POLYMER FIBERS: PREPARATION AND APPLICATIONS

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Abstract

One-dimensional continuous nanomaterials, particularly polymer nanofibers, have profoundly changed modern materials science. Their defining traits—high surface-area-to-volume ratios, interconnected pore structures, and mechanical resilience—make them highly versatile. Producing these fibrous matrices generally relies on either electrospinning or centrifugal spinning. Electrospinning forms ultrafine fibers through the application of electrostatic forces. However, scaling up this process is notoriously difficult, and overall mass throughput remains low. Centrifugal spinning addresses these production bottlenecks. By utilizing rapid centrifugal force, this method generates fibers much faster and completely eliminates the need for high-voltage power sources or electrically conductive solutions. In the biomedical field, these fibrous networks closely mimic the human extracellular matrix. This physical similarity, combined with adjustable degradation and drug release kinetics, makes them ideal for targeted drug delivery. They are especially effective when formulated as amorphous solid dispersions, which significantly boost the bioavailability of pharmaceuticals that dissolve poorly in water. Beyond medicine, optimizing the structural alignment and electroactive phases of poly(vinylidene fluoride) nanofibers yields highly sensitive piezoelectric sensors. Environmental engineering also benefits heavily from tailored fiber architectures. Highly hydrophobic elastomer microfibers capacity for absorbing oil during oil-water separation tasks. Meanwhile, electrospun membranes made from recycled polyethylene terephthalate effectively filter out fine airborne particles. Expanding the practical applications of functional nanomaterials across pharmaceutical, environmental, and electromechanical sectors will depend heavily on the continued refinement of these scalable spinning technologies.

Keywords: polymer, fiber, electrospinning, centrifugal spinning, filtration, drug delivery.

Introduction

Polymer nanofibers, structurally defined as one-dimensional continuous nanomaterials with diameters ranging from tens to several hundreds of nanometers, have established a transformative paradigm in contemporary materials science (Li & Xia, 2004). The dimensional reduction from the macroscopic scale to the nanoscale engenders a profound alteration in bulk physicochemical behavior. This transition most notably yields an exponential augmentation of the specific surface-area-to-volume ratio alongside superior inter-fiber porosity within non-woven matrices (Huang et al., 2003). These intrinsic morphological advantages grant polymer nanofibers exceptional structural flexibility, robust tensile properties, and highly tunable surface chemistries that significantly outperform conventional bulk polymeric films (Ramakrishna et al., 2001). Furthermore, the extreme spatial confinement of macromolecular chains inherently drives a high degree of macromolecular alignment and supramolecular crystallization along the longitudinal fiber axis. This structural anisotropy translates directly into an elevated Young's modulus and enhanced thermomechanical stability, effectively bridging the gap between flexible organic polymers and high-strength reinforcing materials (Zong et al., 2002). By leveraging a vast array of synthetic and naturally derived biopolymers, researchers can precisely tailor the degradation kinetics, hydrophilicity, and mechanical resilience of these nanostructures to meet highly specialized functional requirements (Agarwal et al., 2008).

The highly advantageous physicochemical profile of polymer nanofibers has catalyzed their extensive integration across diverse fields of application, particularly within biomedical engineering and regenerative medicine. These nanostructures possess a critical architectural homology to the native human extracellular matrix (ECM), making them highly efficacious topographical scaffolds that actively mediate cellular adhesion, proliferation, and phenotypic differentiation (Ma et al., 2005). Consequently, polymeric nanofibrous constructs are heavily utilized in advanced tissue engineering applications. Specific successes include the fabrication of functional vascular grafts (Stitzel et al., 2006), matrices for osteogenic regeneration (Yoshimoto et al., 2003), and aligned conduits for directed neural regeneration (Yang et al., 2005). Concurrently, their substantial volumetric loading capacity and customizable degradation pathways position them as optimal vectors for localized and sustained pharmacological drug delivery (Kenawy et al., 2002). By incorporating therapeutic agents directly into the highly porous polymeric network, these fibers enable stringently regulated release kinetics that maximize targeted bioavailability while simultaneously minimizing systemic toxicity (Sill & von Recum, 2008).

Beyond the biomedical sphere, the structural advantages of polymer nanofibers have driven critical innovations within environmental engineering and advanced energy storage systems. In filtration technology, their sub-micron pore networks enable the exceptionally high-efficiency interception of airborne particulates (Barhate & Ramakrishna, 2007), while chemically functionalized variants are utilized for the removal of aqueous heavy metal contaminants and pathogenic microbes (Botes & Cloete, 2010; Gopal et al., 2006). Crucially, they achieve this advanced filtration capacity while maintaining a distinctly minimal trans-membrane pressure drop, rendering them vastly more energy-efficient than conventional porous filtration membranes. Furthermore, the energy conversion and storage sectors heavily rely on intrinsically conductive and highly porous polymer nanofibers as indispensable components in next-generation electrochemical devices (Thavasi et al., 2008). They are routinely integrated as high-performance precursor architectures for carbon-based electrodes in supercapacitors (Kim et al., 2006) and highly permeable separator membranes in lithium-ion batteries (Choi et al., 2003; Cavaliere et al., 2011). Within these electrochemical environments, the interconnected porous networks of the nanofibrous mats facilitate rapid liquid electrolyte infiltration and drastically accelerate ion transport kinetics, thereby maximizing power density and operational cycling stability.

Fiber preparation

There are several ways to prepare polymer fibers, however electrospinning and centrifugal spinning belong to the simplest and most straight forward fiber production methods. In the next chapters these two methods are discussed

2.1 Electrospinning: Among the various methodologies employed for fiber formation, electrospinning remains the most prevalent. This highly versatile technique leverages electrostatic forces to generate ultrafine fibers from viscous polymeric solutions. Key advantages of this approach include rapid drying kinetics, operational simplicity, and compatibility with thermolabile active pharmaceutical ingredients, rendering it an optimal candidate for formulating nano-amorphous solid dispersions of poorly water-soluble therapeutics (Yu et al., 2018; Xue et al., 2019). The fundamental operating principles of

electrospinning are extensively documented in the literature. Briefly, a polymer solution is continuously extruded through a spinneret, which is typically subjected to a positive electrical potential, while the collection substrate is grounded. Accumulation of charge within the polymer solution induces distortion of the droplet at the spinneret tip, yielding a characteristic Taylor cone (Taylor, 1969). When electrostatic repulsive stresses surpass the surface tension of the solution, polymer jets are ejected and accelerated toward the grounded collector via electrostatic attraction. During this flight, rapid solvent evaporation occurs, facilitating the deposition of solid fibers on the collector (Bhardwaj & Kundu, 2010; Khan et al., 2013; Gergely et al., 2019).

A primary limitation of conventional single-needle electrospinning (SNES) is its inherently low mass throughput (Guarino et al., 2019; Wu & Chou, 2020). Industrial scale-up strategies focus on multiplying the number of functional Taylor cones and are generally categorized into multi-needle configurations and free-surface electrospinning setups (Vass et al., 2019). In multi-needle systems, production rates are augmented by parallelizing the number of emitter needles. However, this configuration often distorts the localized electric field profile due to the electrostatic interference among adjacent charged jets (Theron et al., 2005). An additional drawback involves significant operational and maintenance challenges, as industrial arrays may incorporate thousands of needles. Consequently, spinneret cleaning becomes highly complex, and nozzle occlusion during processing introduces severe operational disruptions (Theron et al., 2005; Kim et al., 2006).

Conversely, in needleless electrospinning architectures, multiple fluid jets are spontaneously initiated directly from the free surface of a bulk polymeric solution (Liu et al., 2019). While numerous promising free-surface techniques exist (Liu et al., 2019; Niu et al., 2012), the utilization of an exposed liquid surface makes the system susceptible to atmospheric water absorption and premature solvent evaporation; this alters the solution composition and can negatively impact process stability. Furthermore, these techniques typically necessitate substantially higher applied voltages (>50 kV) compared to single-needle configurations.

2.2 Centrifugal spinning:

Centrifugal spinning represents an alternative methodology for producing non-woven polymeric fiber mats. The core component of a centrifugal spinning apparatus is a rotating chamber equipped with radially positioned nozzles. A schematic of a centrifugal spinning head is depicted in Figure 1.

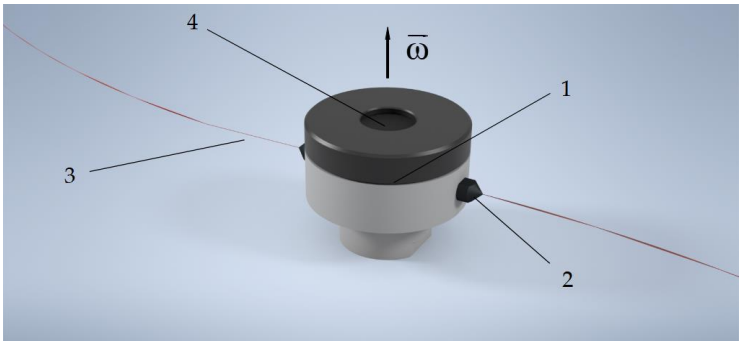

Figure 1. Basic centrifugal spinning configuration: 1 – spinneret head, 2 – nozzle; 3 – polymer solution jet; 4 – solution reservoir.

The spinneret head rotates at angular velocities ranging from 3000 to 15000 rpm, expelling the internally housed solution through the peripheral nozzles. Upon exiting the nozzle, a fluid jet is formed and subsequently elongated by centrifugal forces, complemented partially by

Coriolis forces. During this elongation phase, rapid solvent evaporation occurs, culminating in the formation of dry fibers. These fibers are subsequently deposited onto a screen or alternative barrier surrounding the spinneret, collectively termed the collector. Continuous fiber generation is sustained as long as the polymer solution is fed into the rotating chamber. A principal distinction between centrifugal and electrospinning is the absence of a high-voltage requirement in the former (relying instead on a motor). More crucially, the requisite polymer solutions do not need to possess electrical conductivity. This confers greater flexibility in selecting polymer-solvent systems and optimizing formulations, particularly for non-polar polymers.

Literature indicates minimal variance in fiber diameters obtained via centrifugal and electrospinning, with the exception of the sub-100 nm regime (Rogalski et al., 2017). Arguably the most significant advantage of centrifugal spinning over electrospinning is its vastly enhanced productivity, particularly when comparing fundamental laboratory-scale configurations. A standard single-nozzle electrospinning setup typically operates at volumetric flow rates between 1 and 3 mL/h (yielding 0.1–1 g/h of dry fibers) (Jindal et al., 2018; Farkas et al., 2019), whereas dual-nozzle centrifugal spinning systems can achieve production rates of approximately 20–60 g/h of dry fibers under analogous laboratory conditions (Padron et al., 2013).

Applications of polymer fibers

The following chapters contain some of the applications that our research group worked on.

3.1 Drug delivery: Recent research continuously highlights the significant utility of advanced spinning technologies in formulating amorphous solid dispersions to profoundly improve the dissolution and bioavailability profiles of poorly water-soluble pharmaceutical compounds. Initially, conventional electrospinning has been effectively and widely employed to produce polyvinylpyrrolidone (PVP)-based microfibrous sheets loaded with active ingredients such as fenofibrate (Sipos et al., 2020) and lapatinib (Bitay et al., 2021). However, to address the inherent challenges associated with low production rates in traditional setups, researchers have successfully scaled up fenofibrate fiber manufacturing by utilizing innovative corona-electrospinning techniques (Bitay et al., 2021). Furthermore, remarkable solubility enhancements for fenofibrate formulations were achieved by incorporating the therapeutic agent into highly soluble 2-hydroxylpropyl-β-cyclodextrin polymer fibers (Bitay et al., 2025). Simultaneously, as a robust and high-yield alternative to electrostatic methods, centrifugal spinning has proven to be highly efficient for generating ultrafine microfibers without requiring high voltages. This particular method was successfully investigated and systematically optimized for the continuous production of amorphous solid dispersions containing complex drugs like lapatinib (Bitay et al., 2022) and aceclofenac (Bitay et al., 2023). Most recently, this versatile approach facilitated the one-step preparation of novel chlorzoxazone solid dispersions (Bitay et al., 2024), definitively solidifying centrifugal spinning as a highly scalable, economically viable, and modern pharmaceutical manufacturing technique.

3.2 Sensors: Gergely et al. investigated the effect of electrospinning parameters on the resulting poly(vinylidene fluoride) fiber diameter and crystal structures. Employing a three-factorial Box-Behnken experimental design, we successfully prepared bead-free PVDF nanofibers

ranging from 510 to 1300 nm. The analysis did not show significant influence of the studied process parameters under the used boundary conditions on the fiber diameter, thus indicating the robustness of the process. FTIR spectroscopy confirmed the presence of electroactive β and γ crystalline phases in all samples in the range of 36-42% with respect to the α phase. The sensitivity of the electrospun piezoelectric PVDF samples was comparable to the control, a commercially available PVDF film. (Gegrely et al., 2021).

3.3 Filtration: Recent studies have continuously investigated various fiber-based sorbents and membranes for environmental remediation applications, specifically focusing on oil-water separation and air filtration. Kántor and Gergely (2025) explored the oil sorption properties of polylactic acid (PLA) fiber-based sorbents prepared by multiple methods. Bead-free PLA fibers were produced with electrospinning, yielding an oil sorption of 94.05 g/g, while beaded fibers from centrifugal spinning achieved 30.53 g/g, and 3D printed porous sorbents indicated 2.05 g/g. In a related study, Kántor et al. (2024) successfully produced poly(styrene-b-isobutylene-b-styrene) thermoplastic elastomer microfibers by centrifugal spinning. These bead-free and smooth-surfaced fibers proved highly hydrophobic and oleophilic. The oil uptake showed a strong correlation with oil viscosity, reaching sorption capacities of 23.8 g/g for gear oil. Although the elastomer fiber mat outperformed the polypropylene industry standard, the polystyrene fiber mat demonstrated the best oil sorption performance. The optimization of this microfiber production was detailed by Kántor et al. (2023). They found that optimal fiber production conditions were achieved when using a 25% w/w solution concentration in an 80/20 tetrahydrofuran/toluene solvent system at 8000 rpm, which produced highly hydrophobic fibers with fast absorption kinetics. Additionally, fibrous structures from recycled materials show promise for air filtration. Gergely et al. (2022) investigated the air filtration performance of nanofiber mats generated from recycled polyethylene terephthalate (PET) water bottles by the electrospinning fiber production method. The electrospinning parameters were optimized to produce bead-free PET fiber mats with an average diameter of 593 nm. A pneumatic test circuit revealed that these recycled PET fiber mats were able to effectively filter out all the visible particles from cigarette smoke; however, they were ultimately unable to filter out the molecules responsible for the smell.

Conclusions

In conclusion one can say that nanofibers are promising structures, that have high potential in several applications. The preparation is the key factor that hinders the wider use of fiber mats. Electrospinning is considered the go-to method, however it has significant disadvantages, the biggest drawback is the low production rate. Although there are methods to increase the production rate, there is only one high production rate needleless electrospinning has been commercialized. Centrifugal spinning overcomes several shortcomings of the electrospinning process, most notably there is no electric field involved, and even at laboratory scale the production rate reaches several g/h. Thus, this process is promising for scale-up production.

References

[1] Agarwal, S., Wendorff, J. H., & Greiner, A. (2008). Use of electrospinning technique for biomedical applications. Polymer, 49(26), 5603-5621.

[2] Barhate, R. S., & Ramakrishna, S. (2007). Nanofibrous filtering media: filtration problems and solutions from tiny materials. Journal of Membrane Science, 296(1-2), 1-8.

[3] Botes, M., & Cloete, T. E. (2010). The potential of nanofibers and nanobiocides in water purification. Critical Reviews in Microbiology, 36(1), 68-81.

[4] Cavaliere, S., Subianto, S., Savych, I., Jones, D. J., & Rozière, J. (2011). Electrospinning: designed architectures for energy conversion and storage devices. Energy & Environmental Science, 4(12), 4761-4785.

[5] Choi, S. S., Lee, Y. S., Joo, C. W., Lee, S. G., Park, J. K., & Han, K. S. (2003). Electrospun PVDF nanofiber web as polymer electrolyte or separator. Electrochimica Acta, 50(2-3), 339-343.

[6] Gopal, R., Kaur, S., Ma, Z., Chan, C., Ramakrishna, S., & Matsuura, T. (2006). Electrospun nanofibrous filtration membrane. Journal of Membrane Science, 281(1-2), 581-586.

[7] Huang, Z. M., Zhang, Y. Z., Kotaki, M., & Ramakrishna, S. (2003). A review on polymer nanofibers by electrospinning and their applications in nanocomposites. Composites Science and Technology, 63(15), 2223-2253.

[8] Kenawy, E. R., Bowlin, G. L., Mansfield, K., Layman, J., Simpson, D. G., Sanders, E. H., & Wnek, G. E. (2002). Release of tetracycline hydrochloride from electrospun poly(ethylene-co-vinylacetate), poly(lactic acid), and a blend. Journal of Controlled Release, 81(1-2), 57-64.

[9] Kim, C., Yang, K. S., Kojima, M., Yoshida, K., Kim, Y. J., Kim, Y. A., & Endo, M. (2006). Electrochemical characterization of electrospun polyacrylonitrile-based carbon nanofibers as an electrode in supercapacitors. Journal of Power Sources, 163(1), 272-277.

[10] Li, D., & Xia, Y. (2004). Electrospinning of nanofibers: reinventing the wheel?. Advanced Materials, 16(14), 1151-1170.

[11] Ma, Z., Kotaki, M., Inai, R., & Ramakrishna, S. (2005). Potential and challenges of macroporous electrospun nanofibrous scaffolds in tissue engineering. Tissue Engineering, 11(1-2), 101-109.

[12] Ramakrishna, S., Fujihara, K., Teo, W. E., Lim, T. C., & Ma, Z. (2001). An introduction to electrospinning and nanofibers. World Scientific.

[13] Sill, T. J., & von Recum, H. A. (2008). Electrospinning: applications in drug delivery and tissue engineering. Biomaterials, 29(13), 1989-2006.

[14] Stitzel, J., Liu, J., Lee, S. J., Komura, M., Berry, J., Soker, S., ... & Atala, A. (2006). Controlled fabrication of a biological vascular substitute. Biomaterials, 27(7), 1088-1094.

[15] Thavasi, V., Singh, G., & Ramakrishna, S. (2008). Electrospun nanofibers in energy and environmental applications. Energy & Environmental Science, 1(2), 205-221.

[16] Yang, F., Murugan, R., Wang, S., & Ramakrishna, S. (2005). Electrospinning of nano/micro scale poly (L-lactic acid) aligned fibers and their potential in neural tissue engineering. Biomaterials, 26(15), 2603-2610.

[17] Yoshimoto, H., Shin, Y. M., Terai, H., & Vacanti, J. P. (2003). A biodegradable nanofiber scaffold by electrospinning and its potential for bone tissue engineering. Biomaterials, 24(12), 2077-2082.

[18] Zong, X., Kim, K., Fang, D., Ran, S., Hsiao, B. S., & Chu, B. (2002). Structure and process relationship of electrospun bioabsorbable nanofiber membranes. Polymer, 43(16), 4403-4412.

[19] Yu, D.-G., Li, J.-J., Williams, G. R., & Zhao, M. (2018). Electrospun amorphous solid dispersions of poorly water-soluble drugs: A review. Journal of Controlled Release, 292, 91-110.

[20] Jindal, A., Puskas, J. E., McClain, A., Nedic, K., Luebbers, M. T., Baker Jr, J. R., dos Santos, B. P., Camassola, M., Jennings, W., Einsporn, R. L., & others. (2018). Encapsulation and release of Zafirlukast from electrospun polyisobutylene-based thermoplastic elastomeric fiber mat. European Polymer Journal, 98, 254-261.

[21] Szabó, P., Sebe, I., Stiedl, B., Kállai-Szabó, B., & Zelkó, R. (2015). Tracking of crystalline-amorphous transition of carvedilol in rotary spun microfibers and their formulation to orodispersible tablets for in vitro dissolution enhancement. Journal of Pharmaceutical and Biomedical Analysis, 115, 359-367.

[22] Kim, H. S., & Yoo, H. S. (2014). Therapeutic application of electrospun nanofibrous meshes. Nanomedicine, 9, 517-533.

[23] Hirsch, E., Vass, P., Demuth, B., Petho, Z., Bitay, E., Andersen, S. K., Vigh, T., Verreck, G., Molnar, K., Nagy, Z. K., & Marosi, G. (2019). Electrospinning scale-up and formulation development of PVA nanofibers aiming oral delivery of biopharmaceuticals. Express Polymer Letters, 13, 590-603.
[24] Efimov, A. E., Agapova, O. I., Safonova, L. A., Bobrova, M. M., Parfenov, V. A., Koudan, E. V., Pereira, F. D. A. S., Bulanova, E. A., Mironov, V. A., & Agapov, I. I. (2019). 3D scanning probe nanotomography of tissue spheroid fibroblasts interacting with electrospun polyurethane scaffold. Express Polymer Letters, 13, 632-641.
[25] Xue, J., Wu, T., Dai, Y., & Xia, Y. (2019). Electrospinning and electrospun nanofibers: Methods, materials, and applications. Chemical Reviews, 119, 5298-5415.
[26] Taylor, G. I. (1969). Electrically driven jets. Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences, 313, 453-475.
[27] Bhardwaj, N., & Kundu, S. C. (2010). Electrospinning: A fascinating fiber fabrication technique. Biotechnology Advances, 28, 325-347.
[28] Khan, W. S., Asmatulu, R., Ceylan, M., & Jabbarnia, A. (2013). Recent progress on conventional and non-conventional electrospinning processes. Fibers and Polymers, 14, 1235-1247.
[29] Gergely, A., Kántor, J., Bitay, E., & Biró, D. (2019). Electrospinning of polymer fibres using recycled PET. Acta Materialia Transylvanica, 2, 19-26.
[30] Ding, Y., Li, W., Zhang, F., Liu, Z., Zanjanizadeh Ezazi, N., Liu, D., & Santos, H. A. (2019). Electrospun fibrous architectures for drug delivery, tissue engineering and cancer therapy. Advanced Functional Materials, 29, 1802852.
[31] Rosenson, R. S. (2008). Fenofibrate: treatment of hyperlipidemia and beyond. Expert Review of Cardiovascular Therapy, 6, 1319-1330.
[32] Filippatos, T., & Milionis, H. J. (2008). Treatment of hyperlipidaemia with fenofibrate and related fibrates. Expert Opinion on Investigational Drugs, 17, 1599-1614.
[33] Sipos, E., Csatári, T., Kazsoki, A., Gergely, A. L., Bitay, E., Szabó, Z.-I., & Zelkó, R. (2020). Preparation and Characterization of Fenofibrate-Loaded PVP Electrospun Microfibrous Sheets. Pharmaceutics, 12(7), 612-625.
[34] Guarino, V., Iannotti, V., Ausanio, G., Ambrosio, L., & Lanotte, L. (2019). Elastomagnetic nanofiber wires by magnetic field assisted electrospinning. Express Polymer Letters, 13, 419-428.
[35] Wu, C. M., & Chou, M. H. (2020). Acoustic–electric conversion and piezoelectric properties of electrospun polyvinylidene fluoride/silver nanofibrous membranes. Express Polymer Letters, 14, 103-114.
[36] Vass, P., Szabó, E., Domokos, A., Hirsch, E., Galata, D., Farkas, B., Démuth, B., Andersen, S. K., Vigh, T., Verreck, G., & others. (2019). Scale-up of electrospinning technology: Applications in the pharmaceutical industry. Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology, e1611.
[37] Theron, S. A., Yarin, A. L., Zussman, E., & Kroll, E. (2005). Multiple jets in electrospinning: Experiment and modeling. Polymer, 46, 2889-2899.
[38] Kim, G., Cho, Y.-S., & Kim, W. D. (2006). Stability analysis for multi-jets electrospinning process modified with a cylindrical electrode. European Polymer Journal, 42, 2031-2038.
[39]
[40] Liu, Z., Zhao, J., Zhou, L., Xu, Z., Xing, J., & Feng, Q. (2019). Recent progress of the needleless electrospinning for high throughput of nanofibers. Recent Patents on Nanotechnology, 13, 164-170.
[41] Niu, H., Wang, X., & Lin, T. (2012). Upward needleless electrospinning of nanofibers. Journal of Engineered Fibers and Fabrics, 7, 17-22.
[42] Bitay, E., Gergely, A. L., Bálint, I., Molnár, K., Fülöp, I., Fogarasi, E., & Szabó, Z.-I. (2021). Preparation and characterization of lapatinib-loaded PVP nanofiber amorphous solid dispersion by electrospinning. eXPRESS Polymer Letters, 15(11).
[43] Bitay, E., Gergely, A. L., Kántor, J., & Szabó, Z.-I. (2022). Evaluation of Lapatinib-Loaded Microfibers Prepared by Centrifugal Spinning. Polymers, 14(24), 5557.
[44] Bitay, E., Gergely, A. L., & Szabó, Z.-I. (2023). Optimization and Production of Aceclofenac-Loaded Microfiber Solid Dispersion by Centrifugal Spinning. Pharmaceutics, 15(9), 2256.
[45] Bitay, E., Gergely, A. L., & Szabó, Z.-I. (2024). One-Step Preparation of Fiber-Based Chlorzoxazone Solid Dispersion by Centrifugal Spinning. Polymers, 16(1), 123.
[46] Bitay, E., Szabó, Z.-I., & Gergely, A. L. (2025). Preparation and Characterization of Fenofibrate-Loaded Fibers Based on 2-Hydroxylpropyl-β-Cyclodextrin. Polymers, 17(8), 1037.

[47] Bitay, E., Szabó, Z.-I., Kántor, J., Molnár, K., & Gergely, A. L. (2021). Scale-up and optimization of fenofibrate-loaded fibers electrospun by corona-electrospinning. eXPRESS Polymer Letters, 15(4), 375-387.
[48] Gergely, A. L., & Kántor, J. (2021). Process Optimization of PVDF Piezoelectric Nanofiber Production via Electrospinning. Acta Universitatis Sapientiae, Electrical and Mechanical Engineering, 13, 1-13.
[49] Kántor, J., & Gergely, A. L. (2025). Oil Sorption Properties of PLA Fiber-Based Sorbents Prepared by Electrospinning, Centrifugal Spinning and 3D Printing. Acta Universitatis Sapientiae Electrical and Mechanical Engineering, 17, 43-56.
[50] Kántor, J., Fekete, G., & Gergely, A. L. (2024). Oil Sorption Properties of Centrifugally Spun Polyisobutylene-Based Thermoplastic Elastomer Microfibers. Polymers, 16(18), 2624.
[51] Kántor, J., Farmos, R. L., & Gergely, A. L. (2023). Optimization of Oil Sorbent Thermoplastic Elastomer Microfiber Production by Centrifugal Spinning. Polymers, 15(16), 3368.
[52] Gergely, A. L., Farmos, R. L., Kántor, J., Kántor, A. É., & Hodgyai, N. (2022). Recycled PET nanofiber membranes for air filtration. IEEE.