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# PRODUCTION OF THREE – DIMENSIONAL OBJECTS ON THE INSTALLATION «3D PRINTING+ELECTROSPINNING»

**Zh.E. Ydyryssova, Ch.B. Daulbaev, Ph.R. Sultanov, Z.A. Mansurov E.T. Aliev**

Institute of combustion problems, Bogenbay batyr str., 172, Almaty, Kazakhstan

zhanara.ydyrysova@mail.ru

**Annotation**

This work shows the possibility of producing three-dimensional nano- sized polymer fibres. The obtained fibres are oriented, this allowing to create three-dimensional objects. The proposed method allows to lay strictly oriented nanofibers from PMMA- polymer with the diameter from 50 to 500 nm. Application of different types of electrodes make it possible to vary the size of nanofibers. Oriented polymer nanofibers were used for construction of bio-frames for biological cells.

**Keywords:** 3D printer, electroformation, nano-sized fibers, nano objects

## Introduction

At present, there are different methods of producing nanomaterials. In its turn, 3D printing reached the stage when the desired product can be obtained irrespective of the complexity of its form. The use of such technology for nanofabrication will allow to produce nano-sized substances with the necessary geometric structure. We propose a novel method which includes the process of electroforming nanofibers under the action of electric field of high voltage and 3D technology. The main difficulty in using electroformation for nanofabrication is internal instability of electrified nanojets under the conditions of mutual Coulomb repulsion. In our method we solve this problem using electrodes of different types which are modifications of «H-like» form as well as two parallel «I I» electrodes. This approach allows changing the directions of electric field lines, this being necessary for production of oriented nanofibers. The proposed method allows to lay strictly oriented nanofibers of the diameter from 50 to 500 nm, constructing «nanowalls» from them. This technology of nanofabrication with the use of 3D printing will find its application in different fields such as medicine, in particular for obtaining a frame for biological cells, production of nanofilters, nanorobotics, nanoelectronics.

3D printing reached the stage when the desired product can be obtained irrespective of the complexity of its form. The use of such technology for nanofabrication will allow to produce nanosized objects. Besides, nanostructures or microstructures can be used as substrates and in this way the complexity can be realizede at the nanolevel This method allows «to draw» with a set of molecules in line with the width of tens of nanometers [1].

It should be noted that it is very difficult to control the form of a jet and the rate of diffusion of polymer molecules contained in a limited volume of the solvent. Electroformation is an attractive process for depositing nano-sized objects which uses nanofibers emitted from a drop of liqud under the action of a strong electric field [2].

Production of 3D – objects by direct deposition of functional materials has been the subjects of intensive study in a large scale production in recent years and 3D printing reached the stage when the desired product can be produced irrespective of the complexity of its form. Thus, 3D printing is a promising technology of production being quick, less expensive and economically profitable. The use of such technology of nanofabrication will allow to use microstructures as substrates and in this way the complexity can be realized at the nanolevel [3].

Electrospinning is a simple and available method for production of nano-sized objects which uses nanofibers emitted from a drop of liquid under the action of a strong electric field. The main difficulty in using of electrospinning for nanofabrication is internal instability of electrified nanojets under the conditions of mutual Coulomb repulsion [4].

The interest to nanosized materials is aroused by the fact that their mechanical properties, such as strength limit, tensile strength, bending strength, compressive strength, moduli og elasticity increase with the decrease in the sizes of particles and reach the theoretical limit at the nanolevel [5]. Using different constructions and modifications of the apparatus, the method of electrospinning allows at present to produce nanofibres from different materials – polymers, composites, semiconductors, metals, ceramics [6].

In the process of electrospinning, the jet is stretched by electrostatic forses and gravity, while surface tension, viscosity and inertia play their role, too. In the process of liquefaction, the surface charge density changes, this influencing the electric field. When the jet transfers from Taylor cone to an almost straight, the movement of a liquid jet is subjected to different forces such as Coulomb force of electric field, the force of applied external electric field, surface tension, gravity and air resistance force [7]. According to the work of D.A. Sevill on electrohydrodynamic processes which take place in Taylor cone, the state of the jet can be presented in the form of four stationary equations: conservation of mass and electric charge, Coulomb law for electric field depending only on the axial position, for convenience of computations.

**Experimental part**

Polymer fibres were obtained on «3D printer+ electrospinning» installation at the Institute of Combustion Problems and Texas Dallas University. The assembled unit included an installation for producing polymer films by the method of electrospinning and 3D printer on which oriented polymer nanofibers were obtained. The unit consisted of 3D printer, high voltage sourse, protective cover, syring pump. The voltage of 10 kv was applied to the needle tip and electrode, the distance between them made up 15cm. In the work, different types of electrodes were used and that allowed us to obtain oriented fibers will the thickness of about 200 nm. Figure 1 presents a schematic view of the installation «3D printer+ electrospinning». 3D printer was modified into which the polymer solution was pumped. High voltage was applied to two electrodes one of which was on the printed circuit board of 3D printer and the second one –on the capillary.

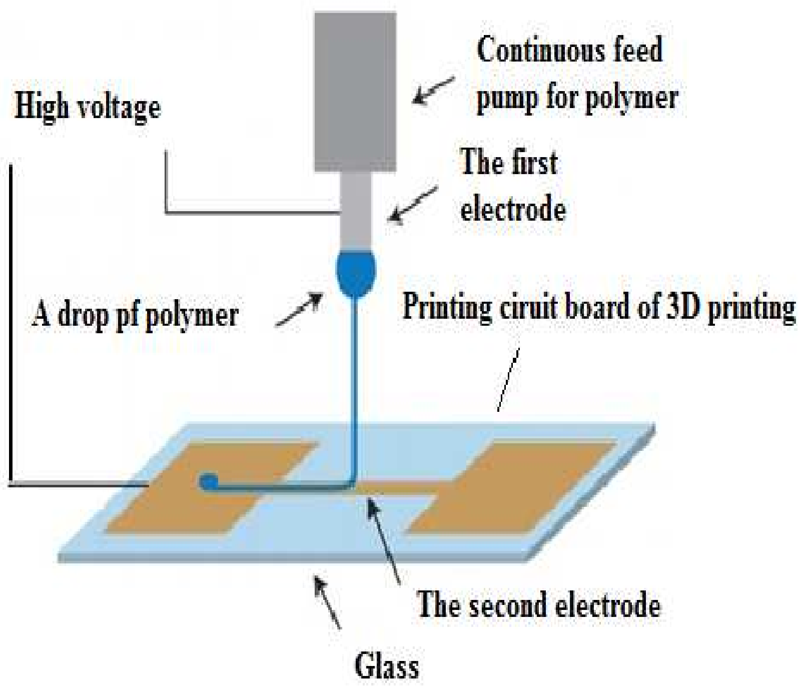


**Fig. 1.** A schematic view of the experimental installation.

It should be noted that the electrodes used in our experiments had different geometric forms. Figure 2 presents their schematic views. This modifications were necessary for changing the electric field lines. This, in its turn, allowed to produce plat «walls» from polymer fibers.

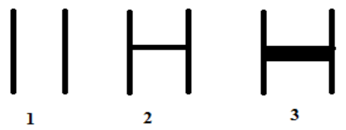


**Fig. 2.** Images of electrodes on the printed circuit board of 3D printer.

At this stage of work, fibre printing is realized, the simplest figures were obtained. Further, it is planned to carry out experiments with three types of polymers as well as works on producing several layers from different types of polymers.

**Results and discussion**

The authors obtained nanosized films from different types of polymers with three types of electodes of the support, the electrodes differed in only the geometric form, the difference in the obtained fibres is expained by the fact that electric field changes with three types of electrodes, this exerting an effect on formation of nanosized polymer fibers. Figure 3 presents images obtained on electron microscope. The images show oriented of fibers the sizes of which make up about 200 nm. The size of the obtained film depends only on the size of the first electrode. In our experiment we obtained films with size of 5*5 cm.

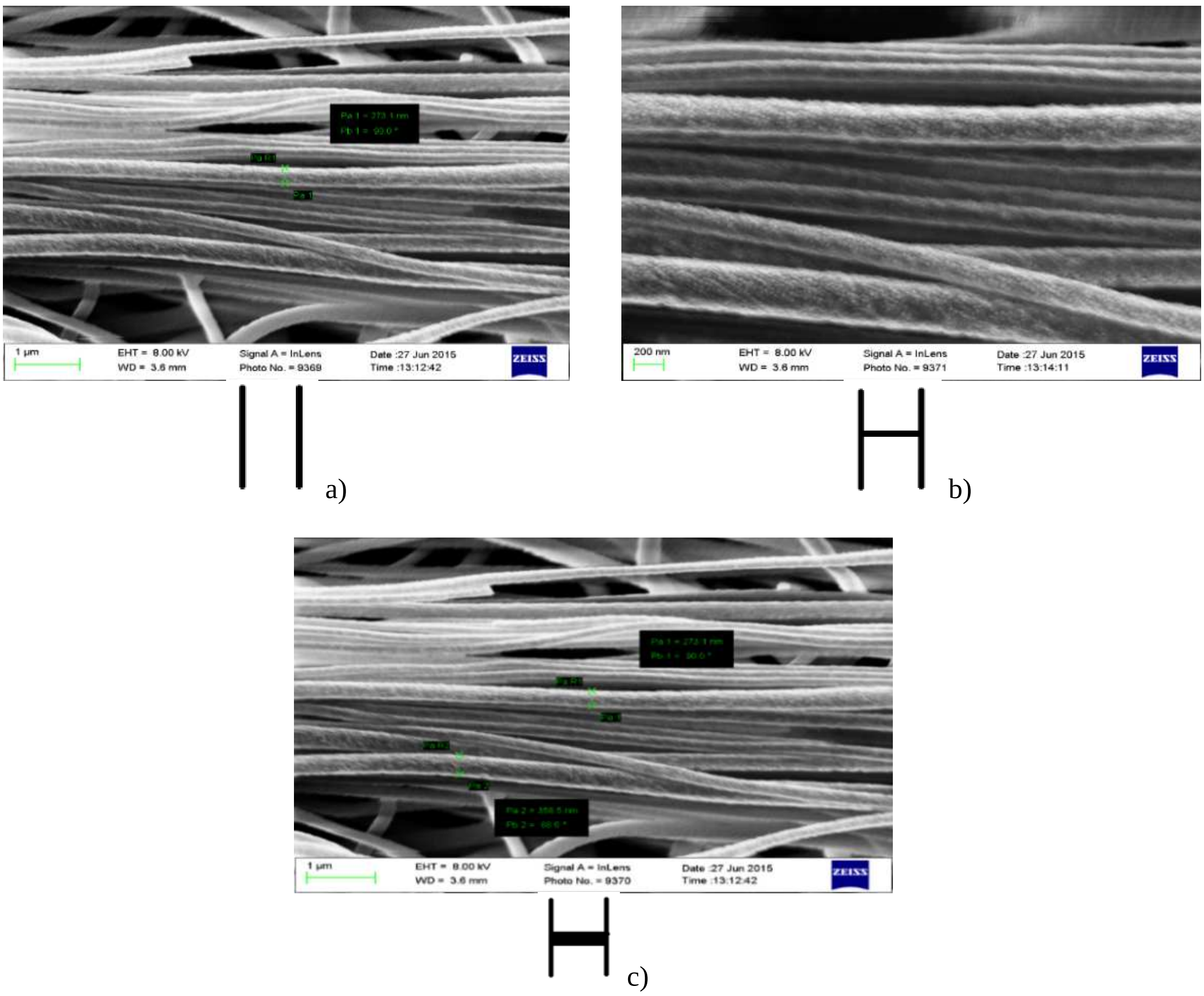


**Fig. 3.** The images obtained on electron microscope (a, b,c corresponding to 1, 2, 3 in Figures 2).

**Conclusion**

The process of producing polymer films by the method of electrospinning was studied. We proposed the method of using 3D prineter in combination with the installation for electrospinning which allowed us to print the simplest nanosized objects with polymer fibers. It is shown that nanosized 3D objects can be produced with the help of electrospinning.

Manipulations over electric field lines, such as electrostatic or magnetic deflectors will allow to realize quick 3D printing of a complex form which can be used for nanofilters, nanorobotics.

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## ОРНАТУ БОЙЫНША ҮШ ӨЛШЕМДІ ОБЪЕКТІЛЕРДІ ӨНДІРУ «3D PRINTING+ELECTROSPINNING»

**Ж. Е. Ыдрысова, Ч.Б. Даулбаев, Ф.Р. Султанов, З.А. Мансуров, Е.Т. Алиев**

Жану проблемалары институты, Богенбай батыр к. 172, Алматы, Қазақстан
zhanara.ydyrysova@mail.ru

**Аннотация**
Бұл жұмыста үшөлшемді наноөлшемді полимерлі талшықтарды алу жұмыстары жүргізілген. Бұл әдісте ПММА- полимерінен диаметрі 50-ден 500нм-ге дейін болатын, тек бағытталған және үшөлшемді талшықтар алынған. Алынған талщықтар бағытталған, яғни үшөлшемді обьектілерді алуға мүмкіндік береді. Электродтардың әр-түрлі типтерін пайдалану наноталшықтардың өлшемін басқаруға мүмкіндік береді. Бағытталған полимерлі наноталшықтар биологиялық клеткалардың биокаркастарын тұрғызуға пайдаланылды.

**Түйінді сөздер:** 3D принтер, наноөлшеді талшықтар, нано объектілер

# ПРОИЗВОДСТВО 3-х МЕРНЫХ ОБЪЕКТОВ НА УСТАНОВКЕ «3D PRINTING+ELECTROSPINNING»

**Ж. Е. Ыдрысова, Ч.Б. Даулбаев, Ф.Р. Султанов, З.А. Мансуров, Е.Т. Алиев**

Институт проблем горения, ул. Богенбай батыра 172, Алматы, Казахстан
zhanara.ydyrysova@mail.ru

**Аннотация**
В данной работе показана возможность получения трехмерных наноразмерных полимерных волокон. Полученные волокна ориентированы, что позволит создавать трехмерные объекты. Предложенный способ позволяет укладывать строго направленные нановолокна из ПММА-полимера с диаметром от 50 до 500 нм. Применения различных типов электродов позволяет варьировать размер нановолокон. Ориентированные полимерные нановолокна были использованы для построения биокаркасов для биологических клеток.
**Ключевые слова:** 3D принтер, электроформирование, наноразмерные волокна, нано объекты