phenomenon is possible to measure directly, and systems are more predictable. Finally, two modes were tested, and potential advantages and disadvantages were qualified.

**Keywords**: EEICT, triboelectric, sensing, PVDF

## 1 INTRODUCTION

Triboelectric systems are very popular for energy harvesting purposes. It opens door for investigation of sensing possibilities in wide industrial branch and also for all sensing of natural process where any movement as acceleration are possible to measure. Triboelectric phenomenon could be used also for sensing of position. There are many applications: self-powered human motion sensors [1], self-powered automobile sensors [2]. Example of sensing is possible to see from [3]. Energy harvesting describe flexible Nano generators [4], internet of things [5], environmental monitoring systems [6]. There are also many other applications in biomedicine as non-invasive biomedical monitoring systems [7]. Our research is based on triboelectric active material where big advantage is large surface which is made by electrospinning method. We started with PVDF material, which could be promising also for piezoelectric potential.

## 2 MANUFACTURING OF ACTIVE MATERIAL

### 2.1 PVDF

Polyvinylidenfluorid material was made by electrospinning method. This procedure is very common for manufacturing of very fine non-woven fabric. Product of used machine is aluminium foil with dimensions 200x270 mm. We are able to change thickness of final product simply by change of manufacturing time. We used spined material on aluminium foil without removing it from substrate for all sensing elements, because it is very problematic procedure which ideally need very clean environment. We prepared material with compressed thickness from 20 to 100 µm. Fibres have diameter from 600 to 1200 nm, and it could be partially controlled by electric field between needle and substrate and partially also by chemical compounds of input solution.

### 2.2 SOLUTION

We used PVDF with molar weigh 275,000 g/mod (Sigma Aldrich, St. Louis, MO, USA). As solvents we used dimethylsulfoxide p.a. (DMSO, Sigma Aldrich, St. Louis, MO, USA) and acetone

(Ac, Sigma Aldrich, St. Louis, MO, USA). Solutions were electrostatically spined by machine 4spin (Contipro a.s., Dolni Dobrouc, Czech Republic), see **Figure 1**.


**Figure 1:** Electrostatic spin device 4spin

Fibres are possible to rectifier to one direction, or it is possible to place them random as non-woven fabric. We used non-woven example, see **Figure 2** for SEM image. We expect isotropic response of triboelectric phenomena from this arrangement for our experiment.

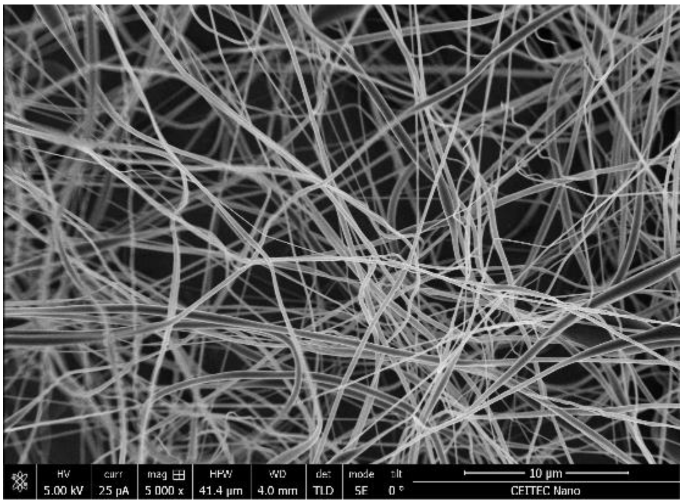


**Figure 2:** Non-woven fabric SEM image.

## 3 SENSING SYSTEM

### 3.1 FLEXIBLE ELECTRODE

We wanted to achieve permanent contact of electrode with PVDF material. The goal was to increase sensitivity of the system and provide good linear response to linear sinus displacement. Sensing element shown on the **Figure 3** is only part of future sensor, is necessary to say that sensing flexible membrane (ground electrode) is very sensitive on shape of exciting tool which is crucial for achieving acceptable distortion factor. We expect that sensing area don't exceed 100 $mm^2$ area.

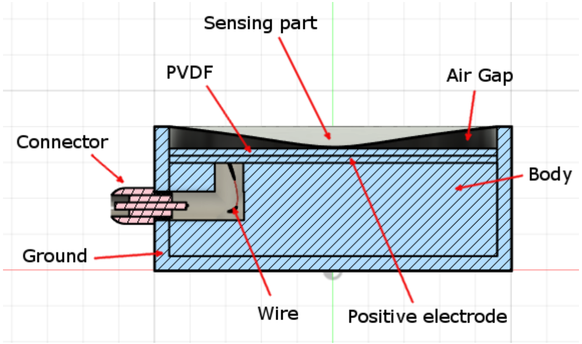


**Figure 3:** Principle of function of the sensing element “Flexible electrode”

### 3.2 EXPERIMENT

Original request of the device (sensing element) was designed for impulse input. We tested this sensing element by impulse excitation. Impulse is 5ms wide, repeating frequency was 1 Hz. Maximal applied displacement was 1.2 mm.

Sensitivity (Change of charge vs change of displacement) was measured by electrometer (charge amplifier) Keithley 6517b (Keithley, USA). Mechanical displacement was controlled by vibration testing system TV 50018 (Tira, Germany). Displacement was measured by interferometer ILD 1402-10 (Micro Epsylon, Germany). It is possible to see on **Figure 4**. Capacity in not loaded conditions was 38 pF.

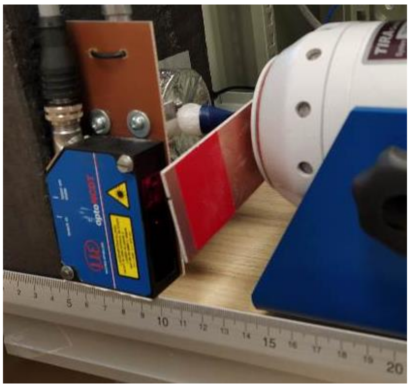

**Figure 4:** Testing apparatuses of the “Flexible electrode” sensing system

Is possible to see that sensing element indicate very promising sensitivity. For details see **Figure 5** a) which show response in time domain and **Figure 5** b) which report charge response for different amplitudes of impulses applied. Graph **Figure 5** b) shows good linearity of output charge with increasing displacement of impacts.

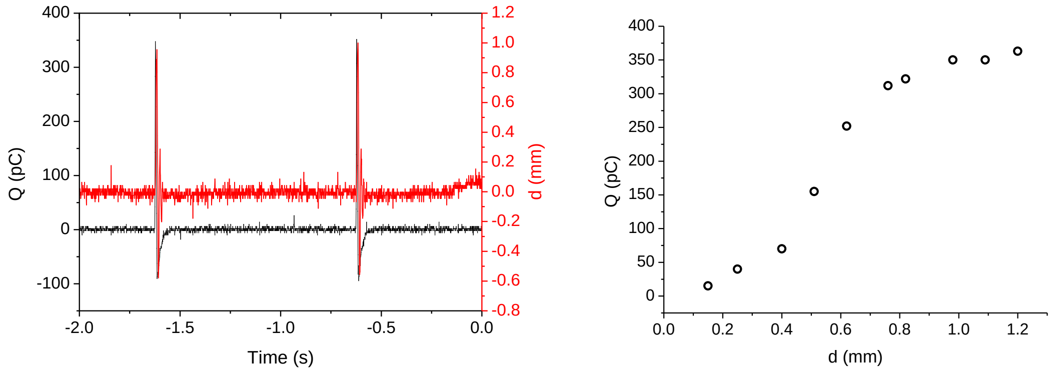


**Figure 5:** charge response a) in time domain and b) charge response for different amplitude of impulse

The sensing element was exposed to different repeat frequency of impulses, for detail see **Figure 6**. There is possible to see constant response with different frequency applied. This stability is very welcomed feature for future applications for sensing purposes.

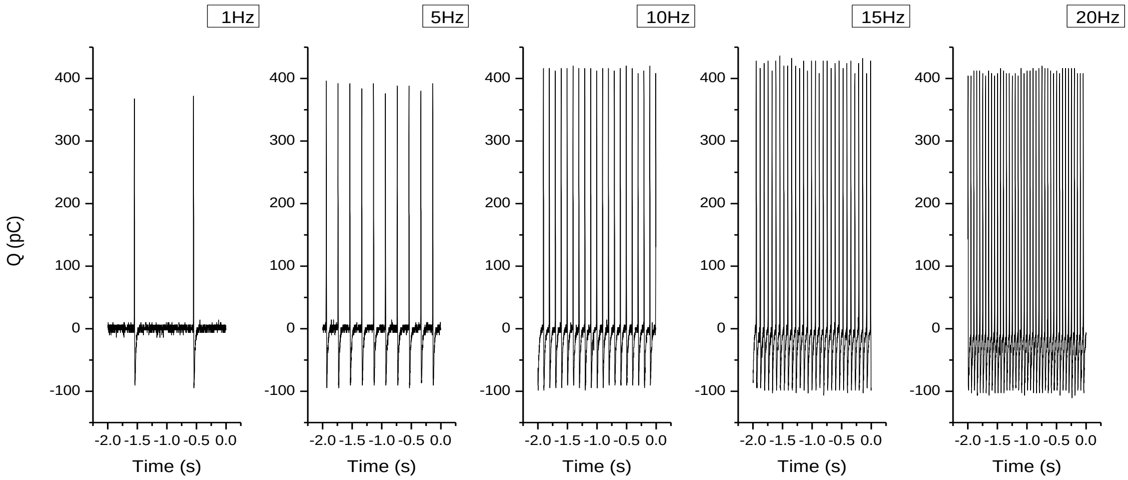


**Figure 6:** Charge response for different repetition frequency

Sensing element didn´t fulfil request for response to slow linear sinus excitation for very low frequencies, it is possible to see on **Figure 7** a). The reason is probably in not guaranteed contact of electrode to PVDF all time of working process, this is space for improve of the design. Higher frequencies don't show such big problems as is possible to see on **Figure 7** b), but there is still possible to see small distortion of output signal.

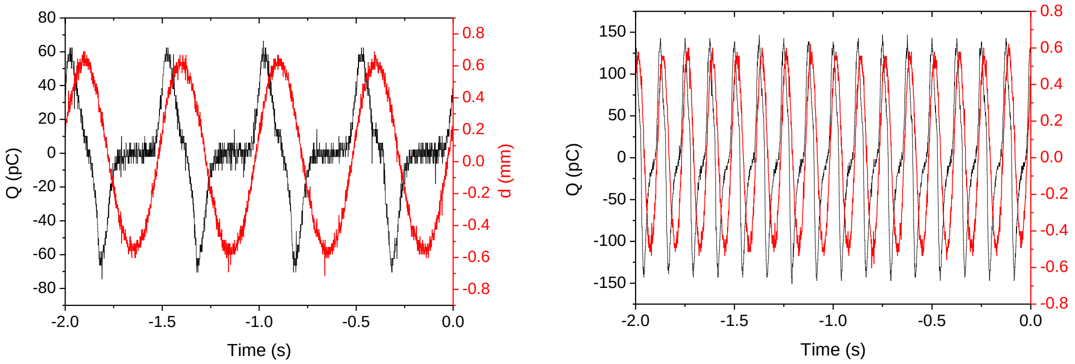


**Figure 7:** Charge response to linear sinus excitation for frequency: a) 2 Hz and b) 8 Hz

## 4 CONCLUSION

The “Flexible electrode” sensing system seems very promising due to high sensitivity and finally the element could be tuned for achieving also requested linearity. Original idea is to use vacuum between PVDF fabric and Flexible membrane, this could guarantee permanent contact of electrode which is crucial for linear response and second welcomed benefit could be increasing of sensitivity due missing atmosphere.

System is suitable for impact measurement. Sensing system is very sensitive, and it could be suitable for pressure change monitoring. The system in bigger configuration could be possible to use for self-power applications as energy harvesting unit due to high sensitivity. This kind of design has also potential to be very thin and could be implemented in many applications.

Advantage of this sensing system compared to conventional piezoceramics is friendly, low-cost economic manufacturing process without lead and other toxic substances.

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