Mass Production of Electrospun Polyimide Nanofiber Membranes for Application in Li-Ion Battery, and Air and Liquid Fine Filtration

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ABSTRACT

Elctrospun nanofibers has been attracting worldwide intensive attention due to its small diameter, high specific area, particularly, being made in an easy way. The electrospun nanofiber nonwovens or self-supporting electrospun nanofiber mats have, however, not been produced in a large scale. In this presentation, we introduce a way to the mass production of electrospun polyimide nanofiber nonwovens by using needled electrospinning nozzle array modules. The production speed of nanofiber nonwovens can reach 2-3 m^2 nanofiber nonwovens with a surface density of 10-15 g/m^2 per minute. The as-produced nanofiber products could be thermally treated to form the nanofiber nonwovens with an as-desired porosity or density for the battery separator application, and for air purification and liquid filtration applications.

Keywords: self-supporting nanofiber nonwovens; needled electrospinning; polyimide nanofibers; mass production; nanofiber separator

Elctrospun nanofibers has been attracting worldwide intensive attention due to (1) its small diameter and high specific area; (2) the highly porous nanofiber nonwovens; (3) particularly, being made in an easy way [1-6]. The highly porous nonwovens are being used or finding uses in separator for lithium battery [7], filtrations [8] among others. Future applications of nanofibers may include solar sails, light sails and mirrors in space [9]. For the above applications, electrospun nanofiber nonwovens should have good mechanical properties in order to meet the winding tension in a mechanized production process and should be able to be produced in an industrial scale for a commercial market.

To date, the electrospun nanofiber nonwovens or self-supporting electrospun nanofiber mats have, however, not been produced in a large scale. Three factors, stress of the electrospun nanofibers, reinforcement of the as-produced nonwovens via adhesion between the nanofibers, and re-dissolution of the as-produced nanofibers by the solvent vapor generated in the mass production process, may be the main reasons that retard the development of the electrospun nanofiber nonwovens. In this presentation, we introduce a way to the mass production of electrospun polyimide nanofiber nonwovens by using needled electrospinning nozzle array modules (Figure 1A). The production speed of nanofiber nonwovens directly depends on the number of used modules (Figure 1B). A production line with 30 such modules could produce 2-3 m^2 nanofiber nonwovens with a surface density of 10-15 g/m^2 per minute (Figure 1). The as-produced nanofiber products could be thermally treated to form the nanofiber nonwovens with an as-desired porosity or density for the battery separator application (Figure 2A), and for air purification (Figure 2B) and liquid filtration applications (Figure 2C).

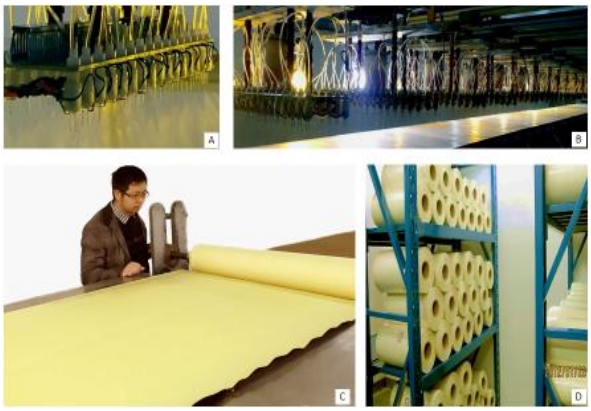

Figure 1. Production line and products of polyimide nanofiber nonwovens: a needled electrospinning nozzle array module (A); a nanofiber production line with 30 needled electrospinning nozzle array modules (B); collection process of polyimide nanofiber nonwovens (C); and products of polyimide nanofiber nonwovens (D).

As a result, the Li-ion battery with polyimide nanofiber separator shows a high safety, a high rate capability and a high cycling stability due to the heat-resistance and high porosity of the electrospun nanofiber separator; the polysulfonamide nanofiber filter shows a 99.99% intercepting efficiency to 0.3 μm particles in air at a nanofiber loading weight of 1.0 g/m^2 on PET nonwoven fabrics; the self-supporting polyimide nanofiber filter shows a 99.9% intercepting efficiency to 4.0 μm particles in engine oil. Overall, self-supporting polymer nanofiber nonwovens could be continuously produced in a large scale by using needled electrospinning nozzle array modules, and the as-produced nanofiber products are being used or finding uses in battery fields, purification and filtration fields. For the moment, the technology level of this equipment is, however, very primitive or backward. We hope to find partners to develop corresponding modern equipment and to promote a commercially production of

self-supporting nanofiber nonwovens for the benefit of our humanity.

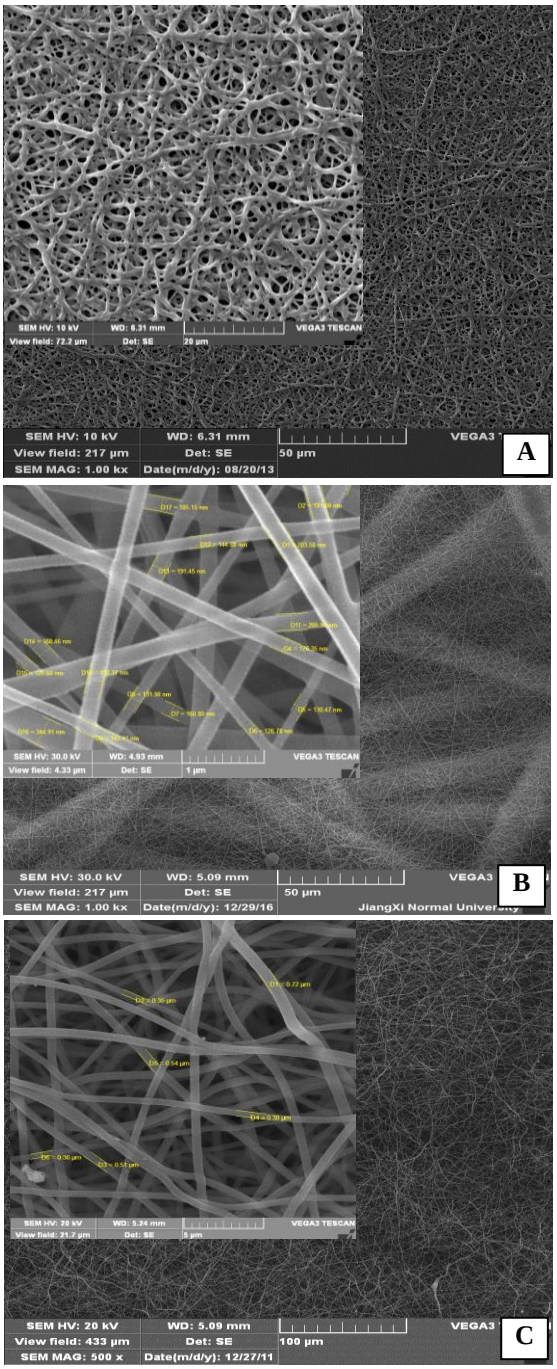

Figure 2. SEM images of polymer nanofiber nonwovens: (A) polyimide nanofiber separator for Li-Ion battery; (B) polysulfonamide nanofiber filter for air purification; (C) polyimide nanofiber filter for liquid filtration. The inserts are correspondingly high magnification SEM images.

Acknowledgments

This research was supported by the National Natural Science Foundation of China (Grants No.: 21174058), the important science and technology special project of Jiangxi province, China (Grants No.:20114ABF05100).

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