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(19) **United States**(12) **Patent Application Publication****Huang et al.**(10) **Pub. No.: US 2010/0084793 A1**(43) **Pub. Date: Apr. 8, 2010**(54) **ELECTRO-SPINNING APPARATUS AND
ELECTRO-SPINNING METHOD**(75) Inventors: **Cheng-Chiang Huang**, Yilan
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Taipei Hsien (TW)(21) Appl. No.: **12/291,763**(22) Filed: **Nov. 12, 2008**(30) **Foreign Application Priority Data**

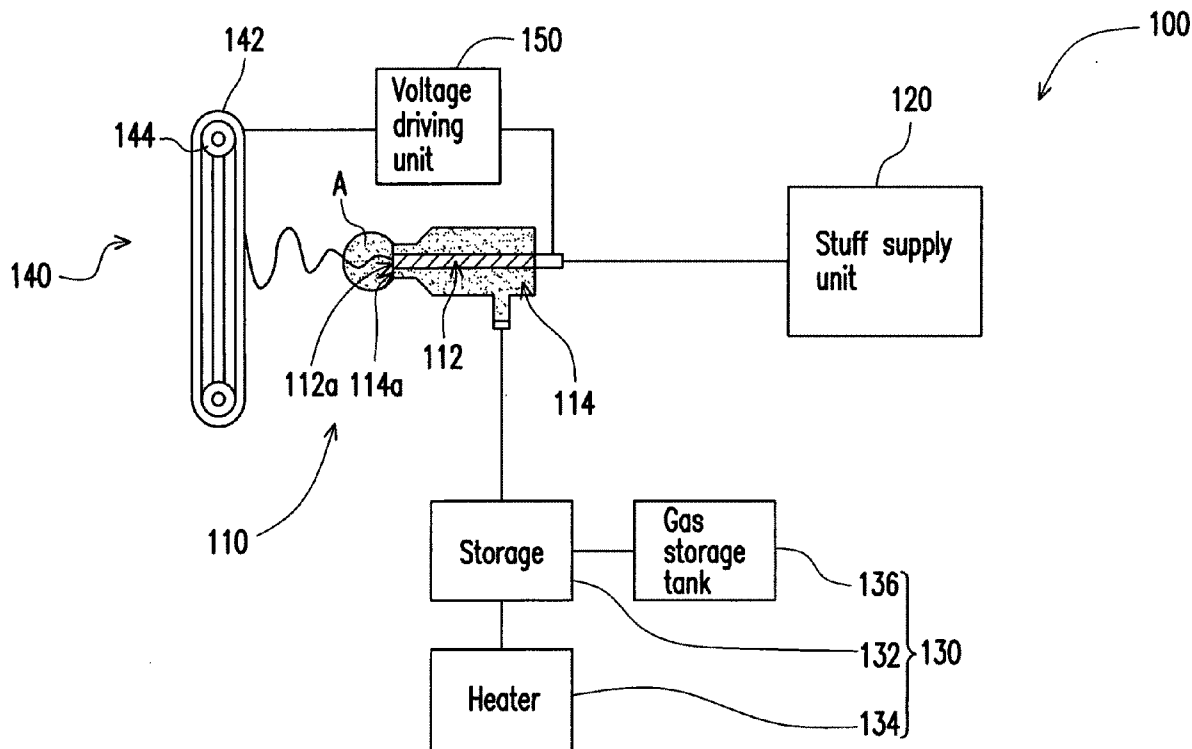
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(57)

ABSTRACT

An electro-spinning apparatus includes a spinning jet, a stuff supply unit, a solvent supply unit, a collection unit, and a voltage driving unit. The spinning jet has a first channel and a second channel. The first channel has a first outlet, and the second channel has a second outlet. The stuff supply unit is connected to the first channel and supplies a liquid stuff to the first outlet. The solvent supply unit is connected to the second channel and supplies a gaseous solvent to the second outlet. The voltage driving unit applies a voltage difference between the spinning jet and the collection unit, so that the liquid stuff is spun and collected to the collection unit after being output from the first outlet and passing through the gaseous solvent released from the second outlet. Besides, an electro-spinning method is also provided.



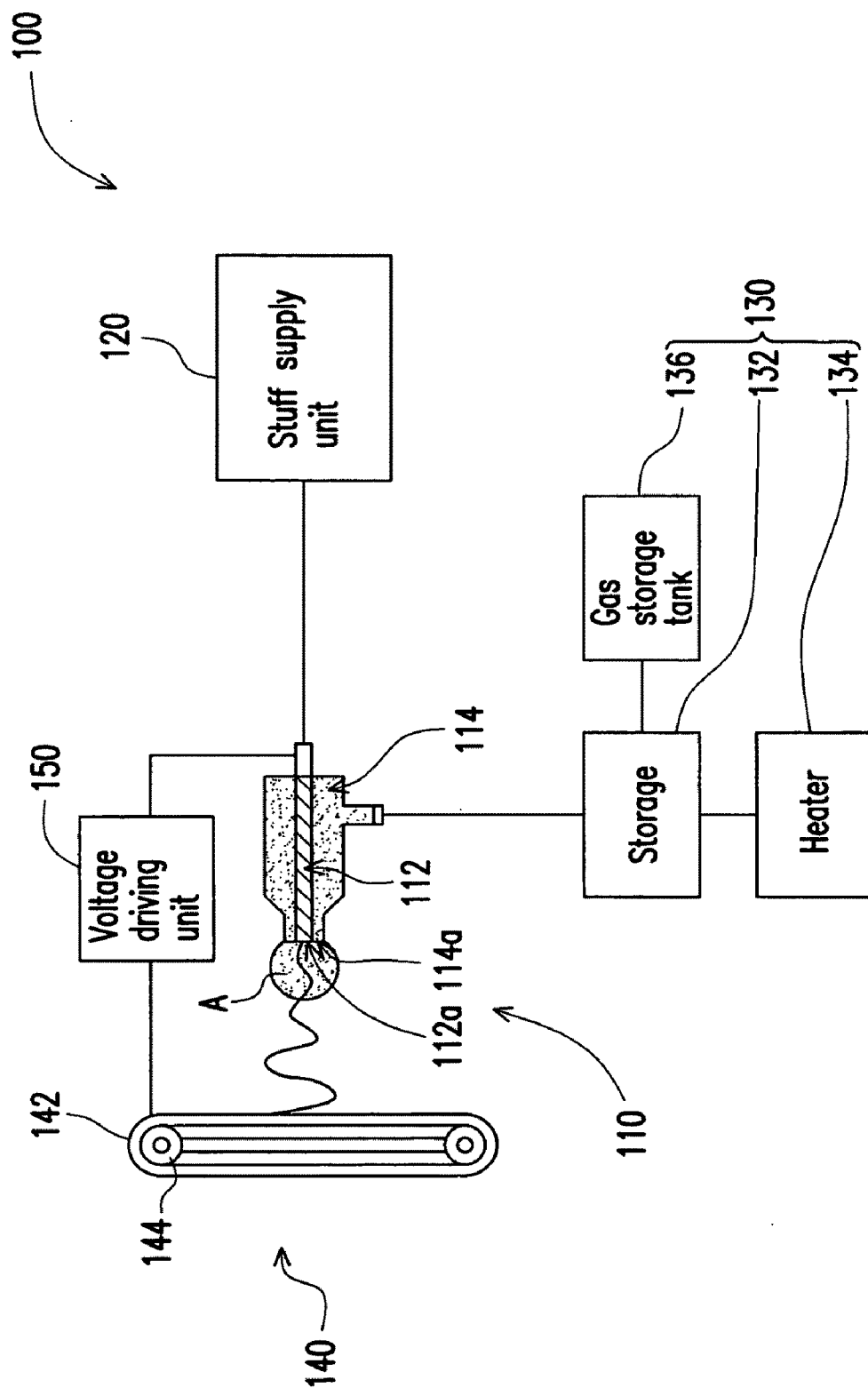


FIG. 1

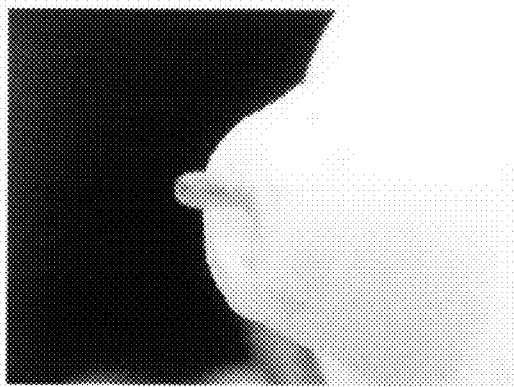


FIG. 2A

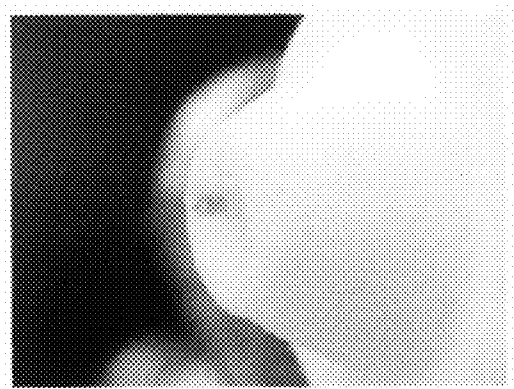


FIG. 2B

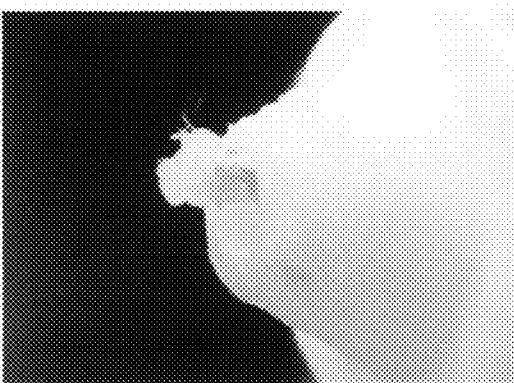


FIG. 2C

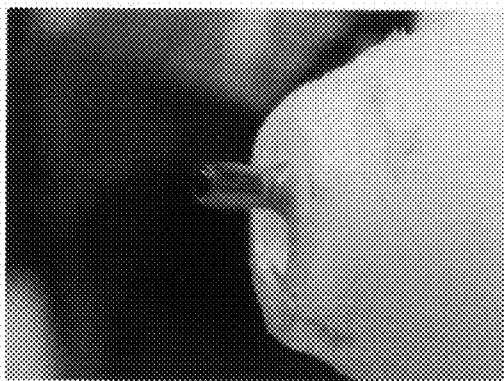


FIG. 3A

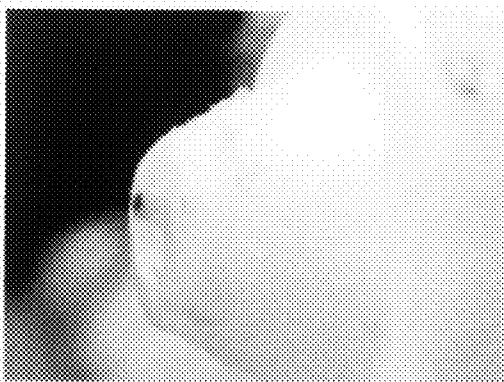


FIG. 3B

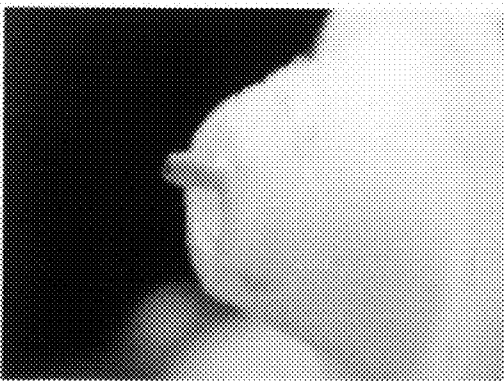


FIG. 3C

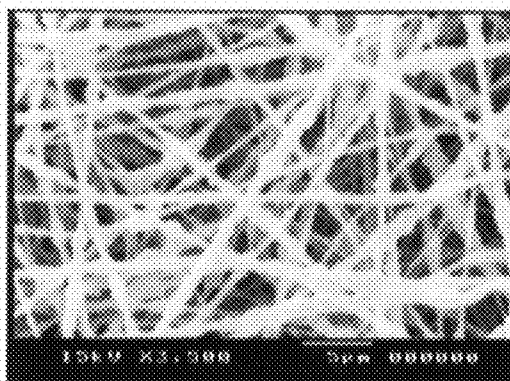


FIG.4A

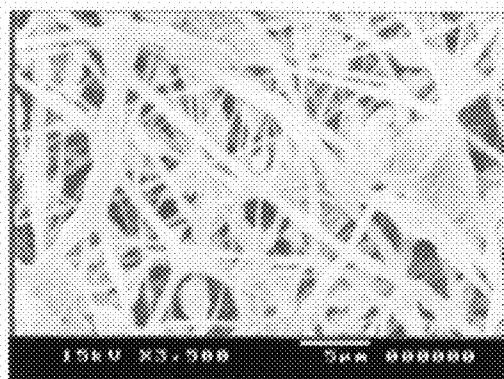


FIG.4B

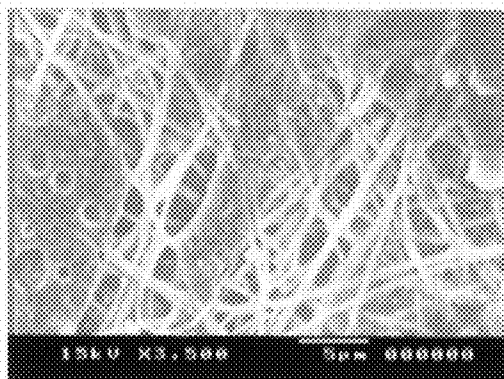


FIG.4C

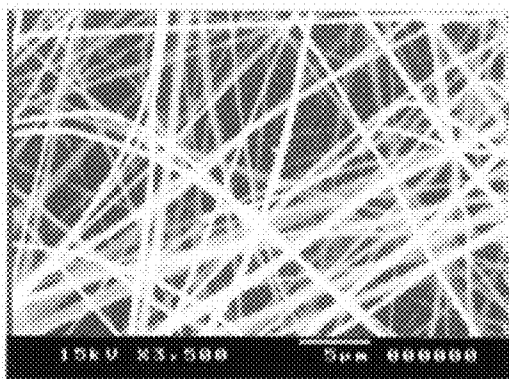


FIG.5A

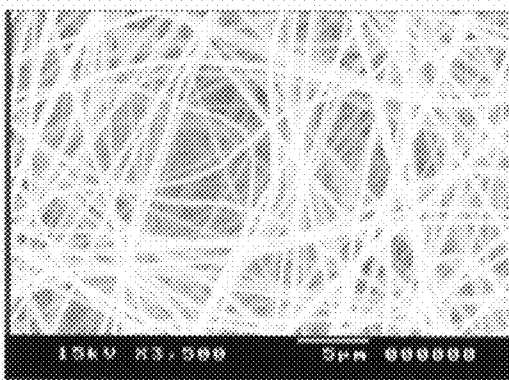


FIG.5B

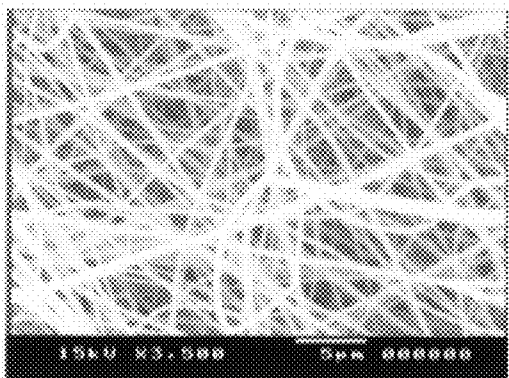


FIG.5C

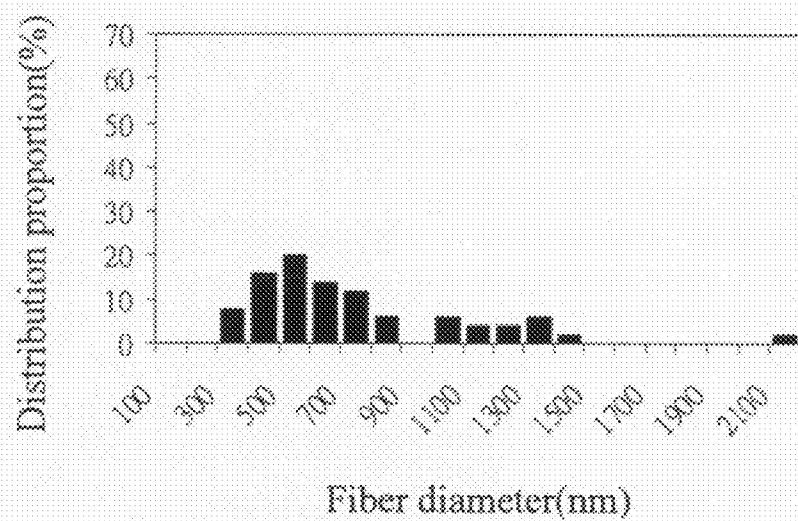


FIG. 6A

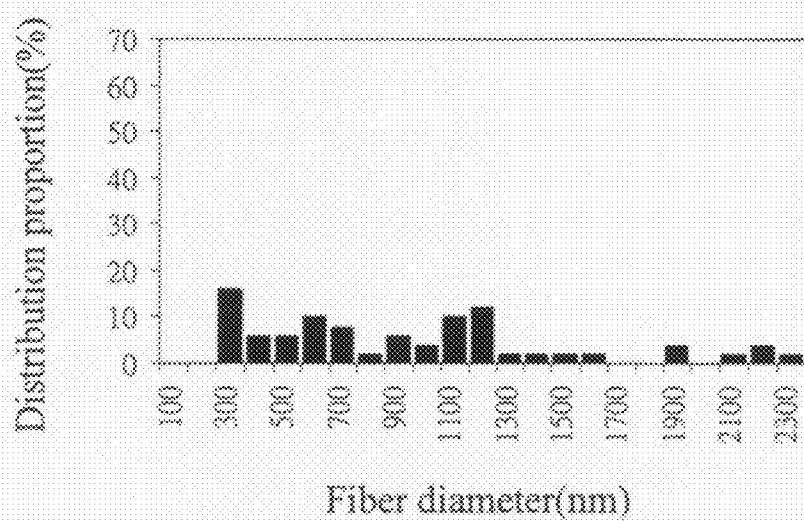


FIG. 6B

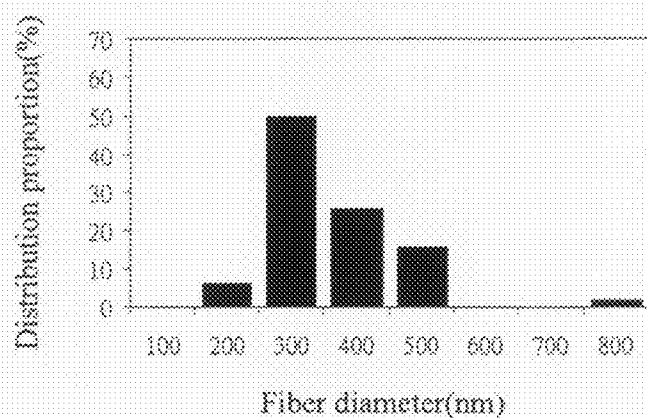


FIG.7A

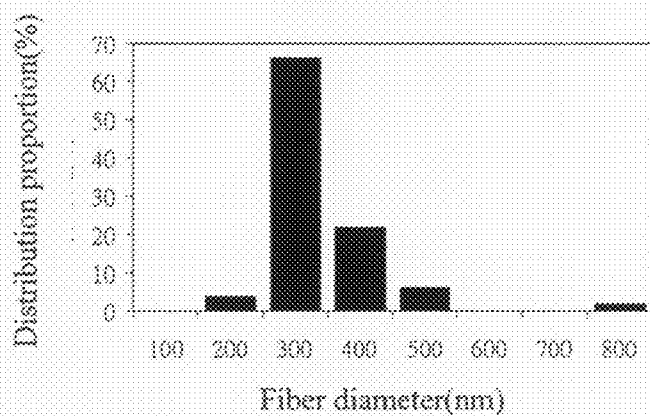


FIG.7B

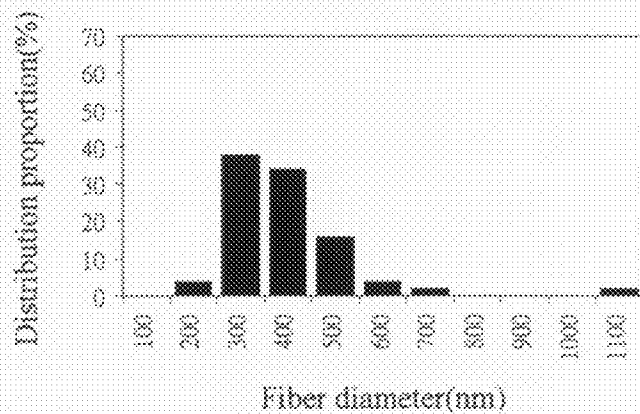


FIG.7C

ELECTRO-SPINNING APPARATUS AND ELECTRO-SPINNING METHOD

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of Taiwan application serial no. 97137958, filed Oct. 2, 2008. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention generally relates to a spinning apparatus and a spinning method, in particular, to an electro-spinning apparatus and an electro-spinning method.

[0004] 2. Description of Related Art

[0005] Since natural fibers are inferior to man-made fibers in terms of application scope, manufacturing cost, process, and other competitive condition, man-made fibers have become the mainstream of the development of fiber materials. With the development of nanotechnology, the electro-spinning technique is gradually valued and applied in the manufacturing of man-made fibers. The electro-spinning technique is characterized by flexible combinations of abundant materials, and nearly one hundred kinds of nanofibers have been successfully manufactured by using the electro-spinning technique.

[0006] Generally speaking, the electro-spinning technique uses a voltage difference between a spinning jet and a collection unit to eject a liquid stuff in the spinning jet into a filament shape and cure the liquid stuff on the collection unit. However, the stuff is usually cured in an outlet of the spinning jet due to an insufficient ejection speed or other environmental factors, which causes a blocking at the outlet of the spinning jet. In addition, the above case further causes an unstable ejection amount of the stuff, such that spinning fibers formed in the collection unit are excessively thick or have non-uniform thicknesses.

SUMMARY OF THE INVENTION

[0007] Accordingly, the present invention is directed to an electro-spinning apparatus, capable of reducing the probability of blocking at an outlet of a spinning jet and avoiding the phenomenon that spinning fibers are excessively thick and have non-uniform thicknesses.

[0008] The present invention is additionally directed to an electro-spinning method, capable of reducing the probability of blocking at an outlet of a spinning jet and avoiding the phenomenon that spinning fibers are excessively thick and have non-uniform thicknesses.

[0009] The present invention provides an electro-spinning apparatus including a spinning jet, a stuff supply unit, a solvent supply unit, a collection unit, and a voltage driving unit. The spinning jet has a first channel and a second channel. The first channel has a first outlet, and the second channel has a second outlet. The stuff supply unit is connected to the first channel and supplies a liquid stuff to the first outlet. The solvent supply unit is connected to the second channel and supplies a gaseous solvent to the second outlet. The voltage driving unit applies a voltage difference between the spinning jet and the collection unit, such that the liquid stuff is spun and

collected to the collection unit after being output from the first outlet and passing through the gaseous solvent released from the second outlet.

[0010] In an embodiment of the present invention, the above second outlet encloses the first outlet.

[0011] In an embodiment of the present invention, the above second channel encloses the first channel.

[0012] In an embodiment of the present invention, the above solvent supply unit includes a storage and a heater. The storage is used for storing a liquid solvent. The heater is used for heating the storage to gasify the liquid solvent into a gaseous solvent.

[0013] In an embodiment of the present invention, the above solvent supply unit further includes a gas storage tank connected to the storage, for providing a stable gas flow to the storage, such that the gaseous solvent is uniformly supplied to the second outlet.

[0014] The present invention further provides an electro-spinning method. A voltage difference is applied between a spinning jet and a collection unit to spin a liquid stuff from an outlet of the spinning jet to the collection unit. Meanwhile, a gaseous solvent is supplied at the outlet, such that the liquid stuff output from the outlet passes through the gaseous solvent at the outlet.

[0015] In an embodiment of the present invention, in the above electro-spinning method, the step of supplying the gaseous solvent further includes supplying the gaseous solvent around the outlet at the same time.

[0016] In an embodiment of the present invention, in the above electro-spinning method, the step of supplying the gaseous solvent further includes adding a liquid solvent to gasify it into a gaseous solvent and supplying the gaseous solvent to the outlet.

[0017] In an embodiment of the present invention, a solute/solvent of the above liquid stuff is ethylene-vinyl alcohol copolymer/isopropanol+water, polyvinyl alcohol/water, polyurethane/dimethyl acetamide, or polyacrylonitrile/dimethyl formamide (DMF).

[0018] In an embodiment of the present invention, a weight percentage of the above ethylene-vinyl alcohol copolymer/isopropanol+water is 8%-12%.

[0019] In an embodiment of the present invention, a weight percentage of the above polyvinyl alcohol/water is 8%-12%.

[0020] In an embodiment of the present invention, a weight percentage of the above polyurethane/dimethyl acetamide is 8%-16%.

[0021] In an embodiment of the present invention, a weight percentage of the above polyacrylonitrile/DMF is 8%-12%.

[0022] In an embodiment of the present invention, a material of the above gaseous solvent is water, ethyl alcohol, DMF, dimethyl acetamide, glacial acetic acid, n-hexane, acetone, or methanol.

[0023] In the electro-spinning apparatus and electro-spinning technique of the present invention, the liquid stuff first passes through the gaseous solvent before being spun to the collection unit, so as to reduce the probability that the liquid stuff is cured at the outlet of the spinning jet to cause the blocking, and to avoid the phenomenon that the spun filaments are excessively thick and have non-uniform thicknesses due to the unstable ejection amount of the stuff.

[0024] In order to make the aforementioned and other objects, features and advantages of the present invention

comprehensible, preferred embodiments accompanied with figures are described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0026] FIG. 1 is a schematic view of an electro-spinning apparatus according to an embodiment of the present invention.

[0027] FIGS. 2A, 2B, and 2C are respectively enlarged views of an outlet of a spinning jet after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes without supplying a gaseous solvent.

[0028] FIGS. 3A, 3B, and 3C are respectively enlarged views of the outlet of the spinning jet after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes with supplying the gaseous solvent.

[0029] FIGS. 4A, 4B, and 4C are respectively enlarged views of spinning fibers formed in a collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes without supplying the gaseous solvent.

[0030] FIGS. 5A, 5B, and 5C are respectively enlarged views of spinning fibers formed in the collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes with supplying the gaseous solvent.

[0031] FIGS. 6A and 6B are respectively bar charts illustrating distribution proportions of diameters of the spinning fibers formed in the collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes and five minutes without supplying the gaseous solvent.

[0032] FIGS. 7A, 7B and 7C are respectively bar charts illustrating distribution proportions of diameters of the spinning fibers formed in the collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes with supplying the gaseous solvent.

DESCRIPTION OF THE EMBODIMENTS

[0033] Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0034] FIG. 1 is a schematic view of an electro-spinning apparatus according to an embodiment of the present invention. Referring to FIG. 1, the electro-spinning apparatus 100 of this embodiment includes a spinning jet 110, a stuff supply unit 120, a solvent supply unit 130, a collection unit 140, and a voltage driving unit 150. The spinning jet 110 has a first channel 112 and a second channel 114. The first channel 112 has a first outlet 112a, and the second channel 114 has a second outlet 114a.

[0035] The stuff supply unit 120 is connected to the first channel 112 and supplies a liquid stuff to the first outlet 112a. The solvent supply unit 130 is connected to the second channel 114 and supplies a gaseous solvent to the second outlet 114a. The voltage driving unit 150 applies a voltage difference between the spinning jet 110 and the collection unit 140, such that the liquid stuff is spun and collected to the collection

unit 140 after being output from the first outlet 112a and passing through the gaseous solvent released from the second outlet 114a.

[0036] In this embodiment, the second outlet 114a encloses the first outlet 112a and the second channel 114 encloses the first channel 112, such that the electro-spinning apparatus 100 further supplies the gaseous solvent around the first outlet 112a via the second outlet 114a while supplying the gaseous solvent and forms a solvent vapor region A at the outlet of the spinning jet 110 for the liquid stuff to pass through.

[0037] Referring to FIG. 1, the solvent supply unit 130 includes a storage 132 and a heater 134. The storage 132 is used for storing a liquid solvent. The heater 134 is used for heating the storage 132 to gasify the liquid solvent into a gaseous solvent. In addition, the solvent supply unit 130 further includes a gas storage tank 136 connected to the storage 132, for providing a stable gas flow to the storage 132, such that the gaseous solvent is uniformly supplied to the second outlet 114a.

[0038] Particularly, the collection unit 140 includes a conveyor belt 142, a plurality of rotating elements 144, and a drive motor (not shown) which are made of a metal material. The rotating elements 144 are disposed in the conveyor belt 142, and the drive motor is connected to the rotating elements 144, so as to drive the rotating elements 144 to rotate continuously or discontinuously and drive the conveyor belt 142 to rotate at the same time.

[0039] An electro-spinning method according to an embodiment of the present invention is illustrated below with reference to FIG. 1. Referring to FIG. 1, in the electro-spinning method of this embodiment, a voltage difference is applied between the spinning jet 110 and the collection unit 140 to spin a liquid stuff from the first outlet 112a of the spinning jet 110 to the collection unit 140, and meanwhile a gaseous solvent is supplied at the first outlet 112a, such that the liquid stuff output from the first outlet 112a passes through the gaseous solvent at the first outlet 112a. In addition, the step of supplying the gaseous solvent further includes adding a liquid solvent to gasify it into a gaseous solvent and supplying the gaseous solvent to the first outlet 112a.

[0040] The step of supplying the gaseous solvent further includes supplying the gaseous solvent around the first outlet 112a at the same time. It should be noted that, the present invention is not limited to the method of supplying the gaseous solvent around the first outlet 112a at the same time. That is, in addition to the manner that the second outlet 114a encloses the first outlet 112a and releases the gaseous solvent shown in FIG. 1, the gaseous solvent may further be supplied around the first outlet 112a at the same time in other manners.

[0041] A solute/solvent of the liquid stuff is, for example, ethylene-vinyl alcohol copolymer/isopropanol+water having a weight percentage of 8%-12%, polyvinyl alcohol/water having a weight percentage of 8%-12%, polyurethane/dimethyl acetamide having a weight percentage of 8%-16%, or polyacrylonitrile/dimethyl formamide (DMF) having a weight percentage of 8%-12%.

[0042] In addition to this, the solute/solvent of the liquid stuff may also be polyethylene glycol/water, polyethylene glycol oxalate/water, polystyrene/DMF, styrene-butadiene-styrene (SBS)/tetrahydrofuran (THF)+DMF, polycarbonate (PC)/TBF+DMF, polycaprolactam (PA)/formic acid, polyimide/phenol, polybenzimidazole/sulfuric acid, polyphenylamine/sulfuric acid, polyaromatic amide/sulfuric acid, polyethylene/p-xylene, poly(arylene sulfide sulfone)/phenol+

tetrachloroethane, polyglycolic acid/DMF, fibroin+chitin/formic acid, polylactic acid/dichloromethane, or gelatin/water.

[0043] A material of the gaseous solvent may be sulfuric acid, p-xylene, phenol, tetrachloroethane, dichloromethane, formic acid, isopropanol, THF, toluene, aqueous ammonia, naphthane, glycerin, water, ethyl alcohol, DMF, dimethyl acetamide, glacial acetic acid, n-hexane, acetone, or methanol.

[0044] FIGS. 2A, 2B, and 2C are respectively enlarged views of an outlet of a spinning jet after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes without supplying a gaseous solvent, and FIGS. 3A, 3B, and 3C are respectively enlarged views of the outlet of the spinning jet after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes with supplying the gaseous solvent. Referring to FIGS. 2A, 2B, and 2C, in the case that the gaseous solvent is not supplied, the outlet of the spinning jet has an obvious blocking phenomenon with the increase of the operation time of the electro-spinning apparatus.

[0045] Then, referring to FIGS. 3A, 3B, and 3C, in comparison with FIGS. 2A, 2B, and 2C, the outlet of the spinning jet does not have the blocking phenomenon with the increase of the operation time of the electro-spinning apparatus in the case that the gaseous solvent is supplied. Therefore, the gaseous solvent supplied by the electro-spinning apparatus 100 (shown in FIG. 1) of this embodiment can reduce the probability of the blocking at the outlet of the spinning jet.

[0046] FIGS. 4A, 4B, and 4C are respectively enlarged views of spinning fibers formed in a collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes without supplying the gaseous solvent, and FIGS. 5A, 5B, and 5C are respectively enlarged views of spinning fibers formed in the collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes with supplying the gaseous solvent. Referring to FIGS. 4A, 4B, and 4C, in the case that the gaseous solvent is not supplied, the spinning fibers formed in the collection unit 140 (shown in FIG. 1) have an obvious phenomenon of becoming thicker and having non-uniform thicknesses with the increase of the operation time of the electro-spinning apparatus.

[0047] Then, referring to FIGS. 5A, 5B, and 5C, in comparison with FIGS. 4A, 4B, and 4C, the spinning fibers formed in the collection unit 140 (shown in FIG. 1) does not have the obvious phenomenon of becoming thicker or having non-uniform thicknesses with the increase of the operation time of the electro-spinning apparatus in the case that the gaseous solvent is supplied. Therefore, the gaseous solvent supplied by the electro-spinning apparatus 100 (shown in FIG. 1) of this embodiment can avoid the phenomenon that the spinning fibers are excessively thick and have non-uniform thicknesses.

[0048] FIGS. 6A and 6B are respectively bar charts illustrating distribution proportions of diameters of the spinning fibers formed in the collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes and five minutes without supplying the gaseous solvent, and FIGS. 7A, 7B and 7C are respectively bar charts illustrating distribution proportions of diameters of the spinning fibers formed in the collection unit after the electro-spinning apparatus in FIG. 1 operates for three minutes, five minutes, and ten minutes with supplying the gaseous solvent. Referring to FIGS. 6A and 6B, in the case that the gaseous solvent is not supplied, the spinning fibers formed in the collection unit 140 (shown in FIG. 1) have an obvious phenomenon of becoming thicker and hav-

ing non-uniform thicknesses with the increase of the operation time of the electro-spinning apparatus.

[0049] Then, referring to FIGS. 7A, 7B, and 7C, in comparison with FIGS. 6A and 6B, the spinning fibers formed in the collection unit 140 (shown in FIG. 1) does not have the obvious phenomenon of becoming thicker or having non-uniform thicknesses with the increase of the operation time of the electro-spinning apparatus in the case that the gaseous solvent is supplied. Therefore, the gaseous solvent supplied by the electro-spinning apparatus 100 (shown in FIG. 1) of this embodiment can avoid the phenomenon that the spinning fibers are excessively thick and have non-uniform thicknesses.

[0050] In view of the above, in the electro-spinning apparatus and electro-spinning technique of the present invention, the liquid stuff first passes through the gaseous solvent before being spun to the collection unit, so as to reduce the probability that the liquid stuff is cured at the outlet of the spinning jet to cause the blocking, and to avoid the phenomenon that the spun filaments are excessively thick and have non-uniform thicknesses due to the unstable ejection amount of the stuff, thereby improving the production yield of the spun filaments.

[0051] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

1. An electro-spinning apparatus comprising:

- a spinning jet, comprising a first channel and a second channel, wherein the first channel comprises a first outlet, and the second channel comprises a second outlet adjacent to the first outlet;
- a stuff supply unit, connected to the first channel of the spinning jet, for supplying a liquid stuff to the first outlet via the first channel;
- a solvent supply unit, connected to the second channel of the spinning jet, for supplying a gaseous solvent to the second outlet via the second channel;
- a collection unit; and
- a voltage driving unit, connected to the spinning jet and the collection unit, wherein the voltage driving unit applies a voltage difference between the spinning jet and the collection unit, such that the liquid stuff is spun and collected to the collection unit after being output from the first outlet and passing through the gaseous solvent released from the second outlet.

2. The electro-spinning apparatus according to claim 1, wherein the second outlet encloses the first outlet.

3. The electro-spinning apparatus according to claim 1, wherein the second channel encloses the first channel.

4. The electro-spinning apparatus according to claim 1, wherein the solvent supply unit comprises:

- a storage, for storing a liquid solvent; and
- a heater, for heating the storage to gasify the liquid solvent into a gaseous solvent.

5. The electro-spinning apparatus according to claim 1, wherein the solvent supply unit further comprises:

- a gas storage tank, connected to the storage, for providing a stable gas flow to the storage, such that the gaseous solvent is uniformly supplied to the second outlet.

6-14. (canceled)

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