

Impact of Overlapping Collector on Orientated Deposition of Electrospun Nanofibers

Changfu Fang¹, Yan Jiang² and Lei Xu^{*,1}

¹School of Mechanical and Electric Engineering, Jingdezhen Ceramic Institute, Jingdezhen 333403, China

²Power Lift Institute, Daqing Petroleum Equipment Group, Taicang 215400, China

Abstract: Standard electrospinning deposits disorderly nanofibers on a conducting collector owing to unstable whipping of the jet. Nevertheless, biological engineering requires orderly electrospun nanofibers to improve mechanical properties and cellular proliferation. An attempt is made to fabricate well-orientated nanofibers by applying an overlapping collector. It turns out that electrospinning deposits random and disorderly nanofibers as usual even if conducting aluminum foil, as a collector, overlaps insulating poly(ethylene terephthalate) (PET) film. When insulating PET film overlapping aluminum foil is applied as a collector, the PET film accumulates ions to repel the whipping filament in the space while non-overlapping aluminum foil attracts the filament such that electrospinning deposits orientated nanofibers on the insulating PET film.

Keywords: Electrospinning, nanofiber, orientated deposition, patterned collector.

1. INTRODUCTION

As an efficient process to produce nanofibers, electrospinning has attracted much attention with the development of micro- and/or nanoscale manufacturing technologies in recent years. Electrospinning can fabricate planar and three-dimensional structures by applying polymeric, metallic, ceramic, and organic materials [1-4]. In laboratories, electrospinning has been widely used to produce composite nanofibers [5], filtering films [6], solar cells [7], microsensors [8], and tissue scaffolds [9].

In standard electrospinning, continuous solution supply results in a pendant adhering to the nozzle exit due to surface tension force. Electric charges are injected from the nozzle into solution and then transferred onto the pendant surface such that the pendant stretches into a cone shape under an applied electric force. A jet, carrying electric charges, issues from the pendant onto a collector once the electric force overcomes the surface tension force and viscous force. The jet has a stable segment adjacent to the pendant tip and an unstable segment. The unstable segment results from a primary instability, also called the spiral whipping, in the space and a secondary instability on the collector under interactions of electric charges [10]. With an evaporation of solvent and spiral extension, the jet grows thin and becomes a filament.

In biological engineering, applied orderly electrospun nanofibers are useful and valid to enhance cellular adherence and proliferation because of their advantages of large aspect ratio, structural uniformity, and better mechanical properties.

Nevertheless, standard electrospinning deposits random and disorderly nanofibers on the collector under instable whipping. This work discusses the effect of overlapping collector on the orientation of electrospun fibers.

2. EXPERIMENT

The experiment used a typical setup [11], in which a high-voltage power supply (Dongwen DW-P503) connects to a grounded collector and a stainless steel nozzle (o.d. = 0.41 mm, i.d. = 0.21 mm). A syringe pump (Ristron RSP01-B) supplied the nozzle with 14 w.t. % poly(ethylene oxide) (PEO, MW = 300,000 g/mol) solution. The nozzle-to-collector distance was 14 cm; the applied voltage was 10 kV.

The applied collector utilized an overlapping configuration of 0.04-mm-thick aluminum foil and 0.2-mm-thick poly(ethylene terephthalate) (PET) film. The upper layer was patterned and round inside but squared outside as shown in Fig. (1); the lower was rectangular and larger than the upper. The inside circle of upper patterned collector was 10 mm in diameter; the side length of outside square was 20 mm. Measured nanofiber samples were extracted from specific locations: Points (A), (B), (C), and (D) on patterned collector.

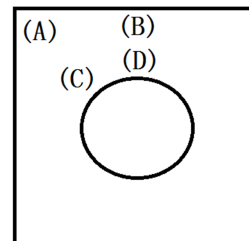


Fig. (1). The patterned collector on which nanofibers are extracted from specific locations: (A), (B), (C), and (D).

*Address correspondence to this author at the School of Mechanical and Electric Engineering, Jingdezhen Ceramic Institute, Taoyang Road, Jingdezhen 333403, China; Tel: +86-798-8465857; E-mail: charlie1975@163.com

3. RESULTS AND DISCUSSION

Fig. (2) shows nanofibers deposited on patterned aluminum foil with overlapping PET film. Fig. (2A-D) are SEM graphs of electrospun nanofibers extracted from corresponding locations of patterned aluminum foil as shown in Fig. (1). It is noted from the illustrations that all the fibers are disorderly as usual in standard electrospinning.

Although patterned aluminum foil, as a collector, overlaps with the insulating PET film, the upper aluminum foil is such a good conductor that electrospinning still has a preferential orientation of deposition on the conducting collector. Furthermore, Fig. (2A) further demonstrates that the quantity of deposited nanofibers at the corner of the aluminum design is fewer than the quantities at other locations, as the spiral whipping of filament results in little deposition at the corner.

Fig. (3) shows nanofibers deposited on the patterned PET film overlapping with the aluminum foil. Fig. (3A-D) are SEM graphs of electrospun nanofibers extracted from corresponding locations of patterned PET film as shown in Fig. (1). It is seen that the insulating PET film collects well-ordered nanofibers in comparison with the conducting aluminum foil.

PET film accumulates a large number of ions due to its low conductivity and long relaxation time. These

accumulated ions have such like polarity with those charges carried by the jet in the space that they repel the random deposition of nanofibers on the PET film. Aluminum foil at the bottom layer, on the other hand, is larger than the patterned PET film at the top layer. Non-overlapping aluminum foil, inside the circle and outside the square of PET design, attracts whipping filament due to the priority-of-conductivity principle during electrospinning. This attraction from both inside and outside of the design stretches the filament over the PET film. Hence, the patterned PET film collects more orderly nanofibers than patterned aluminum foil.

CONCLUSION

Standard electrospinning has a preferential deposition on a conducting collector. The priority-of-conductivity principle as well as the spiral whipping results in random and disordered deposition of electrospun nanofibers on a conducting collector, even if a conducting aluminum foil, as a collector, overlaps insulating PET film. Nevertheless, applied PET film can accumulate ions to repel charged jet in the space when it overlaps conducting aluminum foil. Large-area aluminum foil at the bottom layer of a collector stretches such filaments over the PET film such that electrospinning fabricates well-orderly nanofibers on insulating PET film.

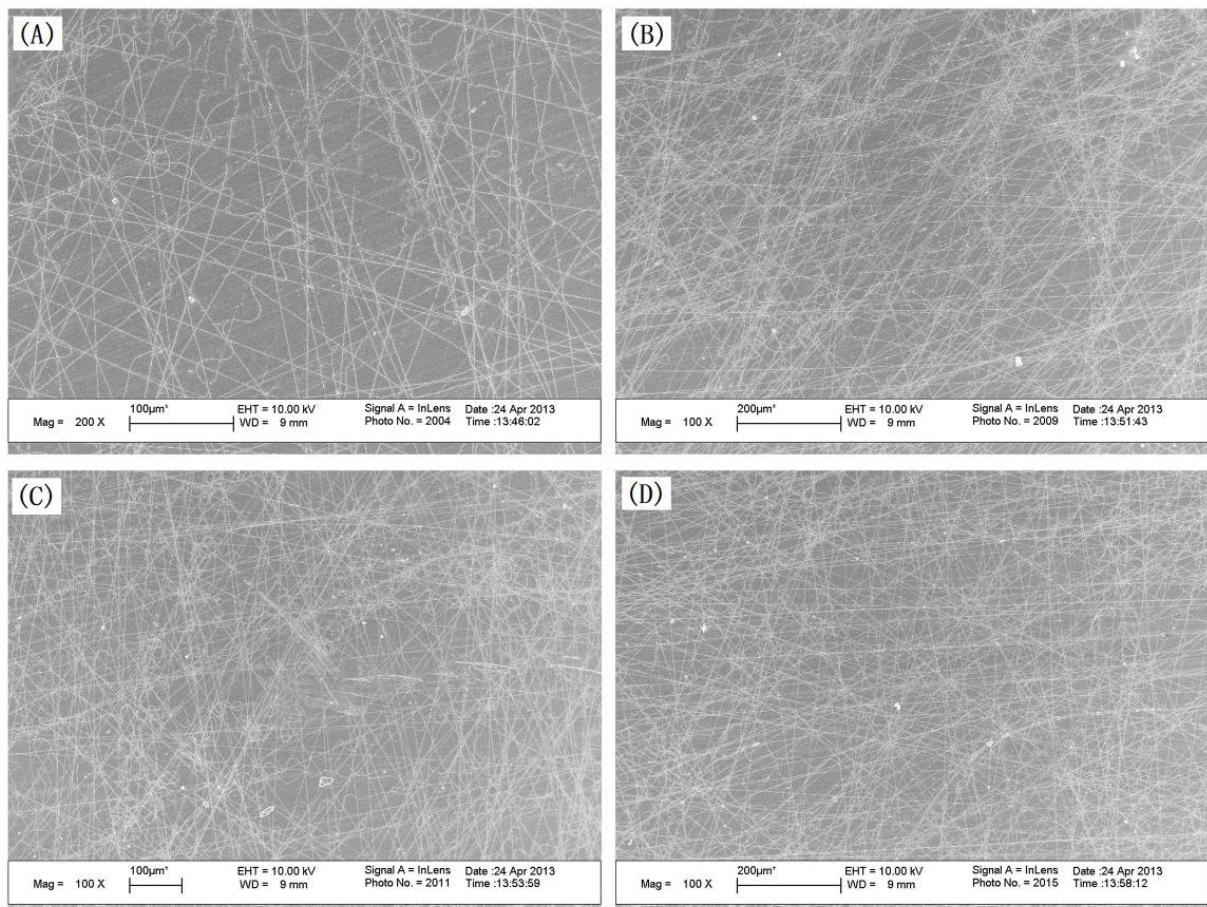


Fig. (2). SEM graphs of deposited nanofibers extracted from corresponding locations of patterned aluminum foil overlapping PET film: (A), (B), (C), and (D).

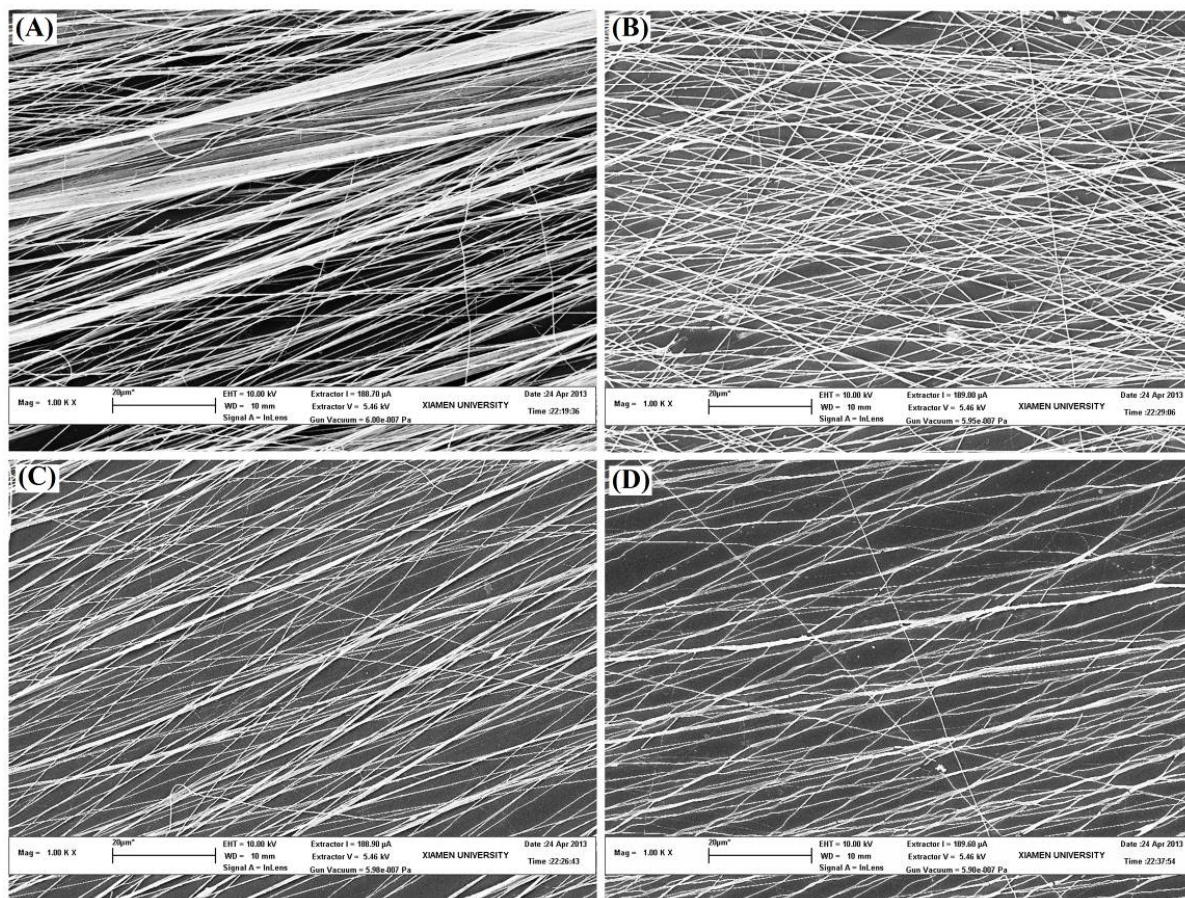


Fig. (3). SEM graphs of deposited nanofibers extracted from corresponding locations of patterned PET film overlapping aluminum foil: (A), (B), (C), and (D).

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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