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(54) **Electrospinning device and method.**

(57) An electrospinning device is provided with a container for holding a liquid comprising a polymer melt or a polymer solution, and a nozzle arranged to outlet a stream of the liquid from the container. A collector collects electro spun material during electrospinning so as to form a fibrous structure. The device comprises an optical measurement system that measures a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector, and also measures a momentary distance between the optical measurement system and a momentary top layer of the fibrous structure during the electrospinning process. A processor calculates a momentary thickness of the fibrous structure. Once a required thickness is reached the electrospinning can be stopped.

ELECTROSPINNING DEVICE AND METHOD

FIELD OF THE INVENTION

The invention relates to an electrospinning device and a method of producing a fibrous structure using such a device. The invention also relates to a measuring device for measuring a thickness of a fibrous structure and to a method of measuring a thickness of a fibrous structure.

BACKGROUND ART

Electrospinning is a method to produce continuous fibers with a diameter ranging from a few tens of nanometres to a few tens of micrometres. To electrospin fibers, a suitable liquefied material may be fed through a small, electrically conductive nozzle. The liquefied material may be electrically charged by applying a high voltage between the nozzle and a counter electrode. The generated electric field causes a cone-shape deformation of the droplet at the nozzle tip. Once the surface tension of this droplet is overcome by the electrical force, a jet is formed out of the droplet and a fiber forms that moves towards the counter electrode. During the flight towards the counter electrode the fiber is continuously stretched and elongated by the different forces acting on it, reducing its diameter and allowing it to solidify (by evaporation of the solvent or cooling of the material) such that a solid fiber is deposited on the collector (which is placed just before the counter electrode or the counter electrode is used as collector directly).

When an electrospinning process is run for a certain time, a structure of fibrous layers is formed on the counter electrode or collector. Due to the extremely small fiber diameter and the porous nature of this structure, it is difficult to accurately measure the thickness of the resulting fibrous structure because the structure's surface consists of very thin fibers and is hence compressible. Furthermore, the structure's surface is not smooth but consists of a (random or oriented) mesh of fibers and pores.

Thickness measurement methods that require direct contact with the structure will yield inaccurate results since the mechanical contact of the measuring device will compress the fibrous structure. Other measuring methods like SEM and light microscopy are destructive since they require slicing of the fibrous structure to allow the measurement system to "look" at the cross-section of the structure.

SUMMARY OF THE INVENTION

Drawback of the known methods for thickness measurement on electrospun fibrous structures is that they can only be applied after the fibrous structure is produced and hence not in situ.

One of the objects of the present invention is provide an electrospinning device that enables in-situ measuring of a thickness of the produced fibrous structure.

A first aspect of the invention provides an electrospinning device comprising:

- a container for holding a liquid comprising a polymer melt or a polymer solution;

- a nozzle arranged to outlet a stream of the liquid from the container;

- a collector for collecting electro spun material coming from the nozzle during an electrospinning process so as to form a fibrous structure on the collector;

- a voltage supply system arranged to create a voltage difference between the nozzle and the collector;

- an optical measurement system arranged to measure a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector corresponding to a plurality of predefined coordinates, and arranged to measure a momentary distance for a plurality of points on a momentary top layer of the fibrous structure at the predefined coordinates during the electrospinning process, and

- a processor arranged to receive the measured baseline distance and the momentary distance for the plurality of predefined coordinates from the optical measurement system and to calculate a momentary thickness of the fibrous structure for all the predefined coordinates.

By using an optical measurement system in an electrospinning device that measures a distance to the collector and a distance to the momentary top layer, an in-situ measurement is possible at a plurality of coordinates which can be predefined by a user or operator. So during the electrospinning process, the device is measuring the thickness of the electro spun fibrous structure being produced. This will give an improved control over the production process, as compared to known thickness measurements in which measurements are done after the spinning process. Furthermore, the fibrous structure does not need to be touched or cut into pieces. The thickness can be measured very accurately by measuring the distance from the collector to the optical measurement system and the distance from the (momentary) top layer to the optical measurement system at the predetermined coordinates. By also measuring the distance from the collector to the optical measurement system, a kind of initial height map or baseline can be made, so that fluctuations in the collector surface are corrected for. In case the collector is a rotatable collector, the fluctuations due to of axis orientation of the collector can be compensated for.

In an embodiment, the collector is movably arranged relative to the nozzle. In this way relatively large collectors can be used that may be covered with electro spun material over a wide area resulting in large fibrous structures. Furthermore, by moving the nozzle relative to the collector, both even and uneven distribution of fibers and thus structure thickness on the collector are possible.

In an embodiment, the processor is arranged to control at least one out of the following:

- the voltage difference;
- a material feed through the nozzle;
- a nozzle position relative to the collector;

in dependency on the calculated momentary thickness of the fibrous structure at at least one of the predefined coordinates.

So in this embodiment, the feedback of the momentary thickness is used to control or adjust the voltage difference and/or the material feed and/or the nozzle position relative to the collector. This online feedback of the measured thickness results in a controlled production of the structure and enables a continuation of the spinning process towards a predefined structure thickness. Besides, a reduction of waste of electrospinning material may be achieved as compared to known devices.

In an embodiment the processor is arranged to control the voltage supply system so as to stop the electrospinning process once a required thickness of the fibrous structure has been reached. This provides for the ability to continue the spinning process towards a predefined structure thickness. Also an additional reduction of waste of electrospinning material may be achieved.

In an embodiment the collector is rotatable around a rotation axis. The collector may be cylindrical or have a more complex freeform shape. When using such rotating shapes, a multiple number of structures are conceivable. A relatively simple structure may be a tubular structure that could be used as a stent in the medical field. The tubular structure may also be cut and flattened to create a substantially flat layer of electro spun material.

In an embodiment, the optical measurement system comprises a laser device and an optical sensor, wherein the laser device is arranged to send a light beam towards the collector and the sensor is arranged to measure reflected radiation coming from the collector and/or the fibrous structure.

As mentioned above, optical measurement makes contactless measurement possible and no damage to the fibrous structure will occur. The optical system may comprise a laser and an optical sensor that can be placed at a certain distance away from the collector to avoid interference of the measurement system during the electrospinning process.

In an embodiment, the optical sensor is a 1D or 2D sensor array arranged to detect radiation along at least one axis, wherein the processor is arranged to translate radiation intensities along the axis of the sensor into a reflection curve and to detect a first peak in the reflection curve, wherein the first peak is used by the processor to determine the distance between either the collector or the momentary top layer of the fibrous structure and the optical measurement system.

By using the first peak of the reflection curve, a reproducible distance measurement for the different types of reflection surfaces, being solid or porous, is possible.

In a specific embodiment, the optical measurement system comprises a laser triangulation sensor. Such a sensor is both contactless, accurate and cost-effective. Moreover, a relatively long distance between the optical measurement system and the collector can be used so that interference of the measurement device with can be avoided.

In an embodiment, the laser device is arranged to produce a laser beam having a cross section between 25 µm and 5000 µm, preferably between 70 and 2500 µm. The spot produced by the laser may be circular-, oval- or line shaped. The preferred cross section of the laser beam is large enough to cover a number of fibers and pores at the momentary top layer of the electro spun fibrous structure to yield sufficient reflection (detectable amount of radiation intensity) from the momentary top layer of the electro spun fibrous structure, although small enough to be able to distinguish between small height (distance) differences in a region of interest on the momentary top layer of the electro spun fibrous structure.

In an embodiment, the device comprises a user interface wherein the processor is arranged to receive the predefined coordinates from a user via the user interface. The user may freely select one or more coordinates at which the thickness of the fibrous structure is calculated. Selection of the coordinates may be done by the user or operator interacting with control software loaded on the processor prior to the measurement.

In an embodiment, the device further comprises a position measurement system arranged to measure a position of the collector relative to the optical measurement system, wherein the processor is arranged to receive position information from the position measurement system and to trigger the optical measurement system in dependency on the received position information.

A user may select some measurement positions on the collector at which a measurement is desired (i.e. the predefined coordinates), these locations may be programmed in a so-called trigger controller incorporated in the processor that triggers the acquisition of a measurement point with the optical measurement system on the selected measurement positions. In this way it is possible to measure repeatedly and accurately at exactly the predefined coordinates.

According to a further aspect there is provided a measuring device for measuring a thickness of a fibrous structure, the measuring device comprising:

- a frame;
- optionally, a rotatable drive shaft;
- a carrier for supporting the fibrous structure, the carrier being detachable from the frame and/or the drive shaft;
- an optical measurement system movably coupled to the frame and arranged to measure a baseline distance between the carrier and the optical measurement system for a plurality of points on a surface of the carrier corresponding to a plurality of predefined coordinates, and arranged to measure a top layer distance for a plurality of points on a top layer of the fibrous structure, present on the carrier, at the predefined coordinates, and
- a processor arranged to receive the measured baseline distance and the top layer distance for the plurality of predefined coordinates from the optical measurement system and to calculate a thickness of the fibrous structure for all the predefined coordinates.

The measuring device can be used to calculate a thickness of an electro spun fibrous structure produced in an electrospinning device. The electro spun fibrous structure can be transported from the electrospinning device to the measurement device by detaching the collector from the electrospinning device, and by attaching (i.e. mounting) the collector (with the fibrous structure on it) to the measurement device. In this way, the fibrous structure does not need to be removed from the collector and thus not need to be touched, thereby avoiding damages to the fibrous structure.

In an embodiment the measuring device further comprises a position measurement system arranged to measure a position of the carrier relative to the optical measurement system, wherein the processor is arranged to receive position information from the position measurement system and to trigger the optical measurement system in dependency on the received position information.

The position-based triggering of the optical measurement system enables an accurate repetition of the measurements at the predefined coordinates (e.g. to measure baseline and top layer distance at exactly the same coordinate so the difference calculation is representative for the thickness of the fibrous structure at that coordinate).

In an embodiment, the measuring device comprises a mounting system to install the carrier with a fixed orientation relative to the frame.

In an embodiment, the carrier is movable relative to the optical measurement system in at least one dimension. This enables the measuring of the thickness for multiple coordinates.

In an embodiment, the carrier is substantially cylindrical and rotatable relative to the optical measurement system. This enables the measuring of tubular structures or other freeform or 3D structures.

According to a further aspect there is provided a method of producing a fibrous structure, the method comprising:

- providing an electrospinning device comprising a collector and an optical measurement system;

- optically measuring a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector corresponding to a plurality of predefined coordinates;

- creating an electro spun fibrous structure on the collector by way of electrospinning using the electrospinning device;

- and while electrospinning, optically measuring a momentary distance for a plurality of points on a momentary top layer of the fibrous structure at the predefined coordinates;

- processing the measured baseline distance and the momentary distance for the plurality of predefined coordinates during the electrospinning process to calculate a momentary thickness of the fibrous structure for all the predefined coordinates.

In an embodiment the method comprises:

- stopping the electrospinning process, or only continuing electrospinning at certain areas of the collector, depending on the calculated momentary thickness at at least one of the predefined coordinates.

According to yet a further aspect, there is provided a method of measuring a thickness of a fibrous structure, the method comprising:

- mounting a collector without an electro spun fibrous structure on it into a measurement device comprising an optical measurement system;

- optically measuring a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector corresponding to a plurality of predefined coordinates;

- removing the collector from the measurement device and placing the collector in an electrospinning device for creation of an electro spun fibrous structure on the collector;

- mounting the collector with the electro spun fibrous structure on it into the measurement device;

- optically measuring a top layer distance between a top layer of the fibrous structure and the optical measurement system for a plurality of points on the top layer of the fibrous structure corresponding to the predefined coordinates;

- processing the measured baseline distance and the top layer distance for the plurality of predefined coordinates to calculate a thickness of the fibrous structure for all the predefined coordinates.

This method may be applied to check the quality of electro spun fibrous structures by comparing the actual thickness with a desired or required value. An advantage of this method is that it allows for using special measurement devices that comprise measuring configurations not possible in the electrospinning devices that may have insufficient space for a measurement device.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter. In the drawings,

Fig. 1 schematically shows a side view of a first embodiment of the electrospinning device;

Fig. 2 shows a perspective view of the mounting system used in Figure 1 according to an embodiment;

Fig. 3 schematically shows a further embodiment of the electrospinning device;

Figure 4A is a perspective view the connection interface according to an embodiment;

Figure 4B schematically shows a cross section of the connection interface of Figure 4A;

Figure 5 schematically shows a side view of the collector 1, the fibrous structure and the optical measurement system comprising the laser 8 and the optical sensor;

Fig. 6 schematically shows a measuring device for measuring a thickness of a fibrous structure according to an embodiment of the invention;

Fig. 7 shows a flow chart of a method of producing a fibrous structure according to an embodiment;

Fig. 8 shows a flow chart of a method according to a specific embodiment wherein a rotational collector is used, and

Fig. 9 shows a method of measuring a thickness of a fibrous structure according to an embodiment.

It should be noted that items which have the same reference numbers in different Figures, have the same structural features and the same functions, or are the same signals. Where the function and/or structure of such an item has been explained, there is no necessity for repeated explanation thereof in the detailed description.

DETAILED DESCRIPTION OF EMBODIMENTS

Figure 1 schematically shows a side view of a first embodiment of the electrospinning device 100. In this example, the device 100 comprises a container 50 for holding a liquid comprising a polymer melt or a polymer solution, and a nozzle 51 arranged to outlet a stream of the liquid from the container 50. It should be noted that the container 50 can be arranged remote from the nozzle 51 wherein it is in fluidic connection with the nozzle 51 by means of for example a tube. The device 100 further comprises a collector 1 for collecting electro spun material coming from the nozzle 51 during an electrospinning process. A voltage supply system 14 is arranged to create a voltage difference between the nozzle 51 and the collector 1. The voltage supply system 14 may comprise one AC or DC voltage supply to create the voltage difference or it may comprise two voltage supplies, one creating a voltage difference between the collector 1 and ground and one creating a difference between the nozzle 51 and ground. Due to the applied voltage(s), an electro spun fiber 52 is created that flies from the nozzle 51 to the collector 1 on which it is collected to form an electro spun fibrous structure 53.

The electrospinning device 100 also comprises an optical measurement system (OMS) 108 arranged to measure a distance between the collector 1 or the electro spun fibrous structure 53 and a reference point 13 of the OMS 108. In this example, the OMS 108 comprises a laser 8 and an optical sensor 12. The reference point 13 is situated at the front of the optical sensor 12. It is noted that the reference point 13 can be located at other locations, as will be clear to the skilled person. The reference point 13 can be used in the processing of the measured signals in order to calculate an absolute distance if needed. The laser 8 is arranged to create a laser beam 9 which is directed to the collector 1 and depending on the situation, hits the empty collector 1 or the electro spun fibrous structure 53 at a measurement position 54. The measurement position 54 can correspond to a predefined coordinate at which a distance measurement is to be taken. The laser beam 8 is reflected by the collector and/or by the electro spun fibrous structure 53 on the collector 1 and is detected by the optical sensor 12 as a reflected beam 11.

The electrospinning device 100 also comprises a processor 111. The processor 111 is arranged to receive the measured distances for a plurality of predefined coordinates from the OMS 108 before the electrospinning process and also during the electrospinning process. The processor 111 is arranged to calculate a momentary thickness during the electrospinning process of the fibrous structure for all the predefined coordinates using the received distances.

The electrospinning device 100 may comprise a metrology frame 107 arranged to support the collector 1 and the OMS 108. In the example of Figure 1, the OMS 108 can be positioned relative to the metrology frame 107 by means of OMS positioning module 109 indicated in Figure 1 by way of arrows 109. The arrows 109 indicate that the movement of the OMS 108 relative to the metrology frame 107 is possible in up to six degrees of freedom (DOF). As shown by three other arrows 112, the nozzle 51 can be positioned relative to the OMS 108, i.e. relative to the sensor 12. So, this positioning is also possible in up to 6 DOF. It is noted that the above mentioned relative positioning of the OMS 108 and of the nozzle 51 are optional and that the different elements shown in Figure 1 could all be fixed to the frame 107. To be able to produce a fiber layer on multiple areas on the collector 1, it is preferred that the nozzle 51 is able to move relative to the collector 1. This may be done using the above mentioned positioning means or a different separate system (not shown) arranged to move the collector relative to the frame 107. It is noted that the collector 1 in Figure 1 may have a top surface with different shapes such as rectangular, square shaped, disc shaped or any other suitable form depending on the structure to be produced. The top surface could be flat or curved. The collector could also have indentations or recesses, and/or it may have extensions so as to create different fibrous structures. In the embodiment of Figure 1, the collector is mounted onto the frame 107 by means of a mounting system comprising a mount top element 201 and a mount bottom element 202. The mounting system is arranged to removably position the collector 1 relative to the frame 107. In an embodiment the mounting system is a kinematic coupling system.

Figure 2 shows a perspective view of the mounting system used in Figure 1 according to an embodiment. In this example, the mounting system is a kinematic coupling system comprising a top element 201 and a bottom element 202. The top element 201 comprises three semi-spherical elements 203 while the bottom element 202 comprises three grooves 204. The bottom element 202 comprises an orientation pin 205, while the top element 201 comprises a clearance hole 206 cooperating with the orientation pin 206. The top element 201 comprises threaded hole 207 for receiving an outer end of a drawbar 208, the draw bar 208 being biased by means of a spring 209.The top element 201 can only be positioned and connected in one way on top of the bottom element 202. This is due to the orientation pin falling in the clearance hole 206 and the semi-spherical elements 203 falling in the grooves 204.The positioning of the mounting elements relative to each other is very accurate and reproducible as will be appreciated by the skilled person. It is noted that other types of mounting systems are conceivable.

It is also noted that the mounting system 201,202 is optional, however its presence will enable the user to remove the collector 1 from the electrospinning device and place it into another device for measuring purposes or other operations on the fibrous structure in which accurate alignment is preferred.

Figure 3 schematically shows a further embodiment of the electrospinning device 100. In this embodiment, the electrospinning device 100 comprises a substantially cylindrical collector 1 which is rotatable relative to the nozzle 51. In this way, a cylindrical fibrous structure can be created during an electrospinning process. Since the collector 1 is rotatable, it is also referred to as the rotating mandrel 1. The nozzle 51 is also referred to as the spinneret 51 which may be charged with a high voltage for fiber fabrication similar to the process described with reference to Figure 1.

As shown in Figure 3, an electrospun fiber 52 is ejected as a droplet at (a tip of) the nozzle 51 and it flies from the nozzle 51 to the collector 1 while it stretches and solidifies in an electrostatic field between the charged nozzle 51 and the charged collector 1. On an outer surface of the collector 1 electrospun fibers are collected that form a porous fibrous layer 53 on the collector 1, also referred to as electro spun fibrous structure 53.

The electrospinning device 100 also comprises a drive shaft 101 connecting the collector 1 to actuator components 102-106. The actuator components in this example comprise amongst others two bearings 102a, 102b of which bearing 102b is optional. The bearings 102a, 102b are arranged to support the drive shaft 101 that holds the rotating collector 1. Each bearing is arranged on one end of the collector 1. The electrospinning device 100 also comprises a HV (high voltage) contact unit 103 arranged to provide a high-voltage or a grounded connection to the rotating collector 1. An HV isolating transmission 104 is arranged to decouple the HV-charged collector 1 from a motor 105 so as to protect the motor 105. The motor 105 may be a DC, AC, a stepper, or a servomotor.

In the embodiment of Figure 3, the device 100 comprises a first connecting interface 114a and a second connection interface 114b. The first connecting interface 114a and the second connection interface 114b are also referred to as the mounting system 114. The mounting system is arranged to removably mount the collector 1 into the device 100. The mounting system 114 is preferably arranged to fix the collector 1 onto the shaft 101 in 6 DOF. So for example, the first connecting interface 114a may cause the collector 1 to be fixed in 4 DOF while the second connection interface 114b is arranged to fix the collector in 2 DOF. It is noted that the bearing 102b is optional and in that situation the second connecting interface 114b is absent; in that case the first connection interface may be arranged to fixate the collector 1 relative to the shaft 101 in 6 DOF.

The electrospinning device 100 also comprises a processor 111. The processor 111 may be arranged to send a motor setpoint signal 105a to the motor 105. The setpoint signal 105a may comprise position and/or velocity information.
The actuator components further comprise a rotational position sensor 106, which may be a rotational encoder (absolute or incremental). The rotational position sensor 106 is arranged to send a rotational position signal 106a to the processor 111 that can be used by the processor 111 to trigger a measurement acquisition process at a predefined coordinate. During the measurement acquisition process a trigger is sent by the processor 111 to the OMS 108. At receipt of the trigger the OMS 108 takes a

sample of the momentary distance value X and sends it back to the processor 111. In an embodiment, the OMS 108 is arranged to sample at a rate above 50 kHz; for high collector positioning speeds the sample rate is typically between 100-400 kHz. An OMS with such a high sample rate enables a thickness measurement at relatively high collector positioning speeds. Sample rates below 50 kHz are possible for situations where the measured positions are static.

The electrospinning device 100 also comprises a metrology frame 107 that, in this embodiment, forms the frame of reference for all measurements. An OMS 108 is arranged on the opposite side of the rotating collector 1 as compared to the nozzle 51. As a result, a measured position 54 is located at the other side of the rotating collector 1 as compared to the fiber collection side of the rotating collector 1. It is noted that the OMS 108 does not need to be arranged opposite the nozzle but that it is preferred that the OMS 108 is located at such a position that it does not interfere with the fiber production process by the nozzle 51. As was shown in the embodiment of Figure 1, the OMS 108 may even be located at the same side as the nozzle relative to the collector 1 (i.e. mandrel). The OMS 108 may determine a thickness of the produced electro spun fibrous structure 53 by means of several techniques e.g. Laser Triangulation, Spectral Interference (Laser) Displacement, or Time Of Flight. Please note that the mentioned techniques could also be used in parallel.

The measured position 54 can either be a single position or multiple positions to examine the distribution of the fibrous layer buildup. This enables the device or the user thereof to produce a fibrous structure according to pre-defined thickness specifications. Preferably, the measurement is performed perpendicular to a local curvature of the collector 1. In this way no correction for a possible angle deviation is required on the calculation of a thickness value.

In the embodiment of Figure 3, the OMS 108 sends a distance measurement sensor signal 108a to the processor 111, which will process these signals together with the position information 106a.

The electrospinning device 100 also comprises an OMS positioning module 109. The position of the OMS 108 can be fixed relative to a main axis of the rotating collector 1. In this case only a single position along the main axis can be measured. Alternatively, the position of the OMS 108 can be automatically adjusted by means of the OMS positioning module 109 when a number of measurement positions along the main axis is required.

The processor 111 may be arranged to send an OMS positioning setpoint signal 109a to the OMS positioning module 109. This OMS positioning setpoint signal 109a may comprise position and/or velocity information.

The electrospinning device 100 also comprises an OMS position sensor 110, which may be a linear encoder. The OMS position sensor 110 measures a position of the optical measurement system 108 relative to the metrology frame 107 and thus to the rotating collector 1. The OMS position sensor 110 may be arranged to send an OMS position signal 110a to the processor 111 that can be used by the processor 111 for triggering a measurement acquisition process at a predefined coordinate.

In this embodiment, the electrospinning device 100 also comprises a nozzle positioning module 112. It is noted that the nozzle 51 can be fixed relative to the rotating collector 1. Alternatively, the position of the nozzle 51 can be automatically adjusted by means of the nozzle positioning module 112, resulting in wider and/or more homogenous coverage of the rotating collector 1 with an electro spun fibrous structure.

The processor 111 may be arranged to send a nozzle positioning setpoint signal 112a to the nozzle positioning module 112. This nozzle positioning setpoint signal 112a may comprise position or velocity information.

In the embodiment of Figure 3, the electrospinning device 100 also comprises a nozzle position sensor 113, which may be a linear encoder, or a rotational encoder combined with a linear driver belt. The nozzle position sensor 113 may be arranged to send a nozzle position signal 113a to the processor 111. The nozzle position signal 113a may comprise position or velocity information.

In an embodiment, the processor 111 is arranged for performing the following functions:

- receive the predefined coordinates from the user or operator;
- setpoint generation for the actuators 105, 109, 112;
- data recording from the position sensors 106, 110, 113;
- triggering of measurement acquisition;
- data recording from distance sensor(s) 108;
- thickness calculation THK = X2 – X1.

Figure 4A is a perspective view the connection interface 114a according to an embodiment. The connection interface 114a comprises a collector mount 41 and a tapered shaft mount 42. The tapered shaft mount 42 is fixed onto or a part of an outer end of the drive shaft 101.

Figure 4B schematically shows a cross section of the connection interface 114a of Figure 4A. As can be seen from Figure 4B, the collector mount 41 in this case is a cylinder comprising a recess for receiving part of the tapered shaft mount 42. The recess is formed by a tapered socket 44 and a threaded hole 45. A keyway 46 is arranged to receive a key 47 from the tapered shaft mount 42. Figure 4B shows a draw bar 48 at the outer end of the tapered shaft mount 42 which can be inserted into the threaded hole 45. By inserting the tapered shaft mount 42 into the collector mount 41, the collector will be mounted onto the drive shaft with a high degree of positioning accuracy, preferably in 6 DOF.

Figure 5 schematically shows a side view of the collector 1, the fibrous structure and the OMS 108 comprising the laser 8 and the optical sensor 12. The optical sensor 12 in this embodiment may be an optical receiver such as a Line-, CCD-, or CMOS sensor. At the bottom of Figure 5, a corresponding received radiation intensity is shown as a function of X where X is the distance between the reflecting surface of the object (reflection surface) and the reference point 13 of the OMS 108. The graph of Figure 5 shows two curves that are measured on different moments in time. Curve 6 is the received radiation as a function of X when the collector is still empty before the electrospinning has started. Curve 7 is the received radiation as a function of X when the collector is (partly) covered with a fibrous structure 2 during the electrospinning process, or just after the process has stopped. In Figure 5, X1 relates to the distance from the reference point 13 of the OMS 108 to the surface of the collector 1 (baseline) and X2 is the distance from the reference point 13 of the OMS 108 to the momentary top layer of the fibrous structure 5.

At the top part of Figure 5, the laser beam 9 hits the top layer of the fibrous structure 2. The arrow 4 indicates the position of the surface of the collector 1 while the arrow 5 indicates the momentary top layer of the fibrous structure 2.

The top layer of fibrous structure 2 has an inconsistent fiber density as indicated with fibers 3. According to an embodiment, the laser beam cross section 10 is bigger than the expected pores in the fibrous structure 2. Typical values for the cross section of the laser beam 9 are in a range between 25 – 5000 µm. The preferred cross section of the laser beam is large enough to cover a number of fibers and pores at the momentary top layer of the electro spun fibrous structure to yield sufficient reflection (detectable amount of radiation intensity) from the momentary top layer of the electro spun fibrous structure, although small enough to be able to distinguish between small height (distance) differences in a region of interest on the momentary top layer of the electro spun fibrous structure.

Please note that in Figure 5, the cross section of the beam 9 is exaggerated at the end by the oval 10.

In an embodiment the OMS processes the reflection curve 6 or 7 to determine the distance X1 or X2 corresponding with the first peak in each respective curve, and output this distance value to the processor 111. Triangulation methods can be used by the OMS to calculate the values of X1 and X2. The processor 111 processes the received distances to calculate the thickness of the fibrous structure. The thickness *THK*, see Figure 5, is determined using the formula: $THK = X2 – X1$.

The inventors have realized that a response of a laser triangulation measurement method is a bell-curve (reflection curve) signal resulting from a fibrous (porous) structure that gives little reflection from the top (more porous) layers of fibers, increased reflection from more dense sublayers of fibers, and decreased reflection from deeper layers of the fibrous structure. The distance (between the reference point 13 of the OMS and the reflection surface of the object (collector 1 or the momentary top layer of the fibrous structure 5) can be derived from the corresponding bell-curves e.g. by taking the position of the peak of the corresponding curves 6 or 7.

Figure 6 schematically shows a measuring device 600 for measuring a thickness of a fibrous structure according to an embodiment of the invention. In this embodiment, the measuring device 600 comprises a frame 107, a rotatable drive shaft 101, a carrier for supporting the fibrous structure, the carrier being detachable from the frame and/or the drive shaft. The device 600 also comprises an OMS 108 movably coupled to the frame 107 and arranged to measure a baseline distance between the carrier and the OMS 108 for a plurality of points on a surface of the carrier corresponding to a plurality of predefined coordinates, and arranged to measure a distance for a plurality of points on a top layer of the fibrous structure at the predefined coordinates. The measuring device 600 also comprises a processor 611 arranged to receive the measured baseline distance and the top layer distance for the plurality of predefined coordinates from the optical measurement system and to calculate a thickness of the electro spun material for all the predefined coordinates.

As can be seen from Figure 6, the measuring device 600 resembles the electrospinning device of Figure 3 to a certain extent. However, the measuring device 600 does not comprise the nozzle 51, the container 50, the positioning 112 of the nozzle, the voltage supply system 14 nor the HV contact unit 103. It is noted that the bearing 102b and the mounting element 114b are optional in Figure 6.

Figure 7 shows a flow chart of a method of producing a fibrous structure according to an embodiment. The method could be performed using the electrospinning device 100. The method 400 comprises optically measuring, see block 401, a first (baseline) distance between a collector of an electrospinning device and the optical measurement system for a plurality of points on a surface of a collector of an electro spinning device, the points corresponding to a plurality of predefined coordinates. Block 401 is followed by creating a fibrous structure on the collector by way of electrospinning, see block 402. While electrospinning, a second distance for a plurality of points on a momentary top layer of the fibrous structure at the predefined coordinates is optically measured, see block 403. The measured first and second distance from the optical measurement system are processed for the plurality of predefined coordinates during the electrospinning process to calculate a momentary thickness of the fibrous structure for all the predefined coordinates, see block 404. Optionally the method comprises stopping the electrospinning process, see block 405, depending on the determined momentary thickness at at least one of the predefined coordinates. Electrospinning can be continued at certain areas of the collector while electrospinning at other areas could be stopped depending on the required local thickness.

Figure 8 shows a flow chart of a method 500 according to a specific embodiment wherein a rotational collector is used. The method 500 starts with a block 501 indicating that a collector is attached/fixed to the driveshaft of the setup of Figure 3. Next, in a step 502, the collector 1 is positioned in a desired starting position. A block 503 indicates that the readings from sensors 106 and 110 are set to zero in the processor 111. At block 504 a plurality of predefined coordinates is programmed in the processor by e.g. a user. These predefined coordinates can be multiple measurement positions over the circumference of the collector 1. In an embodiment multiple sensors are used to measure distances at different measurement positions in parallel. Block 505 indicates that the desired OMS positions (relative to the zero position) at which a measurement acquisition process should be triggered are programmed for OMS positioning. Note that this positioning / position programming is not required when the OMS 108 is at a fixed position. A block 506 indicates the starting of the rotation of the collector 1 and to wait for it to reach a desired rotational speed. The rotational angle of the rotating collector 1 can be accurately tracked by readout of the rotational position sensor 106 by the processor 111. A block 507 indicates the starting of the measurement process. A measurement point can be defined by the measured distance between the OMS 108 and the reflection surface 4, 5. A block 507A indicates the triggering, acquiring and recording of a measurement point for a plurality of predefined coordinates. A block 507B indicates that the readings from the OMS 108 can optionally be set to zero in the processor 111.

A number of measurement points can be taken for a plurality predefined coordinates on an empty collector for averaging purposes (determining the baseline distance), see block 507C.

Block 508 indicates the starting of the electrospinning process. Fibers will start to collect on the rotating collector 1 forming an electro spun fibrous structure 53 (with uneven distribution on a micro scale). If desired, the nozzle 51 can be positioned at programmed positions or can be moved at a specific speed. Block 509 indicates that during the collection of fibers the distance between OMS and reflection surface is recorded for a plurality of predefined coordinates. As the thickness of the electro spun fibrous structure 53 increases during the electrospinning process, the distance between the OMS 108 and the reflected surface decreases. The momentary thickness of the electro spun fibrous structure may be defined as the momentary distance minus the baseline distance. A block 510 indicates that after electrospinning for a desired time, or reaching a desired thickness, the electrospinning process can be stopped (or interrupted). Optionally, the collector 1 keeps rotating after the electrospinning process has stopped, and a number of measurement points at a plurality of predefined coordinates are taken on the electro spun fibrous structure for averaging purposes. At block 511 the measurement process is stopped. At block 512 the rotating is stopped and at block 513 the collector 1 is detached from the driveshaft 101, see also Figure 3. The distance (between the reference point 13 of the OMS and the object (collector 1 or the momentary top layer of the fibrous structure 5) can be derived from the corresponding bell-curves e.g. by taking the position of the peak of the corresponding curves 6 or 7.

In an embodiment, each measured distance is derived from an individual reflection curve detected by the sensor of the OMS, recorded after receiving a trigger to start a measurement acquisition process. The distance value X may be derived from the reflection curve by taking the position of the first peak in the reflection curve signal (closest to the OMS). Any additional peaks in the reflection curve signals are left out of account. The distance value X relating to the position of the first peak represents the distance between the reference point 13 of the OMS and the object.

If the sensor 12 and the collector surface 4 are able to move relatively to each other, distance information at different spatial coordinates can be obtained. In this way accurate measurement of structure thickness at different spatial coordinates on the structure can be achieved. In such cases the measurement method/device must have a sufficiently small field of view to detect local variations in thickness. This can be achieved by using a laser spot size suitable for the size of the region of interest.

The contactless measurement method described above has many advantages. However, contactless methods must allow for sufficient distance between the collector 1 and the OMS 108 to avoid interference of the sensor/device with the electrospinning process since:

- The device 100 can alter the electric field when it is too close to the nozzle 51 or collector 1;
- The device 100 can build up static electric charge and starting to act as an electrode (attracting or repelling fibers onto the device rather than on the collector);
- The device 100 can get damaged by electric discharges between the (high voltage) nozzle 51 or collector 1 and the device 100.

Another solution to avoid interference of the sensor/device with the electrospinning process is to produce the fibrous structure in an electrospinning device which comprises a demountable collector that can be placed into the measuring device 600 shown in Figure 6. The thickness can then be measured using a method as described below.

Figure 9 shows a method 900 of measuring a thickness of a fibrous structure, the method comprising:

- mounting a collector without an electrospun structure on it into a measurement device comprising an optical measurement system, see block 901
- optically measuring a baseline distance between the optical measurement system and the collector for a plurality of points on a surface of the collector, the points corresponding to a plurality of predefined coordinates, see block 902;
- removing the collector from the measurement device and placing the collector in an electrospinning device for creation of an electro spun structure on the collector, see block 903;
- mounting the collector with the electrospun structure on it into the measurement device, see block 904;
- optically measuring a top layer distance between the optical measurement system and a top layer of the fibrous structure for a plurality of points at the predefined coordinates, see block 905;
- processing the measured baseline and top layer distance for the plurality of predefined coordinates from the optical measurement system to determine a thickness of the fibrous structure for all the predefined coordinates, see block 906.

The method of measuring a thickness of a fibrous structure as shown in Figure 9 is not being performed while producing, so this method is referred to as an offline thickness measuring method.

The in-situ and offline local thickness measurements described above preferably have a high degree of accuracy over a wide range. The thickness of an electro spun structure can be as high as several millimetres while the build-up over time of this structure is determined by the pore size and fiber diameter itself and these typically lie between a few tens of nanometres and a few tens of micrometres. The preferred accuracy of thickness measurement for process adjustment or quality control purposes is typically 10 μm - 50μm. This high degree of accuracy may be achieved by:

- Using accurate distance measurement methods, for instance laser triangulation, spectral interference etcetera;
- Accurate positioning of the collector and the optical measurement system;
- High speed triggering of measurement acquisition for increased repeatability accuracy at high positioning speeds of the OMS and/or the collector;
- Ability to average the thickness over numerous measurement points;
- Ability to measure distances over an area that in average is representative for the region of interest.

Below, a number of embodiments are listed:

Embodiment 1: An electrospinning device (100) comprising:

- a container (50) for holding a liquid comprising a polymer melt or a polymer solution;

- a nozzle (51) arranged to outlet a stream of the liquid from the container;

- a collector (1) for collecting electro spun material coming from the nozzle during an electrospinning process so as to form a fibrous structure on the collector;

- a voltage supply system (14) arranged to create a voltage difference between the nozzle and the collector,

- an optical measurement system (8,12;108) arranged to measure a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector corresponding to a plurality of predefined coordinates, and arranged to measure a momentary distance for a plurality of points on a momentary top layer of the fibrous structure at the predefined coordinates during the electrospinning process;

- a processor (111) arranged to receive the measured baseline distance and the momentary distance for the plurality of predefined coordinates from the optical measurement system and to calculate a momentary thickness of the fibrous structure for all the predefined coordinates.

Embodiment 2: The electrospinning device according to embodiment 1, wherein the collector is movably arranged relative to the nozzle.

Embodiment 3: The electrospinning device according to embodiment 1 or 2, wherein the processor is arranged to control at least one out of the following:

- the voltage difference;
- a material feed through the nozzle;
- a nozzle position relative to the collector;

in dependency on the calculated momentary thickness of the fibrous structure at at least one of the predefined coordinates.

Embodiment 4: The electrospinning device according to embodiment 3, wherein the processor is arranged to control the voltage supply system so as to stop the electrospinning process once a required thickness of the fibrous structure has been reached.

Embodiment 5: The electrospinning device according to any of the preceding embodiments, wherein the collector is rotatable around a rotation axis.

Embodiment 6: The electrospinning device according to any of the preceding embodiments, wherein the optical measurement system comprises a laser device and an optical sensor, wherein the laser device is arranged to send a light beam towards the collector and the sensor is arranged to measure reflected radiation coming from the collector and/or the fibrous structure.

Embodiment 7: The electrospinning device according to embodiment 6, wherein the sensor is a 1D or 2D sensor array arranged to detect radiation along at least one axis, wherein the processor is arranged to translate radiation intensities along the axis of the sensor into a reflection curve and to detect a first peak in the reflection curve, wherein the first peak is used by the processor to determine the distance between either the collector or the momentary top layer of the fibrous structure and the optical measurement system.

Embodiment 8: The electrospinning device according to any of the preceding embodiments, wherein the optical measurement system comprises a laser triangulation sensor.

Embodiment 9: The electrospinning device according to any of the embodiments 6-8, wherein the laser device is arranged to produce a laser beam having a cross section between 25 μm and 5000 μm, preferably between 70 μm and 2500 μm.

Embodiment 10: The electrospinning device according to any of the preceding embodiments, wherein the device comprises a user interface and wherein the processor is arranged to receive the predefined coordinates from a user via the user interface.

Embodiment 11: The electrospinning device according to any of the preceding embodiments, wherein the device further comprises a position measurement system (106,110) arranged to measure a position of the collector (1) relative to the optical measurement system (108), wherein the processor (111) is arranged to receive position information from the position measurement system and to trigger the optical measurement system (108) in dependency on the received position information.

Embodiment 12: A measuring device for measuring a thickness of a fibrous structure, the measuring device comprising:

- a frame (107);
- optionally, a rotatable drive shaft (101);
- a carrier for supporting the fibrous structure, the carrier being detachable from the frame and/or the drive shaft;
- an optical measurement system (8,12;108) movably coupled to the frame (107) and arranged to measure a baseline distance between the carrier and the

optical measurement system for a plurality of points on a surface of the carrier corresponding to a plurality of predefined coordinates, and arranged to measure a top layer distance for a plurality of points on a top layer of the fibrous structure, present on the carrier, at the predefined coordinates;

- a processor (111) arranged to receive the measured baseline distance and the top layer distance for the plurality of predefined coordinates from the optical measurement system and to calculate a thickness of the fibrous structure for all the predefined coordinates.

Embodiment 13: The measuring device according to embodiment 12, wherein the device further comprises a position measurement system (106,110) arranged to measure a position of the carrier (1) relative to the optical measurement system (108), wherein the processor (111) is arranged to receive position information from the position measurement system and to trigger the optical measurement system (108) in dependency on the received position information.

Embodiment 14: The measuring device according to embodiment 12 or 13, wherein the device comprises a mounting system to install the carrier with a fixed orientation relative to the frame (107).

Embodiment 15: The measuring device according to any of the embodiments 12-14, wherein the carrier is movable relative to the optical measurement system in at least one direction.

Embodiment 16: The measuring device according to any of the embodiments 12-15, wherein the carrier is substantially cylindrical and rotatable relative to the optical measurement system.

Embodiment 17: A method of producing a fibrous structure, the method comprising:

- providing an electrospinning device comprising a collector and an optical measurement system;
- optically measuring a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector corresponding to a plurality of predefined coordinates;
- creating an electro spun fibrous structure on the collector by way of electrospinning using the electrospinning device;

- and while electrospinning, optically measuring a momentary distance for a plurality of points on a momentary top layer of the fibrous structure at the predefined coordinates;
- processing the measured baseline distance and the momentary distance for the plurality of predefined coordinates during the electrospinning process to calculate a momentary thickness of the fibrous structure for all the predefined coordinates.

Embodiment 18: The method of producing according to embodiment 17, wherein the method comprises:
- stopping the electrospinning process, or only continuing spinning at certain areas of the collector, depending on the determined momentary distance at at least one of the predefined coordinates.

Embodiment 19: A method of measuring a thickness of a fibrous structure, the method comprising:
- mounting a collector without an electro spun fibrous structure on it into a measurement device comprising an optical measurement system;
- optically measuring a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector corresponding to a plurality of predefined coordinates;
- removing the collector from the measurement device and placing the collector in an electrospinning device for creation of an electro spun fibrous structure on the collector;
- mounting the collector with the electro spun fibrous structure on it into the measurement device;
- optically measuring a top layer distance between a top layer of the fibrous structure and the optical measurement system for a plurality of points on the top layer of the fibrous structure corresponding to the plurality of predefined coordinates;
- processing the measured baseline distance and the top layer distance for the plurality of predefined coordinates to calculate a thickness of the fibrous structure for all the predefined coordinates.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. In the device claims several means are enumerated. These means may be embodied by one and the same item of hardware or software. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CONCLUSIES

1. Elektrospin-inrichting (100) omvattende:

- een houder (50) voor het houden van een vloeistof die een polymeersmelt of een polymeeroplossing omvat;

- een mondstuk (51) ingericht om een stroom van de vloeistof uit de houder te laten;

- een collector (1) voor het verzamelen elektro-gesponnen materiaal uit het mondstuk gedurende een elektrospinproces teneinde een vezelachtige structuur op de collector te vormen;

- een voedingspanningssysteem (14) ingericht om een spanningsverschil tussen het mondstuk en de collector te creëren;

- een optisch meetsysteem (8,12, 108) ingericht om een basislijnafstand tussen de collector en het optische meetsysteem te meten voor een veelheid van punten op een oppervlak van de collector behorende bij een veelheid van vooraf gedefinieerde coördinaten, en ingericht om een momentane afstand te meten voor een aantal punten op een momentane toplaag van de vezelstructuur op de vooraf gedefinieerde coördinaten tijdens het elektrospinproces;

- een processor (111) ingericht om de gemeten basislijnafstand en de momentane afstand voor de veelheid van vooraf bepaalde coördinaten van het optische meetsysteem te ontvangen en een momentane dikte van de vezelstructuur te berekenen voor alle vooraf gedefinieerde coördinaten.

2. Elektrospin-inrichting volgens conclusie 1, waarbij de collector beweegbaar is ingericht ten opzichte van het mondstuk.

3. Elektrospin-inrichting volgens conclusie 1 of 2, waarbij de processor is ingericht om ten minste één van de volgende maatregelen te besturen:

- het spanningsverschil;

- een materiaaltoevoer door het mondstuk;

- een mondstukpositie ten opzichte van de collector;

in afhankelijkheid van de berekende momentane dikte van de vezelstructuur op tenminste één van de vooraf gedefinieerde coördinaten.

4. Elektrospin-inrichting volgens conclusie 3, waarbij de processor is ingericht om de spanning te besturen teneinde het elektrospinproces te stoppen als eenmaal een vereiste dikte van de vezelachtige structuur is bereikt.

5. Elektrospin-inrichting volgens één der voorgaande conclusies, waarbij de collector roteerbaar is rond een rotatieas.

6. Elektrospin-inrichting volgens één der voorgaande conclusies, waarbij het optische meetsysteem een laserinrichting en een optische sensor omvat, waarbij de laserinrichting is ingericht om een lichtbundel naar de collector te verzenden en de sensor is ingericht om gereflecteerde straling te meten vanaf de collector en/of de vezelstructuur.

7. Elektrospin-inrichting volgens conclusie 6, waarbij de sensor een 1D of 2D sensorgrid is dat is ingericht om straling te detecteren langs ten minste één as, waarbij de processor is ingericht om stralingsintensiteiten langs de as van de sensor te vertalen in een reflectiecurve en om een eerste piek in de reflectiecurve te detecteren, waarbij de eerste piek wordt gebruikt door de processor om de afstand tussen hetzij de collector of de momentane toplaag van de vezelstructuur en het optische meetsysteem te bepalen.

8. Elektrospin-inrichting volgens één der voorgaande conclusies, waarbij het optische meetsysteem een laser triangulatie sensor omvat.

9. Elektrospin-inrichting volgens één van de conclusies 6-8, waarbij de laser is ingericht om een laserbundel te produceren met een doorsnede tussen 25 µm en 5000 µm, bij voorkeur tussen 70 µm en 2500 µm.

10. Elektrospin-inrichting volgens één der voorgaande conclusies, waarbij de inrichting een gebruikersinterface omvat en waarbij de processor is ingericht om de vooraf gedefinieerde coördinaten via de gebruikersinterface te ontvangen van een gebruiker.

11. Elektrospin-inrichting volgens één der voorgaande conclusies, waarbij de inrichting verder een positiemeetsysteem (106,110) omvat die is ingericht om een positie van de collector (1) ten opzichte van het optische meetsysteem (108) te meten,

waarbij de processor (111) is ingericht om positie-informatie van het positiemeetsysteem te ontvangen en om het optische meetsysteem (108) in afhankelijkheid van de ontvangen positie-informatie te activeren.

12. Meetinrichting voor het meten van een dikte van een vezelachtige structuur, de meetinrichting omvattende:

- een frame (107);
- eventueel een roteerbare aandrijfas (101);
- een drager voor het ondersteunen van de vezelstructuur, waarbij de drager losneembaar is van het frame en/of de aandrijfas;
- een optisch meetsysteem (8,12; 108) beweegbaar gekoppeld aan het frame (107) en ingericht om een basislijnafstand tussen de drager en het optische meetsysteem te meten op een veelheid van punten op een oppervlak van de drager overkomende met een aantal vooraf gedefinieerde coördinaten en ingericht om een toplaagafstand te meten voor een aantal punten op een toplaag van de vezelachtige structuur, aanwezig op de drager, op de vooraf bepaalde coördinaten;
- een processor (111) ingericht om de gemeten basislijnafstand en de toplaag- afstand voor de veelheid van vooraf bepaalde coördinaten van het optische meetsysteem te ontvangen en een dikte van de vezelachtige structuur te berekenen voor alle vooraf gedefinieerde coördinaten.

13. Meetinrichting volgens conclusie 12, waarbij de inrichting verder een positie meetsysteem (106,110) omvat die is ingericht om een positie van de drager (1) ten opzichte van het optische meetsysteem (108) te meten, waarbij de processor (111) is ingericht om de informatie van het positiemeetsysteem te ontvangen en het optische meetsysteem (108) in afhankelijkheid van de ontvangen positie-informatie te activeren.

14. Meetinrichting volgens conclusie 12 of 13, waarbij de inrichting een montagesysteem omvat voor het installeren van de drager met een vaste oriëntatie ten opzichte van het frame (107).

15. Meetinrichting volgens één van de conclusies 12-14, waarbij de drager ten opzichte van het optische meetsysteem in ten minste één dimensie beweegbaar is.

16. Meetinrichting volgens één van de conclusies 12-15, waarbij de drager in hoofdzaak cilindervormig is en roteerbaar ten opzichte van het optische meetsysteem.

17. Werkwijze om een vezelachtige structuur te produceren, waarbij de werkwijze omvat:

- het verschaffen van een elektrospin-inrichting omvattende een collector en een optisch meetsysteem;
- het optisch meten van een basislijnafstand tussen de collector en het optische meetsysteem voor een veelheid van punten op een oppervlak van, die overeenkomen met een aantal vooraf bepaalde coördinaten;
- het creëren van een elektro-gesponnen vezelstructuur op de collector met gebruikmaking van de elektrospin-inrichting;
- en tijdens het elektrospinproces, het optisch meten van een momentane afstand voor een veelheid van punten op een tijdelijke toplaag van de vezelachtige structuur op de vooraf bepaalde coördinaten;
- het verwerken van de gemeten basislijnafstand en de momentane afstand voor de veelheid van vooraf bepaalde coördinaten tijdens het elektrospinproces om een momentane dikte van de vezelachtige structuur te berekenen voor alle vooraf gedefinieerde coördinaten.

18. Werkwijze voor het vervaardigen volgens conclusie 17, waarbij de werkwijze omvat:

- het stoppen van het elektrospinproces of alleen voortzetten van het elektrospinproces in bepaalde gebieden van de collector, afhankelijk van de bepaalde momentane afstand op tenminste één van de vooraf gedefinieerde coördinaten.

19. Werkwijze voor het meten van een dikte van een vezelachtige structuur, waarbij de werkwijze omvat:

- het bevestigen van een collector zonder elektro-gesponnen vezelachtige structuur in een meetsysteem omvattende een optisch meetsysteem;
- het optisch meten van een basislijnafstand tussen de collector en het optisch meetsysteem en voor een veelheid van punten op een oppervlak van de collector, overeenkomende met een aantal vooraf bepaalde coördinaten;

- het verwijderen van de collector van het meetapparaat en het plaatsen van de collector in een elektrospin-inrichting voor het creëren van een elektro-gesponnen vezelachtige structuur op de collector;

- het monteren van de collector met de elektro-gesponnen vezelachtige structuur daarop in de meetinrichting;

- het optisch meten van een toplaagafstand tussen een toplaag van de vezelachtige structuur en het optische meetsysteem voor een veelheid van punten op de toplaag, overeenkomende met de veelheid aan vooraf bepaalde coördinaten;

- het verwerken van de gemeten basislijn- en toplaagafstand voor de veelheid van vooraf bepaalde coördinaten om een dikte van de vezelachtige structuur te bepalen van alle vooraf bepaalde coördinaten.

Fig. 1

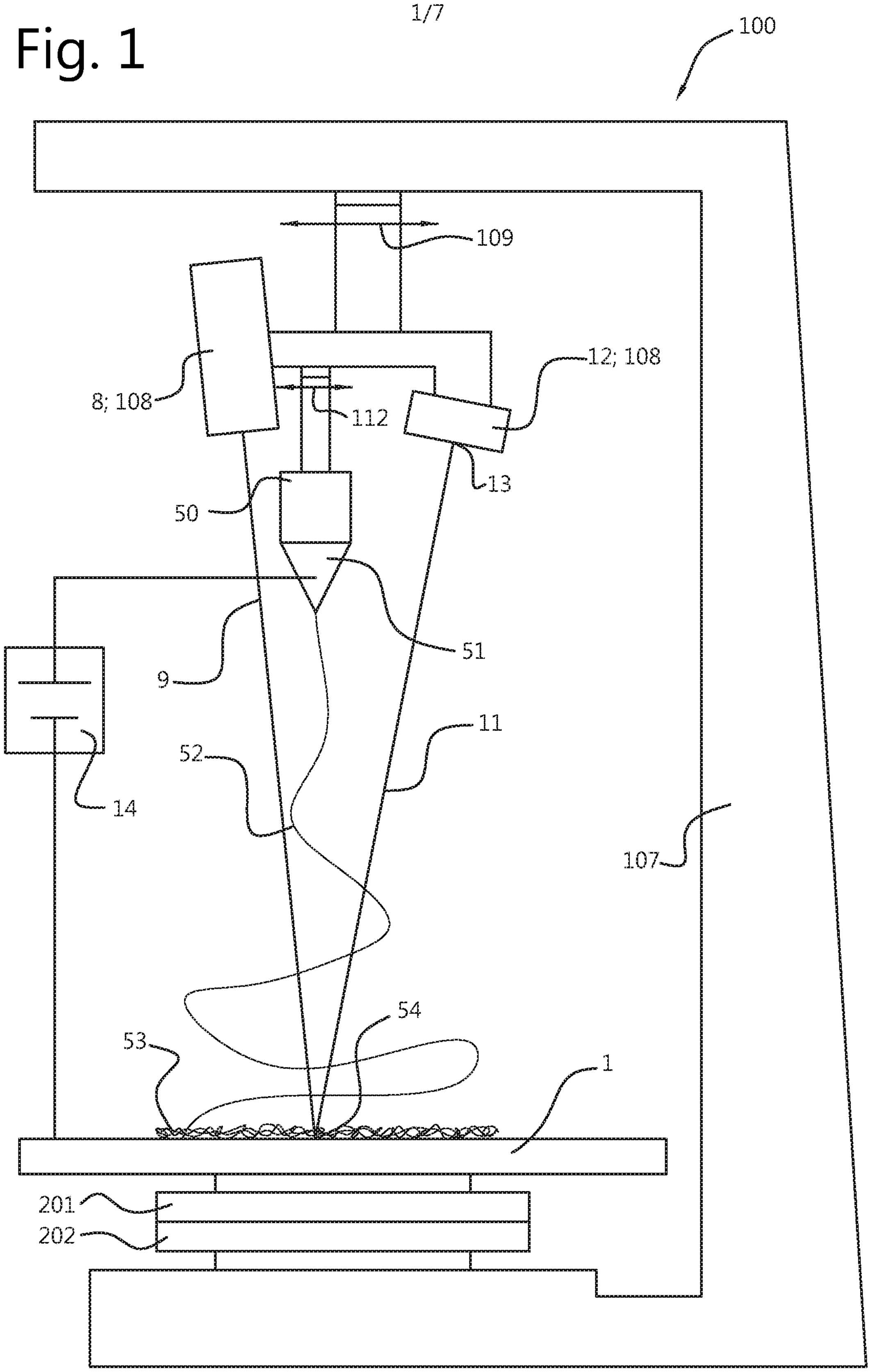


Fig. 2

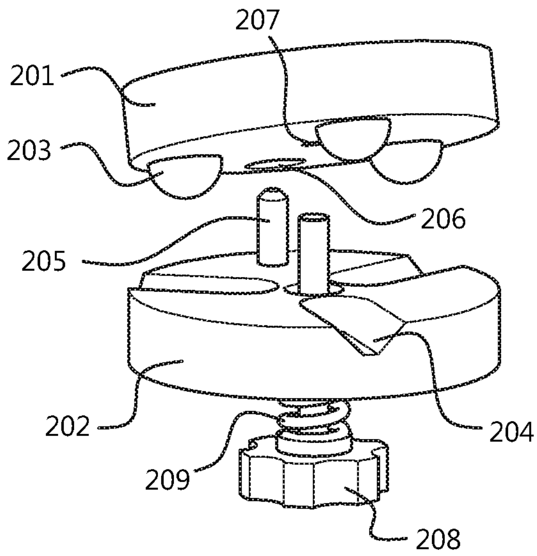


Fig. 4A

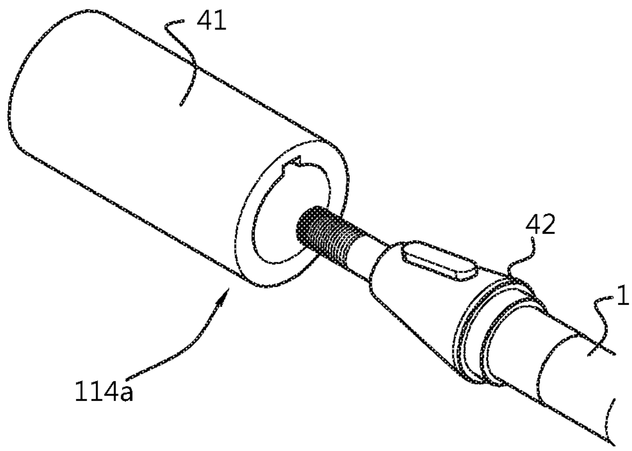
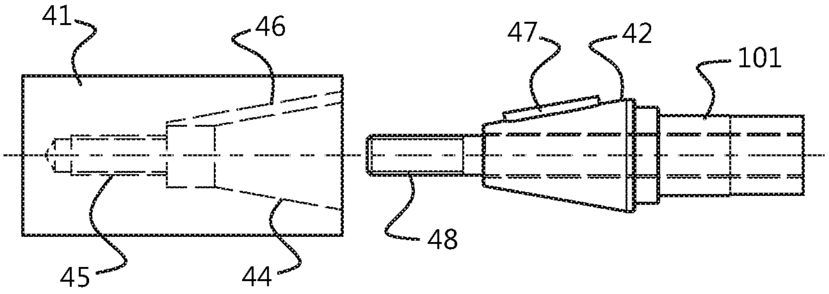
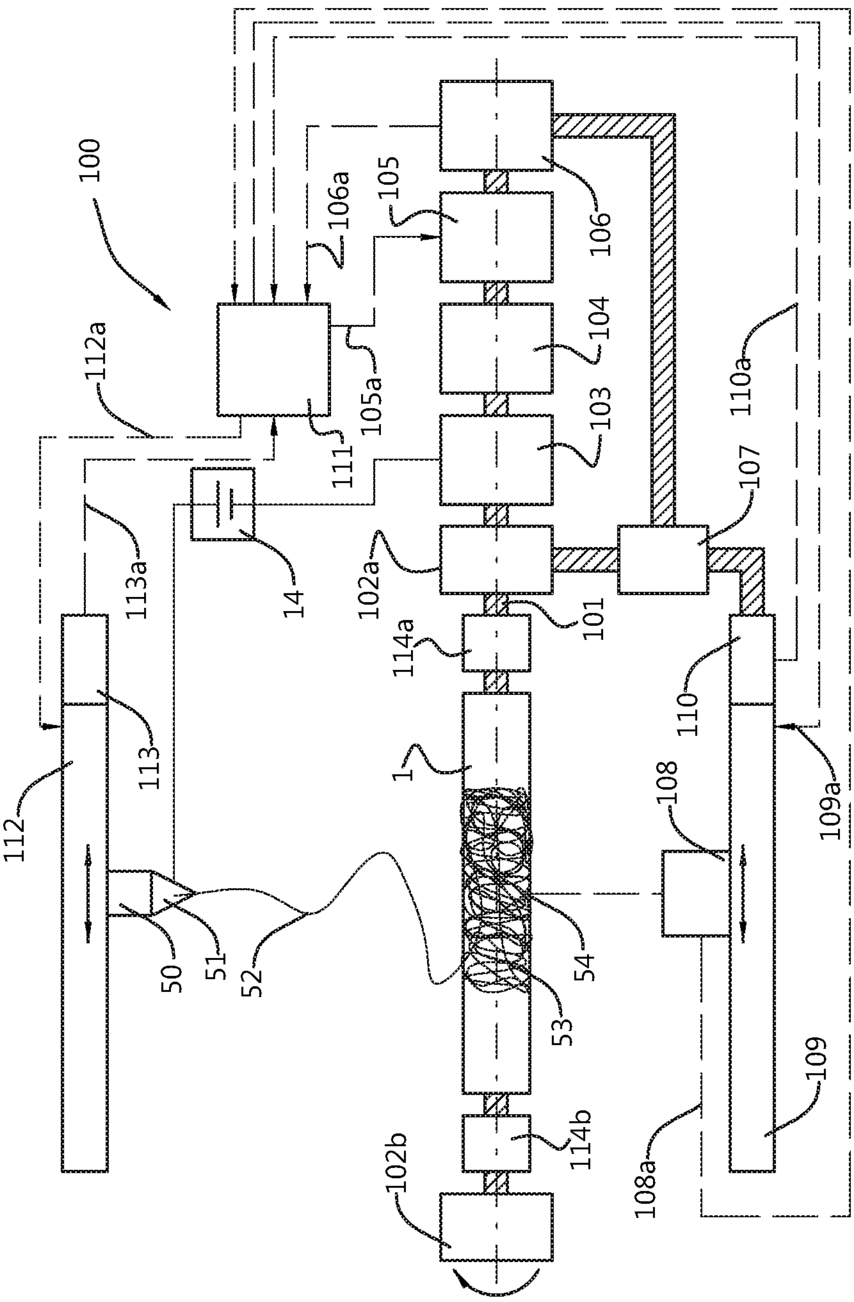


Fig. 4B





100
112a
106a
105
111
105a
106
104
103
107
110a
113a
14
102a
101
114a
112
113
110
1
108
109a
50
51
52
54
53
109
114b
102b
108a

Fig. 3

Fig. 5

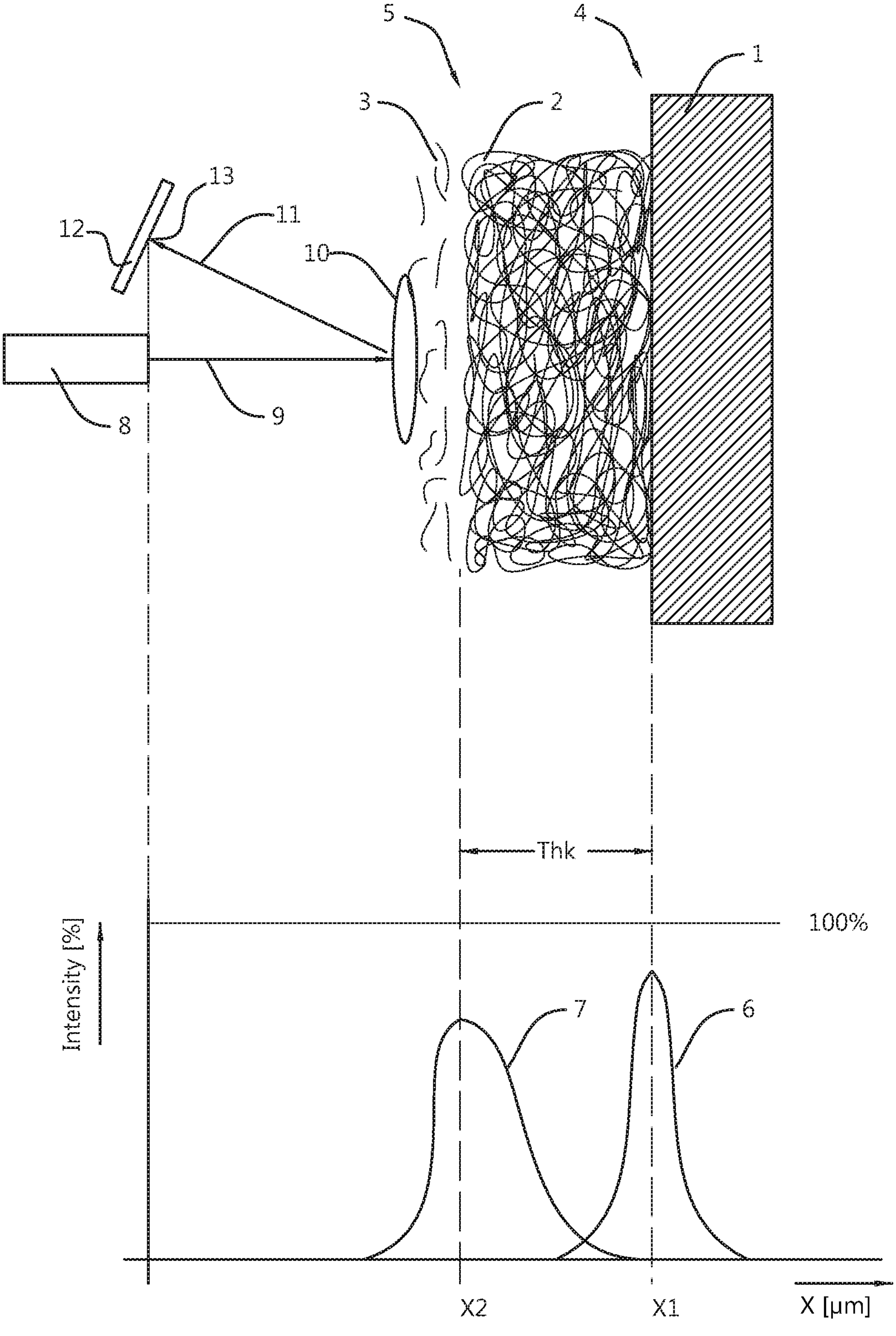
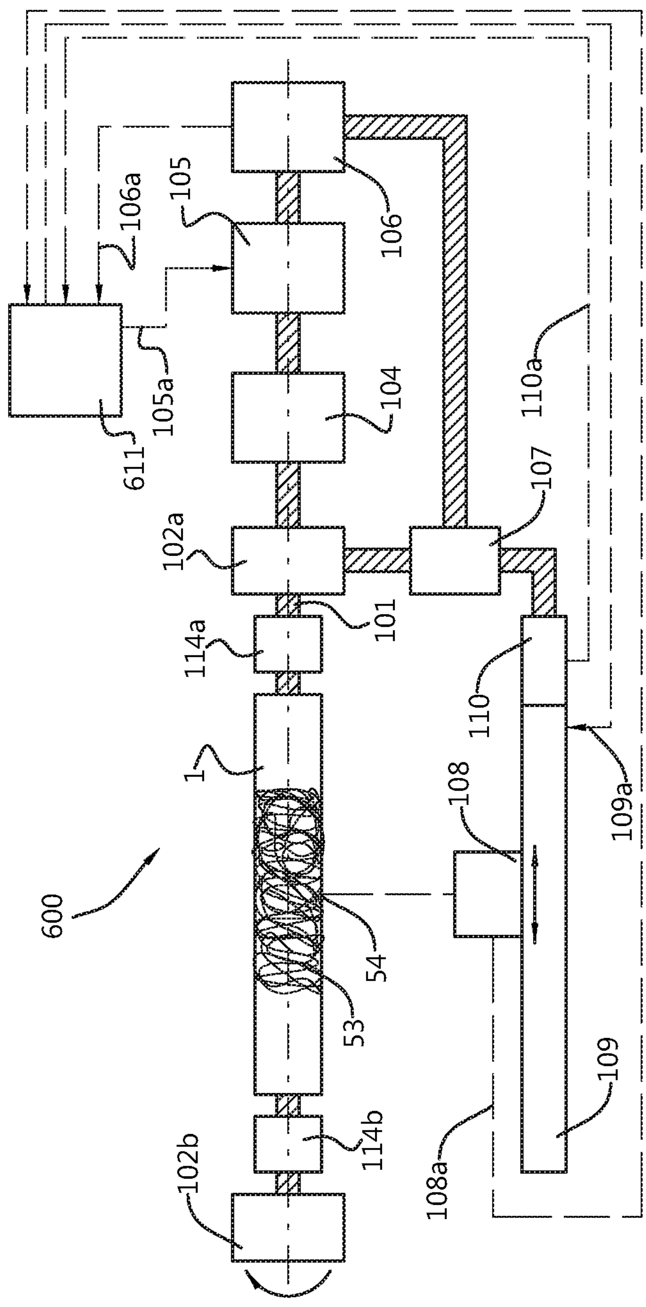


Fig. 6


106a
105
106
105a
611
104
107
102a
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101
114a
110
1
108
109a
600
54
53
109
114b
102b
108a

Fig. 7

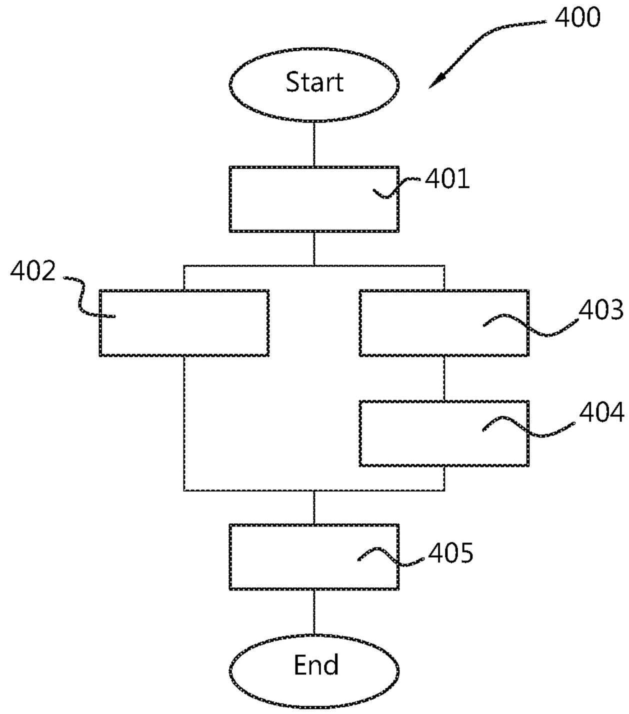
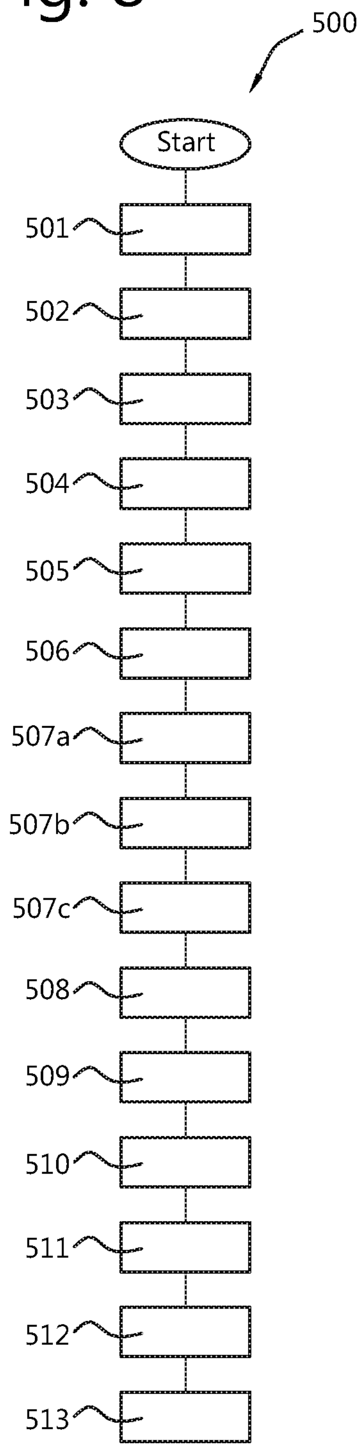


Fig. 8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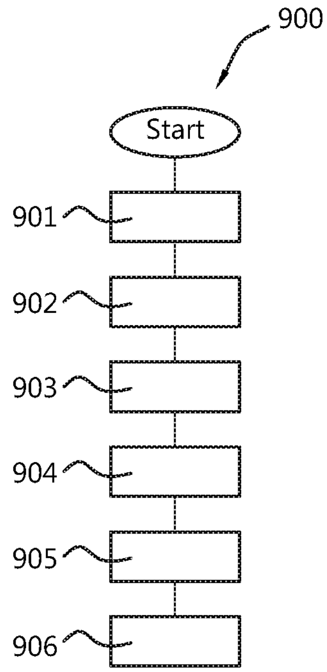
Start
501
502
503
504
505
506
507a
507b
507c
508
509
510
511
512
513

Fig. 9


900
Start
901
902
903
904
905
906

ABSTRACT

An electrospinning device is provided with a container for holding a liquid comprising a polymer melt or a polymer solution, and a nozzle arranged to outlet a stream of the liquid from the container. A collector collects electro spun material during electrospinning so as to form a fibrous structure. The device comprises an optical measurement system that measures a baseline distance between the collector and the optical measurement system for a plurality of points on a surface of the collector, and also measures a momentary distance between the optical measurement system and a momentary top layer of the fibrous structure during the electrospinning process. A processor calculates a momentary thickness of the fibrous structure. Once a required thickness is reached the electrospinning can be stopped.

(Figure 3)

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	231.001 NLp
Nederlands aanvraag nr. **2016652**	Indieningsdatum **21-04-2016**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Innovative Mechanical Engineering Technologies B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **25-06-2016**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN66701**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

D01D5/00;D01D13/00;D04H1/728

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC	**D01D;B82Y;D04H**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES	(opmerkingen op aanvullingsblad)
IV.	☐	GEBREK AAN EENHEID VAN UITVINDING	(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2016652

A. CLASSIFICATIE VAN HET ONDERWERP
INV. D01D5/00 D01D13/00 D04H1/728
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte mimimum documentatie (classificatie gevolgd door classificatiesymbolen)
D01D B82Y D04H

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
Y	US 2009/130301 A1 (BAHNMULLER STEFAN [DE] ET AL) 21 mei 2009 (2009-05-21) * alineas [0015], [0033], [0035], [0038], [0039] * -----	1-19
Y	JP 2012 122155 A (TOPTEC CO LTD; UNIV SHINSHU) 28 juni 2012 (2012-06-28) * alineas [0021], [0022], [0040], [0045], [0054] - [0057], [0066] - [0068], [0089] * -----	1-19
A	US 2013/337101 A1 (MCGRATH JON [US] ET AL) 19 december 2013 (2013-12-19) * alinea [0007]; figuur 1 * -----	12

☐ Verdere documenten worden vermeld in het vervolg van vak C.

☒ Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

21 september 2016

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie

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De bevoegde ambtenaar

Van Beurden-Hopkins

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek

NL 2016652

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2009130301 A1	21-05-2009	CN 101790601 A	28-07-2010
		DE 102007040762 A1	05-03-2009
		DK 2185749 T3	18-11-2013
		EP 2185749 A2	19-05-2010
		ES 2434241 T3	16-12-2013
		HK 1146737 A1	28-03-2014
		JP 5326076 B2	30-10-2013
		JP 2010537438 A	02-12-2010
		JP 2013076203 A	25-04-2013
		KR 20100051088 A	14-05-2010
		PT 2185749 E	13-11-2013
		US 2009130301 A1	21-05-2009
		WO 2009030355 A2	12-03-2009
JP 2012122155 A	28-06-2012	JP 2012122155 A	28-06-2012
		KR 101040064 B1	09-06-2011
		WO 2012077873 A1	14-06-2012
US 2013337101 A1	19-12-2013	EP 2659034 A2	06-11-2013
		US 2013337101 A1	19-12-2013
		WO 2012092138 A2	05-07-2012

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN66701	21.04.2016		NL2016652

International Patent Classification (IPC)
INV. D01D5/00 D01D13/00 D04H1/728

Applicant
Innovative Mechanical Engineering Technologies B.V.

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the application
- ☐ Box No. VIII Certain observations on the application

Examiner
Van Beurden-Hopkins

Application number

WRITTEN OPINION

NL2016652

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	1-19
	No:	Claims	
Inventive step	Yes:	Claims	
	No:	Claims	1-19
Industrial applicability	Yes:	Claims	1-19
	No:	Claims	

2. Citations and explanations

   see separate sheet

WRITTEN OPINION

Box No. VII Certain defects in the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1 US 2009/130301 A1 (BAHNMULLER STEFAN [DE] ET AL) 21 mei 2009 (2009-05-21)

D2 JP 2012 122155 A (TOPTEC CO LTD; UNIV SHINSHU) 28 juni 2012 (2012-06-28)

1. Lack of inventive step

1.1 The present application does not meet the criteria of patentability, because the subject-matter of claim 1 does not involve an inventive step.

D1 is regarded as being the prior art closest to the subject-matter of claim 1, and discloses (paragraphs [0015], [0033], [0035], [0038], [0039]) an electrospinning device comprising a container for holding a liquid comprising a polymer melt or a polymer solution;

a nozzle arranged to outlet a stream of the liquid from the container; a collector for collecting electro spun material coming from the nozzle during an electrospinning process so as to form a fibrous structure on the collector;

a voltage supply system arranged to create a voltage difference between the nozzle and the collector;

an optical measurement system arranged to measure a baseline distance between the collector and the optical measurement system;

a processor arranged to receive the measured baseline distance and the momentary distance for the plurality of predefined coordinates from the optical measurement system and to calculate a momentary thickness of the fibrous structure for all the predefined coordinates.

The subject-matter of claim 1 differs from D1 in that it discloses an electrospinning device that enables in-situ measuring of a thickness of the produced fibrous structure by way of anoptical measurement system which measures a plurality of points on a surface of the collector corresponding to a plurality of predefined coordinates, and is arranged to measure a momentary distance for a plurality of points or a momentary top layer of the fibrous structure at the predefined coordinates during the electrospinning process.

The problem to be solved by the present invention may therefore be regarded as solving the drawback of the known methods for thickness measurement on electrospun fibrous structures in that they can only be applied after the fibrous structure is produced and hence not in situ.

The solution proposed in claim 1 of the present application cannot be considered as involving an inventive step because D2 discloses (paragraphs [0021], [0022], [0040], [0045], [0054] - [0057], [0066] - [0068], [0089]) a thickness measurement system comprising of a pair of laser rangefinders 43 and 44 which measure the distance of the fibrous sheet using predefined coordinates as defined in claim1.

The skilled person would easily arrive at the solution of claim 1 by starting from D1 and combining the teachings of D2.

1.2 The same reasoning applies, mutatis mutandis, to the subject-matter of the corresponding independent claims 12 and 17 which therefore are also considered not inventive.

1.3 Dependent claims 2-11,13-16,18,19 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of inventive step.

Re Item VII

Certain defects in the application

Although claims 1 and 12 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought. The aforementioned claims therefore lack conciseness.