DEVELOPMENT OF MODIFIED DEVICE FOR PRODUCTION OF PARALLELIZED NANOFIBRES

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Abstract

Nowadays production of parallel structured nanofibers is widely evolving and is gaining popularity in various fields. This research is about the development of a modified device for production nanofibers yarns that would be capable of ensuring production of high quality oriented nanofibers. The main requirement to the device is to simplify the production of homogeneous nanofibers layers and also to allow the user to change settings to conduct experimentation. This article describes design process of the device in accordance with the technological requirements, its construction and prototyping. The article also includes an overview of the main disadvantages of existing device and describes the advantages of the modified device. The main feature of the developed device is the precise control of the rotational speed of the collecting element. This is done in order to make the collecting fibers process in strictly parallel form. Also important is modification of collecting element that allows you to change the parameters of the nanofibers collection process. Using this device it will be able to test new materials for the production of nanofibers. The device has been already tested with several materials and we have got positive results.

Keywords: nanofibers, oriented structure, electrospinning, prototyping, device design, motion control.

1. INTRODUCTION

Electrospinning is a technology of nanofibres production. Using this technology allows the production of various nanofibres or microfibres structure. There is used the effect of the electrostatic forces acting on the polymer solution [1]. This article deals with the production of parallelized nanofibers by the electrospinning technology from the polymer solution. To achieve an oriented structure of the resulting layer is necessary to use special collector. Using the rotating carousel is very simple and proven method. This device has been previously constructed. Performance tests in the laboratory have large amounts of disadvantages. Considering its disadvantages, it was necessary to construct a modified device which would allow for a greater range of materials spinnability and improved quality of oriented layers.

This device is only part of a huge project for the production of complex structures of nanofibres. One of the main objectives is to provide a tube of nanofibers possible and multilayer tube.

2. FIRST EXPERIENCE

The first experiments with a rotating collective head were carried out using a device assembled from some improvised material. The main task was to transfer the voltage to bars and rotate them. After successful experiments and the obtained nanofibres samples, it was decided to continue with the experiments in this direction [2]. With this device, we managed to receive structured nanofibers, but the device was not stable, such as contact with bars was temporarily lost and the speed of rotation were not high enough for the necessary experiments. The distance between the bars on the head were fixed, but that's not enough for testing with a variety of polymers solutions. To change the speed it was necessary to change the gearbox or use a new engine. All these operations take up a tremendous amount of time and they require financial expenses, but even when a new device is made, should be noted that it used for one type of experiment with a specific polymer solution. Due to the instability of the device and the complexities of changes in the parameters of the experimentation it was pretty hard to conduct a series of experiments under the same conditions and to collect the necessary amount of data for statistical analysis.

Based on the above, it was decided to develop a working prototype of the device, which would take into account the shortcomings of the first model, namely to ensure a stable contact with the bars, have a stable and controlled rotational speed of the collective head, provide the possibility of changing the distance between the bars, as well as to position this head in the space so as to ensure further operation to collect nanofibers from bars.

3. HARDWARE

First of all, was created a 3D model of the future product (Fig 1 (a) (b)). As the main goal at this stage is to create a working prototype, it was decided to make most of the details on the 3D printer.

(a) (b)

Fig 1. (a) 3D model of developed device, (b) Inside view

For the manufacture of the majority of spare parts 3D printer Dimension SST 768 was used. The printing material was ABS plastic. 3D printing technology has been chosen because it is relatively fast and high quality way to manufacture parts of complex shape.

Design feature of the new model of the device is that the majority of units are easily replaceable, modernization and repair of construction is possible to produce quickly and without making big design changes. This is due to the fact that is first of all a prototype and during the experimentation may break or may need in the rapid modernization of a particular node. For example, if we want to change the engine and a new motor has a different mount from the previous one - we can print only a small adapter, not a whole body where our engine fixed.

To transfer voltage were used brushes which pressured by a spring to a rotating shaft, which is attached to the rotating collective head. Even though they are erased with the passage of time, but provide a stable contact. This brush can be easily changed. If a method of transferring the voltage to the shaft for any reason ceases to satisfy us, the modular design of the device makes it possible to replace one system voltage transfer to any other without redoing the entire device.

Based on the experience of previous experiments, an important parameter is the speed of rotation of the head with bars. There have been many experiments at low speed (one rotation per minute), but there was not experiments with the higher speed. To maintain the stability and positioning accuracy of the rotation was used a stepper motor SH1603-5240, working together with the driver HY-DIV168N. This combination allows obtaining 6400 steps per 360 degrees. As the controller at the present stage Arduino Mega 2560 r3 board was used. Based on technical description it is capable of speeds 3.3 rpm. But to increase the speed was decided to add a gear train. Transfer ratio is 1: 4. This greatly increased the speed of rotation without any loss in the positional accuracy of the head. As was mentioned earlier, this device is one of the links in the production process in future. The next step involves the automatic collection of the resulting nanofibers from the rotating head. It was necessary to do this to ensure accurate positioning of the bars relative to the collective unit. This problem was solved by the establishment of optical sensors in the lower part of the device (Fig 2).

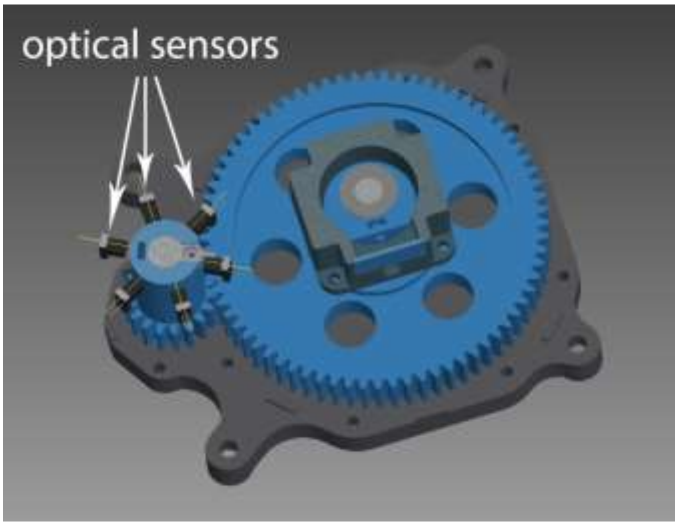

Fig 2. Optical sensors

An important feature of the new model of the device - a quick change heads with different distances between the bars. Replacing the head takes less than one minute. This increases the number of various experiments, using different types of polymer solutions. During the development of the rotary head was given attention to form and aerodynamic of the bars, that can occurs the high speed airflow. Sometimes this flow can destroy the resulting nanofibers. Previously, was used the flat rods, but they were replaced in the new device to cylindrical bars.

4. SOFTWARE

The main idea in the manufacture of the device is that any possible parameters for experimentation can be changed. This will increase the number and variety of tests with different parameters, on the same device with minimal downtime. Currently this devise is programmed for working in test-mode to debug and fix all possible problems [3].

5. EXPERIMENTAL PART

Functional prototype was tested in the laboratory and its performance was compared with the existing device. Oriented structures were obtained from two polymers solutions.

The first experiment: Polyvinylidene fluoride (PVDF; Kynar 720) was obtained from Arkema. Polyethylene oxide (PEO; Mw 900 000) was obtained from Sigma Aldrich. Dimethylacetamide (DMAC) from Penta. Polymer solution was prepared from PVDF and PEO (at ratio 10:1) dissolved in DMAC at 60°C. Concentration of solution was 16,7% by weight. Electrospinning: Electrospinning was carried out from a polymer solution, heated on 60°C, in the syringe to a opposite charge rotation collector for 10 minutes. Voltage on the needle was 20 kV negative and on the collector was 4 kV possitive. The speed of rotation of the collector was 200 rev./min, collector was powered by DC Regulated Power Supply (model RXN-302D-3). The distance between the end of the needle and the collector was 20 cm. All experiments were carried out at 23°C relative air humidity 60%.

The second material: Polyvinyl alcohol (PVA; Mw 60 000) was obtained from Sigma Aldrich. Polymer solution was prepared from PVA dissolved in destilled water (concentration was 12%). Electrospinning: Voltage on the needle was 15kV negative and on the collector was 4kV possitive. Other conditions were the same as in the previous experiment.

Characterization: Oriented electrospun fibers were coated with gold using sputter coating and their morphology including fiber diameter was observed under scanning electron microscopy (SEM; Tescan Vega 3SB Easy Probe).

6. RESULTS

At the moment, two experiments were conducted using a new device. The morphology charactestics of result oriented structures obtained from PVDF/PEO and PVA solutions were studied by SEM. Image analysis are shown on fig. 3.

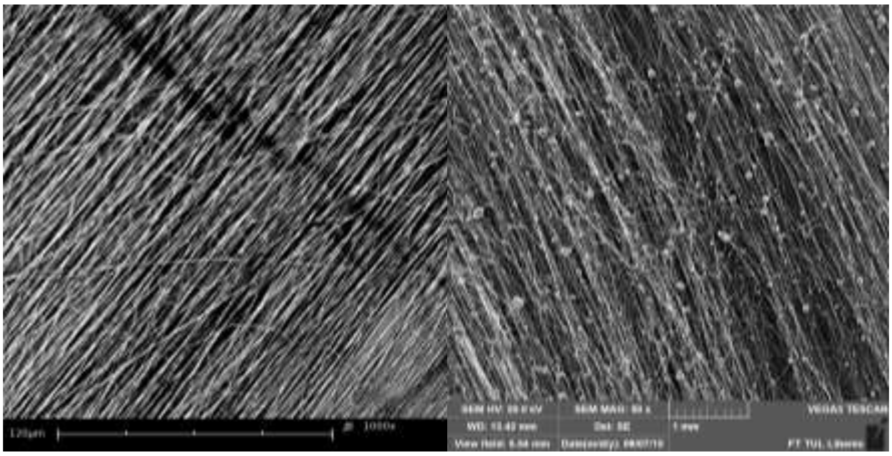

Fig. 3 Image analysis: (a) PVA layer, (b) PVDF layer

The averages electrospun fibers diameters and parallelized percentage of fibers are summarized in table 1.

Table 1 The averages electrospun fibers diameters and parallelized percentage of fibers

Sample	Fiber diameter [nm]	% of parallelized fibers
PVA	280±68	92
PVDF/PEO	3185±260	75

There was carried an experiment to compare the diameters of fibers in the production of three different technologies. The first layer was made by classical method for producing nanofibers – Nanospider. The second was from the original carousel and the third was from the modified device. As we can see on the figure 4, the novel method is the able to produce a highly parallelized structure. All experiments were carried out from a solution of PVDF/PEO under the conditions described in the previous experiment.

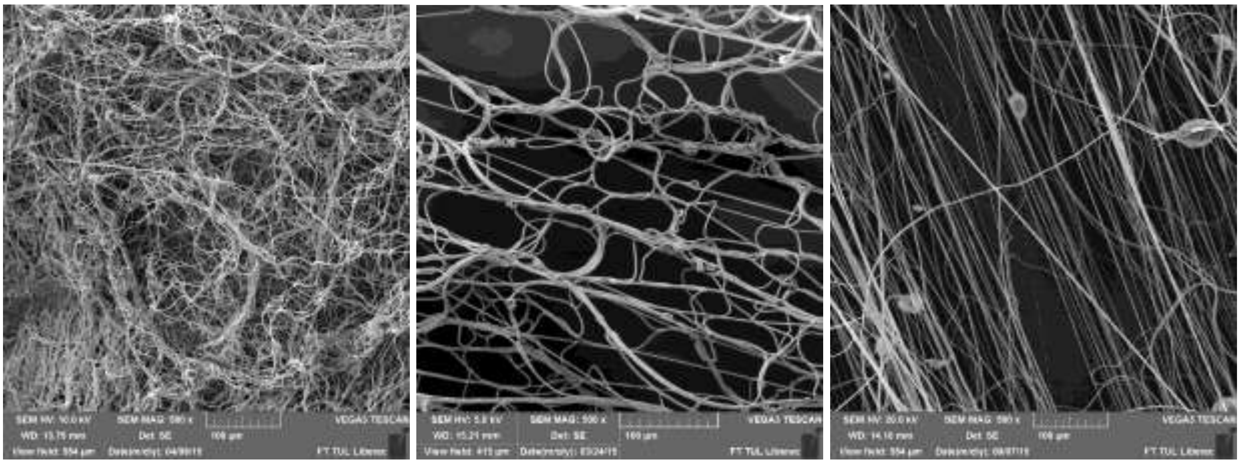

Fig. 4 Image analysis: (a) PVDF/PEO Nanospider layer, (b) PVDF/PEO layer from original device (c) PVDF/PEO from the novel device

7. CONCLUSIONS

The result, which we expect to receive - a wide range of experiments on the production of a variety of structured nanofibers using different polymer solutions. The resulting nanofiber primarily planned use in medicine. Namely for spectrographic test various liquid substances, the manufacture of nanowires and nanotubes for transfer of substances directly into the nucleus of cells, or to drain of intraocular fluid in glaucoma disease. Possible applications may also be the production of artificial muscle with the aid of electrically conductive parallel nanofibres and their ability to contraction or tension due to the effect of voltage. The formation of nano parallelized yarn there is a great potential for use as a exact probes, for example at AFM microscopy.

Area of application of structured nanofibers each day is expanding and therefore requires to make a lot experiments using different polymers to make them. The new model developed device just allows us to increase the amount of experimentation required.

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