Bubble-Electrospinning: A Novel Method for Making Nanofibers

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Abstract: Nanofibers produced by electrospinning are already being used in a vast array of products in many industries. However, the volume of production of nanofibers has been a bottleneck restricting their applications. In this work we reported a novel method to fabricate continuous and uniform nanofibers by electrospinning using an aerated polymer solution in an electric field. Multiple jets, which were a prerequisite for increasing the volume of production, were found in this electrospinning process. The morphology of the deposited fibers was straight, coiled and helix observed by a scanning electron microscope (SEM) and an optical microscopy. The results showed that the product of this process was similar to that of a traditional electrospinning process and illustrated a good prospect of application.

1. INTRODUCTION

Electrospinning technology was invented about 100 years ago [1-3]. It is already seen as a key source of production for nanofibers, which have been applied successfully in various industries such as healthcare, biotechnology, textiles, environmental engineering, defense and security, energy storage and other fields [4-9]. A traditional and typical electrospinning setup mainly consists of a syringe, a syringe pump, a high-voltage power and a grounded collector as described in many literatures [10-14]. But the volume of production of nanofibers is one of the major shortcomings that restricts their applications. In the open literatures, there were a great variety of new methods of electrospinning process [15-22], often with little success.

Recently, we have presented a new electrospinning process, bubble-electrospinning, using aerated solution with compressed gas in an electric field, and preliminarily discussed the feasibility and potential ability for mass production[23]. In this study, we aim to use bubble electrospinning technology to produce nanofibers and investigate the morphology of nanofibers.

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2. EXPERIMENTAL

The polymer, polyvinylpyrrolidone (PVP-k30, $M_w = 40,000\, g/\text{mol}$), was purchased from Shanghai Sinopharm Chemical Reagent Co., Ltd. The solvents, pure alcohol and the distilled water, were bought from Shanghai Chemical Co., Ltd. All the chemicals were used as received. The polymer was dissolved into an alcohol/water mixture with the weight ratio of 9:1. The PVP solution concentration was 30wt%. The system of bubble electrospinning as described in previous work[23].

The morphology of the obtained nanofibers in this new electrospinning process was determined by a scanning electron microscope (DXS-10A, Shanghai Electron Optical Technology Institute, China), a biological microscope (XSP-8CA, Shanghai Optical Instrument Factory). An OLYMPUS digital compact camera (FE-160, Japan) were employed to capture the jets in the experiments.

3. RESULTS AND DISCUSSION

One or several bubbles or humps were generated on the free surface of the aerated polymer solution. The projection was semi-globular or cone-shaped, which closely resembled the Taylor cone in traditional electrospinning process. The solution was charged after imposing a strong electrostatic field. The jets of polymer solutions were then ejected when the voltage was above the threshold value. Figure 1 showed multiple jets ejected from the bubble on the surface of 30wt% PVP solution. The number of multiple jets was significantly related to the number and size of bubble, and even the applied voltage. The multiple jets were a prerequisite for increasing the volume of production of nanofibers. Generally, the number and size of bubbles depended on the gas pressure and the properties of the solution (such as the surface tension, viscosity), and it could be adjusted.

![Figure 1](image_url)

Figure 1 Multiple jets were ejected from PVP solution.

The morphology of PVP nanofibers in this experiment were observed through SEM micrographs illustrated in Figure 2. There were some beads among the fibers and some thick fibers, which showed that the jets hardly had time to solidify before falling on the collector at a low polymer solution concentration and a high voltage in this experiment (see Figure 2a). Because the acceleration of the
jets was increased by a higher voltage and the jets moved faster in a constant distance. When the applied voltage was lower, the fibers were in the majority (see Figure 2b).

Figure 2. SEM photograph of PVP electrospun nanofibers.

Figure 3 showed typical optical images of PVP fibers in this experiment. There were some coiled and helix fibers (see Fig 3(b)) besides some disorders straight fibers (see Fig 3(a)), which were common phenomena in the traditional electrospinning process. The fibers mat was a typical nonwoven mat with the disorganized fibers and much porosity among fibers. The mat with this unique structure was very popular for the application of many fields.

Figure 3. Optical images of PVP fibers in this experiment. (a) morphology of fibers mat, (b) coiled and helix fibers.

4. CONCLUSION
A novel electrospinning process, bubble electrospinning, was introduced briefly in this work. Multiple jets, which were a prerequisite for mass production of nanofibers, were observed in our experiment. The morphology of produced nanofibers was investigated by SEM photographs. The electrospinning system might be used as potential application for mass production of nanofibers. Further research will be carried out based on the new electrospinning system developed here.

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