The Simulation of Electric Field Distribution in Electrospinning Process

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Abstract

Electrospinning of polymer solutions has gained much attention as an economical and straightforward method to produce nanofibers.

The process of electrospinning contains the presence of electrostatic charge to a polymeric solution under a high electric field. The major form of operation entails charge induction in the solution through contact with a high voltage electrode. The induced surface charges cause the solution drop to distort into the shape of a cone, which is called Taylor cone [1]. Above a critical level of voltage, a thin jet of solution that is erupted from the Taylor cone travels to the negative or grounded electrode undergoing stretching and whipping motions [2].
We have recently demonstrated that electric field distribution influences the jet motion in the electrospinning process thus affecting the resultant nanofiber morphology [3, 4]. More uniform electric field distribution produces finer and more homogeneous fibers.

The electric field plays a very important role in the electrospinning process, which needs to be seriously considered in the electrospinning configuration developing. High voltage involved in electrospinning process leads to difficulty in measuring the electric field. Numerical simulation is used to design the electric field, and experiments are carried out to validate the spinneret and collector designs.The COMSOL Multiphysics® software provides a numerical technique to simulate the electric field using the finite element method (FEM). The electric field intensity and distribution can be visualized using the FEM calculation with the practical dimensions and material properties of the electrospinning setup.
Figure 1 shows the traditional single needle electrospinng and a flat spinneret electrospinning setup. The electric field distributions of the two electrospinning configurations shows in figure 2. As can be seen the flat spinneret configuration creates a more uniform electric field, which indicates the smaller diameter fiber can be produced by the flat electrospinning setup.

To improve the productivity of the electrospinng process, the multihole electrospinning configuration is developed. The electric field distributions in the xy-plane at $z = 1$ mm for the flat multihole spinneret and the multistep multihole spinneret are illustrated in Figure 3. It is clear that the electric field is intensified at the hole positions. For the flat spinneret, as seen in Figures 3a and 3b, the weakest electric field is formed at the central position, and the strongest electric field is at the outside position.

The 3D model of the multihole electrospinning configurations with flat spinneret and multistep spinneret were created to simulate the electric field lines during the electrospinning by the COMSOL Multiphysics® software. The simulated electric field lines created by the two types of spinneret are shown in Figure 5. It seems that the electric field lines generated in the multistep spinneret are more concentrate to the spinning line. For the flat spinneret, the electric field lines are scattered outwards at the edge of the spinneret, which may lead to scattered fiber mats.

Reference

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Figures used in the abstract

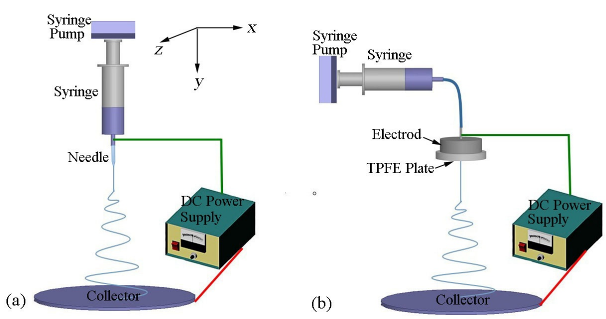

Figure 1: The electrospinning setups: (a) single needle electrospinning and (b) single hole flat spinneret electrospinning.

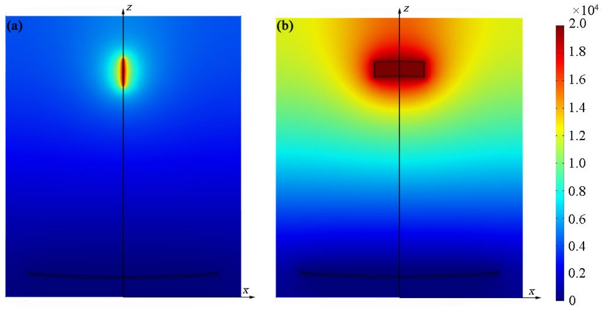

Figure 2: The simulated electric field distribution of the two setups: (a) single needle and (b) flat spinneret.

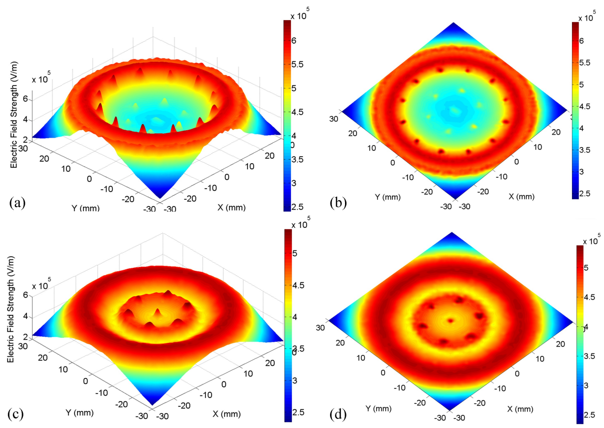

Figure 3: Calculated electric field distribution in xy-plane at z = 1 mm : (a) 3D view of the flat spinneret, (b) top view of the flat spinneret, (c) 3D view of the multistep spinneret, and (d) top view of the multistep spinneret.

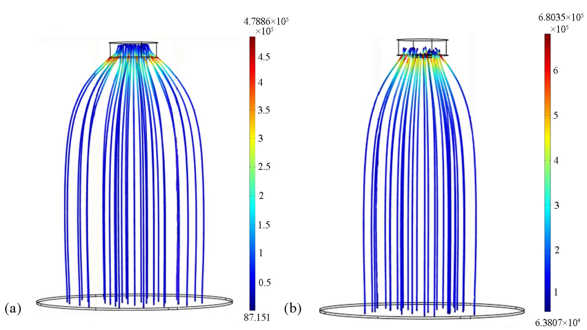

Figure 4: Electric field lines simulated by COMSOL software: (a) the flat spinneret configuration, and (b) the multistep spinneret configuration.