Sensing Sound with Electrospun Piezo Materials on a 3D-Printed Structure

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Abstract. The acoustic sensing capability of a non-woven textile made of piezoelectric nanofibers electrospun on a 3D-printed cellular structure, is investigated in this paper. The non-woven textile is made of a complex aggregation of piezoelectric nanofibers that form a porous material. The electro-mechanical response of the textile once exposed to a sound source, is monitored through metallic electrodes that, in a sandwich configuration, let the non-woven textile be directly exposed to sound. The functionality of this unique acoustic sensor was then validated by comparing the sensors response and the response of a commercial microphone when subjected to a 3-minute sweep sound from 10Hz to 10KHz, being the sound source placed at 3cm. The preliminary results confirmed the capability of this textile to greatly monitor acoustic waves with highest performance between 600 and 900 Hz. Such a frequency range makes these devices interesting to be used for micro-damage detection via ultra-light acoustic monitoring.

Introduction

Structural health monitoring systems (SHM) represent a promising solution to deliver structures that can function for an extended lifetime while improving their performance and reliability. Several are the works in the literature showing the capability of piezoelectric sensor/actuator arrays mounted or embedded in structures for structural health monitoring. Despite the extended work in the literature to minimize the impact of such systems in a hosting material or structure [1], there are still challenges to be solved with respect to the material integrity and networks complexity. Recent trends are looking into the development of non-contact approaches, to assess structural integrity. Among those, acoustic waves have been proposed in the literature taking advantage of the fact that such waves are released by a material when damaged [2]. Acoustic monitoring instead is not as established as the PZT technology. The few studies in the literature show the conceptual feasibility in using acoustic waves for structural monitoring with the support of external and large-in-scale microphones. Despite the interesting outcomes of these initial studies, the major limitation is obviously related to the complexity in coupling and isolating such microphones to a structure or material. For this reason, this approach has not been widely explored so far. A great potential to overcome the major limitations in sound monitoring for structural damage, can be found in the usage of novel multifunctional nanostructured materials which could be directly coupled with the structure. With this in mindIn this paper an acoustic sensor made of a piezoelectric fiber mat electrospun directly on a 3D-printed cellular structure is explored and characterized in its frequency response.

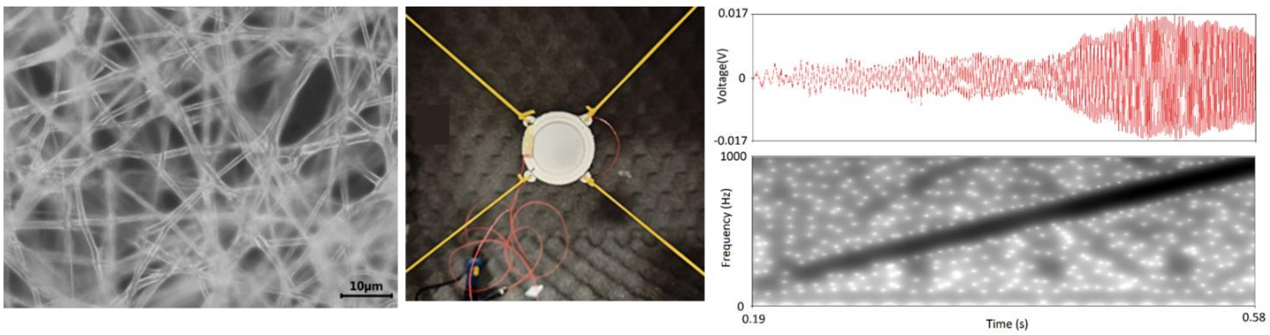

Figure 1: (Left) Electrospun micro-fiber mat; (Center) Suspended hybrid device; (Right) Voltage vs. Time and Spectrogram.

Hybrid cell design and results

A hybrid acoustic sensing device made of a piezoelectric non-woven textile fabricated directly on a 3D-printed, flexible, cell structure, is presented in this paper. This material is fabricated by electrospinning a piezoelectric polymer in the form of nano/microfibers assembled in a random configuration, giving rise to an ultra-light and mechanically flexible porous mat. The electromechanical response of such a mat, when it is exposed to an acoustic wave, is recorded with the support of an oscilloscope. The response of the mat is superior with respect to a commercial microphone because it allows the detection of a pure signal, is lighter, more flexible in its installation and its response frequency can be fine-tuned with that desired for a specific application. Such characteristics make it ideal for the implementation of an unconventional and indeed non-contact monitoring device, as, for instance, for micro-damage detection.

References

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