Polish-Israeli Conference on Electrospinning and Tissue Engineering

Programme and Abstracts

04 - 05 October 2018

Warsaw, Poland

Organizers

Laboratory of Polymers & Biomaterials at Institute of Fundamental Technological Research, Polish Academy of Sciences (IPPT PAN) based on the fundamental knowledge in the area of polymer physics, materials science, chemistry and biotechnology, focuses its recent activity on biomaterials for tissue engineering. Great part of our activity is related to polymeric biodegradable scaffolds, mostly formed by electrospinning as nanofibrous structures, both for tissue regeneration and materials for controlled drug release.

Nano Engineering Group at Technion Israel Institute of Technology is focused on research in the field of molecular engineering of soft matter. The particular activities are related to the electrospinning including optimization of the parameters of the process, deep understanding of the fundamental physical facets of electrospinning as well as designing a composite materials for tissue engineering applications.

Objectives

The goal of PICETE conference is to bring together experts from around the world in order to exchange their knowledge, experience and research innovation in the basics of the electrospinning and the broad area of biomedical materials covering topics related to designing, fabrication, characterisation and tissue engineering applications.

The conference will include the following topics:

- Fundaments of electrospinning
- Optimization of electrospinning
- Properties of electrospun nanofibers
- Functionalization of electrospun nanofibers
- Electrospun nanofibers as scaffolds for tissue engineering/drug delivery systems
- Current trends in designing of polymeric biomaterials for tissue engineering/drug delivery systems

PICETE2018

	Scientist:	Presentation title:	time [min]
9.00-11.00	Prof. Lucas David	Stability analysis of AC electrospinning leads to nonlinear physics	25+5
	Prof. Saikiewicz Paweł	Smart piezoelectric scaffolds	25+5
	PhD Gradys Arkadiusz	Core-shells fibers	25+5
	PhD Stachewicz Urszula	Surface potential controlled electrospun fibers for tissue engineering	25+5
11.00-11.20	Coffee break		
11.20-13.30	Prof. Kowalewski Tomasz	Transport properties of electrospun hydrogel nanofilaments: perspective use for drug delivery and tissue repair	25+5
	Prof. El-Fray Mirosława	Helically coiled structures via wet electrospinning	25+5
	Prof. Zussman Eyal	Electro-Spinning of Polyelectrolyte-Complex Fibers	25+5
	PhD st Wojasiński Michal	Spinnability window of polymer solutions in solution blow spinning	15+2
	PhD Mzyk Aldona	Cardiac progenitor cells response to scaffolds modified by Polyelectrolyte Multilayer Films	15+2
13.30-14.30	Lunch break/coffee		
14.30-16.30	Ms. Hozdova Kristyna	Free Liquid Surface Electrospinning - Lab Scale Process Optimization	15+2
	PhD Kołbuk-Konieczny Dorota	Selected microenvironmental and material factors deciding about scaffold efficiency	10+2
	PhD Solovieva Anastasiya	Platelet-rich plasma coated polycaprolactone nanofibers boost viability and proliferation of human mesenchymal stem cells	10+2
	PhD st Urbanek-Swiderska Olga	The effect of electrospinning parameters on selected properties of polyelectrolyte fibres	10+2
	PhD st Szewczyk Piotr	Tailoring crystallinity and piezoelectricity of electrospun PVDF fibers	10+2
	PhD st Jeznach Oliwia	Surface functionalization of polymer nanofibers for tissue engineering applications	10+2
	PhD st Dulnik Judyta	Polycaprolactone/gelatin bicomponent nanofibres: How do we save gelatin?	10+2
	PhD st Niemczyk Beata	The effect of chemical composition on crosslinking kinetics of Methylcellulose/Agarose Hydrogel	10+2
	PhD st Zaszczyńska Angelika	Polymerization shrinkage of biomaterials	10+2
16.30-17.30	Poster session		

PICETE2018

Polish-Israeli Conference on Electrospinning and Tissue Engineering

Welcome Addresses

On behalf of the Organizing Committee, I would like to welcome all of you to the Polish- Israeli Conference of Electrospinning and Tissue Engineering. It is also my real pleasure to welcome you to the Warsaw – The Capital City of Poland, our Institute of Fundamental Technological Research of Polish Academy of Sciences (IPPT PAN).

IPPT PAN is an Institute of Polish Academy of Sciences, which is focused on fundamental research in the wide range of interdisciplinary fields such as mechanics, mechanical engineering, materials science, electronics, civil engineering and IT. The Laboratory of Polymers and Biomaterials is constantly growing and developing independent group, connecting a basic and applied research of polymer science. Basing on fundamental knowledge in the area of polymer physics we are entering deeper into rapidly growing field of tissue engineering. Great part of our activity is related to polymeric biodegradable scaffolds for tissue regeneration as well as materials for drug release. Being open for various methods of scaffolds formation, at the moment we are concentrated on the formation of scaffolds by electrospinning.

The PICETE meeting is organised by the international multiannual cooperation between two Institutes: IPPT PAN in Poland and Technion - Israel institute of Technology in Haifa, Israel. This is the first joint endeavour, which is gather not only Polish and Israeli experts, but also scientists and entrepreneurs from around the world.

The most important in every conference are the people and from this point of view I would like to express my sincere gratitude to the Keynote Speakers – prof. Eyal Zussman, prof. Tomasz Kowalewski, as well as prof. Urszula Stachewicz.

The conference program covers the topics concerning various aspects of electrospinning, as well as current trends in designing polymeric biomaterials for tissue engineering applications.

I hope that you will enjoy both, the scientific part, and the entertainment part that we have prepared for you.

Prof. Paweł Sajkiewicz

Head of the Laboratory of Polymers and Biomaterials

IPPT PAN

Organizing Committee

Conference Chair

Prof. Paweł Sajkiewicz
Head of the Laboratory of Polymers and Biomaterials
IPPT PAN, Warsaw, Poland

Prof. Eyal Zussman
Head of the NanoEngineering Group
Technion - Israel institute of Technology, Haifa, Israel

Organizers

Olga Urbanek-Swiderska

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Judyta Dulnik

Piotr Denis

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Beata Niemczyk

Angelika Zaszczynska

Olga Cegielska

Arkadiusz Gradys

Laboratory of Polymers and Biomaterials
IPPT PAN, Warsaw, Poland

General Information

Conference Venue

The conference is being held in the building of Institute of Fundamental Technological Research Polish Academy of Sciences (IPPT PAN) located at Ochota Campus.
Address:

IPPT PAN
Pawińskiego 5B, 02-106 Warsaw, Poland.

Main hall, 2nd floor- Thursday 4th October

S3 conference room, 3rd floor- Friday 5th October

Registration Desk

The registration desk is located on Level 0, in the main hall.
Opening times are as follows:

Thursday 4th October	9:00 – 18:00
Friday 5th October	9:00 – 12:00

Badges

Name badges will be issued to all participants upon registration. All participants are asked to wear them all the time.

Poster sessions

Poster Sessions will be held in the hall (2nd floor)

Coffee breaks and lunch area

Coffee break 11:00-11:20

Lunch break 13:30 -14:30

Keynote speakers

Paweł Łukasz Sajkiewicz

Professor, Head of the Laboratory of Polymers and Biomaterials
IPPT PAN, Warsaw, Poland

Title:" Smart piezoelectric scaffolds"

Friday, 5th October 9:30

PAWEL LUKASZ SAJKIEWICZ is a professor of Materials Science and Engineering, leader of the Laboratory of Polymers and Biomaterials, at the Institute of Fundamental Technological Research, Polish Academy of Sciences (IPPT PAN). Expert in the field of synthetic and natural polymers, their structure, with recent emphasis on electrospun micro/nanofibers, both from fundamental and applied perspective as biodegradable scaffolds for tissue regeneration. Graduated from Faculty of Materials Science at Warsaw Technical University, PhD and habilitation at IPPT; postdoctoral Research Associate at the University of Tennessee, Materials Science and Engineering Department, Knoxville, Tennessee, USA.

Eyal Zussman

Professor, Head of the NanoEngineering Group

Technion - Israel institute of Technology, Haifa, Israel

Title:" Helically coiled structures via wet electrospinning"

Thursday, 4th October 12:00

EYAL ZUSSMAN is a professor in the Department of Mechanical Engineering at the Technion - Israel institute of Technology. He holds a DSc degree from the Technion in mechanical engineering. He held postdoctoral appointment at Technical University in Berlin, Germany. Since joining the faculty at the Technion, he has served as Director of the NanoEngineering Group. His group research is in the area of molecular engineering of soft matter, in particular the development of process-structure-property relationships, through the use of simulations and experiments, and the development of functional electrospun fibers. He was Visiting Professor at the Northwestern University (2003), and at the National University of Singapore (2010-2015). He has published over 130 peer-reviewed journal articles.

Keynote speakers

Tomasz Kowalewski

Professor, Department of Biosystems and Soft Matter
IPPT PAN, Warsaw, Poland

Title:" Transport properties of electrospun hydrogel nanofilaments: perspective use for drug delivery and tissue repair"

Thursday, 4th October 11:00

TOMASZ KOWALEWSKI is a professor of Biocybernetics and Biomedical Engineering at IPPT PAN (Institute of Fundamental Technological Research, Polish Academy of Sciences). His present work spans fundamental and applied research areas in micro and nanoscale transport effects in fluids, biological and medical applications of nanomaterials, nanofibrous materials, microfluidics, microPIV, and thermochromic liquid crystals. He has deep experience in flow visualization, experimental and numerical modelling, including natural convection, solidification, free surface and atmospheric flows.

Urszula Stachewicz

Professor, International Centre of Electron Microscopy for Materials Science
AGH University of Science and Technology, Krakow

Title:" Surface potential controlled electrospun fibers for tissue engineering "

Thursday, 4th October 10:30

URSZULA STACHEWICZ is an associate professor at AGH University of Science and Technology in Poland. She graduated from Delft University of Technology with PhD in electrohydrodynamic of liquids to use electrospray as on demand deposition method, with research performed at Philips Research Laboratories in Eindhoven, the Netherlands. She conducted postgraduate study at Queen Mary, University of London (UK) and work at spin-out company Nanoforce Technology Ltd. In the research she is developing advance 3D tomography protocols using focus ion beam and scanning electron microscopy (FIB-SEM) for nanofibrous biomaterials and membranes. Her group core themes are on electrospun polymer nanofibers and their interactions with cells for tissue engineering, and liquids to collect water; in situ mechanical testing of synthetic and naturally structured materials.

Abstracts: Oral sessions

Stability analysis of AC electrospinning leads to nonlinear physics

David Lukáš[1]

Manikandan Sivan, Tomáš Kalous, Petr Mikeš, Eva Košťáková and Pavel Pokorný[1]
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Abstract

AC electrospinning [1] is a method of forming a nanofibrous mass resulting from electro-hydrodynamic instabilities caused by the effect of an external altering electric field. Hydrodynamic instabilities are traditionally studied by Rayleigh's linear stability analysis. The periodically variable electric field intensity provides with the instability that is governed by a second-order linear differential equation for the time evolution of the capillary wave amplitude [2]. This equation has an oscillating parameter and is called Mathieu's equation.

$$\frac{\partial^2 A(\tau)}{\partial \tau^2} + (a - 2q\cos 2\tau)A(\tau) = 0,$$

where $A(\tau)$ is the wave amplitude, which argument is the dimensionless time τ [2]. Dimensionless parameters a and q encompass physico-chemical parameters of a spun polymeric solution (surface tension and mass density), parameters of the physical fields (amplitude, frequency of an electric field and acceleration of the gravitational field) and the wave number of the destabilized liquid surface.

According to Floquet's theorem, instable solutions of Mathieu's equation are represented by a product of exponential functions $e^{\pm i\mu\tau}$ with the periodic function $\phi(a, q, \tau)$ [3]. The parameter $\mu(a, q)$ is so-called Mathieu characteristic exponent that can be evaluated numerically using Wolfram Mathemetica software. Maximal values of Mathieu characteristic exponent enables to predict basic features of the fastest forming instability, i.e., the distance between neighbouring jets (their wavelength λ) and characteristic hydrodynamic time of AC electrospinning onset.

A result of such analysis is introduced in Fig. 1, where a universal curve for DC electrospinning is compared with the AC one based on spinning of Polyvinyl butyral (PVB) nanofibers from ethanol solution. An important feature of this comparison is that AC electrospinning provides destabilization even for subcritical values of electrospinning number [4], $\Gamma_c < \frac{\varepsilon_0 a_c E_0^2}{2g\varrho}$.

Image

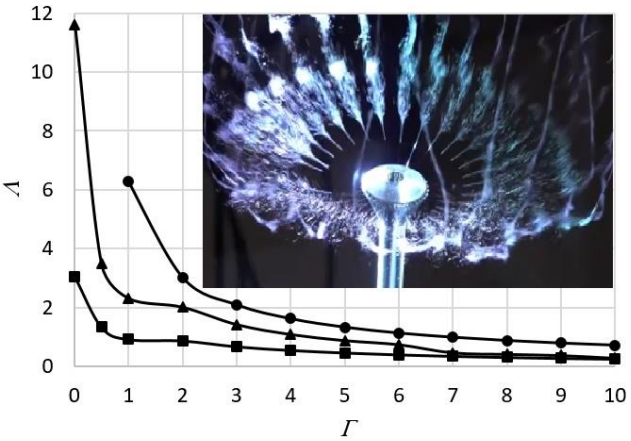

Figure 1: Dependence of a dimensionless wavelength Λ on the dimensionless electrospinning number Γ for DC (upper curve) and AC (lower curves) variant of electrospinning. AC electrospinning data are plotted for PVB solution in ethanol and electric field frequency 50 Hz (□) and 200 Hz (■). The imbedded photograph depicts the spinning electrode (diameter25 mm) with a rosette of jets around its periphery.

References

1. Lukas D. Pokorny P. Kostakova E. Sanetrnik F. et al., Effective AC needleless and collectorless electrospinning for yarn production, *Physical Chemistry and Chemical Physics* 2014, 16(48): 26816-26822.
2. Yih, Chia-Shun Stability of a horizontal fluid interface in a periodic vertical electric field. *The Physics of Fluids* 1968, 11(7): 1447–1449.
3. Whittaker E. T. and Watson G. N. *A Course of Modern Analysis*, Cambridge University Press; 4th edition, 1927.
4. Lukas D. Sarkar A. Pokorny P. *Self-organization of jets in electropinning from free liquid surfaces: A general approach* 2008, Journal of Applied Physics, 103(8): 084309 1-7.

Acknowledgments

This work is supported by the Czech Science Foundation (GAČR) through the project no. 17-02448S.

Biography

Career: *Professor, Textile technology,* Faculty of Textile Engineering, Technical University of Liberec, Czech Republic, 1996.
Associated professor, Textile technology, Faculty of Textile Engineering, Technical University of Liberec, Czech Republic, 1993.
Ph.D. in Textile Technology, Faculty of Textile Engineering, Technical University of Liberec, Czech Republic, 1993.
Master's in Biophysics and Chemical Physics, Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic, 1982.
Bachelor in Physics, Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic, 1980.
Interests: Electro-hydrodynamics of electrospinning, polymer physics, tissue engineering.

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Smart piezoelectric scaffolds

Paweł Sajkiewicz

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Abstract

The discovery of electric fields in biological tissues has led to great efforts in developing methods utilizing electrical stimulation for therapeutic applications. Native tissues, such as cartilage and bone, containing collagens and glycosamineglycans exhibit piezoelectric behavior, with electrical activity generated due to mechanical deformation through simple physiological movement. However, the use of piezoelectric materials in tissue engineering has still largely been unexplored.

The most important piezoelectric polymers will be discussed with emphasis on polyvinylidene fluoride (PVDF) and its copolymers. PVDF has relatively large piezelectricity among polymers, which is highly dependent on supermolecular structure which in turn is governed by conditions of material formation [e.g. 1, 2]. The relations between the conditions of formation, supermolecular structure and piezoelectricity of PVDF will be discussed. Recent achievements in the field of piezoelectric scaffolds, including nanofibrous scaffolds formed by electrospinning, for regenerative medicine strategies will be shown. Recent data [ ] indicate the possibility of stimulation of mesenchymal stem cell differentiation and corresponding extracellular matrix/tissue formation by piezoelectric scaffolds in physiological loading conditions. Preliminary results of PVDF nanofibers electrospinning performed in the Laboratory of Polymers and Biomaterials IPPT PAN at various parameters will be provided.

References

1. Sajkiewicz P., Wasiak A., Gocłowski Z., Phase transitions during stretching of poly(vinylidene fluoride), Eur. Polym. J., 35, 1999, 423-429
2. Gradys A., Sajkiewicz P., Adamovsky S., Minakov A., Schick C., Crystallization of poly(vinylidene fluoride) during ultra-fast cooling, Thermochimica Acta, 461, 2007, 153-157
3. Damaraju S. M., Shen Y., Elele E., Khusid B., Eshghinejad A., Li, J., Jaffe M., Arinzeh T. L., Three-dimensional piezoelectric fibrous scaffolds selectively promote mesenchymal stem cell differentiation, Biomaterials, 149, 2017, 51-62.

Biography

Pawel Lukasz Sajkiewicz is a professor of Materials Science and Engineering, leader of the Laboratory of Polymers and Biomaterials, at the Institute of Fundamental Technological Research, Polish Academy of Sciences (IPPT PAN). Expert in the field of synthetic and natural polymers, their structure, with recent emphasis on electrospun micro/nanofibers, both from fundamental and applied perspective as biodegradable scaffolds for tissue regeneration. Graduated from Faculty of Materials Science at Warsaw Technical University, PhD and habilitation at IPPT; postdoctoral Research Associate at the University of Tennessee, Materials Science and Engineering Department, Knoxville, Tennessee, USA.

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Core-shell fibers, geometrical stability

Arkadiusz Gradys

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Abstract

In recent decades, we may observe high scientific and practical interest in studies on physical properties under confinement, which, with decrease in size, manifest as deviations in the behavior as observed in bulk. One type of confined systems, fibers, characterized by quasi one-dimensional geometry are, so far, least studied.

Coaxial electrospinning proves as very convenient and prospective technique for fabrication of the quasi one-dimensional geometry model system, enabling encapsulation of a model substance for studies of confinement effects. Studies were performed using liquid oligomer polyethylene glycol (PEG, Mn= 400 g/mol) encapsulated in atactic polystyrene (PS) fibers. Studies on the phase transitions of encapsulated PEG by differential scanning calorimetry (DSC) revealed deviations from behavior as observed in the bulk. Firstly, the deviations seem to have geometrical origin, which was described using Avrami formalism and nucleation theory as proposed by Turnbull and Fisher. According to the approach, crystallization in micrometer fibers starts from heterogeneous nucleation with three-dimensional crystal growth - as in bulk - but changes to two and further to one-dimensional, terminated by rapid homogeneous nucleation and three-dimensional growth of tiny crystals. Secondly, deviations in the crystallization kinetics and thermodynamic parameters are observed with decrease in fiber size (fiber cross-section). Post-spinning thermal treatment of fibers, which is performed at elevated temperatures, in vicinity of Tg of fiber shell polymer (PS) leads to change in fiber cross-section area [1]. This property of the fibers was applied in order to systematically study the fiber size effect on the phase transitions. Electro-spun core-shell fibers were annealed at 80 °C in vacuum oven for various time. Using DSC, it was observed, as expected, a systematic shift of crystallization thermal effects towards lower temperatures (Fig.1a), due to decrease in crystallization rate (Fig.1b), which was accompanied by systematic changes in the melting temperature (Fig.1c). As revealed by scanning electron microscopy (SEM) analysis, the area of fiber cross-section changed from 20 μm^2, for fibers as spun, to 10 μm^2, for fibers annealed for 65 hours. The latter sample showed no crystallization, no melting, only glass transition (bottom DSC scans in Fig.1a and c), indicating complete inability for crystallization of the encapsulated oligomer. However, unexpectedly, systematic, thorough and detailed analysis of SEM images of other samples annealed for shorter times, did not reflect systematic changes in crystallization kinetics, as observed by DSC. Fig.1d shows for these fibers values of the area of fiber cross-section scattered in quite broad range, what indicates that they cannot be considered as reliable. The reason for this seems to be connected with geometrical instability of the fiber cross-section, what requires further studies.

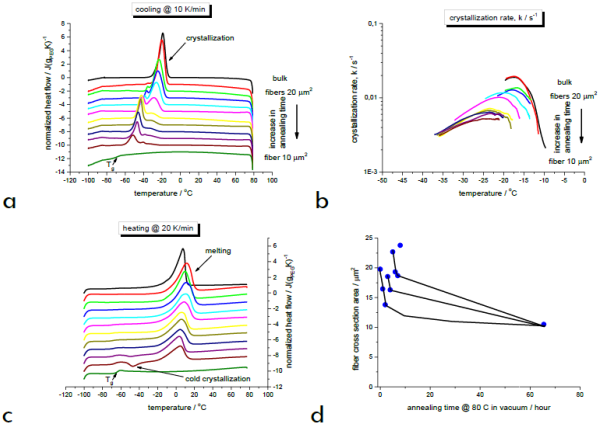

Fig 1. a) DSC cooling scans (crystallization), b) crystallization rate, c) DSC heating scans (melting) of oligomer PEG encapsulated in PS fibers annealed for various time at 80 °C in vacuum and d) average area of fiber cross-section as determined from SEM images.

References

1. A. Gradys, Geometrical effects during crystallization under confinement in electrospun core-shell fibers. DSC study of crystallization kinetics, Polymer, 108 (2017) 383.

Acknowledgments

This work was supported by the National Science Center, Poland, under grant SONATA 2014/13/D/ST8/03140.

Biography

I am assistant professor in Laboratory of Polymers and Biomaterials. An experimental scientist inclined towards fundamental studies in the field of polymer physics. From the beginning of the adventure with polymer physics in 2000 focused on phase transitions, their kinetics and polymorphism. Currently focused on properties of electrospun polymer fibers, especially, on confinement effects, as well as new approach using polarized light for studying behavior of oriented systems.

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Surface potential controlled electrospun fibers for tissue engineering

Urszula Stachewicz, PhD, DSc

International Centre of Electron Microscopy for Materials Science
and Faculty of Metals Engineering and Industrial Computer Science,
AGH University of Science and Technology in Krakow, Poland

Abstract

The next-generation tissue scaffolds are on a high demand in bone regenerative medicine and not only. During my talk I will show the unique study of the polymer scaffolds with the controlled and stable surface potential without any additional biochemical modifications for bone tissue regeneration, which are able to promote in very fast way a bone growth *in vitro* study.

To produce scaffolds, we use a single-step electrospinning to tailor surface potential on polymer fibers. Tuning surface chemistry of polymers by altering voltage polarity during electrospinning allow us to control the surface potential on produced fibers. This innovative and facile way of fibers production regulates the interfacial properties to enhance cells adhesion and filopodia formation on the scaffolds. These electrospun fibers create well-engineered scaffolds that are able to increase significantly cell biointegration through the electrostatic interactions between cells and fibrous scaffolds. Thus, the controlled surface potential on fibrous scaffolds speeds up collagen formation and mineralization, which are crucial in bone regeneration. This phenomenon is especially explicit when the fibers scaffolds have similar surface potential to the membrane of cells used in the *in vitro* studies.

Biography

Urszula Stachewicz is an associate professor at AGH University of Science and Technology in Poland. She graduated from Delft University of Technology with PhD in electrohydrodynamic of liquids to use electrospray as on demand deposition method, with research performed at Philips Research Laboratories in Eindhoven, the Netherlands. She conducted postgraduate study at Queen Mary, University of London (UK) and work at spin-out company Nanoforce Technology Ltd. In the research she is developing advance 3D tomography protocols using focus ion beam and scanning electron microscopy (FIB-SEM) for nanofibrous biomaterials and membranes. Her group core themes are on electrospun polymer nanofibers and their interactions with cells for tissue engineering, and liquids to collect water; in situ mechanical testing of synthetic and naturally structured materials.

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Transport properties of electrospun hydrogel nanofilaments: perspective use for drug delivery and tissue repair

Tomasz A. Kowalewski[1], Sylwia Pawłowska[2], Filippo Pierini[3]

[1,2,3]Biosystems and Soft Matter Department, Institute of Fundamental Technological Research of Polish Academy of Sciences, Pawińskiego 5B, 02-106 Warsaw, Poland

Abstract

We reported on our experimental analysis of the dynamics of nanoobjects suspended in a liquid. The research will make it possible to appreciate the role played by hydrodynamic and ionic interactions on the transport properties of Brownian solid spherical objects, as well as strongly deformable nanofilaments and macromolecules. The analysis of the Brownian fluctuations of spherical nanoparticles suspended in electrolytes demonstrated the influence of the medium ionic strength and the wall on the size of the apparent (hydrodynamic) diameter of these spherical nanoobjects. Behaviour of deformable hydrogel nanofilaments with a structure similar to long macromolecules was investigated to analyse mechanisms responsible for their coiling – uncoiling and cross-flow migration. An experimental system used to analyse the dynamics of filament deformation in the oscillating flow simulated intercellular and inter-tissue flows in living organisms. The basic goal of the analysis of the dynamics of nanofilaments is the possibility to use them as models of elongated biological particles, such as proteins and DNA. An important aim of this work is to offer the possibility of using such highly deformable, biocompatible objects in biomedical applications, like drug delivery, neural tissue recovery or as diagnostic objects.

Biography

Tomasz Kowalewski is a professor of Biocybernetics and Biomedical Engineering at IPPT PAN (Institute of Fundamental Technological Research, Polish Academy of Sciences). His present work spans fundamental and applied research areas in micro and nanoscale transport effects in fluids, biological and medical applications of nanomaterials, nanofibrous materials, microfluidics, microPIV, and thermochromic liquid crystals. He has deep experience in flow visualization, experimental and numerical modelling, including natural convection, solidification, free surface and atmospheric flows.

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Helically coiled structures *via* wet electrospinning

Wcislek Aleksandra[1], Stepien Karolina[1], Sahay Rahul[1], Sui XiaoMeng[2], Sobolewski Peter[1], Wagner H. Daniel[2], El Fray Miroslawa[1]

[1]West Pomeranian University of Technology, Szczecin, Polymer Institute, Functional Materials and Biomaterials, Szczecin, Poland
[2]Weizmann Institute of Science, Department of Materials and Interfaces, Rehovot, Israel

Abstract

Polymeric fiber structures intended to mimic the fiber morphology of native extracellular matrix (ECM) are commonly fabricated by electrospinning. These structures have been extensively studied in the context of scaffolds for tissue regeneration. Unfortunately, the compactness of collected structures using typical flat collector, can limit cell infiltration and tissue ingrowth when used as scaffolds for tissue regeneration. Therefore, fabrication of truly 3D helically coiled structures was performed by wet-electrospinning method [1], a modification of the traditional electrospinning process in which a coagulation bath (non-solvent system for the electrospun polymer) is used as the collector. We adapted this method to process segmented copolyester poly(butylene succinate-co-dilinoleic succinate) (PBS-DLS)[2], containing 70:30 wt.% of hard to soft segments, into 3D helically coiled structures (HCS). Fabricated structures showed high tortuosity and marked increase in cell proliferation (Fig. 1).

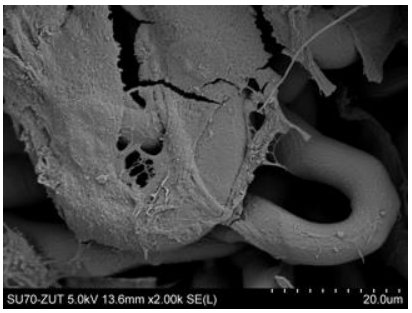

Fig. 1 L929 cells seeded on HCS prepared from PBS-DLS copolymer.

References

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2. Liverani L. Piegat A, Niemczyk A, El Fray M, Boccaccini AR. Electrospun fibers of poly(butylene succinate–co–dilinoleic succinate) and its blend with poly(glycerol sebacate) for soft tissue engineering applications. *Eur. Polym. J.* 2016,81: 295-306

Acknowledgments

This work was supported by the National Science Center (NCN) under grant UMO 2014/14/M/ST8/00610

Biography

Miroslawa El Fray is full professor at the West Pomeranian University of Technology, Szczecin. She is director of the Polymer Institute and head of the Division of Functional Materials and Biomaterials, and director of the Nanotechnology Centre for Education and Research. She was a post-doc at the Technical University Hamburg-Harburg and at the University Bayreuth, Germany and she received the Royal Society fellowship at the Imperial College London, UK. Her scientific background spans polymer synthesis and characterization, biodegradation, and modification towards specific biomedical applications.

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Electro-Spinning of Polyelectrolyte-Complex Fibers

Eyal Zussman

NanoEngineering group, Technion-Israel Institute of Technology, Israel

Abstract

Polyelectrolyte complexes (PECs) have a great potential for stimuli responsive applications due to their adaptable physical properties depending on pH level, ionic strength, and stoichiometric ratio. Simple mixing of oppositely charged polyelectrolytes (PEs), generally leads to precipitation of unordered microstructure. Layer-by-layer method is commonly used to assemble oppositely charged PEs, alternately forming multilayer system. This assembly is assumed to have randomly coiled inter-diffusing macromolecules that bear sporadic short ordered segments securing PECs stability.

Electrospinning is an alternative processing method for PECs assembly. In this process, an electrical field is applied on a semi-dilute polymer solution. When the electrical field overcomes the surface tension, a jet is ejected. Rapid evaporation and elongation occurs resulting in nanoscale fibers comprising stretched macromolecules in a non-equilibrium state.

The goal in this work is to tailor the order in the PEs solution-state and further increase the order via applied electrostatic forces, obtaining packed PECs in quasi 1D-fiber. Controlling parameters such as PEs stoichiometry and viscosity, solution pH and ionic strength, and solvents composition may influence the microstructure in the solution-state. Further on, applying elongation force on the solution will result in stable and responsive fibers with ordered PECs.

Biography

Eyal Zussman is a professor in the Department of Mechanical Engineering at the Technion - Israel institute of Technology. He holds a DSc degree from the Technion in mechanical engineering. He held postdoctoral appointment at Technical University in Berlin, Germany. Since joining the faculty at the Technion, he has served as Director of the NanoEngineering Group. His group research is in the area of molecular engineering of soft matter, in particular the development of process-structure-property relationships, through the use of simulations and experiments, and the development of functional electrospun fibers. He was Visiting Professor at the Northwestern University (2003), and at the National University of Singapore (2010-2015). He has published over 130 peer-reviewed journal articles.

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Solution blow spun fibrous composite materials for bone tissue regeneration

Michał Wojasiński[1], Joanna Latocha[1], Paweł Sobieszuk[1], Tomasz Ciach[1]

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Abstract

The aim of this work is to present a robust method for composite fibrous mats production. Present material is suitable for regeneration of the bone tissue. Solution blow spun mats can be applied on the surface of any bone tissue implant.

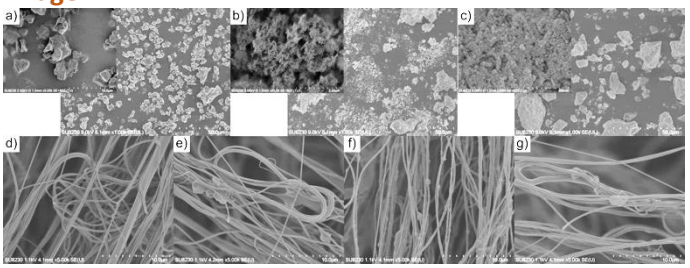
For production of solution blow spun fibrous composite mats the poly-L-lactic acid (PLLA, Biomer L9000, Mw>200kDa) was used as a matrix, and three ceramics: β-tricalcium phosphate (βTCP), hydroxyapatite nanoparticles (nHAp) (both Sigma Aldrich), and hydroxyapatite nanoparticles modified with phosphatidylcholine (nHAp-LE, self-synthesized, in continuous reactor)[1] were used as reinforcements. Polymer was dissolved in chloroform:acetone (3:1v/v) in 6 %w/w concentration and each ceramic was added (separately) in 1:3 mass ratio to polymer and mixed by ultrasounds for 5 minutes. Fibers were produced using previously described SBS system[2].

Ceramic aggregates were investigated by scanning electron microscopy (SEM). Composites were examined by SEM, goniometer, FTIR spectroscopy and Alizarin Red staining (ARS). Also, the cytotoxicity test (XTT, L929 cell line) and cell proliferation test (MG63 cell line) were conducted.

SEM analysis indicated that βTCP and nHAp-LE create aggregates with sizes up to 50 µm, whether nHAp aggregates are less than 40 µm in size. All aggregates were incorporated in SBS fibers. From all proposed reinforcements, nHAp distributes the most uniformly within fibers. Regardless of applied ceramic, all fibrous mats were composed of fibers with mean fiber diameter of about 200 nm. Addition of ceramics did not affect the volumetric porosity (about 90%) and water contact angle (about 110º). FTIR analysis indicates peaks typical for each ceramic in each type of fibrous composites, and ARS shows presence of calcium within whole structure of the mats. Cytotoxicity XTT test on L929 cell culture according to ISO 10993 indicates no cytotoxic response (>80% cell viability). Results of MG63 cells proliferation on the surface of the composite fibrous mats in comparison to plain PLLA fibers is greater (according to SEM, and fluorescence measurements).

Solution blow spun fibrous composite mats, applicable on various surfaces, can be successfully and robustly produced. Addition of the reinforcement does not affect structure of the fibers, but increases cellular positive response.

Image



SEM images of the ceramic particles: a) βTCP, b) nHAp, c) nHAp-LE, and fibrous materials: d) PLLA, e) PLLA/βTCP, f) PLLA/nHAp, g) PLLA/nHAp-LE

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Acknowledgments

Authors acknowledge funding: "Innovative polymer composites for filling bone defects"-INPOLYBOND. NCBR/EC, Smart Growth Operational Program for 2014-2020 of European Regional Development Fund, (POIR.04.01.04.00-0133/15)

Biography

Graduated in Chemical Engineering at Faculty of Chemical and Process Engineering, Warsaw University of Technology (2011). Now, he is finishing his PhD there. His research interest covers processes of nanostructures formation – polymer nanofibers and ceramic nanoparticles – for application in tissue engineering/regenerative medicine. Currently, he works on a description of a process of air blowing of polymer fibers and on a continuous method for production of hydroxyapatite nanoparticles. He co-authored about 30 papers, including 8 from JCR list (h index of 3 with 31 citations).

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Cardiac progenitor cells response to scaffolds modified by Polyelectrolyte Multilayer Films

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Abstract

Biomaterials engineering gives a great promise for the reconstruction of damaged myocardium. In recent years cardiac progenitor cells (CPCs) have become an important source of cells for the infarcted myocardium regeneration. Their therapeutic effect is associated with potential to differentiate into cardiomyocytes, endothelial and cardiac muscle cells as well as capacity to secrete exosomes that regulate the damaged tissue reconstruction process[1,2]. An effective cell transfer into human body takes place only with application of a biomaterial carrier[3]. For this purpose, it is necessary to design materials regulating niche-specific cellular response. This is not possible without knowledge on fundamental relations between scaffold parameters and mechanism of adhesion, differentiation, as well as exosomal activity of cells. Therefore our studies are focused on delivery system for cardiac progenitor cells, which will provide with cells response regulation. Scaffolds functionalized by Polyelectrolyte Multilayer Films (PEMs) facilitate control over surface properties such as stiffness, roughness, surface wettability and thus proteins adsorption as well as cellular response (Figure 1). Properties of PEMs were controlled by structural changes through the chemical cross-linking process and nanoparticles *in situ* nucleation. The obtained results of cardiac progenitor cells – scaffold interaction indicated that PEMs modification has improved cell adhesion and proliferation rate. Scaffolds functionalization by PEMs was essential for the paracrine activity of CPCs. The crucial parameter that influence cellular response was an architecture of scaffold and the PEM stiffness.

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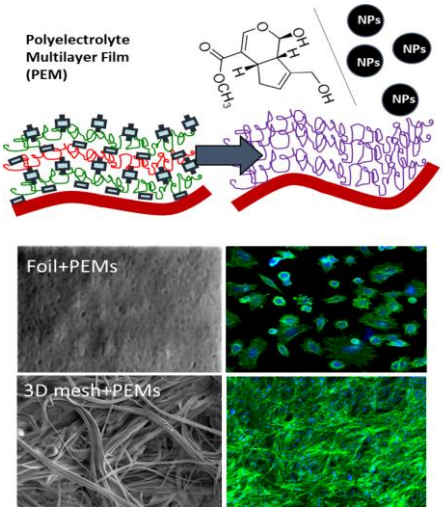

Fig. 1. Cardiac progenitor cells response to scaffolds modified with PEMs.

Acknowledgments

This work was supported by the grant No. 2014/15/N/ST8/02601 of the Polish National Center of Science.

Biography

Aldona Mzyk, PhD is the assistant professor at the Institute of Metallurgy and Materials Science, Polish Academy of Sciences in Kraków. She has a scientific background in Biotechnology (MSc) and Materials Science (PhD). Aldona is specialized in cell-biomaterial interaction analysis. Her research work is focused at design and fabrication of polymer (mainly the Polyelectrolyte Multilayer Films) based biomaterials dedicated to contact with blood which also provides implants and devices with antimicrobial properties. She is highly interested in novel type of scaffolds for delivery and regulation of the cardiac progenitor cells response. She has been developing methods of hemocompatibility and in general cell response evaluation under the dynamic conditions.

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Selected microenvironmental and material factors deciding about scaffold efficiency

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Abstract

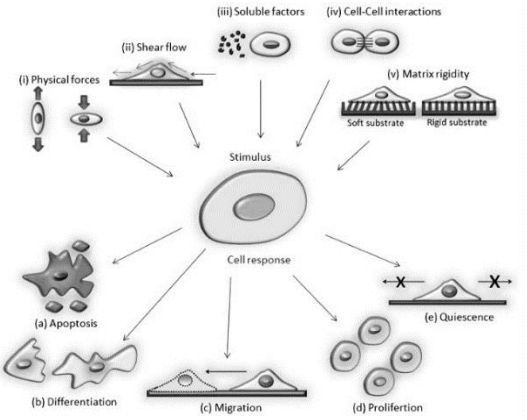
The quality of life of millions of patients has been greatly improved by the development and deployment of permanent implants in the clinical setting such as total knee joint prostheses, cardiovascular stents and breast implants, as well as medical devices including plates, screws and nails, and artificial organs [1-3]. The global regenerative medicine market is expected to reach USD 38.70 Billion by 2021 from USD 13.41 in 2016 [4].

In general, all developed materials needs to be biocompatible, nontoxic, and fulfil properties suitable for specific application. Additionally, scaffold for different tissue regeneration need to fulfil different chemical and mechanical requirements. It is because of differences in microenvironmental stimuli between regenerated tissues types.

The aim of this presentation is to show the literature background as well as selected research done in topic of crucial factors in scaffold development for regenerative medicine.

Main tasks of our group will be presented. Literature about scaffolds requirements dedicated to various tissue types regeneration will be presented. Fundamental research investigations about materials development, structural and surface properties in terms of material-cells interaction will be analysed. The second field of interest are grafts for knee repair (ligaments, bone and cartilage). In this last interest, specific needs e.g.: mechanical, surface, biological properties and degradation conditions are investigated.

Image



A schematic showing the different factors of cells stimuli in vitro [5].

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Biography

Dr Dorota Kołbuk-Konieczny is an alumna of at the Institute of Fundamental Technological Research of the Polish Academy of Sciences (PL), the Socrates-Erasmus Program (ILK, DE), the SCIEX Program (EMPA St. Gallen, CH) and Top 500 Innovators Program (UK).
Her professional research currently focuses on the molecular structure of polymers/biopolymers and tissue engineering, and scaffold development for ligament, cartilage and bone regeneration. Her scientific results have been presented at several international conferences and published in reputable scientific journals.

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Platelet-rich plasma coated polycaprolactone nanofibers boost viability and proliferation of human mesenchymal stem cells

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Abstract

The problem of reconstruction of tissues is one of actual problems of fundamental and applied biomedical science. Most of the available polymer nanofibers are superhydrophobic and biologically inert, while the structure of nanofibers has a similar structure with extracellular matrix and therefore this material has great potential for tissue engineering. Surface modification of nanofibers needs to be effective for immobilization of biological active molecules. The aim of this project is to study the deposition of plasma polymer films containing functional COOH groups and the immobilization of PRP (platelet reach plasma) on adhesion, proliferation and apoptosis of derived bone marrow mesenchymal stromal cells (MSCs).

Methods: In this work, the surface of PCL nanofibers is modified by Ar/CO2 /C2H4 plasma depositing active COOH groups that were later used for immobilization of platelet-rich plasma (PRP). Cell attachment were analyzed by stained cytoskeleton (Phalloidin). Cell Proliferation were investigated using the EdU AF™ 488 Imaging Kit.

Results: It was shown that the adhesion of MSCs to the modified surfaces (PCL-COOH-PRP) resulted in the formation of the significant actin-rich cytoskeleton. The percentage of proliferating cells on PCL-COOH-PRP nanofibers was equal to 44 ± 2.7% after 24 hours incubation. At the same time the percentage of proliferating cells on PCL-COOH was only 20±3.4%. On unmodified nanofibers the percentage of proliferating cells was 6±0.8%. The cell proliferation slows down after 72 h incubation on PCL-COOH-PRP due to contact inhibition (reach confluence). It was found that after 24 h 23±5% nucleus of adhered cells to unmodified PCL scaffold showed some features of apoptosis, while the modified PCL nanofibers exhibited low percentages of apoptotic/death cells (1±0.06%). *Conclusion:* Our results have shown the bonding of PRP with modified PCL nanofibers will influence the cell proliferation level and cell viability and this material is highly promising for tissue engineering.

Image

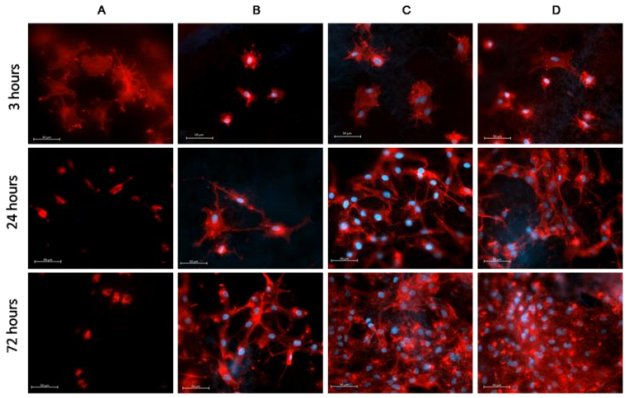

Figure 1. Adhesion of mesenchymal stromal cells (MSCs) on the surface of PCL-ref (A); PCL-COOH (B); PCL-COOH-PRP (ion connection) (C) and PCL-COOH-PRP (covalent bond) (D). The actin filaments of cytoskeleton are stained by Phalloidin (red) while the cell nucleus is stained by Hoechst 33342 (blue).

Acknowledgments

This work was supported by the Russian Science Foundation (Grant № 18-75-10057).

Biography

Academic background: 9/1999 – 6/2007: graduate student, Novosibirsk State University; 10/2007-9/2010: PhD student; 12.11.2014 -PhD in cell biology, cytology and histology. From 2017 Head of laboratory of pharmaceutical active compounds in Research Institute of Clinical and Experimental Lymphology – branch of ICG SB RAS. The main areas of work: regenerative medicine, stem cells, screening of synthesized compounds, determination of their cytotoxicity, studies of mechanism and kinetics of intracellular penetration and excretion, intracellular distribution. Determination of the specific activity of synthesized compounds, acute and chronic toxicity in vivo. Pathomorphological studies.

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The effect of electrospinning parameters on selected properties of polyelectrolytes' fibres

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Abstract

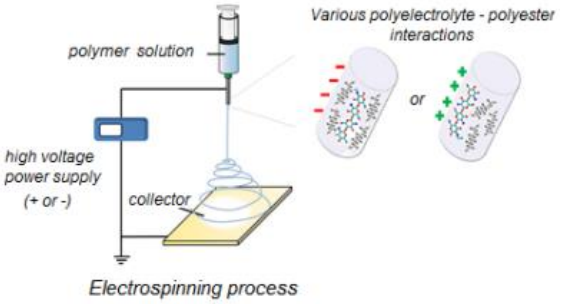
The processing of polyelectrolytes using electrospinning technique is difficult due to the accumulation of charges in the polymer solution and complex interactions of polyelectrolytes with solvent [1]. Moreover, the polarity applied to the spinning nozzle may influence on components interactions and final material properties [2,3].

The studies were divided into two stages. On the first stage the aim of the research was to investigate the effect of two solvent systems on poly(ε-caprolactone)/chitosan (PCL/CHT) fibres' spinnability, structure and properties. On the second stage the effect of polarity applied to the spinning nozzle on the structure and properties of bicomponent PCL/CHT fibres were analysed. amino groups on the fibers surface and its further surface modification with chondroitin sulfate (CS). For this research PCL/CHT nanofibers with 5-25% w/w of chitosan were formed by electrospinning technique.

Results obtained by various experimental methods clearly indicated the effect of the solvent system on the structure and properties of the fibres. Viscosity measurements and infrared spectroscopy (AFM-IR, FTIR) studies confirmed different polymer–solvent interactions, revealing the chitosan salts formation in the case of the AA/FA solvent system. Consequently this differences affected fibres morphological and structural characteristic [4].

On the second stage of the research, results indicated stronger interactions while negative polarity was applied to the spinning nozzle. As a result fibres diameter revealed different size distribution and PCL crystallinity were changed. Moreover, some properties like wettability, mechanical properties as well as the efficiency of adsorption of bioactive compounds (chondroitin sulphate, CS) were changed. In order to analyse presented issues, techniques like atomic force microscopy (AFM), scanning electron microscopy (SEM), differentl scaning calorimetry (DSC) or X-ray photoelectron spectroscopy (XPS) were used [5].

Image



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Acknowledgments

The project was financed by National Science Centre within the PRELUDIUM grant No. 2014/15/N/ST8/03757.

Biography

A motivated and enthusiastic materials science engineer interested in polymers for tissue engineering, its surface modification and processing. Currently, focused on electrospinning of polyelectrolytes blends. The author of 7 scientific papers in the field of electrospun biomaterials and conductive fibres for organic solar cells. The laureate of the Kosciuszko Foundation Award and the author/ principal investigator of research project for young scientists (PRELUDIUM grant).

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Tailoring crystallinity and piezoelectricity of electrospun PVDF fibers

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Abstract

Piezoelectric polymers show a lot of potential in harvesting ambient mechanical energy for powering small electronic devices. Poly(vinylidene fluoride) is a semi-crystalline polymer, which exhibit piezoelectric properties due to its crystalline phases [1]. Piezoelectricity of PVDF is mainly attributed to β-phase, which is formed by mechanical stretching followed by electric field poling of the α-phase. The planar all-trans (TTTT) conformation in β-phase results in a large dipole moment, that can be controlled via electrospinning to produce fibers. To tailor piezoelectric properties of PVDF, we used positive and negative voltage polarity and controlled the humidity during electrospinning. PVDF crystallinity was verified using transmission electron microscopy (TEM), see Fig.1., Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD). Additionally, surface chemistry was analyzed with X-ray photoelectron spectroscopy (XPS) and surface potential with Kelvin Probe Force Microscopy (KPFM). Within this study we show possibility of enhancing piezoelectric properties of PVDF via controlled electrospinning process and correlate structural changes of fibers with their surface properties.

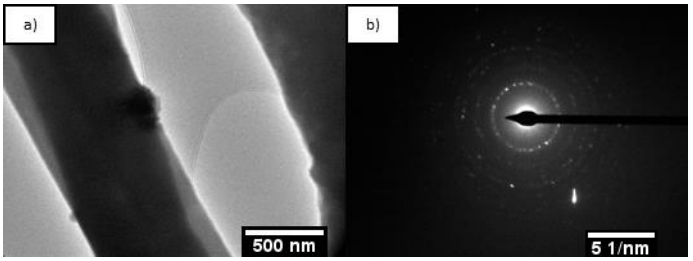

Fig. 1 TEM images showing (a) PVDF fibers in bright field, (b) diffraction pattern from selected area on PVDF fiber showing the crystalline phase.

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Acknowledgments

This research was conducted within the funding from the Sonata Bis 5 project granted by National Science Centre, No 2015/18/E/ST5/0023.

Biography

Oct. 2017-Up to date PhD student: Materials Engineering at AGH University of Science and Technology, Krakow, Poland as a part of project funded by National Science Centre in Poland with topic "Bioinspired design of nanofibers network for water and energy collection"

Research interest:

-Tissue engineering and biomaterials
-Electrospun polymer nanofibers
-3D imaging and 3D tomography based on FIB-SEM
-Wetting behaviour of nanofibers

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Surface functionalization of polymer nanofibers for tissue engineering applications

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Abstract

Polyesters, such as polycaprolactone, polylactide and poly(lactide-co-caprolactone) are commonly used polymers in tissue engineering applications, especially in the form of electrospun nanofibers scaffolds. Their attractiveness is associated with good mechanical properties as well as appropriate morphology, which is similar to extracellular matrix (ECM) architecture. However, hydrophobicity and the lack of reactive functional groups on their surface limit their effective interactions with cells [1]. To overcome this problem, polymer nanofibers are subjected to different kinds of surface modifications. One of them is aminolysis combined with immobilization of cells-adhesive proteins. Aminolysis reaction improves wettability of nanofibers and provides free amino groups, which are exposed on the surface for further functionalization with biological molecules, such as collagen, gelatin or fibronectin [2].

In this study, polycaprolactone, polylactide and poly(lactide-co-caprolactone) electrospun nanofibers were aminolyzed using ethylenediamine solution. After that, gelatin immobilization was carried out. At given conditions surface modification did not cause change of morphology. On the basis of ninhydrin test for detection of amino groups and measurements of contact angle (Fig.1.) it was confirmed that surface modification was effective for polylactide and poly(lactide-co-caprolactone) electrospun nanofibers. Aminolysis seems to be uneffective for polycaprolactone nanofibers, but the explanation of this phenomena requires further studies.

Image

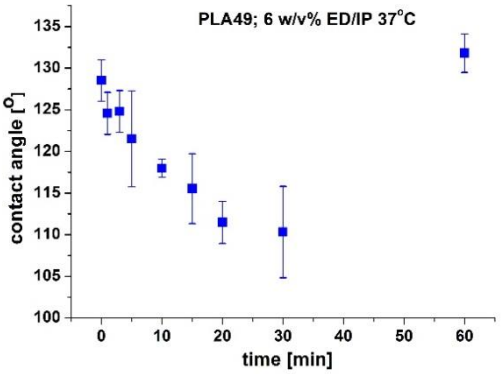

Fig. 1. Decrease of water contact angle of polylactide nanofibers after aminolysis reaction.

References

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Acknowledgments

This work was supported by the OPUS project: The use of collagen in the surface
functionalization by chemical methods of nanofibers made of polycaprolactone formed in electrospinning (UMO-2016/23/B/ST8/03409) operated by the
National Science Centre.

Biography

Oliwia Jeznach graduated from Warsaw University of Technology with Master's degree in Material Engineering. Currently, she is PhD student at Institute of Fundamental Technological Research, Polish Academy of Sciences. Her research interests are focused on surface modification of electrospun nanofibers for improvement of cells-scaffold interaction.

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Polycaprolactone/gelatin bicomponent nanofibres: How do we save gelatin?

Judyta Dulnik

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Abstract

Bicomponent polycaprolactone/gelatin electrospun nanofibres have promising properties as scaffold material in both their good mechanical properties as well as bioactivity and hydrophilicity granted by the presence of biopolymer. This material composition can by successfully electrospun from less toxic and cheaper solvents where typically used perfluorinated alcohols are replaced with acetic and formic acid [1,2].

As our previous research have shown [3], regardless of the solvent used, under biodegradation conditions the loss of gelatin is rapid and decreases materials' bioactive potential.

The goal of this work was to establish and optimize a method of crosslinking gelatin, and thus saving it from its depletion from fibres when confronted with biodegradation conditions (37°C, PBS). Based on criteria such as low toxicity and innovative potential four crosslinking agents were chosen. It was systematically investigated how a set off different concentrations and experiment times affected fibres' morphology and gelatin mass left in the material after 24h biodegradation test.

Image

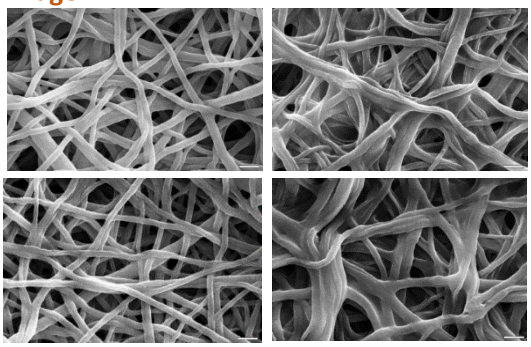

Fig. The influence different crosslinking agents have on the morphology of PCL/gt nanofibres: up left – EDC/NHS; up right – BDDGE; down left – genipin; down right – transglutaminase. Marker 1 µm.

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3. Dulnik J, Denis P, Sajkiewicz P, Kołbuk D, Choińska E. Biodegradation of bicomponent PCL/gelatin and PCL/collagen nanofibers electrospun from alternative solvent system. *Polymer Degradation And Stability* 2016, 130: 10-21.

Acknowledgments

This work was funded by the Polish National Science Center (NCN) under the Grant No.: 2015/17/N/ST8/02027.
Part of the investigations was done on the instruments purchased from Structural Funds under the Project CePT POIG.02.02.00-14-024/08.

Biography

Specialist in the Laboratory of Polymers and Biomaterials, Institute of Fundamental Technological Research, Polish Academy of Sciences (from 2013)
Master's Degree in Biomedical Engineering with major in biomaterials, Multidisciplinary School of Engineering in Biomedicine, AGH University of Science and Technology, Cracow (2011).
My research interests include are polymeric materials for tissue engineering and regenerative medicine, artificial organs.

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The effect of chemical composition on crosslinking kinetics of methylcellulose/agarose hydrogel

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Abstract

Injectable thermosensitive hydrogels are investigated as scaffolds for tissue engineering applications. They are inserted into the body using minimally invasive way thorough injection, and crosslink within injured tissue providing complete filling of the lesion and effective delivery of therapeutics [1].

Methylcellulose (MC) and methylcellulose/agarose (MC/AGAR) systems were investigated. In this study the kinetics of cross-linking, mechanical properties as well as the heat effects of MC and MC/AGAR were determined. These studies allow to obtain an optimal chemical composition for tissue engineering applications. The crosslinking is the result of hydrophobic bonds formation which is the part of physical crosslinking. The mechanism consists of 2 steps: the 1st is present at 37°C in which hydrophobic domains are formed and organized into 3-D network, the 2nd appears near 60°C degree in which water is took from the solution and entrapped inside the network cells, resulting in enlargement of these cells and increase of materials mechanical properties [2, 3, 4].

The agarose addition is important for MC crosslinking due to greater affinity to water resulting in faster crosslinking of MC. Additionally, agarose chains react with MC chains that increase the mechanical properties of MC/AGAR systems [5, 6].

The cross-linking kinetics of MC and MC/AGAR aqueous solutions were carried out by dynamic mechanical analysis (DMA) at the physiological temperature and under isothermal conditions. The time dependence of the storage modulus (G') was determined and parameters of cross-linking were established as the time position and the height of the maximum of the time derivative of G' (Figure 1.a). After numerical analysis including integration the final modulus of hydrogels was estimated (Figure 1.b), which is crucial from the practical perspective.

Another investigations were focused on heat effects from MC. Measurements were carried out the conditions of constant heating rate 0,5 K/min, in the temperature range 19-70°C using hermetic pans in order to prevent water evaporation.

All of the heat effects comes from MC and are endothermic, all of the heat flows were normalized to MC weight. The Figure 1 c and d present respectively the thermal effects and crosslinking heats from MC aqueous solution. All of the curves show multiple effect- the 1st peak represents the 1st stage of crosslinking (which is shifted toward higher temperature values), the 2nd represents the 2nd stage of crosslinking that according to the literature appears above 60°C [2, 4].

Image

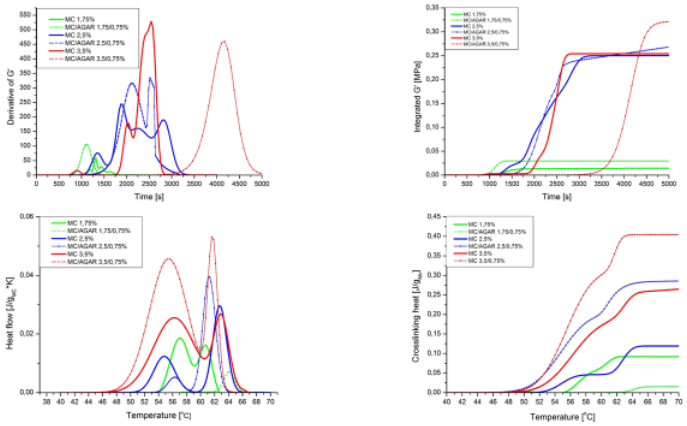

Fig. 1. DMA (a, b) and DSC (c, d) results for MC and MC/AGAR at various concentrations: a) time derivative of the G' at 37 ºC, b) G' vs. time at 37 ºC, c) thermal effects of MC, d) Crosslinking heat of MC and MC/AGAR.

Conclusions

The higher concentration of MC results in faster crosslinking and higher final G'.DMA measurements show that addition of AGAR to MC influences the cross-linking kinetics and increases the final hydrogel stiffness.

DSC results prove 2-stage character of the crosslinking of MC and show that, lower concentrations of MC results in decreased thermal effects, while the higher concentrations of MC show amplified thermal effects of MC.

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Biography

Research interest: Hydrogels, polymers, tissue engineering, biomaterials

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Polymerization shrinkage of biomaterials

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Abstract

Composite light-cured materials appeared in the 90's. From this moment, we are looking for a worthy replacement for amalgam, which should be functional and aesthetic. Dentists using light-cured composite materials for restoration and teeth repair expect a product with many advantages: properties similar to tooth tissues, fast application technique, good durability and protection against secondary caries [1,2]. The dental composites include a resin which reduces its volume during polymerization process[3].

In this study, the new method of polymerization shrinkage was applied to evaluate the volumetric and linear shrinkage of selected materials. Determination of linear and volumetric shrinkage correlation was tested.

Materials used in this study were:

- Flow-Art (Arkona) - 38% wt. of Bis-GMA, UDMA, TEGDMA and Bis-EMA) and 62% wt. of fillers (BaAl-Si glass and nanosilica), marked as “FA shade” (shade = A1, A2 or A3, FIG. 1A),
- Flow-Color (Arkona) - the same composition as above + pigments, marked as “FC colour” (colour = orange, yellow, blue, green, violet and pink, FIG. 1B),
- Charisma Opal Flow (Heraeus), which was composed of Bis-GMA resin and about 58% wt. of fine inorganic fillers (BA-Al glass and silica). Marked as “CHA-A1”, FIG.1C.

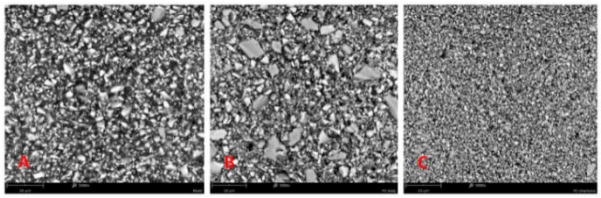

FIG 1. SEM microstructures: A-Flow-Art, B-Flow-Color, C- Charisma.

Volumetric shrinkage measurements was conducted using microCT Skyscan 1174 (Bruker microCT) with accuracy of 6.5 µm. Volume of composite’s drop was measured assuming it is a body of revolution, formed by rotation of half of its cross-section. A drop of composite (volume of about 3 mm^3) was placed on tip made of PE (d = 3 mm).

5 images were taken in different angle position (0, 45, 90,135 and 180°). In next step composite was cured using Cromalux 75 halogen lamp with special limiter. After curing and additional time of 1 min (dark polymerization) another set of 5 images were taken in appropriate angular position.

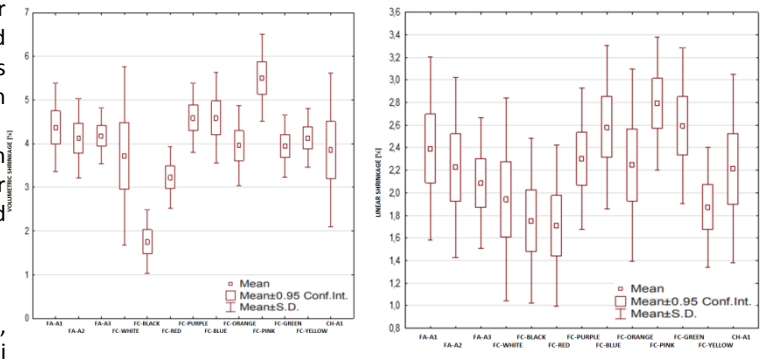

FIG 2. Volumetric and linear shrinkage of tested materials.

Conclusions

The tests showed that the polymerization shrinkage does not depend of the type of matrix material. Differences in the shrinkage results of FC materials and FA materials is from the presence of pigments which can affect the absorption of light and can also change the chemical properties of the resin. The influence of material composition on polymerization shrinkage was demonstrated.

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Acknowledgments

Authors acknowledge ARKONA Laboratorium Farmakologii Stomatologicznej for sharing materials to the tests.

Biography

I am assistant in Laboratory of Polymers&Biomaterials, Institute of Fundamental Technological Research, Polish Academy of Sciences. The main topic of my interest are new biomaterials for tissue engineering and regenerative medicine, especially, piezoelectric nanofibers.

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Internal structure of electrospun polymer nanofibers: formation of this structure and its effect on the nanofiber properties

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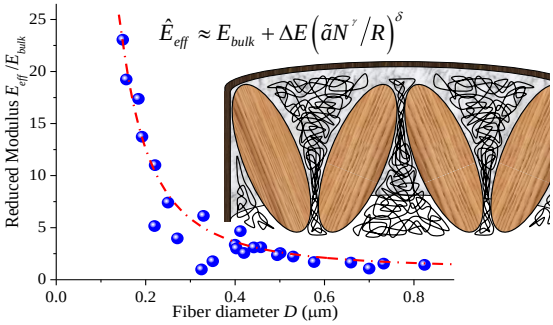
Abstract

Electrospun polymer nanofibers demonstrate outstanding mechanical and unusual thermodynamic properties as compared to macroscopic-scale structures. Now-a-days it is wide accepted that these features are attributed to nanofiber microstructure. It is clear that this microstructure is formed during the electrospinning process characterized by a high stretching rate and rapid evaporation. The first circumstance (high stretching rate) results in formation of non-equilibrium supermolecular structure; whereas the second one (rapid evaporation) provides the fixing of the formed internal non-equilibrium structure of electrospun polymer nanofibers. The physical aspects of the problem in question will be discussed on the base of confinement concept, assuming that size-dependent behaviour is related to confinement of non-equilibrium supermolecular microstructure of electrospun polymer nanofibers which is being formed during their fabrication.

Image



Acknowledgments

This work was supported by the Kamea program of the Israel Ministry of Absorption

Biography

Arkadii Arinstein received his PhD degree in Theoretical and Mathematical Physics from the Landau Institute for Theoretical Physics of the Russian Academy of Sciences in 1982. For many years he worked in N.N. Semenov Institute for Chemical Physics of the Russian Academy of Sciences where he received Doctor of Sciences (habilitation) degree in 1995, and thereafter, Professor's rank. Now, Arkadii Arinstein is the Research-Professor at the Nano-Engineering Group in Technion – Israel Institute of Technology. His research interests include statistical physics of polymers and disordered systems; non-linear and kinetic phenomena; etc. Last 10 years his studies are devoted to the physics of electrospun polymer nanofibers.

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Abstracts: Posters

A comparison study of structural and biological properties of carbon nanofibers modified with bioactive ceramics: SiO_2 and TCP

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Abstract

Micrometric carbon fibre biomaterials are used in medicine in the form of nonwovens and oriented fibres (1D, 2D). However, current trends have shifted towards carbon nanomaterials including carbon nanotubes (CNT) and graphene (GR). At the same time, there are many studies reporting controversial nature of both those materials, ie. CNTs [1]. Bearing in mind already proven biocompatibility of amorphous carbon fibres from one side, and vast possibilities of nanoparticles from the other, submicron polyacrylonitrile (PAN) fibres were produced by electrospinning [2]. The polymer was used as a precursor of carbon fibres and, when in the form of a solution, modified with nanoparticles: SiO_2 and TCP. Parameters of electrospinning process were optimized for three types of nonwovens: reference PAN nonwoven and nanocomposites: PAN/SiO_2 and PAN/TCP. In the next stage, the nonwovens were subjected to two-step thermal conversion. First, they were oxidized (240 °C/30 min) to obtain: oxyPAN, oxyPAN/SiO2 and oxyPAN/TCP. The second stage, ie. carbonization, was conducted in a protective atmosphere (750 °C/5 min; 1050 °C/5 min), allowing to obtain CNF, CNF/SiO_2 and CNF/TCP samples. Structural changes taking place during thermal processing were evaluated in a model FTIR-ATR spectroscopic study. The *in situ* FTIR measurements were carried out using Bruker spectrometer equipped with a high-temperature chamber. Measurements of fiber diameters (based on SEM images) and EDS analysis confirmed the presence of SiO_2 and TCP nanoparticles within the fibres. Around 10% increase in fibre diameter was observed for composite nonwovens. The introduced modifiers enhanced bioactivity of the fibres – apatite-like/Ca-P crystallites layer formed on the surface of the modified nonwovens (simulated body fluid (SBF) assay) (Fig 1). The surface of the nanocomposite nonwovens was hydrophilic with a constant value of surface free energy (SFE, Owens-Wendt). Finally, biological properties were significantly enhanced: high proliferation rate and better adhesion of osteoblast-like cells (MG-63) were observed (cell number assay, vinculin staining) for the cells cultured on the modified nonwovens as compared to the reference CNF sample. Cells contacted with the nanocomposite nonwovens showed also higher osteocalcin levels.

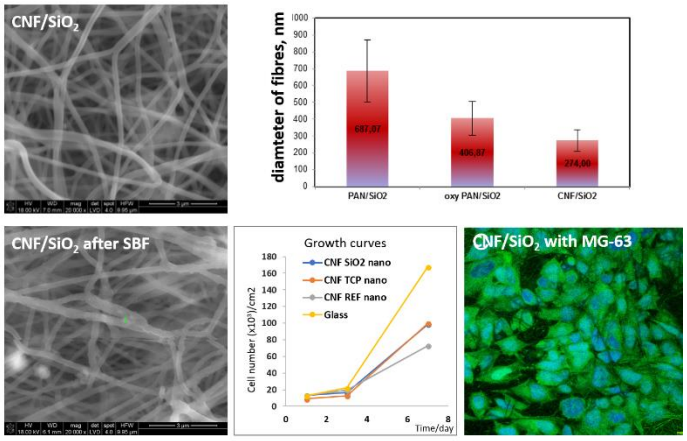

Fig 1. Morphology of carbon nanofiber with SiO2 and their changes during thermal conversion process, nanocomposite scaffold with apatite layer on the fibers with selected biology data: viability and morphology of cells contacted with CNF/SiO_2.

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Acknowledgments

This work was supported by the National Science Center, Poland, under grant no. UMO-2015/19/B/ST8/02594.

Biography

I am assistant professor in Department of Biomaterials and Composite in UST-AGH. The main topic of main interest are new biomaterials (mostly composite and nanocomposite) for tissue engineering and regenerative medicine. I agree with thesis that conventional polymer matrix modified with fibers (micro- or nanometric) or nanoparticels give grate potential new materials and its should be used in different filed of biomedical engineering. Cooperating with biologist, medical doctor and veterinary doctor many of 2D (membrane), 3D (scaffold) materials obtaining by electrospinning, phase inversion, casting, freez-drying were tested in in vitro or in vivo conditions. In the interdisciplinary team we try to find correlation between structure of materials and biology response (cells interaction, tissue interaction). Still open is the question what is happened with the nanofiller into the body in long term of observation.

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Extracellular matrix model obtaining by electrospinning process

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Abstract

Many research possibilities as well as high application potential are attributed to the extracellular matrix. The ability to obtain a biomimetic microstructure as well as a chemical system gives a chance to create mimic environment like the conditions in which cells grow and proliferate [1]. The repetitive process of forming a fibrous matrix can be achieved by using an electrospinning technique. In the work were used two types of polymers: synthetic polylactide (PLA) and biopolymer sodium hyaluronate (HA). PLA fibers were the scaffold for polysaccharides fibers (HA) modified short-chain $(WWC)_2$ system (Fig 1). Peptides were characterized by DLS method. All nonwovens materials were tested for structural (FTIR-ATR), microstructure (SEM) and physicochemical (contact angle) properties. The diameter of PLA fibers depends on the concentration of the spinning solution and the temperature of the electrospinning. Stable fibers with comparable diameters (0.65-1.25 µm) are obtained by increasing the chamber temperature (about 45°C). Their surface is hydrophobic (100°) and the surface energy is maintained at 50 mJ/m^2. The addition of hyaluronic fibers increases the hydrophilicity of the material and the decrease of surface energy (the polar energy component increases significantly from 35 to 42 mJ/m^2). HA fibers form a heterogeneous layer on PLA nonwoven, which is confirmed by both physicochemical and structural studies. All materials: pure PLA fibers, PLA/HA hybrid materials and PLA/HA/$(WWC)_2$ were contacted with cells line (fibroblast Hs680.Tr, ATCC). It has been shown that the fibrous form of hyaluronan is a good carrier for the peptide; which easily connects to the spinning solution. Cells morphology and proliferation were the best on the hybrid materials PLA/HA/$(WWC)_2$.

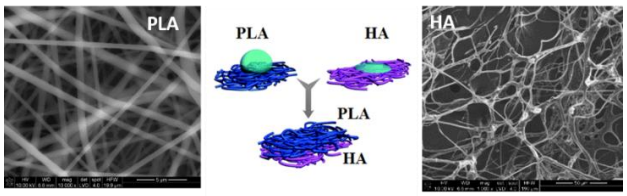

Fig.1 Schema of composition hybrid materials PLA/HA/$(WWC)_2$

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Acknowledgments

This work was supported by the National Science Center Poland, under grant no. UMO-2015/19/B/ST8/02594.

Biography

I am an assistant professor in the Department of Biomaterials and Composites of the AGH-UST. The main topic of main interest is new biomaterials (mostly composites and nanocomposites) for tissue engineering and regenerative medicine. I agree with the thesis, that conventional polymer matrix modified with fibres (micro- or nano-metric) or nanoparticles gives great potential new materials and it may be used in different fields of biomedical engineering. In co-operation with biologists, medical doctors and veterinary doctors many 2D (membrane) or 3D (scaffold) materials obtained by electrospinning, phase inversion, casting and freeze-drying methods were tested in in vitro or in vivo conditions. In the interdisciplinary team we try to find some correlations between structure of the materials and biological response.

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Electrospun nonwovens with poly(glycerol sebacate)

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Abstract

The objective of this research is to determine the conditions of forming, using electrospinning method, and then systematic characterization of the structure and properties of nonwovens, which contain poly(glycerol sebacate) (PGS) and the other polymer – biodegradable polyester. The issue of the project concerns production of such two-component fibrous material, in which elastic properties of poly(glycerol sebacate) will be utilized.

PGS was synthesized using equimolar ratio of glycerol and sebacic acid monomers. Efficiency of crosslinking of PGS depends on degree of esterification (DE) – the extent of reaction between carboxyl groups in sebacic acid and hydroxyl groups in glycerol. Prepolymer in soft-wax form features usually DE of around 45% - 65%. To achieve crosslinked PGS, first DE must be at 76% level minimum [1].

Two types of prepolymers were synthesized – one with relatively low DE (prepolymeric, Prep), and the other one with higher DE (semi-crosslinked, S-C). Next it was blended with poly(lactic acid) (PLA) in 1:3, 1:1 and 3:1 ratios, and was electrospun using hexafluoroisopropanole (HFIP) solvent. Subsequently nonwovens were cured at high temperature (135°C) within 3h - 48h, under vacuum in order to crosslink PGS. Electrospinning process was optimized at preliminary stage.

Our results indicate that nonwovens do not become much more elastic, contrary to pure prepolymer which becomes elastomeric after treatment in such conditions. Applied crosslinking conditions were selected on the basis of two meaningful publications about optimizing PGS properties [1, 2]. What is good for pure PGS prepolymer, does not have to be good when considered its blend with other polymer, when PGS chains are diluted and potentially there can be steric barriers against effective crosslinking.

According to mechanical tests pure PLA has highest tensile strength, but at the same time it is the most rigid material with lowest elongation at break. Annealing in temperature of crosslinking reduces considerably stiffness of the samples – due to structural relaxation in PLA and crosslinking of PGS. Materials with semi – crosslinked prepolymer exhibit most elastomeric nature, with high elongations at break, relatively high tensile strength, and especially after crosslinking – low stiffness.

Electrospinning of PGS blended with PLA does not bring difficulties, but obtaining elastomeric properties of nonwovens is problematic. Even though PGS has many potential advantages over other polyesters when soft tissue engineering is considered, its full utilization via electrospinning process is much harder in practice.

Images

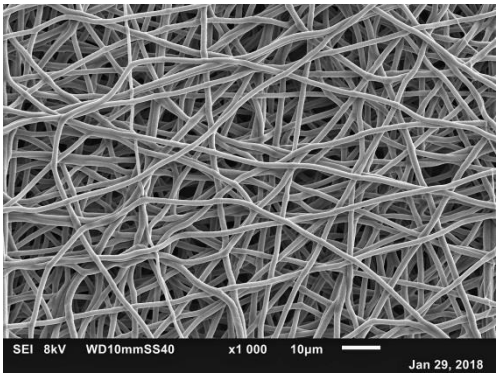

Fig 1. Electrospun PLA:PGS 50%:50% fibers

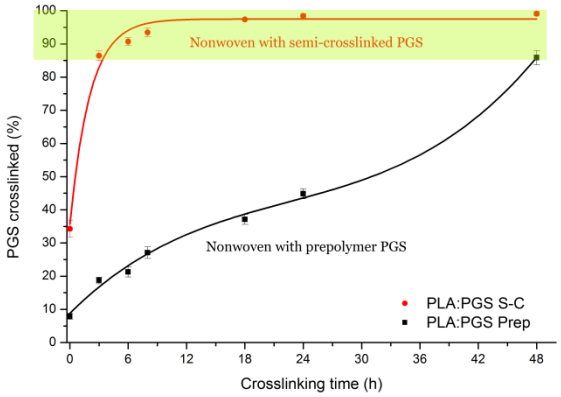

Fig 2. Crosslinking efficiency of PGS in nonwoven, by the example of electrospun PLA:PGS 50%:50% fibers, crosslinked during 24h; after 1h-long leaching in ethanol.

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Acknowledgments

That research is supported by Polish National Science Centre (NCN), "Preludium" grant no. 2016/23/N/ST8/03692. PGS was synthesized in the Laboratory of Technological Processes, Faculty of Chemistry, Warsaw University of Technology. Authors would like to express their gratitude to Agnieszka Gadomska-Gajadhur, PhD and to Michał Wrzecionek, MSc for their contribution and commitment in this work.

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Production of composite based on hydrophobic and hydrophilic polymer fibers for water harvesting applications

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Abstract

World's water resources are shrinking therefore water harvesting is one of the most critical issue in current research. One of the smart ideas to capture water droplets are fog collectors [1], which designs can be improved by incorporating large surface area that can be obtained with electrospun fibers.

In our studies, fibers were obtained by electrospinning (Apparatus EC-DIG with Climate-control – IME Technologies) from solutions of polystyrene (PS) and polyamide 6 (PA6) dissolved in the appropriate solvents. The polymers were electrospun simultaneously from two nozzles to produce composites from hydrophobic PS and hydrophilic PA6 fibers, as shown in Fig.1. The controlled fraction of PA6 nanofibers with average diameter of 0.11 ± 0.03 µm allowed us to reduce the water contact angles, ranging for PS 129.50 ± 2.64 [°] to just PA6 44.60 ± 2.45 [°]. The average diameter for PS was 4.80 ± 0.22 µm. The composite structure was verified by SEM imaging fibers morphology and size distribution analysis and roughness. The surface chemistry of composites was verified using X-ray photoelectron spectroscopy (XPS).

Additionally, the mechanical properties of composite in tensile testing were increased by controlled fraction of PA6 fibers. This fundamental approach to produce fiber-based composites for water harvesting applications has a great potential in designing fiber nets

with controlled wettability and enhanced ability to catch water droplets.

Image

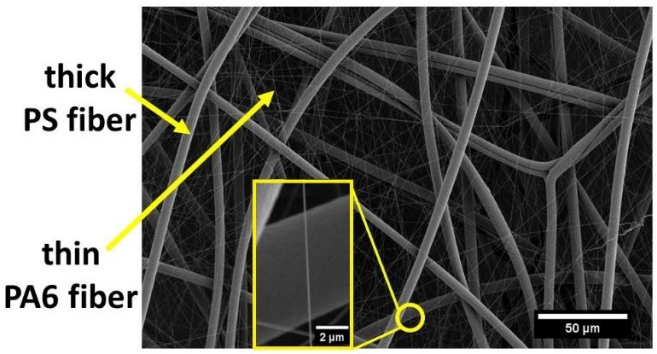

Fig.1. *SEM micrograph of composite with hydrophilic PA6 and hydrophobic PS fibers.*

References

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Acknowledgments

The study was conducted within the funding from SONATA BIS 5 project granted by National Science Centre in Poland, No 2015/18/E/ST5/00230.

Biography

2017 – up to date: PhD student of the AGH University of Science and Technology in Krakow at the Faculty of Metals Engineering and Industrial Computer Science in the field of study materials engineering, ***Supervisor****: Dr hab. inż. Urszula Stachewicz*

Topic of research*: "Investigation of wetting effects with controlled surface properties of electrospun polymer nanofibers"*

Education: *2012 – 2017: Masters Studies – The AGH University of Science and Technology in Krakow, the Faculty of Materials Science and Ceramics in the field of study Chemical Technology with major in Technology of Ceramics and Refractory Materials.*

2010 – 2015: Masters Studies – The AGH University of Science and Technology in Krakow, the Faculty of Non – Ferrous Metals, in the field of study Metallurgy with major in Metallurgy and recycling

Research interest: *electrospinning of polymer fibers, wettability of materials, metallurgy of non-ferrous metals, refractory materials.*

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Interfacial and mechanical properties of electrospun PMMA fiber networks

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Abstract

The electrospun fibers have unique mechanical and surface properties due to the manufacturing method [1]. The applied voltage used in electrospinning process have significant role in molecular orientation of functional groups at surface of fibers. Fibers produced with positive or negative voltage polarity cause accumulation of the positive or negative charge at the surface of the liquid jet [2].

The aim of this study was to determine the effect of voltage polarity on polymetacrylate methyl (PMMA) fibers in terms of their surface and mechanical properties. Mechanical performance of electrospun networks depends not only on the mechanical performance of individual fibers, but also on the adhesion forces between them. That can be attributed to molecular interactions as suggested in previous research [3].

In this work, we used a PMMA (12 %wt) dissolved in dimethyloformamide (DMF) to produce random electrospun fibers, with apparatus EC-DIF integrated with climate system (IME Technologies, The Netherlands). The voltage applied to the nozzle was +/- 12 kV with polymer solution flow rate at 4ml h^{-1}. The temperature in the chamber during electrospinning was T=25°C and humidity H=35%. The fiber morphology and diameter were similar for both type of PMMA fibers (1.44 ± 0.22 µm with positive and 1.74 ± 0.32 µm negative voltage polarity), see Fig.1.

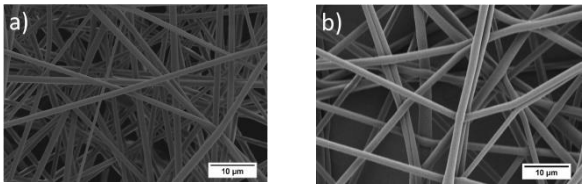

Fig 1. SEM micrographs of electrospun PMMA fiber produced with a) positive and b) negative voltage polarity

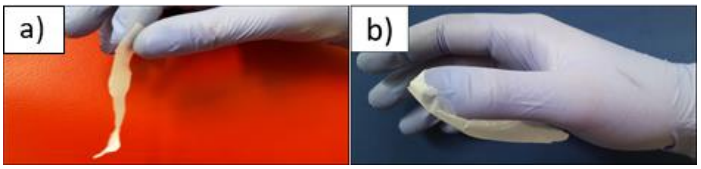

Fig 2. PMMA electrospun mats interactions with surfaces a) produced with positive and b) negative voltage polarity.

The photograph of PMMA fibers behavior, shown in Fig 2. the differences of mats interaction with surfaces, fibers produced with negative voltage stick to the gloves.

Surface chemistry of electrospun PMMA fibers was analyzed by XPS (PHI VersaProbe II) and the mechanical properties by mechanical tensile tester (Kammrath & Weiss GmbH, Germany) with 1N load cell.

Within this study the mechanical performance of PMMA fiber networks was used to verify the interfacial properties between the same polymer fibers with different surface chemistry. The interfacial properties of polymer fibers can be controlled with voltage polarity changes during electrospinning.

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Acknowledgments

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Biography

2017 – up to date PhD student, topic: *'Investigation of mechanical and wetting properties of electrospun polymer nanofibers' supervised by Dr Urszula Stachewicz, within the Sonata Bis 5 nr 2015/18/E/ST5/00230 project "Bioinspired design of nanofibers network for water and energy collection"*

Research interest: *Polymeric nanofibers, mechanical properties of polymeric nanofibers, electrospinning*

Conferences: *4th International Conference on Biomedical Polymers and Polymeric Biomaterials 2018, 15-18.07.2018 Krakow, Poland – poster presentation on Charge Assisted Tailoring of Electrospun PMMA Fibers: Surface Chemistry and Wetting Properties*

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COOH modified polycaprolactone nanofibers for burn wound treatment

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Abstract

Treatments of skin injuries caused by burns are among the most considerable medical problems. Extracellular matrix (ECM) plays an important role in wound healing, providing a structural support for intercellular contact, serves as a reservoir for signaling molecules, thus regulating cell migration, proliferation and angiogenesis. It is a 3D structure consisting of fibrin fibers, proteoglycans and polysaccharides, secreted by fibroblasts. The modification of PCL nanofibers by COOH groups and platelet rich plasma (PRP) are able to provide sufficient support for cellular adhesion and proliferation [1]. Fibroblasts seeded on PCL nanofibers enrich ECM mimic scaffold and wound with natural fibrils and different bioactive molecules and thus leading to faster formation of the most important layers of natural skin: the dermis and the epidermis. *Methods*: PCL modified surfaces (PCL-COOH-PRP) were prepared as described in our article [1]. Cell attachment were analyzed by stained cytoskeleton (Phalloidin). Cell proliferation was investigated using the EdU AF™ 488 Imaging Kit. Cell apoptosis was determined by Hoechst 33342 staining. The effectiveness of PCL-COOH-PRP scaffold covered by rat lungs fibroblasts (PCL-COOH-PRP-Fb) for burn treatment was tested in vivo. The study protocols was approved by the Ethics Committee of the RICEL-branch of ICG SB RAS. *Results: The* modification of the PCL nanofibers by COOH groups led to significantly increased survival of fibroblasts (15% of apoptotic cells versus 31% on PCL ref), the additional modification PCL-COOH by PRP reduces the level of apoptosis (down to 5%) and increased cell proliferation from 7% PCL-COOH to 11% PCL-COOH-PRP seven days after cell seeded on PCL-COOH. Fibroblasts survived exclusively in cell islets by fibroblasts producing components of the natural ECM on hydrophobic PCL ref. On COOH-PRP modified cells were seeded evenly and have a high level of proliferation. The PCL-COOH-PRP-Fb scaffolds increases speed of the healing of burns (IIIA degree), decrease of degree of inflammation, provides of earlier rejection of the scab and the formation of layers of the epidermis.

Conclusion: We have shown that the PCL nanofibers modified with COOH groups and covered by cells are perspective for the creation of skin grafts for the therapy of burns.

Image

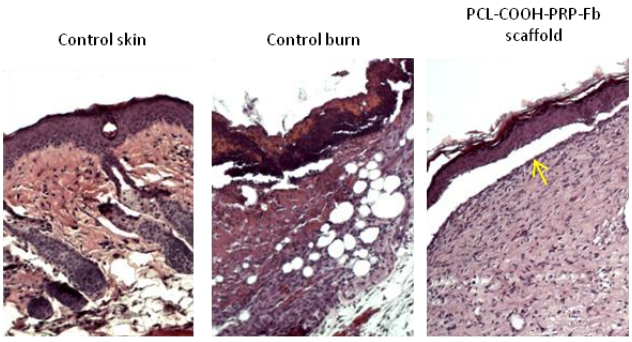

Figure 1. Bright field micrographs of hematoxylin and eosin (H&E) stained wounded skin tissue sections determining the changes in healing events in PCL-COOH-PRP-Fb scaffolds treated and control rat groups at 14 days post wound. Yellow arrow point to epidermis formation.

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Acknowledgments

This work was supported by the Russian Science Foundation (Grant № 18-75-10057).

Biography

The main areas of work: regenerative medicine, stem cells, screening of synthesized compounds, determination of their cytotoxicity, studies of mechanism and kinetics of intracellular penetration and excretion, intracellular distribution. Determination of the specific activity of synthesized compounds, acute and chronic toxicity in vivo. Pathomorphological studies.

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Tin-carbon composite material by electrospun deposition for lithium ion battery

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Abstract

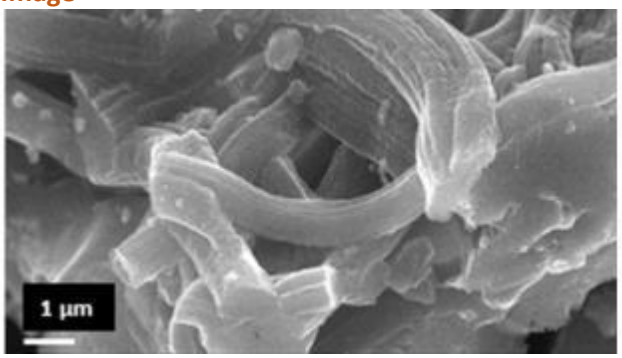
The study and the realization of performing materials has allowed a remarkable development in the study of lithium ion batteries. Polyacrylonitrile is considered one of the best materials of interest in this field, thanks to its particular characteristics not common in other polymers. In this poster we report some results obtained through the realization of a porous carbon obtained from the calcination of fibers made by electrospinnng, starting from a blend of Polyacrylonitrile (PAN) and polymethylmethacrylate (PMMA). These two selected polymers are immiscible among them and they carry out two different functions: during the calcination the PMMA is sacrificed and disappears and the PAN reshapes its carbon structure in a more stable form. In fact, with a specific operating protocol, in a first step in air, at a maximum temperature of 280 °C, the PMMA reacts with oxygen turning himself into carbon dioxide and in a second step in a reducing environment (Argon/Hydrogen 95/5) the PAN cyclizes. The best solution achieved was formed by an equal percentage of PAN and PMMA.

The use of the electrospinning system give a fairly regular filament to the polymers, with diameters of micro-nanometric size. A fixed collector guaranteed a homogeneous and random distribution of the same fibers and a presence of a very pronounced macroporosity.

Tin was introduced as an organic precursor and electrospinning with the polimeric blend. Particular attention was given to the calcining operative protocol and to the preparation of the sample itself.

Concluding, in this poster it was report a good system to obtein a specific carbon conteined Tin particles with a regular and fibrous structure, where a huge microporosity joins the initial macroporosity.

Image



Reference

1. High-performance Sn@carbon nanocomposite anode for lithium batteries. Journal of Power Sources 2013, 226: 241-248.

Acknowledgments

The researches leading to these results have received funding from the European Union Seventh Framework Programme (FP7/ 2007-2013) under grant agreement n 265644, Project "APPLES Advanced, High Performance, Polymer Lithium Batteries for Electrochemical Storage"

Biography

Degree in Chemistry and Pharmaceutical Technologies, PhD in Biomolecular and Pharmaceutical Sciences and Post Doc at the University of G.d'Annunzio University, Department of Pharmacy; 'Erasmus' at the University of Porto, Department of Pharmacy; 'Research Visitor' at the Chalmers University of Technology, Applied Physics Department.
Fields of interest: polymers, electrospinning/electrospray, drug release, polymeric scaffolds, lithium-ion battery.

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The Centrifugal "Snow gun" as a Nanofibrous Stream Generator

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Introduction

A force or centrifugal spinning is a very old method for fiber production. By the end of the 19th Century centrifugal spinning was first used for the production of cotton candy. (Interestingly, cotton candy also contains a little sugar nanofibers.)

Exist many patents for centrifugal spinning in various applications. For example, companies FibeRio and PARDAM use a classic arrangement for centrifugal spinning for production a nanofibrous layers. Force spinning nanofiber films use a large amount of air for storing fibers. This means significant energy input and device dimensions.

Solution

For our use, we needed a centrifugal device that produces plenty of nanofibers in a compact stream. We were inspired by two old US patents [1], [2].

Our solution [3] combines both US patents and complements them with a solution to eliminate defects of nanofibrous material. Our solution uses a two-phase flow of air to bend the fiber trajectory and arrange it into a continuous stream. Figure 1 shows the layout of our device. Two fans with 36 W power draw the air into the interspace between the inner perforated cylinder and the outer case. Part of the compressed air enters through the holes in the inner shell to the spinneret equipped with a propeller. This air-directed spinneret bends the trajectory of nanofibres that fly out of the spinneret in the plane of rotation. Unrefined droplets of polymer solution and other defects fly through a stream of air that bends the fibers and falls on the wall of the inner shell. Liquid defects flow into the reservoir and can be reused as a starting material.

The second part of the compressed air flows in the interspace along the outer case. This creates an air wall that will not allow contact between the outer case of the device and the nanofibers. The composition of the internal and external air stream inside the device cases works a relatively continuous stream of nanofibers. The outer case diameter is 315 mm.

The polymer solution flows through the inside of the spineret and spills over the inside of the spineret. According to our experience, it is necessary that the flow path along the surface of the spineret be at least about 2 cm long without any difference of the polymer solution used. Otherwise, liquid beams will not be reliably formed on the surface of the spineret. Then these nanofibers are formed from these liquid beams. Very important for permanent operation is a knife that cuts dry portions of the polymer solution in close proximity to the edge of the spineret.

Our spineret has a diameter of about 60 mm and the speed varies according to the type of solution in the range 2500 - 6000 rpm. The electric input of the spinneret high speed motor (ATAS FT4C52R) is approx. 500 W. The spineret propeller is used from a fan with a diameter of 80 mm for PC cooling.

It is not a problem to push the spineret with 20 ml of solution per minute. The amount of solution to be used is determined by the properties of the polymer solution and must always be tested.

Conclusion

We can use nanofibrous stream in different ways. For example, as a precursor of nanofibrous yarns, a powerful source of nanofibres for fluffy nanofibrous layers for tissue engineering, and as an interesting source of fiber to create a garment directly on the model's body.

Centrifugal spinning carried out by this device allows the formation of composite materials of nanofibres - solid particles. By introducing the solid particles into the internal air stream through the particle ejector, it creates the desired mixture of fibers and particles. This material utilizes the particle size sorption capacities to the maximum and can be used as a very good and sorption material for the capture of pollutants.

So far, we've tested PVB, PA, PVA, PCL with good results. Other polymers have not yet been tested. The number of types of polymer solutions may be larger than for electrospinning.

Further development of the device will be in the direction of miniaturization of the device in the form of a handgun.

Image

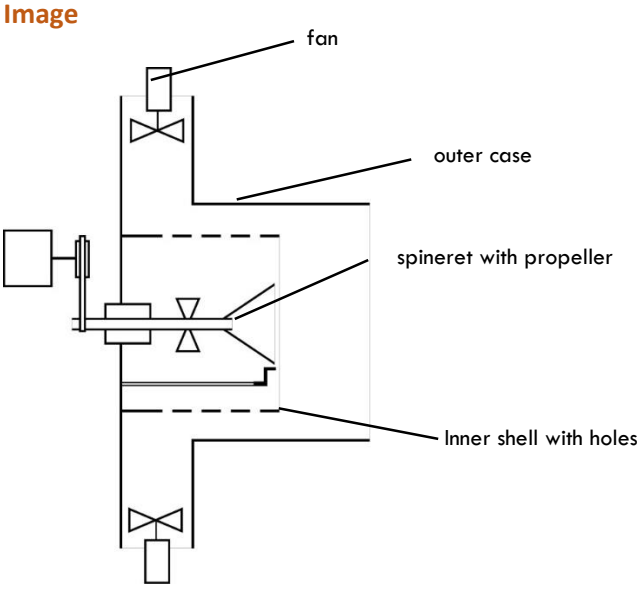

Figure 1: Schematic diagram of centrifugal spinning equipment [3]

Figure 2: The centrifugal spinning device

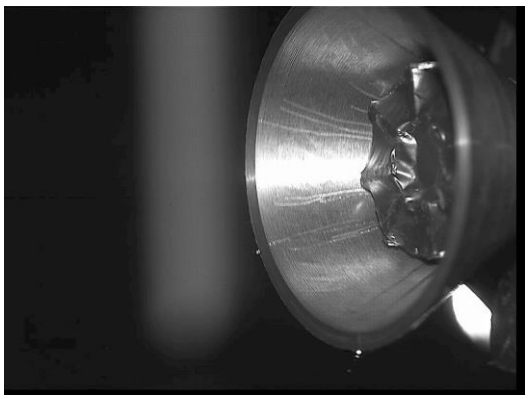

Figure 3: Photograph of the polymer solution beams on the surface spinneret. (High speed camera Olympus i-speed 3, 5000 fps, speed of spinneret 3600 rpm).

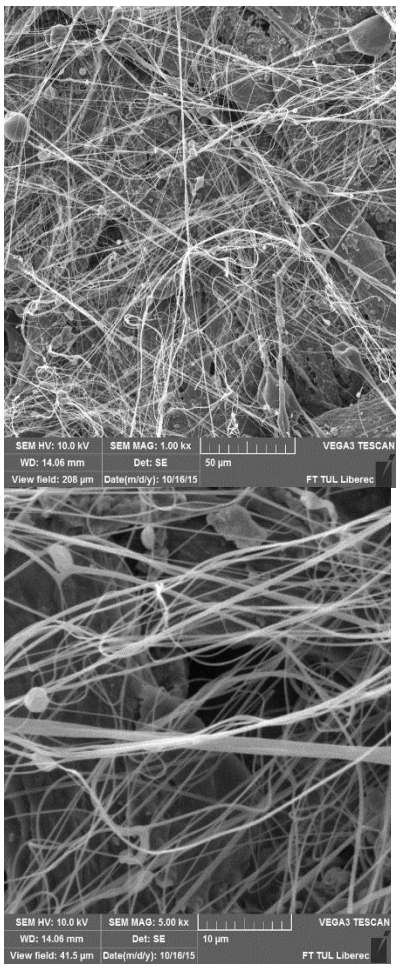

Figure 4: SEM photographs of PVB nanofibers from centrifugal spinneret

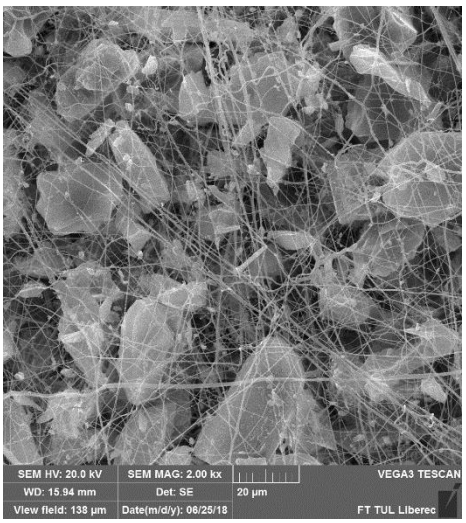

Figure 5: SEM photograph of composite material PVB nanofibres - milled activated carbon.

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Acknowledgments

This work was supported by a grant from the Ministry of the Interior of the Czech Republic number VI20172020059 Intelligent fabric against CBRN substances

Biography

Career: Associated professor, Textile technology, Faculty of Textile Engineering, Technical University of Liberec, Czech Republic, 2016.
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