ELECTROSPINNING AND SOLUTION BLOW SPINNING PRODUCTIONS METHODS OF POLYMER SCAFFOLDS FOR TISSUE ENGINEERING

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Modern medical technologies are aimed to solve problems related to improving the quality and the human's life span. It is required to control structural and functional state of regenerating cells deliberately in order to provide successful recovery of living functions and rehabilitation of patients especially in such cases as oncological and cardiac diseases, disorders in the musculoskeletal system, in stomatology. Three-dimensional non-woven scaffolds used for such purposes due to their architectonics are capable of controlling the functional state of cells and manage the recovery processes of living tissues. Polymer materials used to produce scaffolds should have certain physical, mechanical, chemical and biological properties. Depending on properties of raw polymer materials scaffolds may be either - biodegradable or biostable which define their field of application. Therefore, the enhancement of non-woven scaffold forming methods for regenerative medicine is a vital problem.

There are several methods of forming polymer non-woven scaffolds including an electrospinning and solution blow spinning. The electrospinning is a method of forming thin fibers with diameter varying from nanometers to micrometers and materials with high specific surface area with the help of electrostatic powers [1]. A schematic circuit of the electrospinning consists of syringe pump, high-voltage supply and collector (fig. 1). The scaffolds obtained with the electrospinning can be characterized with homogeneous diameter distribution of fibers, high mechanical properties and high biocompatibility.

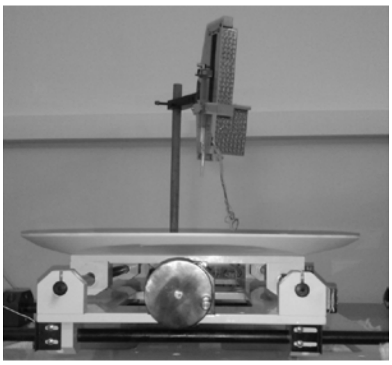

Fig. 1. A schematic circuit of the electrospinning

The solution blow spinning is a method of forming polymer non-woven materials out of solutions and melts of polymer (fig. 2). Heated/compressed air or gas of a high speed is used for extension of fibers [2]. This method is unique because of capability to produce microfibers (diameter is about micron) which size is several orders smaller than the size of materials formed by any other method.

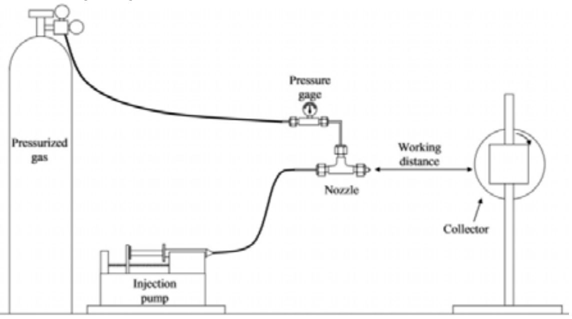

Fig. 2. A schematic circuit of the solution blow spinning [2]

The non-woven materials with required morphology and fiber diameter can be formed by varying technological parameters [1-3]. The morphology of polymer non-woven scaffolds defines the field of applications, therefore its analysis is of the top-priority.

Scaffolds were formed from solution of copolymer tetrafluoroethylene with vinylidene fluoride (TFE/VDF) in dissolvent of low toxicity – acetone. Parameters of process of non-woven materials forming by the electrospinning are as follows: the solution consumption 2 µl/min, the nozzle diameter for supplying the solution 0.1 mm, the distance between the nozzle and the collector 15 cm, voltage between the collector and the needle 16 kV. Forming parameters for the solution blow spinning are as follows: the solution consumption 25 µl/min, the pressure of compressed air 3.5 bar, the nozzle diameter for supplying the polymer solution 0.35 mm, the nozzle diameter for supplying the compressed air 0.53 mm, the distance between the nozzle and the collector 40 cm.

The surface morphology analysis of non-woven polymer scaffolds was carried out by a method of the scanning electron microscopy (SEM) on Quanta 400 FEG without deposition of conductive coatings at low vacuum regime in water steam atmosphere (the residual pressure in the camera is 60 Pa, the accelerating voltage is about 20 kV, the current of the beam is 5 µA).

The scaffolds surface morphology formed from the solution of copolymer TFE/VDF by the electrospinning is in figure 3.

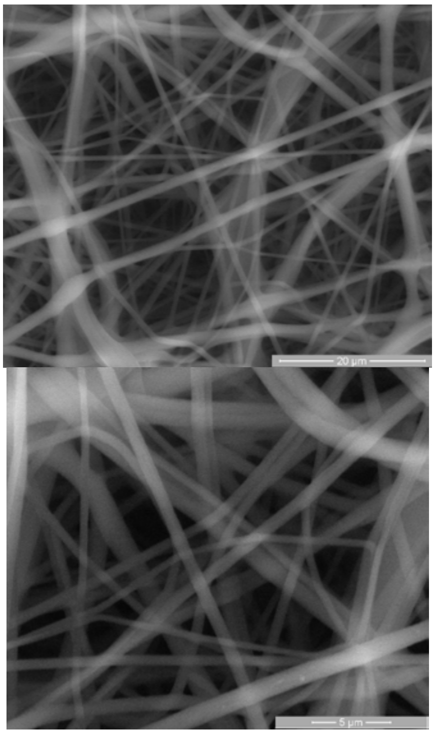

Fig. 3. The surface morphology of TFE/VDF scaffolds formed by the electrospinning

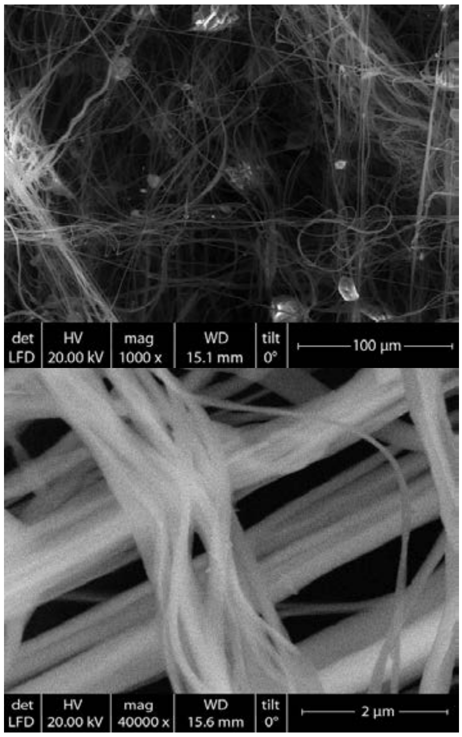

Fig. 4. The surface morphology of TFE/VDF scaffolds formed by the solution blow spinning

The obtained results (fig. 3) correlate with optic microscopy data (Motic) and demonstrate that non-woven materials, formed by the electrospinning consist of rough, single nanofibers which are compact and strongly tangled. The average porosity of the electrospinned scaffolds, which was calculated according to the data of optical microscopy with the help of Image J 1.38 software, was about 45 %. The average pore size is about 3 µm. The thickness of the fibrous material at chosen forming parameters after 5 minutes from the process beginning was about 38 µm.

The surface morphology of scaffolds formed from the solution of copolymer tetrafluoroethylene with vinylidene fluoride by the solution blow spinning is in figure 4. The analysis of the scaffolds morphology formed by the solution blow spinning showed that the scaffolds had a complicated spatial ordering with more easy packed bundles of aligned microfibers in their structure, which contain 10 up to 100 nanofibers per bundle. Average pore sizes of the scaffolds formed by the solution blow spinning varied from 8 to 17 µm. The average thickness of the non-woven material after 5 minutes from the process beginning was about 290 µm and the porosity was about 65%.

The comparative appraisal of the non-woven polymer scaffolds formation variants shows that the scaffolds obtained by the solution blow spinning have more complicated spatial ordering with enough porosity and high formation speed. The electrospinning method allows to obtain sub-micron fibers with different orientation, high surface area and regulated porosity. These parameters are favorable for elaborate cells growth *in vitro* and *in vivo* because they directly influence the cells adhesion, cells expression, oxygen and nutrients delivery to cells.

The definite application field in tissue engineering is typical for each method of non-woven materials formation depending on used raw materials. Thus, different polymer nanofibers are used as scaffolds for cartilages, cutaneous tissue, bones etc. The electrospinned fibers are widely used, for instance, as arterial blood vessel, scaffolds for heart and nerves. The scaffolds obtained by the solution blow spinning find a special application for producing parenchymatous organs. However, the most optimal and most perspective variant is combining methods in order to get the required properties of scaffolds and to create hybrid materials.

References

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