Locally Actuated Electrospun Piezoelectric Webs

Giulia Lanzara*, **Federico Fabriani**, Edoardo Bemporad
Department of Engineering, University of Rome Tre, Rome, Italy
*giulia.lanzara@uniroma3.it

Abstract. Piezoelectric materials are widely used for sensing and actuation for structural control and heath monitoring systems. The rapid development of multifunctional materials is requiring advances of piezoelectric devices in order to favour flexibility, lightness and tuneable material responses over time and over the material domain. Current materials are not suitable for such purpose. In this work a novel intelligent membrane is presented. The membrane forms a net of electrospun piezoelectric porous filaments that electromechanically work independently one to the other allowing local actuation and sensing capacity over the net extension. The functionality of the net as well as the dynamic response of the filaments, as individual elements and, will be discussed in detail.

Introduction

Development of technology and the use of smart materials is allowing the realization of devices that are increasingly functional, flexible, non-invasive and ultralight. Electroactive polymers (EAP), among which piezoelectric polymers, are among the intelligent materials most widely used. Indeed, piezoelectric polymers are an excellent candidate for the manufacture of sensors or actuators thanks to their excellent properties, such as high flexibility, lightness and non-invasiveness [1-2]. Electrospun polyvinylidene fluoride (PVDF) piezoelectric fibres, in addition to possessing these characteristics, can acquire excellent piezoelectric properties directly with a manufacturing process known as electrospinning. This is in contrast with standard polarisation processes, that are costly and time consuming, which are typically performed as a step that follows the material production. In electrospinning the fibres are subjected to a high electric field and mechanical stretching, which enables the direct transformation of the non-polar phase into the polar phase [3]. For this reason, in this paper, electrospun PVDF fibers are used for the fabrication of an intelligent membrane, consisting of electromechanically independent filaments, which allow localised actuation. The functional capability and the piezoelectric response of the membrane are studied through dynamic characterization.

Results and discussion

PVDF fibers are manufactured by electrospinning. The process parameters, such as flow rate, tension and distance between the collector and the needle, are tuned to achieve fibres with a uniform diameter and without any defects (Fig.1 left).

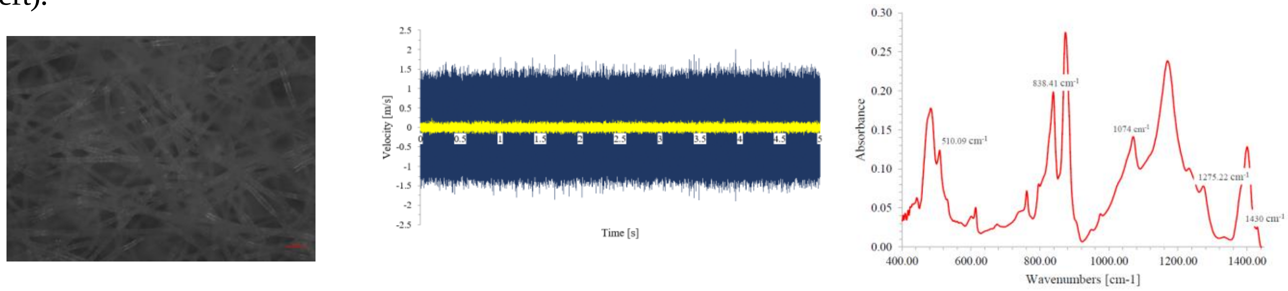

Figure 1: left) Optical image of PVDF electrospun fibers; right) FT-IR spectrum of PVDF fibers; center) Dynamic response of the mat.

Mechanical stretching and high electric field allow the material to be polarised directly in situ, transforming the non-polar phase into a polar one. The correct polarisation is verified by a Fourier transform infrared spectroscopy (FT-IR) analysis. The results are shown in the right-hand side of Fig. 1, where it is evident the presence of the characteristic bands of the polar phase, while those of the non-polar phase are absent. After the molecular characterization, a study in dynamic regime is carried out to study the material actuation induced by the inverse piezoelectric effect of the material. When an electrical input is applied, the material produces a mechanical output, which can be interpreted in terms of dynamic vertical displacement or vibration. Fig. 1 (center) shows the dynamic response recorded by a laser Doppler vibrometer (Polytec, MSA-500 Micro System Analyzer), both in the case where no signal is applied (yellow curve) and in the case where an AC electrical signal with a precise frequency is applied to the sample. As can be seen, the signal significantly excites the fibers producing considerable vibrations. Moreover, the frequency of these oscillations is equal to that of the applied signal, confirming a correct actuation phenomenon, since all the electrical signal is converted into mechanical energy.

References

[1] Bar-Cohen, Yoseph, and Iain A. Anderson. "Electroactive polymer (EAP) actuators back-ground review." Mechanics of Soft Materials 1.1 (2019)
[2] Bae, Ji-Hun, and Seung-Hwan Chang. "PVDF-based ferroelectric polymers and dielectric elastomers for sensor and actuator applications: a review." Functional Composites and Structures 1.1 (2019)[3] Baji, Avinash, et al. "Electrospinning induced ferroelectricity in poly (vinylidene fluoride) fibers." Nanoscale 3.8 (2011).