Increased Production of Nanofibrous Materials by Electroblowing From Blends of Hyaluronic Acid and Polyethylene Oxide

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Natural and synthetic nanostructured polymers in the form of fibers are used in medical and cosmetic applications. One of the main advantages of the electrospinning method is its flexibility, which allows to use airflow in the vicinity of a spinneret to increase production. The acceleration of solvent evaporation rate allows the solution feed rate to be increased. Experimental results confirmed a significant increase in the production of hyaluronic acid and poly(ethylene) oxide nanofibers. The increase occurs when higher airflow velocity and higher airflow temperature are used, causing a decrease in the partial pressure of solvent vapours and relative humidity when a supercritical intensity of the electrostatic field is applied. The obtained results indicate that the electroblowing method offers some significant advantages, making it suitable not only for the research and development of new nanofibrous materials but also for the potentially successful production of such materials for targeted applications. POLYM. ENG. SCI., 00:000–000, 2016. © 2016 Society of Plastics Engineers

INTRODUCTION

Nanomaterials and nanofibers are developed for various potential applications [1], some of which have already been commercialized (e.g., air and liquid filters, medical stents, scaffolds for tissue engineering etc.). One of the methods used for the preparation of these materials is electrostatic spinning, a highly flexible method which can be scaled-up for industrial production [2, 3]. The development of new materials necessitates more efficient technological equipment and greater maximum production volumes [4, 5]. The electrostatic spinning method applied in the production of nano- and microfibrous materials uses a pair of electrodes connected to opposite electrostatic potentials [6, 7]. One of these electrodes comprises a spinning nozzle which distributes doses of the polymer solution used for fiber production. The forces of the strong electric field produce the so called Taylor cone [8] which propels the injected solution (in the form of a jet) toward the opposite, collector electrode. As the jet follows a very complicated trajectory, the solvent evaporates and the solution solidifies into fibers [9]. The process forms a continuous layer of randomly oriented fibers of

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small diameters on the collector (generally ranging from tens of nanometres to micrometres). Solvent evaporation rate is one of the key criteria for attaining the desired fiber quality and yield. In order to successfully produce fibers in a strong electric field and to attain sufficient efficiency of the spinning process, a set of environmental conditions, physical-chemical properties of the polymer solution as well as electrode geometries must be optimally set [10]. For this purpose, the core electrostatic spinning method is complemented with other technological elements. One such example is the implementation of airflow in the vicinity of the spinning nozzle. This enhanced form of electrospinning is called “air/gas assisted electrospinning” or more simply “electroblowing” [11].

The combination of electrostatic spinning and airflow was probably first used in the making of Petrynov-FiltersVs [12]; the authors named their method “electro-gasodynamic injection.” Its main advantages, as cited by the authors, are that the flowing air prevents the solution from overflowing the spinning nozzles and breaks up the solution into a large number of jets at the Taylor cone. Both of these advantages improve the stability of production and material quality. Another argument for incorporating airflow is that it supports the formation of the Taylor cone and helps initiate, stabilise and complete the spinning process [13]. Airflow positively influences fiber morphology in a way that leads to a narrow distribution of fiber diameters and small mean flow pore size, resulting in enhanced filtering efficiency, as described for a polycarbonate nanofibrous material by the authors of the article [14]. Electroblowing is used to spin blends which cannot be processed by standard methods due to for example the high viscosities of some polymer solutions even when used in low concentrations, as in the case of hyaluronic acid [15–17]. The combination of airflow and electrospinning is also used for the spinning of very thin nanofibers less than 100 nm thick. For example in Ref. 18, the researchers used a new method called “Supersonic Electronically Assisted Blowing” to break up the