September 2024, Vol:2, Issue:2

International Journal of New Findings in Engineering, Science and Technology

journal homepage: *https://ijonfest.gedik.edu.tr/*

The Characterization of Electrospun PANI/PEO Nanofibers at Different Electrospinning Conditions at Room Temperature

Gözde KONUK EGE [a*], Özge AKAY SEFER [b], Hüseyin YÜCE [b]

[a] *Istanbul Gedik University, Istanbul, 34913, Turkey, gozde.konuk@gedik.edu.tr (*corresponding author)*
[b] *Marmara University, Istanbul, 34722, Turkey, ozge.akay@marmara.edu.tr, huseyin@marmara.edu.tr*

Abstract

Nanofiber structures boast a broad range of applications due to their excellent properties, spanning from sensor technologies and biomedical systems to tissue engineering and drug delivery systems.
Nanofiber structures have wide usage area thanks to their excellent properties from sensor technologies, biomedical systems to tissue engineering, drug delivery systems. Electrospinning method is a versatile method that can produce very fine nanofibers with a simple production mechanism. On the other hand, it is important to optimize the fabrication parameters in order to obtain the appropriate nanofiber structure. In this study, PANI/PEO (Polyaniline/Polyethylene oxide) electrospun nanofibers are fabricated under ambient conditions and the effects of solution viscosity and collector rotation speed on fiber structure are discussed. Electrospun PANI/PEO nanofibers structures are investigated by scanning electron microscope (SEM). According to the SEM results, it is seen that the high viscosity nanofibers have straight and rigid structures. However, the low viscosity nanofiber structures break down at each collector speed, but the fiber orientations increase as the collector rotation speed increases. It is estimated that this study will be guide for future work on PANI.

Keywords: *PANI, Nanofiber, Electrospining, Viscosity*

1. INTRODUCTION

Nowadays, technological developments are quite related to the properties of new generation materials. Especially one-dimensional (1-D) nano-materials (nanotubes, nanowires, nanofibers, etc.), offers innovative approaches in terms of miniaturization, lightweight, flexibility and unique electrical, mechanical, optical and magnetic properties [1–5]. Nanofibers are utilized across a vast array of applications due to their exceptional qualities, straightforward manufacturing processes, and the diversity of materials available [6]. High surface-area-to-volume ratio and porosity [3, 4, 7] is unique specifications of nanofibers that ensure high performance in gas sensing process [8]–[12] and it allow multidisciplinary usage area such as membrane utilization [13–15], biomedical applications-tissue engineering [3, 16, 17], textile [5] and defense industry [18, 19].

In addition to the electrospinning method, which is one of the well-known techniques in nanofiber production, mechanical drawing, self-assembly, hydrothermal processing, melt blowing, extraction, phase separation, vapor phase polymerization, mold synthesis and solvent casting methods have also been used [20]. Polymeric materials,

https://doi.org/10.61150/ijonfest.2024020202

metals, small molecules, composites, colloids are used in the production of nanofibers by electrospinning [20, 21]. Electrospinning has a simple set-up structure due to its simple working principle which is based on electrohydrodynamic process and high electrical voltage [21]. Electrospinning set-up consists of three parts: the supply unit, where the power supply is located, the spinneret and the collector unit. Electrospinning suspension parameters such as viscosity, conductivity, molecular weight and the solvents used to prepare the solution are important for the success of nanofiber production. Besides, feed speed, application voltage, distance between needle-collector and needle diameter are factors that affect nano-fiber diameter and quality. Along with these specifications, environmental temperature and humidity are another important factors that should not be ignored in fiber production [21].

Polyaniline (PANI) is one of the most well-known conductive polymers due to its easily reversible conductor-insulator properties with dopants, easy synthesis/processability and fine optical and magnetic properties [4, 6]. 1-D applications of PANI have quite remarkable features compared to conventional PANI and its thin-film applications. As well as the only-PANI nanofiber structure can be produced with electrospinning, the composite structures of PANI with metal oxides or natural fibers are also have quite application area especially in sensor and membrane processes [8, 9, 22–25].

In this study, PANI/PEO composite nanofibers were produced by electrospinning method. PEO were used as a carrier polymer in electrospinning suspension. Electrospun nanofibers are fabricated under ambient conditions and the effects of solution viscosity and collector rotation speed on fiber structure are discussed.

2. EXPERİMENTAL SETUP

2.1 Materials

PANI emeraldine-base (Mw = 50,000), PEO (Mv = 900,000), camphor sulfonic acid (CSA) and sodium dodecyl sulfate (SDS) were purchased from Sigma-Aldrich. Chloroform and dimethylformamide (DMF) which are used to prepare PANI/PEO solution and other chemicals were purchased from Merck and other commercial sources as guaranteed-grade reagents and used without further purification.

2.2 Preparation of PANI/PEO Suspension

PANI solution were prepared two different concentrations at 2% and 3% v/w ratios. CSA was added at 1:1,5 (PANI:CSA) to protonate the PANI and they were stirred in Chloroform:DMF 1:1 suspension for 24h at room temperature. Then, PEO were added 1:1 (PANI:PEO) in the PANI suspension and the mixed PANI/PEO suspension stirred at 1000 rpm for 24h at room temperature. Viscosity and conductivity values of each polymer solution were measured by Brookfield viscometer and electrical conductivity device (Table1).

Table 1. Viscosity and conductivity values of polymer suspensions

Polymer Suspension	Viscosity (cp)	Conductivity (µS/cm)
PANI-1	220	653 - 21,5°C
PANI-2	117,5	623 - 21,5°C

2.3 Electrospining parameters of polymer suspensions

Electrostatic force is used to produce nanofibers. Due to the electrostatic force, the surface tension of the electrically charged polymer solution is overcome and the polymer jet is formed. The polymer solution, which is

sent to the nozzle in a controlled manner with a pump, tends to elongate owing to the electrical force and is collected on the collector by forming a cone form called a taylor cone [26].

Table 2. Electrospining parameters of polymer suspensions

Polymer Suspension	Viscosity (cp)	Collector Speed (rpm)	Voltage(kV)
A-PANI-1	220	100	25
B-PANI-1	220	300	25
C-PANI-2	117,5	100	25
D-PANI-2	117,5	300	25
E-PANI-2	117,5	500	25

In this electrospining process, NE300 Nano Spinner device were used. Electrospining set-up is shown in Figure 1.

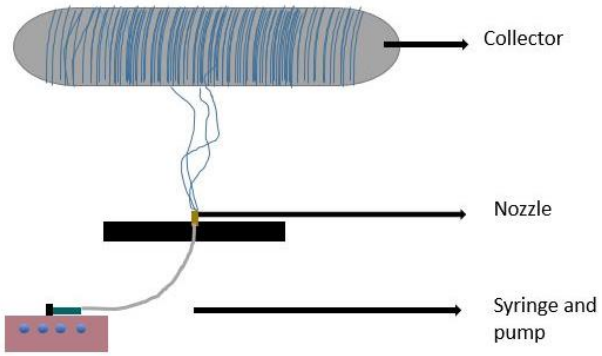


Figure 1. Electrospining Set-Up

PANI/PEO suspensions were added in 10mL syringe. The feed rate was 1.3 mL/h and the applied voltage was 25kV to generate potential difference between the nozzle and the collector. The distance between the nozzle and the collector was 20cm. The electrospining process were performed with 18-gauge nozzle. Each electrospinning process were performed 30 minutes at 23°C-38%RH.
PANI/PEO suspensions were added in 10mL syringe. The feed rate was 1.3 mL/h and the applied voltage was 25kV to generate potential difference between the nozzle and the collector. The distance between the nozzle and the collector was 20cm. The electrospining proses were performed with 18-gauge nozzle. Each electrospinning process were performed 30 minutes at 23°C-38%RH. Electrospining parameters of polymer suspensions are shown in Table 2. PANI/PEO polymer solutions prepared at a ratio of 1.5% v/w and 1.35% v/w with viscosity of 220 cp and 117.5 cp were electrospinned at collector rotational speeds of 100, 300, 500 rpm. (Table 2). In the optimization studies, the effects of electrospinning parameters, polymer concentration, solution viscosity on the nanofiber structure were investigated. The obtained nano-fiber structures were examined with the SEM analysis device, and the appropriate production conditions and solution concentration values were determined.

3. RESULTS AND DISCUSSION

The Electro-spinning parameters affecting the properties of nano-fibers have been the focus of attention of researchers in electrospining processes. In our work, we focused effects of the polymer suspension viscosity and

collector speed on the nano-fiber orientation. PANI is one of the most studied polymers among conductive polymers [25]. Although there are studies on electrospinning of PANI in the literature, the effect of collector speed has not been discussed yet. In this respect, our study is important for the literature. Structural and morphological analyzes of nano-fibers were analyzed by SEM and FT-IR methods.

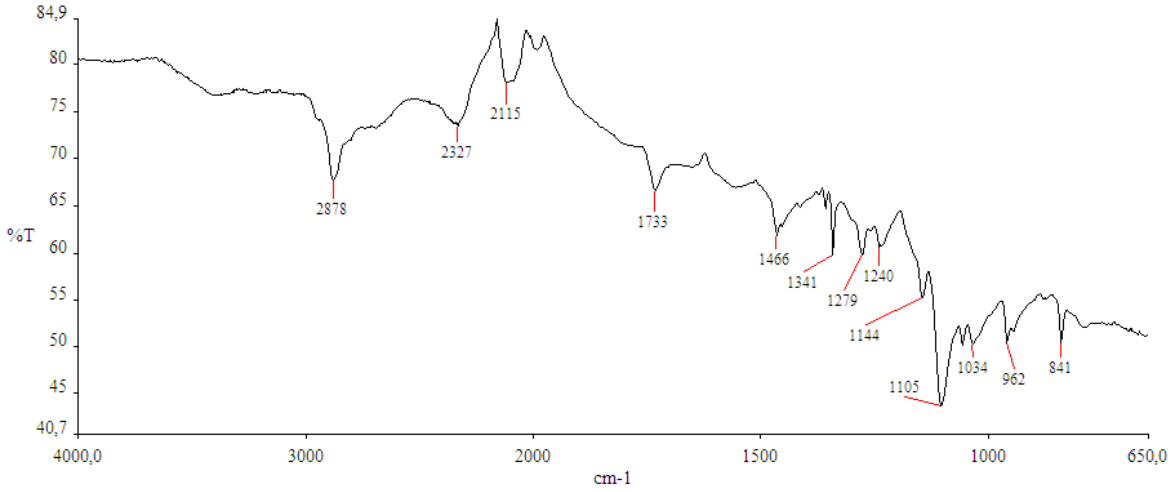
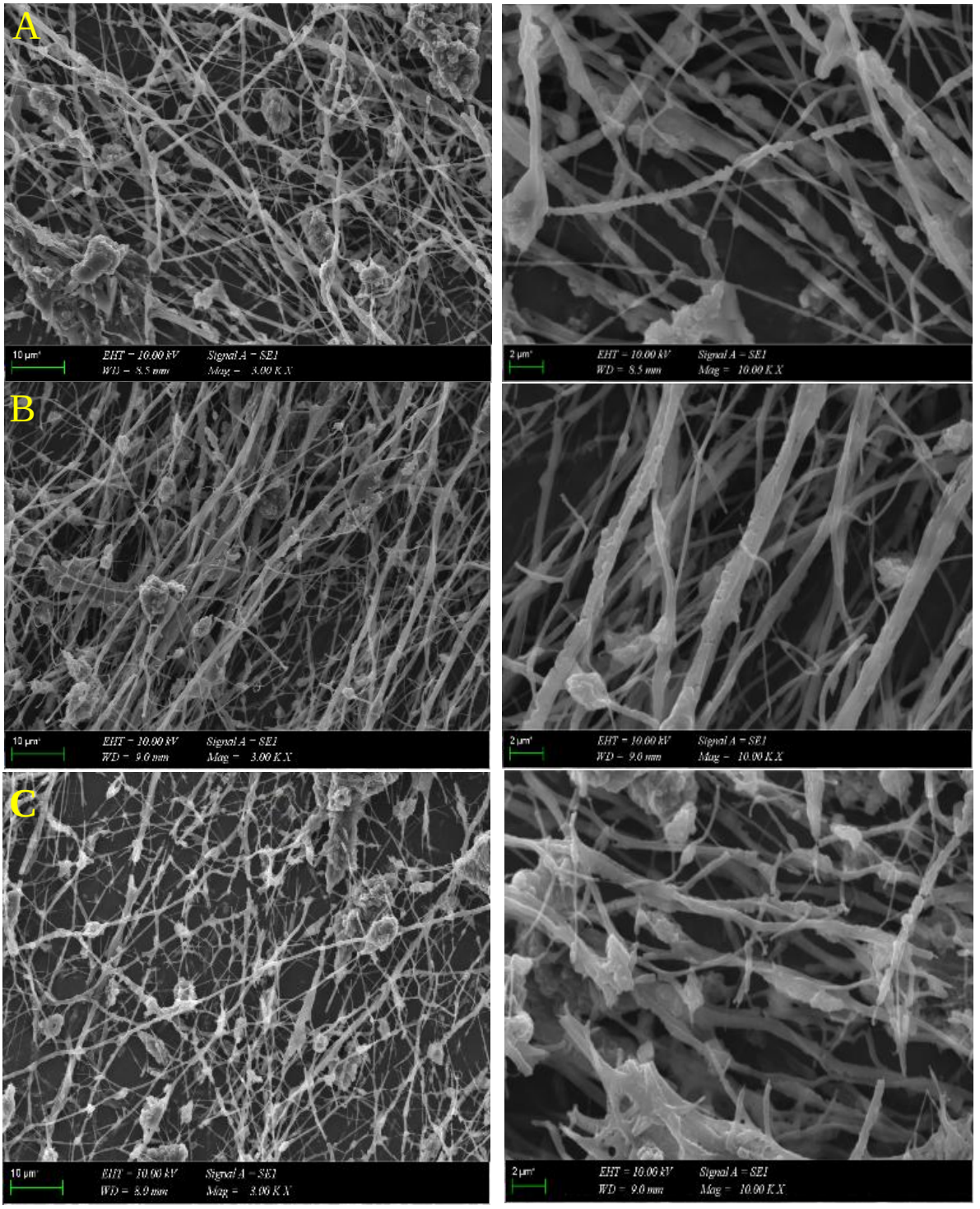


Figure 2. FT-IR Spectra of PANI/PEO

The Perkin-Elmer FT-IR Spectrometer were used to determined functional groups of the PANI /PEO nanofibers. Structures of electrospun PANI/PEO nano-fibers were investigated by Zeiss-Evo Ma10 Scanning Electron Microscope. Through the electrospining process varying conditions affects nano-fiber properties. In this present work, we want to investigate the effects of polymer solution viscosity and collector speed.

Figure 2 shows FT-IR Spectra of PANI/PEO. It is seen a broad peak at the 3,330 cm^{-1} region because of the O—H groups. C—H aliphatic bond were shown at 2878 cm^{-1} peaks region. Peaks at 1,466cm^{-1} region because of C═N, 341 cm^{-1} and 1,279 cm^{-1} were corresponding C—N, peaks at 1034 cm^{-1} and 962 cm^{-1} regions relevent to C—H aromatics and also 841 cm^{-1} peaks were demonstrated of SO_3 group [1].

Figure 3 demonstrates the SEM images of PANI/PEO nanofibers with the difference of viscosity and collector speed of PANI/PEO changes the morphology of the nanofibers. Two different PANI solutions with 220 cp and 117,5 cp viscosity were produced on a collector at different speeds at constant feed rate and voltage. The structure of the electrospun PANI nano-fibers were investigated. The syringe feed rate was 1.3 mL/h and the voltage was 25 kV. The distance between the nozzle and the collector is 20 cm. PANI nanofibers (sample A and B) with a solution viscosity of 220 cp were produced in a collector with a rotational speed of 100 rpm and 300 rpm. The structure of PANI nanofibers is shown in Figure 3 (A-B). PANI nanofibers with a solution viscosity of 117,5 cp were produced in a collector with a rotational speed of 100, 300 and 500 rpm at the same feed rate and power.



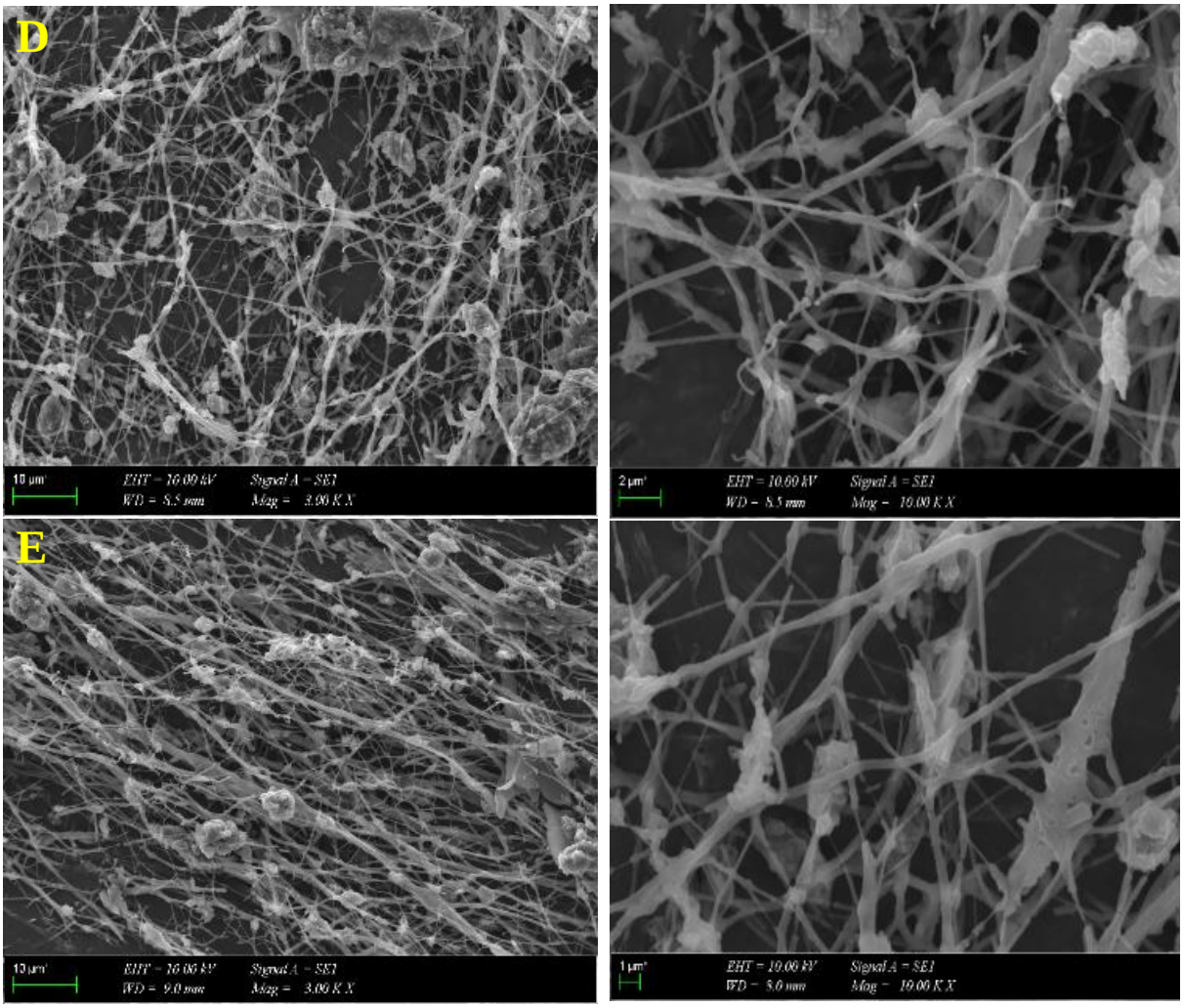


Figure 3. SEM images of PANI.CSA/PEO

Structures of these electrospun nanofibers are shown in Figure 3 (C-E). According the SEM results, as the polymer viscosity decreases, the polymer jet breaks up before it reaches the collector. Accordingly, when the fiber structures in Figure 3 are observed, it is seen that the nano-fiber structures with low viscosity are fragmented at each collector speed, however the fiber orientations increase as the collector roller speed increases [1]. At the same collector roller speed condition, the more continuous nanofibers are attained from the polymer has high viscosity as compared in Figure 3 (B, D). However, the width of the nanofibers cannot be compared in terms of the viscosity of the polymer and the collector speed of the device.

4. CONCLUSION

In this study, PANI/PEO nano-fibers were successfully fabricated by means of the solution electrospinning technique under ambient conditions. Then, the effects of solution concentration and the collector speed on the morphology of the electrospun PANI/PEO nano-fibers were thoroughly investigated. The SEM images indicated

that the increasing of the collector speed, nano-fiber orientations were increased. On the other hand, the lower solution concentration, the diameter distributions were break down and destroyed.

Acknowledgements

This work was supported by Scientific Research Projects Coordination Unit of Istanbul Gedik University, Project number “GDK201905-14”.

References

[1] Konuk Ege, G., Yüce, H., Akay, Ö., Öner, H. and Genç, G. (2023), "A fabrication and characterization of luffa/PANI/PEO biocomposite nanofibers by means of electrospinning", Pigment & Resin Technology, Vol. 52 No. 1, pp. 151-159. https://doi.org/10.1108/PRT-09-2021-0105

[2] S. R. Djafari Petroudy, S. Arjmand Kahagh, and E. Vatankhah, “Environmentally friendly superabsorbent fibers based on electrospun cellulose nanofibers extracted from wheat straw,” *Carbohydr. Polym.*, vol. 251, no. August 2020, p. 117087, 2021.

[3] B. Sun *et al.*, “Advances in three-dimensional nanofibrous macrostructures via electrospinning,” *Prog. Polym. Sci.*, vol. 39, no. 5, pp. 862–890, 2014.

[4] S. Izwan *et al.*, “A Review of Electrospun Conductive Polyaniline Based Nanofiber Composites and Blends: Processing Features, Applications, and Future Directions,” *Adv. Mater. Sci. Eng.*, vol. 2015, pp. 1–19, 2015.

[5] A. Chinnappan, C. Baskar, S. Baskar, G. Ratheesh, and S. Ramakrishna, “An overview of electrospun nanofibers and their application in energy storage, sensors and wearable/flexible electronics,” *J. Mater. Chem. C*, vol. 5, no. 48, pp. 12657–12673, 2017.

[6] C. Bavatharani *et al.*, “Electrospinning technique for production of polyaniline nanocomposites/nanofibres for multi-functional applications: A review,” *Synth. Met.*, vol. 271, no. October 2020, p. 116609, 2021.

[7] G. Acik, “A comprehensive study on electrospinning of poly (Vinyl alcohol): Effects of the tcd, applied voltage, flow rate, and solution concentration,” *J. Turkish Chem. Soc. Sect. A Chem.*, vol. 7, no. 2, pp. 609–616, 2020.

[8] Y. Li, J. Gong, G. He, and Y. Deng, “Fabrication of polyaniline/titanium dioxide composite nanofibers for gas sensing application,” *Mater. Chem. Phys.*, vol. 129, no. 1–2, pp. 477–482, 2011.

[9] Q. Wang *et al.*, “Ammonia sensing behaviors of TiO2-PANI/PA6 composite nanofibers,” *Sensors (Switzerland)*, vol. 12, no. 12, pp. 17046–17057, 2012.

[10] M. Imran, N. Motta, and M. Shafiei, “Electrospun one-dimensional nanostructures : a new horizon for gas sensing materials,” no. 2, 2018.

[11] Q. Nie *et al.*, “Facile fabrication of flexible SiO2/PANI nanofibers for ammonia gas sensing at room temperature,” *Colloids Surfaces A Physicochem. Eng. Asp.*, vol. 537, no. October 2017, pp. 532–539, 2018.

[12] S. Pandey, “Highly sensitive and selective chemiresistor gas/vapor sensors based on polyaniline nanocomposite: A comprehensive review,” *J. Sci. Adv. Mater. Devices*, vol. 1, no. 4, pp. 431–453, 2016.

[13] S. Neubert, D. Pliszka, V. Thavasi, and E. Wintermantel, “Conductive electrospun PANi-PEO / TiO 2 fibrous membrane for photo catalysis,” *Mater. Sci. Eng. B*, vol. 176, no. 8, pp. 640–646, 2011.

[14] W. Wang, Y. Zheng, X. Jin, Y. Sun, B. Lu, and H. Wang, “Nano Energy Unexpectedly high piezoelectricity of electrospun polyacrylonitrile nano fi ber membranes,” *Nano Energy*, vol. 56, no. November 2018, pp. 588–594, 2019.

[15] F. I. M. Ali, F. Awwad, Y. E. Greish, A. F. S. Abu-Hani, and S. T. Mahmoud, “Fabrication of low temperature and fast response H2S gas sensor based on organic-metal oxide hybrid nanocomposite membrane,” *Org. Electron.*, vol. 76, no. October 2019, p. 105486, 2020.

[16] F. K. Mwiiri and R. Daniels, “Chapter 3 - Electrospun nanofibers for biomedical applications,” in *Delivery of Drugs*, R. Shegokar, Ed. Elsevier, 2020, pp. 53–74.

[17] V. Leung and F. Ko, “Biomedical applications of nanofibers,” *Polym. Adv. Technol.*, vol. 22, no. 3, pp. 350–365, 2011.

[18] O. Akampumuza, H. Gao, H. Zhang, D. Wu, and X. H. Qin, “Raising Nanofiber Output: The Progress, Mechanisms, Challenges, and Reasons for the Pursuit,” *Macromol. Mater. Eng.*, vol. 303, no. 1, pp. 1–17, 2018.

[19] M. M. Harussani, S. M. Sapuan, G. Nadeem, T. Rafin, and W. Kirubaanand, “Recent applications of carbon-based composites in defence industry: A review,” *Def. Technol.*, 2022.

[20] G. Acik and C. Altinkok, “Polypropylene microfibers via solution electrospinning under ambient conditions,” *J. Appl. Polym. Sci.*, vol. 136, no. 45, pp. 1–6, 2019.

[21] J. Xue, T. Wu, Y. Dai, and Y. Xia, “Electrospinning and electrospun nanofibers: Methods, materials, and applications,” *Chem. Rev.*, vol. 119, no. 8, pp. 5298–5415, 2019.

[22] Z. Pang *et al.*, “A room temperature ammonia gas sensor based on cellulose/TiO2/PANI composite nanofibers,” *Colloids Surfaces A Physicochem. Eng. Asp.*, vol. 494, pp. 248–255, 2016.

[23] Z. Fan, Z. Wang, N. Sun, J. Wang, and S. Wang, “Performance improvement of polysulfone ultrafiltration membrane by blending with polyaniline nanofibers,” *J. Memb. Sci.*, vol. 320, no. 1–2, pp. 363–371, 2008.

[24] Y. Li, M. Jiao, H. Zhao, and M. Yang, “High performance gas sensors based on in-situ fabricated ZnO/polyaniline nanocomposite: The effect of morphology on the sensing properties,” *Sensors Actuators, B Chem.*, vol. 264, no. 2, pp. 285–295, 2018.

[25] V. Kumar, A. Mirzaei, M. Bonyani, K. H. Kim, H. W. Kim, and S. S. Kim, “Advances in electrospun nanofiber fabrication for polyaniline (PANI)-based chemoresistive sensors for gaseous ammonia,” *TrAC - Trends Anal. Chem.*, vol. 129, p. 115938, 2020.

[26] G. Acik, C. E. Cansoy, and M. Kamaci, “Effect of flow rate on wetting and optical properties of electrospun poly(vinyl acetate) micro-fibers,” *Colloid Polym. Sci.*, vol. 297, no. 1, pp. 77–83, 2019.