Macromolecular Symposia

Macromolecular Symposia

CONFERENCE Times of Polymers and Composites 2025 (TOP25)

www.ms-journal.de

RESEARCH ARTICLE OPEN ACCESS

Nanofibers for Sound Absorption—A Preliminary Investigation

Emanuele Manzi[1] | Emanuele Maccaferri[1,2] | Vincenzo Pettoni Possenti[3] | Gioia Fusaro[3] | Luca Barbaresi[3] | Tiziana Benelli[1,2] | Laura Mazzocchetti[1,2] | Loris Giorgini[1,2]

[1]Department of Industrial Chemistry "Toso Montanari", University of Bologna, Bologna, Italy | [2]Interdepartmental Center for Industrial Research On Advanced Applications in Mechanical Engineering and Materials Technology, CIRI-MAM, University of Bologna, Bologna, Italy | [3]Department of Industrial Engineering, University of Bologna, Bologna, Italy

Correspondence: Emanuele Manzi (emanuele.manzi2@unibo.it) | Laura Mazzocchetti (laura.mazzocchetti@unibo.it)

Received: 24 March 2025 | **Revised:** 24 March 2025 | **Accepted:** 7 November 2025

Guest Editors: Alberto D'Amore and Luigi Grassia

Keywords: electrospinning | nanofibers | nanofibrous morphologies | sound absorption

ABSTRACT

Noise reduction is included in the main tasks to deal with when working in the field of automotive and aerospace industries. When trying to improve comfort, it is crucial to research and enhance acoustic properties. Nanofibers can be a viable solution to address sustainability and noise absorption while ensuring material savings through lightweight nonwoven mats. They are also very intriguing for potentially improving the acoustic properties of conventional materials even in combination with them. The process and connection between improved noise absorption and nanofibrous membranes are still not fully known or confirmed. For this reason, in this preliminary study different nanofibrous morphologies are obtained via electrospinning, leading to the possibility to correlate acoustic absorption with nanoscale morphologies, mainly focusing on nanofibers' diameter, which is easily tailorable. For this reason, an impedance tube was used to draw a first measurement method approach.

1 | Introduction

Sound-absorbing systems are commonly used in engineering applications to control the sound within an enclosed environment (whether it is a building, a car, or an airplane) to improve user comfort from various perspectives (from hearing protection to speech intelligibility). Sound-absorbing systems generally come in the form of porous or fibrous materials, such as foam layers or mineral wool, and are capable of absorbing/dissipating the incident sound energy. Their main purpose is to reduce the reflection of sound waves, thus decreasing the amount of sound energy that remains within an enclosed environment. Each material differs from others based on the amount of energy it can absorb and the frequency range over which it is more effective. The absorption capacity is quantified by the apparent sound absorption coefficient α, defined as the ratio of non-reflected sound energy over incident sound energy. Sound absorption coefficients of a given material with specific morphological characteristics ranges between 0 and 1 based on the incident wave. Typical absorbing materials are porous and characterized by absorption coefficients that increase with frequency [1]. Generally common absorbing materials are voluminous, thus increasing weight and dimension of the manufactured they are inserted in. To overcome this limitation, the use of nanofibrous system is appealing and promising, since it allows weight and space reduction, while opening the possibility to tailor the absorption properties by tuning morphological parameters like nanofibers' diameter and mat grammage [2]. There are several methods for determining the acoustic properties of a material in its prototyping step. In particular, impedance tube measurements

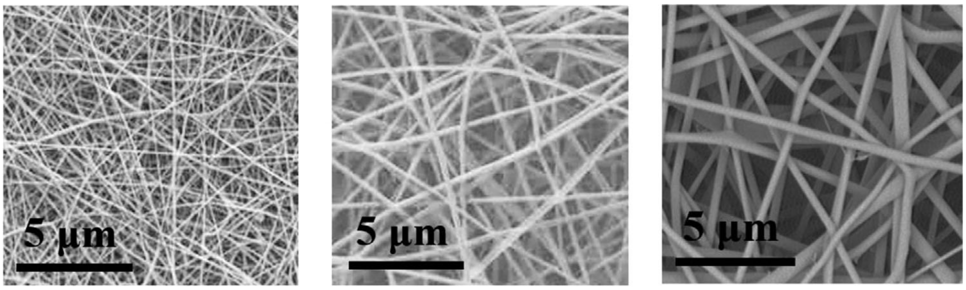

FIGURE 1 | SEM micrographs of Ny180, Ny400, and Ny600 from left to right, respectively.

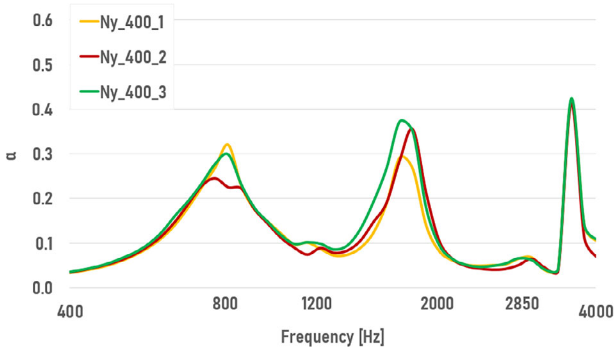

FIGURE 2 | Sound absorption coefficient versus frequency in logarithmic scale of three samples of nanofiber with 400 nm diameter (Ny_400) to understand the repeatability of the measurements.

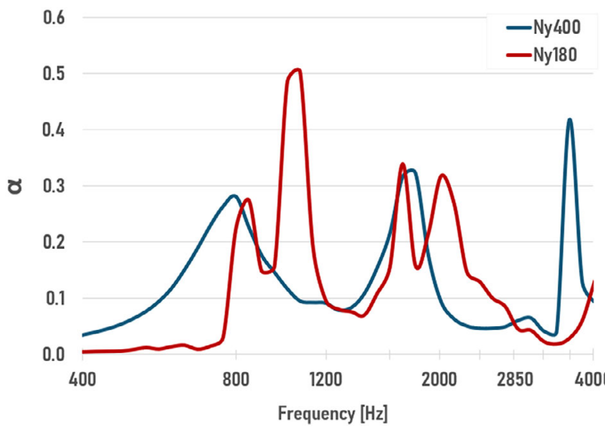

FIGURE 3 | Sound absorption coefficient versus frequency in logarithmic scale of nanofiber with 400 nm diameter (Ny_400) and 180 nm diameter (Ny_180).

are one of the most solid and popular method to investigate sound absorption under plane wave incidence condition [1, 3]. However, the sector of sound absorption using nanofibrous network has not been widely explored, therefore a standardized and optimized method for these nanoscale materials has not been outlined yet.

2 | Results and Discussion

In order to produce a wide insight into the effect of nanofibrous morphologies on acoustic properties, Nylon 6,6 membranes with increasing nanofibrous diameter have been produced via electrospinning. In Figure 1 SEM micrographs of the obtained membranes are reported, highlighting the "cylindrical" shape of the fibers regardless of the diameter. The membranes also display a high level of homogeneity.

The analysis of the acoustic properties of the membranes has been conducted using a rigid backing cavity (RBC) as impedance tube end, as demonstrated in the work by Pettoni Possenti et al. [4].

To see the effects on acoustic properties when changing the diameter of the nanofibers, two membranes were tested with diameters of 400 nm (Ny_400) with 11 $g \cdot m^{-2}$ and 180 nm (Ny_180) with 7 $g \cdot m^{-2}$, respectively. First, the 400 nm diameter membrane was measured to test the repeatability of the measurement in the impedance tube for this particular type of material. To do this, three membranes from the same sample were taken. Figure 2 shows the sound absorption coefficient (α) versus frequency in a logarithmic scale. The results are filtered in 1/12-octave bands. From the graph, it can be seen that the measurement is quite stable. The repeatability is particularly effective at high-frequency range (3600 Hz), however, the peak frequency is also repeatable at lower frequency range (800 and 1800 Hz) with a variation of ± 0.05.

Then, the acoustic performance of the membrane with 180 nm diameter (Ny_180) and 400 nm diameter (Ny_400) were compared as can be viewed in Figure 3. Also in this graph, the results were filtered in 1/12-octave bands. From the graph, it can be seen that decreasing of the fibers' diameter results in an increase in the α peak frequency. In particular, the first absorption peak at 800 Hz for the 400 nm diameter sample (Ny_400) is 200 Hz below the 180 nm diameter sample (Ny_180) peak frequency (1000 Hz). Similarly, between the second absorption peak at 1800 Hz for the Ny_400 sample and the second one for the Ny_180 sample (2000 Hz) there is a gap of 200 Hz.

According to the results, it is reasonable to assume that the frequency of the first resonance peak increase when the fibre diameter of the nanofibrous membrane decreases.

3 | Conclusion

In this work, optimized electrospinning parameters allowed to produce defect-free nanofibrous membranes made of Nylon 6,6 nanofibers with 180, 400, and 600 nm diameters. This preliminary study of the first two samples showed that there is an effect of nanofiber diameter on the sound absorption properties. In

TABLE 1 | Electrospinning parameters for the produced Nylon 6,6 nanofibrous membranes.

Membrane	Solution concentration (% wt.)	Flow rate (mL·h^{-1})	Voltage (kV)	Needle to collector distance (cm)	Mean fiber diameter
Ny180	**9**	**0.3**	**22**	**7**	**180 nm**
Ny400	**18**	**0.8**	**25**	**7**	**400 nm**
Ny600	**18**	**0.7**	**24**	**9**	**600 nm**

particular, the smallest fiber diameters resulted in higher frequencies of the sound absorption peak, confirming the presence of a trend in the relation between noise absorption and nanofibrous morphology. In addition, repeatability measurements showed good results ensuring robustness of the method used. Future tests on 600 nm nanofibers will be useful to better outline the effect of fiber diameter on sound absorption. The preliminary results here presented highlight the capacity of nanoscale structures to provide some sound absorption and pave the way to the development of nanofibrous networks with controlled and tailored morphologies to optimize the acoustic properties of the final material.

4 | Materials and Methods

Nylon 6,6 is by Zytel E53 NC010 (DuPont). The solvents, trifluoroacetic acid (TFA), formic acid and chloroform, were purchased from Sigma-Aldrich and used without further purification. Nylon 6,6 solutions were prepared according to the procedure previously reported in the paper by Maccaferri et al. [5]. Nylon 6,6 membranes were obtained by means of an electrospinning machine (LabUnit from Spinbow). The system used features four 5 mL glass syringes connected to needles with an internal diameter of 0.84 mm using flexible Teflon tubes. The nanofibers were deposited on a rotating drum, moving at a speed of 50 rpm, on which a sheet of polythene-coated paper was placed beforehand. Particularly, nanofibers having a mean diameter of 180, 400, and 600 nm, were targeted and obtained just by changing solution parameters (concentration) and process ones (voltage, flow rate, needle-collector distance). In Table 1 the optimized parameters are reported.

The membrane images were obtained by SEM (PhenomProX). Sound absorption coefficient measurements were carried out using a 40 mm diameter impedance tube.

Acknowledgements

This research was funded by the European Union—NextGenerationEU (National Sustainable Mobility Center CN00000023, Italian Ministry of University and Research Decree n. 1033 - 17/06/2022, Spoke 11 - Innovative Materials & Lightweighting) and Project Ecosister—Ecosystem for Sustainable Transition in Emilia-Romagna, Project funded under the National Recovery and Resilience Plan (NRRP), Mission 04 Component 2 Investment 1.5 – NextGenerationEU, Call for tender n. 3277 dated 30/12/2021, Award Number: 0001052 dated 23/06/2022, within Spoke 1 activities—Materials for sustainability and ecological transition—(CUP J33C22001240001).

Open access publishing facilitated by Universita degli Studi di Bologna, as part of the Wiley - CRUI-CARE agreement.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. T. D. Rossing, ed., *Springer Handbook of Acoustics*, (Springer 2007), https://doi.org/10.1007/978-0-387-30425-0.

2. A. Hurrell, K. V. Horoshenkov, S. G. King, and V. Stolojon, "On the Relationship of the Observed Acoustical and Related Non-Acoustical Behaviours of Nanofibers Membranes Using Biot- and Darcy-Type Models," *Applied Accoustics* 179 (2021): 108075, https://doi.org/10.1016/j.apacoust.2021.108075.

3. D. Urbán, N. B. Roozen, V. Jandák, M. Brothánek, and O. Jiříček, "On the Determination of Acoustic Properties of Membrane Type Structural Skin Elements by Means of Surface Displacements," *Applied Sciences* 11, no. 21 (2021): 10357, https://doi.org/10.3390/app112110357.

4. V. Pettoni Possenti, E. Maccaferri, G. Fusaro, L. Barbaresi, and L. Mazzocchetti, "Preliminary Investigation of Nanofibrous Membranes for Sound Absorption," *INTER-NOISE NOISE-CON Congress and Conference Proceedings* 270, no. 4 (2024): 7051–7057, https://doi.org/10.3397/IN_2024_3903.

5. E. Maccaferri, D. Cocchi, L. Mazzocchetti, et al., "How Nanofibers Carry the Load: Toward a Universal and Reliable Approach for Tensile Testing of Polymeric Nanofibrous Membranes," *Macromolecular Materials and Engineering* 306, no. 7 (2021): 2100183, https://doi.org/10.1002/mame.202100183.