

ELECTROSPINNING SPINNERET

TECHNICAL FIELD

[0001] This invention relates to a spinneret for use in electrospinning production of filament, an associated system for electrospinning production of filament and a method for producing filament.

BACKGROUND ART

[0002] The following discussion of the background art is intended to facilitate an understanding of the present invention only. The discussion is not an acknowledgement or admission that any of the material referred to is or was part of the prior art or common general knowledge as at the priority date of the application.

[0003] Electrospinning is a technique for using an electrical charge to draw very fine (typically on the micro- or nano-scale) fibres or filaments from a liquid. When a sufficiently high voltage is applied to a droplet of liquid, the liquid becomes charged. Electrostatic repulsion counteracts the surface tension of the liquid and the droplet is typically stretched or flattened. At a critical point, a stream of liquid erupts from the surface. This point of eruption is known in the art as the 'Taylor cone'. If the molecular cohesion of the liquid is sufficiently high, stream breakup does not occur and a charged liquid jet is formed.

[0004] Figure 1 shows a basic electrospinning setup 10 known in the art. Such a setup 10 normally comprises a high

voltage power supply 12, a syringe needle 14 connected to the power supply 12, and a counter-electrode collector 16. A syringe 20 is typically used to house a polymer solution 18 from which a filament is spun.

[0005] During electrospinning, a high electric voltage is applied to the polymer solution 18, which highly electrifies the solution droplet at the needle tip. As a result, the solution droplet at the needle tip experiences electric forces, drawing itself toward the opposite electrode collector 16, thus deforming into a conical shape or Taylor cone. When the electric force overcomes the surface tension of the polymer solution, the polymer solution ejects off the tip of the Taylor cone to form a polymer jet. The charged jet is stretched by the strong electric force into a fine filament 22 and collected on the collector 16.

[0006] Typical liquids used for electrospinning include different polymer solutions, sol-gels, particulate suspensions or melts, which can be loaded into the syringe 20. This liquid is typically extruded from the needle tip 14 at a constant rate by a syringe pump, or the like.

[0007] Known electrospinning processes are limited for large-scale production of fibres. Common shortcomings with the existing electrospinning techniques are low production efficiency and clogging problems of the needles or nozzles.

[0008] In addition, corona discharge is also a significant problem with known electrospinning techniques, particularly where nonconductive polymer solutions and melts are required. A high electrical charge transfer rate from the needle or nozzle to the liquid to be spun is essential for the process to work. This is achievable by applying a large electrical field between the needle and the collector.

However, as is well understood in the art, corona discharge on high voltage conductors generally occurs at points with the highest electrical stress, i.e. sharp points. Existing needle designs shown in Figure 1 are inherently prone to such corona discharges.

[0009] The following invention seeks to propose a possible solution in amelioration of the above shortcomings in the prior art.

SUMMARY OF THE INVENTION

[0010] According to a first aspect of the disclosure there is provided a spinneret for use in electrospinning production of filament, said spinneret comprising:

a casing defining a chamber, said casing further defining at least one fluid inlet via which a fluid is able to enter the chamber and at least one discharge port via which the fluid is able to exit the chamber; and

an electrode baffle structure positioned inside the chamber and configured to operationally impart an electrical charge to the fluid in the chamber, said baffle structure shaped and dimensioned to provide a surface-to-volume ratio of at least 5.

[0011] The baffle structure may be selected from a group consisting of wires, meshes, grids, foams, sponges, fabrics, weaves, fins, parallel plates, bonded powder structures, interlaced materials, and/or the like.

[0012] The discharge port may be defined in a substantially planar external surface of the casing in order to minimise coronal discharge, in use.

[0013] The baffle structure may be configured and arranged to regulate a flow rate of the fluid passing through the chamber, in use.

[0014] The casing may comprise an electrode terminal via which the baffle structure is connectable to an external electricity source.

[0015] The discharge port may be circular in shape and define a diameter between 0.1mm and 10mm.

[0016] According to a second aspect of the disclosure there is provided a system for electrospinning production of filament, comprising:

a spinneret having a casing defining a chamber, said casing further defining at least one fluid inlet via which a fluid is able to enter the chamber and at least one discharge port via which the fluid is able to exit the chamber; and an electrode baffle structure positioned inside the chamber and configured to operationally impart an electrical charge to the fluid in the chamber, said baffle structure shaped and dimensioned to provide a surface-to-volume ratio of at least 5;

a power supply having a positive and a negative terminal, one terminal connected to the electrode baffle structure;

a fluid supply configured to supply an electrospinning fluid to the inlet port of the spinneret; and

a collector arranged to receive filament from the discharge port, said collector connected to the other power supply terminal.

[0017] The power supply may comprise a high-voltage direct current power supply.

[0018] The fluid supply may comprise a pump for pumping the fluid under pressure into the spinneret chamber.

[0019] The fluid supply may comprise a heating element for operationally heating the fluid.

[0020] The collector may comprise a cooled plate.

[0021] According to a third aspect of the disclosure there is provided a method for producing filament, comprising the steps of:

providing a spinneret having a casing defining a chamber, said casing further defining at least one fluid inlet via which a fluid is able to enter the chamber and at least one discharge port via which the fluid is able to exit the chamber, and an electrode baffle structure positioned inside the chamber and configured to operationally impart an electrical charge to the fluid in the chamber, said baffle structure shaped and dimensioned to provide a surface-to-volume ratio of at least 5;

providing a power supply having a positive and a negative terminal, one terminal connected to the electrode baffle structure;

providing a fluid supply configured to supply an electrospinning fluid to the inlet port of the spinneret;

providing a collector arranged to collect filament from the discharge port, said collector connected to the other power supply terminal; and

operating the power supply and the fluid supply in order to produce electrospun filament.

BRIEF DESCRIPTION OF THE DRAWINGS

Several non-limiting examples of the current disclosure are exemplified in the accompanying drawings in which:

Figure 1 is a conventional electrospinning setup as is known in the art;

Figure 2 is a side cross-sectional representation of a spinneret for use in electrospinning production of filament, in accordance with an aspect of this disclosure;

Figure 3a is a side cross-sectional representation of another example of a spinneret for use in electrospinning;

Figure 3b is a top view of the spinneret of Figure 3a;

Figure 4 is a side cross-sectional representation of a further example of a spinneret for use in electrospinning;

Figure 5a is a top view representation of another example of a spinneret for use in electrospinning;

Figure 5b is a side cross-sectional representation of the spinneret of Figure 5a;

Figure 6a is a top view representation of another example of a spinneret for use in electrospinning;

Figure 6b is a side cross-sectional representation of the spinneret of Figure 6a;

Figure 7a is a top view representation of another example of a spinneret for use in electrospinning;

Figure 7b is a side cross-sectional representation of the spinneret of Figure 6a;

Figure 8 is a diagrammatic representation of a system for electrospinning production of filament, in accordance with an aspect of the disclosure;

Figure 9 is a photograph showing an example of a spinneret spinning fibres; and

Figure 10 is a scanning electron microscope photograph of filament or fibres produced by the spinneret of **Figure 9**.

DESCRIPTION OF EMBODIMENTS

[0022] Further features of the present disclosure are more fully described in the following description of several non-limiting embodiments thereof. This description is included solely for the purposes of exemplifying the present disclosure and should not be understood as a restriction on the broad summary, disclosure or description of the invention as set out above.

[0023] The recitation of a particular condition or numerical value or value range herein is understood to include or be a recitation of an approximate condition or numerical value or value range, such as to within +/- 20%, +/- 10%, or +/- 5% of the recited condition or value or value range. In an analogous manner, the terms "approximately," "about," and "substantially" refer to approximate conditions or values or value ranges, such as to within +/- 20%, +/- 10%, +/- 5%, +/- 2%, or +/- 1% of a recited condition, value, or value range.

[0024] With reference now to Figure 2 of the accompanying drawings, there is shown an example of a spinneret 30 for use in electrospinning production of filament. The spinneret

30 generally comprises a casing 32 which, in turn, defines a chamber 34, as shown.

[0025] The casing 32 further defines a fluid inlet 36 via which an electrospinning fluid (typically a liquid) is able to enter the chamber 34. The casing 32 also defines a discharge port 38 via which the fluid is able to exit the chamber 34.

[0026] The spinneret 30 further includes an electrode baffle structure 40 which is positioned inside the chamber 34 and is configured to operationally impart an electrical charge to the electrospinning fluid in the chamber 34. Importantly, the baffle structure 40 is shaped and dimensioned to provide a surface-to-volume ratio of at least 5.

[0027] It is to be appreciated that one purpose of the baffle structure 40 is to provide a large surface area to facilitate the easy and quick imparting of electrical charge to the fluid inside the chamber 34. As a result, the baffle structure 40 can take many different forms, such as different arrangements of wires, meshes, grids, foams, sponges, fabrics, weaves, fins, parallel or substantially parallel plates, bonded powder structures, interlaced materials, and/or the like.

[0028] The casing may be manufactured using any suitable conductive and/or nonconductive material, such as metals, plastics, ceramics, stone, wood, paper, bamboo, and/or the like. Similarly, the baffle structure 40 is, in one example, porous with a high surface area to enable direct contact with the liquid when the liquid passes into the chamber 34. The casing 32 and the baffle structure 40 can also be fabricated together as one part using, for example, 3D

printing technology, casting processes, or the like. Embodiments in accordance with the present disclosure can provide high voltage breakdown (e.g. approximately 20 kV/cm), and hence casing materials can be conductive or nonconductive.

[0029] The baffle structure 40 is typically configured and arranged to regulate a flow rate of the fluid passing through the chamber 34, in use. Accordingly, in one example, the configuration of the baffle structure 40 is designed to allow the fluid to have a constant flow rate over the surfaces of the baffle structure 40, so the fluid can be charged evenly into the chamber 34, in use.

[0030] For example, to ensure a constant flow rate of an electrospinning liquid, the example shown in Figure 3a defines a liquid 'storage space' where the inlet 36 enters the chamber 34, as shown.

[0031] In the exemplified embodiments, the casing 32 also comprises an electrode terminal 44 via which the baffle structure 40 is connectable to an external electricity source. Accordingly, in one example, in use, the electrospinning liquid will be positively charged when the terminal 44 is connected to the positive output of a high voltage source, or negatively charged when the terminal 44 is connected to the negative output of the high voltage source (described in more detail below).

[0032] The discharge port 38 is generally defined in a substantially planar external surface 42 of the casing 34 in order to minimise coronal discharge, in use. As described above, corona discharge is a major problem with conventional electrospinning systems due to the use of needle-like

nozzles. It is a particular advantage of this disclosure that the discharge port(s) 38 open on a relatively flat outer surface 42 of the casing 34.

[0033] In one example, the discharge port 38 is circular in shape and defines a diameter between 0.1mm and 10mm. However, it is to be understood that the current disclosure is not limited by this range whatsoever and that different sized discharge ports 38 are within the current scope.

[0034] Figure 3 shows a relatively simple design of a spinneret 30 for mass production. In this example, the spinneret's casing 32 is a capped pipe and tube with any shape or cross sections such as a circle, square, rectangle, hexagon, etc. In this example, the discharge port 38 is elongated, as shown. One side of the capped pipe forms the fluid or liquid inlet 36 and another side the conductive terminal 44 to connect the internal baffle structure 40 to the high voltage power source. There are no constraints for the locations for the fluid inlet 36 and conductive terminal 44 and they may be located at any convenient positions.

[0035] Figure 4 shows an example of a coaxial spinneret design able to produce core-sheath nanofibres. In this example, there are two different liquid inlets 36 on opposite sides of the casing 32 and two chambers 34 in the casing 32, each chamber connected to a separate discharge port 38 and 41, as shown. In effect, one discharge port 38 is arranged co-axially about a central discharge port 41. The two chambers 40 are separated by a conductive separator 43, as shown, so only a single terminal 44 is needed for the spinneret 30.

[0036] Similarly, Figures 5 to 7 show different examples of spinnerets 30, in accordance with the current disclosure. Differences can include shapes of the respective casings 32 and chamber 34, as well as number and layout of discharge ports 38, as shown. Similarly, the relative positions of the terminals 44, the discharge ports 38 and the fluid inlets 36 can vary according to requirements.

[0037] Figure 8 shows an example of a system 50 for electrospinning production of filament. The system 50 uses any of the spinnerets 30 described above. The system 50 typically comprises a spinneret 30, along with a power supply 60 having a positive and a negative terminal, as shown. One terminal (either the positive or negative) is connected to the electrode baffle structure 40 in the spinneret 30 via the terminal 44, as described above.

[0038] The system 50 also includes a fluid supply which is configured to supply an electrospinning fluid to the inlet port 36 of the spinneret 30. Also included is a collector 62 which is arranged to collect filament from the discharge port (not shown) of the spinneret 30. The collector 62 is connected to the other power supply terminal. In this example, the power supply 60 is a high-voltage direct current power supply.

[0039] In this embodiment, the fluid supply comprises a motor 52 which drives a screw-pump feeder arrangement 54 for pumping the fluid under pressure into the spinneret chamber. In such an example, the system uses a polymer material as the electrospinning fluid. Accordingly, the system 50 includes a raw material input 56 leading into an environmental control chamber 58, as shown. The system 50 also includes heating elements 64 to melt the polymer material inside the screw-pump feeder arrangement 54.

[0040] In one example, to keep the polymer material in a molten state, the chamber 58 is kept at a particular temperature, however the heating elements 64 may affect the electrical field distribution for the spinning, therefore infrared is typically used to heat the chamber 58 from a safe distance away. The heaters 64 are typically equipped with focusing mirrors to ensure the efficiency of the heating. To separate the high voltage field applied to the spinneret by the source 60 for the polymer melt from the heating system 64, an electrically nonconductive ceramic tube is typically used to link the spinneret 30 and the screw feeder 54.

[0041] In addition, the collector 62 of the nanofibres is electrically grounded and cooled, so the nanofibres can be collected and solidified as they are discharged from the spinneret 30 and collected on the collector 62.

[0042] The disclosure also includes an associated method for producing filament using the spinneret 30 and the system 50 above. Such a method typically comprises the steps of providing a spinneret 30, providing a power supply 60, having a positive and a negative terminal, one terminal connected to the electrode baffle structure 40 of the spinneret 30, and providing a fluid supply 54 which configured to supply an electrospinning fluid to the inlet port 36 of the spinneret 30.

[0043] The method further comprises the steps of providing a collector 62 which is arranged to collect filament from the discharge port(s) 38 of the spinneret 30, said collector connected to the other power supply terminal,

and operating the power supply 60 and the fluid supply 54 in order to produce electrospun filament, as described above. As such, the spinneret 30 of the current disclosure enables electrospinning of nonconductive liquids whereby a high electrical field can be applied to such a fluid, thereby ensuring proper electrospinning operation. Particularly, the electrode baffle structure 40 within the casing 32 facilitates this advantage.

[0044] In addition, the existing problem of corona discharge and associated interruptions to electrospinning practices is ameliorated by the discharge port(s) arrangement of the current disclosure, particularly such ports being defined on a substantially planar external surface of the casing 32.

[0045] Figure 9 shows an example of a spinneret 30, in accordance with the current disclosure, operatively spinning nanofibers, as described above. In addition, an example of nanofibers produced by such a spinneret 30 is shown under high magnification in Figure 10.

[0046] It should be appreciated that the scope of the invention is not limited to the scope of the embodiments described. Various modifications and improvements may be made to the embodiments described without departing from the scope of the invention.

[0047] Throughout this specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

[0048] It is to be appreciated that reference to "one example" or "an example" of the invention is not made in an exclusive sense. Accordingly, one example may exemplify certain aspects of the invention, whilst other aspects are exemplified in a different example. These examples are intended to assist the skilled person in performing the invention and are not intended to limit the overall scope of the invention in any way unless the context clearly indicates otherwise.

CLAIMS

1. A spinneret for use in electrospinning production of filament, said spinneret comprising:

a casing defining a chamber, said casing further defining at least one fluid inlet via which a fluid is able to enter the chamber and at least one discharge port via which the fluid is able to exit the chamber; and

an electrode baffle structure positioned inside the chamber and configured to operationally impart an electrical charge to the fluid in the chamber, said baffle structure shaped and dimensioned to provide a surface-to-volume ratio of at least 5.

2. The spinneret of claim 1, therein the baffle structure is selected from a group consisting of wires, meshes, grids, foams, sponges, fabrics, weaves, fins, parallel plates, bonded powder structures, and interlaced materials.

3. The spinneret of claim 1, wherein the discharge port is defined in a substantially planar external surface of the casing in order to minimise coronal discharge, in use.

4. The spinneret of claim 1, wherein the baffle structure is configured and arranged to regulate a flow rate of the fluid passing through the chamber, in use.

5. The spinneret of claim 1, wherein the casing comprises an electrode terminal via which the baffle structure is connectable to an external electricity source.

6. The spinneret of claim 1, wherein the discharge port is circular in shape and defines a diameter between 0.1mm and 10mm.

7. A system for electrospinning production of filament, comprising:

a spinneret having a casing defining a chamber, said casing further defining at least one fluid inlet via which a fluid is able to enter the chamber and at least one discharge port via which the fluid is able to exit the chamber; and an electrode baffle structure positioned inside the chamber and configured to operationally impart an electrical charge to the fluid in the chamber, said baffle structure shaped and dimensioned to provide a surface-to-volume ratio of at least 5;

a power supply having a positive and a negative terminal, one terminal connected to the electrode baffle structure;

a fluid supply configured to supply an electrospinning fluid to the inlet port of the spinneret; and

a collector arranged to receive filament from the discharge port, said collector connected to the other power supply terminal.

8. The system of claim 7, wherein the power supply comprises a high-voltage direct current power supply.

9. The system of claim 7, wherein the fluid supply comprises a pump for pumping the fluid under pressure into the spinneret chamber.

10. The system of claim 7, wherein the fluid supply comprises a heating element for operationally heating the fluid.

11. The system of claim 7, wherein the collector comprises a cooled plate.

12. A method for producing filament, comprising the steps of:

providing a spinneret having a casing defining a chamber, said casing further defining at least one fluid inlet via which a fluid is able to enter the chamber and at least one discharge port via which the fluid is able to exit the chamber, and an electrode baffle structure positioned inside the chamber and configured to operationally impart an electrical charge to the fluid in the chamber, said baffle structure shaped and dimensioned to provide a surface-to-volume ratio of at least 5;

providing a power supply having a positive and a negative terminal, one terminal connected to the electrode baffle structure;

providing a fluid supply configured to supply an electrospinning fluid to the inlet port of the spinneret;

providing a collector arranged to collect filament from the discharge port, said collector connected to the other power supply terminal; and

operating the power supply and the fluid supply in order to produce electrospun filament.