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(71) Applicants:
- **National Institute Of Advanced Industrial Science**
  Tokyo 100-8921 (JP)
- **Kato Tech Co., Ltd.**
  Kyoto-shi, Kyoto 601-8447 (JP)
- **Ehime Prefectural Government**
  Matsuyama-shi
  Ehime 790-8570 (JP)

(72) Inventors:
- **KOBARA, Hitomi**
  Tsukuba-shi
  Ibaraki 305-8569 (JP)
- **WAKISAKA, Akihiro**
  Tsukuba-shi
  Ibaraki 305-8569 (JP)
- **SEGAWA, Katsumi**
  Kyoto-shi
  Kyoto 601-8447 (JP)
- **NAKAGAWA, Ryohei**
  Kyoto-shi
  Kyoto 601-8447 (JP)
- **SAKAMOTO, Masaru**
  Imabari-shi
  Ehime 794-0069 (JP)
- **SHINTANI, Tomoyoshi**
  Imabari-shi
  Ehime 794-0069 (JP)
- **HIGAKI, Seiji**
  Imabari-shi
  Ehime 794-0069 (JP)

(74) Representative: **Gill Jennings & Every LLP**
The Broadgate Tower
20 Primrose Street
London EC2A 2ES (GB)

(54) METHOD FOR APPLYING COATING MATERIAL TO FIBER MATERIAL, METHOD FOR PRODUCING FIBER MATERIAL, AND APPARATUS FOR PROCESSING FIBER MATERIAL

(57) The objective of the present invention is to provide novel method and apparatus for processing a fiber material, which are applicable to dyeing, an antibacterial/deodorizing treatment and the like. By having a fiber material impregnated with an electrolyte solution, a coating material that contains a dye, an antibacterial agent, a deodorant or the like can be efficiently applied to the fiber material by means of electrospray.

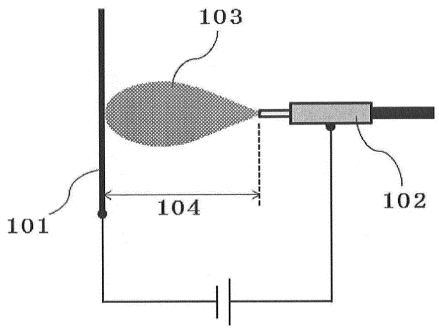

Fig.1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method for applying a coating material onto a fiber material, a method for manufacturing a fiber material, and an apparatus for processing a fiber material, and more particularly to a method for applying a coating material and an apparatus for processing a fiber material that can be used for, for example, dyeing and antibacterial/deodorizing treatment of a fiber material.

BACKGROUND ART

[0002] Production industries such as textile and paper manufacturing are key industries in Japan which contribute greatly, in particular, to local economy, but in recent years, in the face of fierce international competition which is due to the development of emerging economies, a demand has been created for further reduction in manufacturing cost and improvement of performance and quality of products. For example, in the textile industry, the treatment of the so-called dyeing wastewater which is generated in the dyeing process has become an important problem. For example, when cellulose fibers such as cotton or rayon are dyed, the fibers are typically charged into a dyeing bath including a reactive dye, and the fibers are then taken out and the excess dye is washed away. As a result, the dyeing bath and washing water are discharged as wastewater including a large amount of dye. To resolve this problem, it has been suggested to use, for example, a component derived from the Abelmoschus of Malvaceae genus as flocculant for purifying dyeing wastewater (see PTL1). Another problem associated with the conventional dyeing methods is that significant drying treatment is required and the methods are not suitable for small-lot production of a large number of product types. In particular, fuel consumption required for the drying treatment has been reduced by, for example, the transition to fuels other than heavy oil and introduction of energy-saving equipment, but the fuel consumption still reaches 606,000 kL (2011; in crude oil equivalent) in the entire dyeing industry, and further reduction in the amount of fuel used is needed.

[0003] Meanwhile, a phenomenon called "electrospray" in which a liquid is sprayed toward a counter electrode as a result of applying a high voltage between a nozzle filled with the liquid and the counter electrode has been used for mass analysis (see PTL2) and deposition of polymer compounds, etc. (see PTL3). Since the electrospray phenomenon enables ionization without requiring such conditions as high temperature, it is advantageous for mass analysis of easily destructible compounds such as biopolymers. It is also well known that because very small droplets of easily vaporizable solvents can be sprayed, the electrospray phenomenon is advantageous for forming nanoparticles or carbon nanofibers, etc.

CITATION LIST

PATENT LITERATURE

[0004]

PTL 1: Japanese Patent Application Publication No. 2013-006174.
PTL 2: Japanese Patent Application Publication No. H06-215729.
PTL 3: Japanese Patent Application Publication No. 2007-070738.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] As indicated in PTL 1, adequately purifying the dyeing wastewater generated in the fiber material dyeing process is a very important issue, but it is also important to minimize the amount of the dyeing wastewater itself. For example, where utilization efficiency of dye, etc. is increased by improving the dyeing method, etc., or the method is made suitable for small-lot production of a large number of various products, the production cost and environmental load can be reduced.

[0006] Further, in recent years a demand has been created for fibers having various functions such as antibacterial/deodorizing activity and fire resistance, and the treatment performed to impart those functions has also become a factor causing the generation of a large amount of wastewater.

[0007] It is an objective of the present invention to provide novel processing method and processing apparatus for a fiber material which are capable of resolving the above-described problems associated with the dyeing and antibacterial/deodorizing treatment, etc.

SOLUTION TO PROBLEM

[0008] The inventors have conducted a comprehensive study aimed at the resolution of the above-described problems. The results obtained have demonstrated that by comprising an electrolyte solution in a fiber material, it is possible to apply efficiently a coating material comprising a dye, an antibacterial agent, and a deodorant to the fiber material by using the electrospray phenomenon. This finding led to the creation of the present invention.

[0009] Thus, the present invention relates to:

<1> A method for applying a coating material to a fiber material, the method comprising: a preparation step of preparing a fiber material comprising an electrolyte solution; and a spraying step of spraying the coating material onto the fiber material by electrospray.

<2> The method for applying according to <1>, wherein the electrolyte solution comprises at least one selected from a group consisting of alkali metal salts, alkaline earth metal salts, aluminum salts, ammonium salts, and transition metal salts.

<3> The method for applying according to <1> or <2>, wherein the preparation step comprises at least one selected from a group consisting of: immersing the fiber material into the electrolyte solution; spraying the electrolyte solution onto the fiber material; and dropping the electrolyte solution onto the fiber material.

<4> The method for applying according to any one of <1> to <3>, wherein the coating material comprises at least one selected from a group consisting of a dye, an antibacterial agent, a deodorant, a water and oil repellent, a flame retardant, a bleaching agent, a softener, a sizing agent, and an anti-fouling agent.

<5> The method for applying according to any one of <1> to <4>, wherein with the fiber material comprising a reducing agent and with the coating material being a solution that comprises a metal ion, when the coating material comprising the metal ion is sprayed onto the fiber material in the spraying step, the metal ion reacts with the reducing agent, and as a result a metal particle is generated in the fiber material.

<6> The method for applying according to any one of <1> to <5>, wherein the spraying step comprises spraying one or two or more types of coating materials by using two or more electrospray sprayers.

<7> The method for applying according to <6>, wherein the spraying step comprises spraying one or two or more types of coating materials continuously by moving the fiber material and/or the electrospray sprayers.

<8> The method for applying according to any one of <1> to <7>, wherein the preparation step and the spraying step are performed continuously by moving the fiber material comprising the electrolyte solution.

<9> The method for applying according to any one of <1> to <8>, wherein the fiber material is a yarn, woven fabric, nonwoven fabric, knitted fabric, paper, or a film.

<10> A method for manufacturing a fiber material, comprising at least one step selected from a group consisting of (1) to (8) below:

(1) a dye treatment step comprising dyeing a fiber material by applying a coating material comprising a dye by the method for applying according to any one of <1> to <9>;

(2) an antibacterial/deodorizing treatment step comprising imparting an antibacterial activity and/or a deodorizing activity to a fiber material by applying a coating material comprising an antibacterial agent and/or a deodorant by the method for applying according to any one of <1> to <9>;

(3) a water and oil repelling treatment step comprising imparting a water and oil repelling activity to a fiber material by applying a coating material comprising a water and oil repellent by the method for applying according to any one of <1> to <9>;

(4) a flame retardant treatment step of making a fiber material less flammable by applying a coating material comprising a flame retardant by the method for applying according to any one of <1> to <9>;

(5) a bleaching treatment step comprising bleaching a fiber material by applying a coating material comprising a bleaching agent by the method for applying according to any one of <1> to <9>;

(6) a softening treatment step comprising softening a fiber material by applying a coating material comprising a softener by the method for applying according to any one of <1> to <9>;

(7) a sizing treatment step comprising sizing a fiber material by applying a coating material comprising a sizing agent by the method for applying according to any one of <1> to <9>; and

(8) an anti-fouling treatment step comprising imparting an anti-fouling activity to a fiber material by applying a coating material comprising an anti-fouling agent by the method for applying according to any one of <1> to <9>.

<11> The method for manufacturing a fiber material according to <10>, further comprising at least one step selected from a group consisting of a fiber forming step, a stretching step, a spinning step, a knitting and weaving step, and a scouring step.

<12> An apparatus for processing a fiber material, comprising: an electrolyte solution contact mechanism performing

at least one selected from a group consisting of immersing the fiber material into an electrolyte solution, spraying the electrolyte solution onto the fiber material, and dropping the electrolyte solution onto the fiber material; an electrospray sprayer that sprays a coating material toward the fiber material comprising the electrolyte solution; and a fiber material feed mechanism for moving the fiber material comprising the electrolyte solution to a spray target for the electrospray sprayer.

<13> The apparatus for processing a fiber material according to <12>, comprising two or more electrospray sprayers.

<14> The apparatus for processing a fiber material according to <12> or <13>, comprising an electrospray sprayer that sprays at least one coating material selected from a group consisting of (1) to (8) below as the electrospray sprayer:

(1) a coating material comprising a dye;
(2) a coating material comprising an antibacterial agent and/or a deodorant;
(3) a coating material comprising a water and oil repellent;
(4) a coating material comprising a flame retardant;
(5) a coating material comprising a bleaching agent;
(6) a coating material comprising a softener;
(7) a coating material comprising a sizing agent; and
(8) a coating material comprising an anti-fouling agent.

ADVANTAGEOUS EFFECTS OF INVENTION

[0010] According to the present invention, the coating material can be efficiently applied to the fiber material. Therefore, by using such technique for dyeing and antibacterial/deodorizing treatment, it is possible to decrease the amount of wastewater generated in such treatment and reduce the drying treatment. At the same time, the technique can be used for small-lot production and production of products of a large number of types, and the production cost of the fiber products and the environmental load can be reduced.

BRIEF DESCRIPTION OF DRAWIONGS

[0011]

[Fig. 1]
Fig. 1 is a conceptual diagram representing the state in which a coating material is sprayed toward a fiber material by electrospray.

[Fig. 2]
Fig. 2(A) is a conceptual diagram showing how one or two or more coating materials are continuously sprayed by moving the fiber material. Fig. 2(B) is a conceptual diagram showing how one or two or more coating materials are sprayed at the same position of the fiber material. Fig. 2(C) is a conceptual diagram illustrating how the spraying is performed while moving an electrospray sprayer.

[Fig. 3]
Fig. 3(A) is a conceptual diagram illustrating how the spraying step is continuously performed after the fiber material has been immersed into an electrolyte solution in the preparation step. Fig. 3(B) is a conceptual diagram illustrating how the spraying step is continuously performed after the electrolyte solution has been sprayed onto the fiber material in the preparation step. Fig. 3(C) is a conceptual diagram illustrating how the spraying step is continuously performed after the electrolyte solution has been dropped onto the fiber material in the preparation step.

[Fig. 4]
Fig. 4(A) is a photograph (photograph replacing the drawing) illustrating the state in which ethanol of Example 1 is sprayed. Fig. 4(B) is a photograph (photograph replacing the drawing) illustrating the state in which ethanol of Comparative Example 1 is sprayed. Fig. 4(C) is a conceptual diagram showing how droplets sprayed from the nozzle are focused toward a cotton yarn.

[Fig. 5]
Fig. 5(A) is a conceptual diagram of the device used in Example 2. Fig. 5(B) is a top view of an electrospray sprayer portion of the device used in Example 2.

[Fig. 6]
Fig. 6 is a photograph (photograph replacing the drawing) illustrating the state in which the dye solution of Example 2 is sprayed.

[Fig. 7]
Fig. 7(A) is a conceptual diagram of the device used in Example 3. Fig. 7(B) is a top view of an electrospray sprayer

portion of the device used in Example 3. Fig. 7(C) is a photograph (photograph replacing the drawing) illustrating the state in which the dye solution of Example 3 is sprayed.

[Fig. 8]

Fig. 8 is a photograph (photograph replacing the drawing) of a cotton yarn which has been multicolor dyed in Example 3.

[Fig. 9]

Fig. 9 is a photograph (photograph replacing the drawing) illustrating the state in which the dye solution of Comparative Example 2 is sprayed.

[Fig. 10]

Fig. 10(A) is a conceptual diagram of the device used in Example 4. Fig. 10(B) is a top view of an electrospray sprayer portion of the device used in Example 4.

[Fig. 11]

Fig. 11 is a conceptual diagram of the device for washing the cotton yarn with water.

[Fig. 12]

Fig. 12(A) shows a photograph (photograph replacing the drawing) of a cotton yarn before impregnation with metallic silver particles (left side) and a photograph of the cotton yarn impregnated with metallic silver particles in Example 4 (right side), and Fig. 12(B) is a scanning electron microphotograph (photograph replacing the drawing) of the cotton yarn impregnated with metallic silver particles in Example 4.

[Fig. 13]

Fig. 13 is a conceptual diagram illustrating how a cotton yarn successively passes through a tank filled with an electrolyte solution, a dyeing treatment step, a functional material addition (antibacterial/deodorizing treatment) step, a sizing treatment step and a heating and drying device.

[Fig. 14]

Fig. 14 is a graph representing the relationship between the feed rate of a cotton yarn and the impregnated amount of metallic silver particles.

[Fig. 15]

Fig. 15(A) is a conceptual diagram of the device used in Example 6, and Fig. 15(B) is a photograph (photograph replacing the drawing) of a silk yarn subjected to plant dyeing in Example 6.

[Fig. 16]

Fig. 16(A) is a conceptual diagram of the device used in Example 7, and Fig. 16(B) is a photograph (photograph replacing the drawing) of a cotton yarn subjected to gradation dyeing in Example 7.

[Fig. 17]

Fig. 17(A) is a conceptual diagram of the device used in Example 8, and Fig. 17(B) is a photograph (photograph replacing the drawing) of a silk yarn subjected to gradation dyeing in Example 8.

[Fig. 18]

Fig. 18(A) is a conceptual diagram of the device used in Example 9, and Fig. 18(B) is a photograph (photograph replacing the drawing) of a cotton yarn subjected to deep-color dyeing in Example 9.

[Fig. 19]

Fig. 19 is a photograph (photograph replacing the drawing) of a paper yarn dyed in Example 10.

[Fig. 20]

Fig. 20 is a photograph (photograph replacing the drawing) of a cotton yarn dyed by using various reactive dyes.

DESCRIPTION OF EMBODIMENTS

[0012] The method for applying a coating material to a fiber material, the method for manufacturing a fiber material, and the apparatus for processing a fiber material, which are the embodiments of the present invention, are explained hereinbelow in detail by referring to specific examples, but they are not limited to the contents described hereinbelow and can be changed, as appropriate, provided that they do not depart from the essence of the present invention.

<Method for applying a coating material to a fiber material>

[0013] A method for applying a coating material to a fiber material which is an aspect of the present invention (can be referred to hereinbelow as "application method according to the present invention") is characterized in comprising a preparation step of preparing a fiber material comprising an electrolyte solution (can be referred to hereinbelow in abbreviated form as "preparation step"), and a spraying step of spraying the coating material onto the fiber material by electrospray (can be referred to hereinbelow in abbreviated form as "spraying step").

[0014] The inventors have conducted a comprehensive research of novel methods for processing fiber materials that can be used for dyeing and antibacterial/deodorizing treatment, etc. The results obtained have demonstrated that a

coating material comprising a dye, an antibacterial agent, a deodorant, etc., can be efficiently applied to a fiber material by comprising an electrolyte solution in the fiber material and using an electrospray phenomenon. With the electrospray phenomenon, a high voltage is applied between a nozzle filled with a liquid and a counter electrode to generate an electric field between the nozzle and the counter electrode, whereby the liquid is sprayed toward the counter electrode in the form of charged droplets. The problem associated with this method is that when the spraying object is an insulator such as a fiber material, the electric field is difficult to generate between the insulator and the nozzle, and the coating material cannot be applied with good efficiency. The inventors have discovered that by imparting electric conductivity to the fiber material by comprising an electrolyte solution therein, it is possible to generate an electric field between the fiber material and the nozzle and enable the application using the electrospray phenomenon. The electric field between the nozzle and fiber material can be generated by using, for example, an electric power source and setting the nozzle side to a positive potential and setting the fiber material side to 0 kV or a negative potential, or by setting the nozzle side to a negative potential and setting the fiber material side to 0 kV or a positive potential. Further, since a potential gradient may be created between the nozzle and the fiber material, the electrospray phenomenon can be generated, for example, also when (potential of nozzle) > (potential of fiber material) > 0, or when 0 V > (potential of fiber material) > (potential of nozzle). With such an electrospray method, since the generated charged droplets are drawn by the electric field to the spraying object, the coating material can be applied with good efficiency. Therefore, by using such a method for dyeing and antibacterial/deodorizing treatment, it is possible, for example, to decrease the amount of wastewater generated in such treatment and reduce the drying treatment. Furthermore the method is suitable for small-lot production and production of a large number of various products and can reduce the production cost and environmental load. When the application method according to the present invention is used for dyeing a fiber material, the electrolyte solution also plays the role of a fixing agent ("dyeing enhancer") for fixing the dye to the fiber material. As a result, the dyeing is performed with a very high efficiency.

[0015] The "fiber material", as referred to in the present invention, means a fibrous material comprising a polymer compound as a constituent component, or a material obtained by bundling such fibrous material (cotton, woven fabric, nonwoven fabric, paper, etc.), and the specific material, whether natural fibers or synthetic fibers, and form of the material, etc. are not particularly limited. Further, the present invention is not intended to exclude the use of the application method when processing into garments and paper products, and the application method according to the present invention is also inclusive of the use of the application method with products in which the shape of a fiber material is retained.

[0016] The expression "spraying the coating material onto the fiber material by electrospray" is assumed to mean that the coating material is sprayed onto the fiber material by using the electrospray phenomenon, that is, the coating material is loaded into the nozzle of a sprayer, an electric field is generated between the nozzle and the fiber material which is the spraying object, and the coating material is sprayed toward the fiber material (a device for spraying the coating material by using the electrospray phenomenon can be referred to hereinbelow in abbreviated form as "electrospray sprayer"). A conceptual diagram illustrating the state in which the coating material is sprayed onto the fiber material by electrospray is shown in Fig. 1 (the reference numeral 101 stands for a fiber material comprising an electrolyte solution; 102 - a nozzle of an electrospray sprayer; 103 - a sprayed coating material; and 104 - a distance between the nozzle of the electrospray sprayer and the fiber material; the fiber material 101 and the nozzle of the electrospray sprayer are connected through an electrode, conductive, a power source, and the like). The electrospray sprayer is usually equipped with at least a nozzle for defining the spraying direction, and a power source (voltage-controlled device; includes an electrode, a conductive wire, etc., connecting the nozzle and fiber material) for generating an electric field between the nozzle and the fiber material which is the spraying object (when two or more electrospray sprayers are used, the electrospray sprayers may share a power source, or each of the electrospray sprayers may not be equipped with a power source). The nozzle itself is fabricated from an electrically conductive material, or an electrode (for example, a platinum wire) is disposed in the nozzle. The arrangement is such that the nozzle and the fiber material which is the spraying object are each connected to the power source (voltage-controlled device, etc.) and an electric field is generated between the nozzle and fiber material by applying a voltage thereto.

(Preparation step)

[0017] In the preparation step according to the present invention, a fiber material is prepared which is to be used in the below-describes spraying step. A specific preparation method is not particularly limited, and the fiber material comprising an electrolyte solution may be purchased or may be produced. When the fiber material comprising the electrolyte solution is produced, the production method is not particularly limited, and the examples of suitable methods comprise a method for immersing the fiber material into the electrolyte solution, a method for spraying the electrolyte solution onto the fiber material, and a method for dropping the electrolyte solution onto the fiber material. The preparation step according to the present invention is preferably a step comprising at least one selected from a group consisting of: immersing the fiber material into the electrolyte solution; spraying the electrolyte solution onto the fiber material; and dropping the electrolyte solution onto the fiber material.

[0018] The type, concentration, content, etc. of the electrolyte in the electrolyte solution comprised in the fiber material are not particularly limited and they can be selected, as appropriate, according to, for example, the type of the coating material which is to be applied and the type of the fiber material (for example, a neutral electrolyte or an alkaline electrolyte can be selected according to the type of the fiber material).

[0019] Examples of suitable electrolytes include alkali metal salts, alkaline earth metal salts, and aluminum salts such as sodium carbonate, sodium acetate, sodium sulfate, sodium hydroxide, sodium chloride, magnesium chloride, aluminum sulfate, aluminum carbonate, potassium carbonate, potassium acetate, potassium sulfate, potassium chloride, calcium chloride, and potassium alum, and also ammonium salts such as ammonium carbonate, ammonium acetate, ammonium sulfate, ammonium hydroxide, and ammonium chloride, and transition metal salt such as iron chloride and iron sulfate. Among them, it is preferred that at least one be selected from a group consisting of sodium carbonate, sodium acetate, sodium sulfate, sodium hydroxide, aluminum sulfate, aluminum carbonate, ammonium acetate, potassium alum, and iron sulfate.

[0020] The concentration of the electrolyte solution is generally 0.001% by mass or more, preferably 0.1% by mass or more, more preferably 2.5% by mass or more, and usually 20.0% by mass or less, preferably 15.0% by mass or less, more preferably 10.0% by mass or less. When the concentration is within such ranges, the coating material can be applied with good efficiency.

[0021] The content of the electrolyte solution comprised in the fiber material (mass of the electrolyte solution in 100% by mass the fiber material) is usually 300% by mass or more, preferably 400% by mass or more, more preferably 500% by mass or more, and usually 1000% by mass or less, preferably 850% by mass or less, more preferably 700% by mass or less. Within those ranges, the coating material can be applied with good efficiency.

[0022] The fiber material prepared in the preparation step according to the present invention may comprise a reducing agent. For example, the fiber material comprises a reducing agent, and where a coating material comprising metal ions is sprayed in the spraying step according to the present invention, the metal ions react with the reducing agent, thereby generating metal particles in the fiber material (this procedure will be described hereinbelow in greater detail).

[0023] Examples of the reducing agent include sodium borohydride, lithium aluminum hydride, sulfites, nitrites, hydrazine, ascorbic acid and salts thereof, and oxalic acid and salts thereof. Since these reducing agents also act as an electrolyte, solutions comprising these reducing agents may be used as the electrolyte solution instead of the electrolyte described hereinabove.

[0024] The fiber material prepared in the preparation step according to the present invention is not necessarily required to comprise the electrolyte solution over the entire surface, and the electrolyte solution may be comprised locally. In the electrospray method, the sprayed droplets are drawn to the charged portions. Therefore, the electrospray method can be also used for applying a coating material locally to the fiber material.

[0025] An immersion method which is used when the preparation method of the present invention involves immersing the fiber material into the electrolyte solution is not particularly limited. For example, a method can be used by which the fiber material is immersed in a liquid tank filled with the electrolyte solution. Further, a spraying method which is used when the electrolyte solution is sprayed onto the fiber material is not particularly limited, and a method can be used by which the electrolyte solution is sprayed onto the fiber material by using a well-known sprayer such as a spray gun. A dropping method which is used when the electrolyte solution is dropped on the fiber material is not particularly limited, and a method can be used by which the electrolyte solution is dropped onto the fiber material by using a well-known dropping device.

(Spraying step)

[0026] In the spraying step according to the present invention, the coating material is sprayed by electrospray toward the fiber material prepared in the above-described preparation step. The structure, etc. of the electrospray sprayer to be used is not particularly limited and a well-known structure can be selected as appropriate. The nozzle itself is usually fabricated from an electrically conductive material, or an electrode (for example, a platinum wire) is disposed inside the nozzle, so that the loaded coating material be in contact with the electric field generated by voltage application.

[0027] The diameter of the spraying port of the nozzle of the electrospray sprayer is usually, 0.03 mm or more, preferably 0.05 mm or more, more preferably 0.1 mm or more, and usually 1.0 mm or less, preferably 0.5 mm or less, more preferably 0.3 mm or less. Where the diameter is within those ranges, the coating material can be applied with good efficiency.

[0028] In the spraying step according to the present invention, the coating material is sprayed toward the fiber material by electrospray, but since the sprayed coating material is drawn by the generated electric field to the fiber material, it is not always necessary that the fiber material be present on the spraying direction of the nozzle of the electrospray sprayer. Thus, the fiber material is preferably present in a range within 45°, more preferably in a range within 30° from the spraying direction of the nozzle of the electrospray sprayer. Within those ranges, the coating material can be applied with good efficiency.

[0029] The distance between the nozzle of the electrospray sprayer and the fiber material in the spraying step according

to the present invention (the shortest distance between the nozzle tip of the electrospray sprayer and the fiber material) is usually 5 mm or more, preferably 7 mm or more, more preferably 10 mm or more, and usually 40 mm or less, preferably 30 mm or less, and more preferably 20 mm or less. Within those ranges, the coating material can be applied with good efficiency.

[0030] The applied voltage in the spraying step according to the present invention (the difference in potential generated between the nozzle and fiber material) is usually 5.5 kV or more, preferably 6 kV or more, more preferably 7 kV or more, and usually 16 kV or less, preferably 15 kV or less, and more preferably 12 kV or less.

[0031] Further, the electric potential applied to the nozzle is usually a positive potential, and this potential, in the case of ground taken as a reference potential, is usually +2.0 kV or more, preferably +3.0 kV or more, more preferably +4.5 kV or more, and usually +10.0 kV or less, preferably +8 kV or less, even more preferably +7 kV or less.

[0032] Meanwhile, the electric potential applied to the fiber material is usually a negative potential, and this potential, in the case of ground taken as a reference potential, is usually -5 kV or more, preferably -4 kV or more, more preferably - 3.5 kV or more, and usually -0.5 kV or less, preferably -1 kV or less, even more preferably -2 kV or less.

[0033] Within those ranges, the coating material can be applied with good efficiency.

[0034] The sprayed amount of the coating material in the spraying step according to the present invention is usually 3 μL/min or more, preferably 5 μL/min or more, more preferably 7 μL/min or more, and usually 50 μL/min or less, preferably 30 μL/min or less, more preferably 20 μL/min or less. Within those ranges, the coating material can be applied with good efficiency.

[0035] Components to be comprised in the coating material which is to be sprayed in the spraying step according to the present invention can be selected, as appropriate, according to the application target (usage of the application method). The components to be comprised in the coating material can be classified, for example, into (a) modifying and functionalizing components and auxiliary components that are used for modifying the fiber material or for imparting functions to the fiber material; (b) starting material compounds of the substances to be formed in the fiber material; and (c) solvents. Those groups (a) to (c) of components will be explained hereinbelow in greater detail.

(a) Modifying or functionalizing components and auxiliary components

[0036] The "modifying and functionalizing components", as referred to herein, mean well-known components that are used for modifying fiber materials or for imparting functions to fiber materials, examples thereof comprising dyes (pigments) for dying fiber materials and also antibacterial agents, deodorants, water and oil repellents, flame retardants, bleaching agents, softeners, sizing agents, and anti-fouling agents. The "auxiliary components" means auxiliary components that are used for processing fiber materials, examples thereof comprising surfactants which are used for increasing dispersivity and fixability of the dye and also acids and bases which are used in the dye. Specific types of dyes, etc., are listed below, but the modifying and functionalizing components that can be used for fiber materials are widely commercially available, and the application method according to the present invention is not limited to the components listed below. The "dye", as referred to in the present invention, is assumed to be also inclusive of "pigments" which are not soluble in solvents.

- Dyes (pigments)

[0037] Direct dyes, acidic dyes (leveling dyes, half-milling dyes, milling dyes), disperse dyes (azo, quinone), reactive dyes, cationic dyes, vat dyes, sulfur dyes, and naphthol dyes.

- Antibacterial agents, deodorants

[0038] Silver, titanium oxide, zinc oxide, gold, platinum, copper, zeolites, charcoal, triazine compounds, phenol compounds, chitin, and chitosan.

- Water and oil repellents

[0039] Fluorine-based polymer compounds, silicon-based polymer compounds, and polyolefin-based polymer organic compounds.

- Flame retardants

[0040] Phosphorus-based organic compounds, halogen compounds, ammonium sulfate, antimony oxide, aluminum hydroxide, and sodium silicate.

(b) Starting material compounds

[0041] The "starting material compounds", as referred to herein, specifically means starting material compounds of the substances that are to be formed in the fiber material, for example, a component effective in applying inorganic solid compounds such as silver and titanium oxide which are used as antibacterial agent and deodorant to the fiber material. Specific examples of the starting material compounds comprise metal ions (metal salts) serving as starting materials for inorganic solid compounds, organometallic compounds, oxidizing agents that oxidize metal ions or organometallic compounds, and reducing agents therefor.

- Metal ions (metal salts)

[0042] Silver nitrate ($AgNO_3$), tetrachloroauric (III) acid ($HAuCl_4$), hexachloroplatinic acid (H_2PtCl_6), and copper (II) chloride ($CuCl_2$).

- Organometallic compounds

[0043] Alkoxysilanes.

- Oxidizing agents

[0044] Hydrogen peroxide, ozone, hydrochloric acid, and sulfuric acid.

- Reducing agents

[0045] Sodium borohydride, lithium aluminum hydride, sulfites, nitrites, hydrazine, ascorbic acid and salts thereof, oxalic acid and salts thereof.

(c) Solvents

[0046] The solvent to be used in the coating material needs to be selected, as appropriate, according to the components etc. to be comprised in the coating material. From the standpoint of cost, water is usually used. Examples of solvents that can be used in addition to water comprise protic polar solvents such as methanol, ethanol, 1-propyl alcohol, 2-propyl alcohol, butanol, acetic acid, and formic acid; aprotic polar solvents such as acetone, methyl ethyl ketone, acetonitrile, N,N-dimethylformamide, N,N-dimethylacetamide, N-methyl-2-pyrrolidone, and dimethyl sulfoxide; and nonpolar solvents such as hexane, cyclohexane, cyclohexanone, dichloromethane, dichloroethane, trichloroethane, chloroform, trichloroethylene, benzene, ethylbenzene, xylene, toluene, diethyl ether, 1,4-dioxane, methyl acetate, ethyl acetate, tetrahydrofuran, and methylene chloride. Those solvents may be used not only individually, but also in combinations of two or more thereof.

[0047] The concentration of the components comprised in the coating material which is to be sprayed in the spraying step according to the present invention is selected, as appropriate, according to the type of the components and the like, but is usually 0.05% by mass or more, preferably 0.1% by mass or more, more preferably 0.25% by mass or more, and usually 2.0% by mass or less, preferably 1.5% by mass or less, more preferably 1.0 mass% or less. Within those ranges, the coating material can be applied with good efficiency.

[0048] In a preferred embodiment of the spraying step according to the present invention, a coating material comprising metal ions is sprayed onto the fiber material. For example, where the fiber material comprises a reducing agent, by spraying the coating material comprising metal ions in the spraying process according to the present invention, it is possible to generate metal particles in the fiber material by a reaction of the metal ions with the reducing agent.

[0049] The type (element) of the metal particles to be produced in such a manner and the form of the particles, etc. are not particularly limited, but noble metals with an ionization tendency less than that of hydrogen are preferred. The preferred specific examples include copper, silver, palladium, platinum, and gold. With such metals, the generation of particles in the fiber material is facilitated, and the antibacterial activity and deodorizing activity based on bacteria growth inhibition are demonstrated. Therefore, the method can be used as an antibacterial and deodorizing method that imparts the antibacterial activity and/or deodorizing activity to the fiber material. Further, the average particle diameter of the generated metal particles is usually 100 nm or less, preferably 70 nm or less, more preferably 50 nm or less, and usually 1 nm or more, preferably 2 nm or more, more preferably 3 nm or more. The average particle size of the metal particles specifically means a volume average particle diameter. It can be measured, for example, by electron microscopy or dynamic light scattering method.

[0050] The spraying step according to the present invention may be a step in which one or two or more coating materials

are sprayed using two or more electrospray sprayers. One or two or more coating materials can be sprayed using two or more electrospray sprayers, for example, in a mode illustrated by Fig. 2(A) in which the fiber material is moved and one or two or more coating materials are sprayed continuously (can be referred to hereinbelow in abbreviated form as "the mode illustrated by Fig. 2(A)"), or a mode illustrated by Fig. 2(B) in which one or two or more coating materials are sprayed on the same position of the fiber material (can be referred to hereinbelow in abbreviated form as "the mode illustrated by Fig. 2(B)") (in Fig. 2, the reference numeral 201 stands for a fiber material comprising an electrolyte solution, 202 - an electrospray sprayer, 203 - a sprayed coating material, and 204 - a sprayed coating material of a type different from that of 203).

[0051] The mode illustrated by Fig. 2(A) can be used, for example, when dyes of the same or different colors are continuously applied and also when an antibacterial agent and/or a deodorant is applied after a dye has been applied. In the mode illustrated by Fig. 2(A), a conductive wire or an electrode for applying an electric potential to the fiber material are not fixed to the fiber material (for example, a voltage applying electrode denoted by the reference numeral 507 in Fig. 5), as an overhead wire and a pantograph in railroad trains, in order to move the fiber material.

[0052] Examples of more specific modes include a dyeing method in which color and shade are continuously changed by applying dyes of different colors (gradation dyeing, see Examples 7 and 8); a dyeing method in which the color tone is adjusted by applying three primary colors, black color, and white color, etc.; and a dyeing method in which a color is darkened by applying the same color (dark dyeing, see Example 9). Further, in those dyeing methods, more sophisticated dyeing, etc. can be performed by adjusting precisely the amount of the fiber material by using a shutter (for example, filter paper shutters 1609, 1709 in Examples 7 and 8) that temporarily blocks the application of the sprayed coating material to the fiber material, or by ON/OFF switching the power supply relay.

[0053] The mode illustrated by Fig. 2(B) can be used, for example, when the same or different coating materials are simultaneously applied to the same position of the fiber material.

[0054] The spraying step according to the present invention may be a step involving spraying while moving the electrospray sprayer. An example of a mode of spraying while moving the electrospray sprayer is presented in Fig. 2(C) (can be referred to hereinbelow in abbreviated form as "the mode illustrated by Fig. 2(C)").

[0055] The mode illustrated by Fig. 2(C) can be used, for example, when a dye is wished to be applied selectively or when a dye is wished to be applied in a focused manner.

[0056] The application method of the present invention is not otherwise particularly limited, provided that it comprises the above-described preparation step and spraying step. Thus the application method may comprise, in addition to the preparation step and spraying step, a washing step of washing away the electrolyte solution and/or coating material from the fiber material, a drying step of drying the fiber material, and a blending step of comprising a reducing agent in addition to the electrolyte solution in the fiber material. Further, the application method of the present invention is not limited to the embodiments in which the preparation step and spraying step are performed once each, and the preparation step and spraying step may be each performed a plurality of times, with the other step being interposed therebetween. Furthermore, in the application method according to the present invention, instead of implementing the preparation step and spraying step individually, the so-called line production method may be used in which the preparation step and spraying step are performed continuously, for example, by moving the fiber material comprising the electrolyte solution. By performing the preparation step and spraying step continuously, it is possible to apply the coating material more efficiently. Examples of modes for "performing the preparation step and spraying step continuously by moving the fiber material" are illustrated by Fig. 3. Thus, Fig. 3(A) illustrates a mode in which the fiber material is immersed in the electrolyte solution as a preparation step, and the spraying step is performed continuously thereafter. Fig. 3(B) illustrates a step in which the electrolyte solution is sprayed onto the fiber material as the preparation step, and the spraying step is performed continuously thereafter. Fig. 3(C) illustrates a step in which the electrolyte solution is dropped onto the fiber material as the preparation step, and the spraying step is performed continuously thereafter (in Fig. 3, the reference numeral 301 stands for a fiber material, 302 - a roller, 303 - an electrospray sprayer, 304 - a sprayed coating material, 305 - a water tank, 306 - an electrolyte solution, 307 - a spray device for spraying the electrolyte solution, 308 - the sprayed electrolyte solution, 309 - a dropping device, and 310 - a dropped electrolyte solution).

(Fiber material)

[0057] The specific material, whether natural fibers or synthetic fibers, and form of the "fiber material", which is the object of the application method of the present invention, are not particularly limited, provided that it is a fibrous material comprising a polymer compound as a constituent component, or a material obtained by bundling such fibrous material (cotton, woven fabric, nonwoven fabric, paper, etc.).

[0058] Examples of the types of the fiber material comprise plant fibers such as hemp and cotton, animal fibers such as wool and silk, regenerated fibers such as rayon, polyamide synthetic fibers, polyester synthetic fiber, acrylic synthetic fibers, polyvinyl alcohol synthetic fibers, polyolefin synthetic fiber, polyurethane synthetic fibers, cellulose-based semi-synthetic fibers, and protein-based semisynthetic fibers.

[0059] The fiber material is preferably a yarn, woven fabric, nonwoven fabric, knitted fabric, paper, or a film.

[0060] The application method of the present invention can be used for a variety of treatments performed in the process of manufacturing or processing the fiber material, and the use thereof is not particularly limited. For example, it can be used in the below-described methods (1) to (8).

(1) a dyeing method for a fiber material in which the fiber material is dyed by applying a coating material comprising a dye;
(2) an antibacterial/deodorizing method for a fiber material comprising imparting an antibacterial activity and/or a deodorizing activity to the fiber material by applying a coating material comprising an antibacterial agent and/or a deodorant;
(3) a water and oil repelling method for a fiber material comprising imparting a water and oil repelling activity to the fiber material by applying a coating material comprising a water and oil repellent;
(4) a flame retardant method for a fiber material by which the fiber material is made less flammable by applying a coating material comprising a flame retardant;
(5) a bleaching method for a fiber material comprising bleaching the fiber material by applying a coating material comprising a bleaching agent;
(6) a softening method for a fiber material comprising softening the fiber material by applying a coating material comprising a softener;
(7) a sizing method for a fiber material comprising sizing the fiber material by applying a coating material comprising a sizing agent; and
(8) an anti-fouling method for a fiber material comprising imparting an anti-fouling activity to the fiber material by applying a coating material comprising an anti-fouling agent.

[0061] The continuous treatment such as depicted in Fig. 13 is a specific mode of using the application method of the present invention (can be referred to hereinbelow in abbreviated form as "the mode illustrated by Fig. 13") (in Fig. 13, the reference numeral 1301 stands for a fiber material before processing (for example, a cotton yarn), 1302 - a water tank that contains the electrolyte solution, 1303 - a dyeing treatment step, 1304 - a functional material addition (antibacterial/deodorizing treatment) step, 1305 - a sizing treatment step, 1306 - an electrospray sprayer, and 1307 - a heating and drying device).

[0062] The mode illustrated by Fig. 13 is a line production method in which a cotton yarn (fiber material) is moved using a roller. The cotton yarn passes successively through the water tank that contains the electrolyte solution, dyeing treatment step, functional material addition (antibacterial/deodorizing treatment) step, sizing treatment step, and heating and drying device.

<Method of manufacturing fiber material>

[0063] It has been mentioned hereinbefore that the application method of the present invention can be used, for example, in the methods (1) to (8), but a method for manufacturing a fiber material that comprises those methods as treatment steps is also an aspect of the present invention (can be referred to hereinbelow in abbreviated form as "the manufacturing method of the present invention").

[0064] Thus, the manufacturing method of the present invention is characterized by comprising at least one step selected from a group consisting of steps (1) to (8) below:

(1) a dye treatment step comprising dyeing a fiber material by applying a coating material comprising a dye by the application method according to the present invention;
(2) an antibacterial/deodorizing treatment step comprising imparting an antibacterial activity and/or a deodorizing activity to a fiber material by applying a coating material comprising an antibacterial agent and/or a deodorant by the application method according to the present invention;
(3) a water and oil repelling treatment step comprising imparting a water and oil repelling activity to a fiber material by applying a coating material comprising a water and oil repellent by the application method according to the present invention;
(4) a flame retardant treatment step of making a fiber material less flammable by applying a coating material comprising a flame retardant by the application method according to the present invention;
(5) a bleaching treatment step comprising bleaching a fiber material by applying a coating material comprising a bleaching agent by the application method according to the present invention;
(6) a softening treatment step comprising softening a fiber material by applying a coating material comprising a softener by the application method according to the present invention;
(7) a sizing treatment step comprising sizing a fiber material by applying a coating material comprising a sizing agent

by the application method according to the present invention; and
(8) an anti-fouling treatment step comprising imparting an anti-fouling activity to a fiber material by applying a coating material comprising an anti-fouling agent by the application method according to the present invention.

[0065] In addition to the above-described steps (1) to (8), the manufacturing method of the present invention may comprise well-known steps that are performed in the processes for manufacturing fiber materials, for example, a fiber forming step (melt fiber forming, dry fiber forming, wet fiber forming), a stretching step, a spinning step, a knitting and weaving step, and a scouring step. In particular, the manufacturing method of the present invention is suitable for continuously implementing the steps of applying a coating material to a fiber material, such as the above-described steps (1) to (8) and makes it possible to increase greatly the productivity of fiber materials when implemented continuously in combination with a fiber forming step or the like.

[0066] Thus, the manufacturing method of the present invention preferably further comprises at least one step selected from a group consisting of a fiber forming step, a stretching step, a spinning step, a knitting and weaving step, and a scouring step.

<Apparatus for processing fiber material>

[0067] The application method of the present invention, in particular the application method in which the preparation step and spraying step are performed continuously by moving the fiber material comprising the electrolyte solution, enables efficient processing of the fiber material, and an apparatus for processing a fiber material that can be used in such application method is also an aspect of the present invention (can be referred to hereinbelow in abbreviated form as "apparatus for processing a fiber material of the present invention").

[0068] Thus, the apparatus for processing a fiber material of the present invention comprises: an electrolyte solution contact mechanism performing at least one selected from a group consisting of immersing the fiber material into an electrolyte solution, spraying the electrolyte solution onto the fiber material, and dropping the electrolyte solution onto the fiber material; an electrospray sprayer that sprays a coating material toward the fiber material comprising the electrolyte solution; and a fiber material feed mechanism for moving the fiber material comprising the electrolyte solution to the spray target for the electrospray sprayer.

[0069] For instance, a device to be used in the electrolyte solution contact mechanism in the apparatus for processing a fiber material of the present invention is not particularly limited, provided that an arrangement is obtained for performing at least one selected from a group consisting of immersing the fiber material into an electrolyte solution, spraying the electrolyte solution onto the fiber material, and dropping the electrolyte solution onto the fiber material. For example, an arrangement in which the fiber material 301 is immersed in the immersion liquid tank 305 into which the electrolyte solution 306 has been loaded, as depicted in Fig. 3(A), an arrangement in which the electrolyte solution 308 is sprayed onto the fiber material 301 by using the spraying device 307, as depicted in Fig. 3(B), and an arrangement in which the electrolyte solution 310 is dropped onto the fiber material 301 by using the dropping device 309, as depicted in Fig. 3(C), can be used.

[0070] The apparatus for processing a fiber material of the present invention is preferably provided with two or more electrospray sprayers. Where two or more electrospray sprayers are provided, coating materials of two or more types can be sprayed, and the above-described modes illustrated by Fig. 2(A) and Fig. 2(B) can be implemented.

[0071] In the electrospray sprayer in the apparatus for processing a fiber material of the present invention, the type of the coating material to be sprayed can be selected, as appropriate, according to the processing object. For example, a coating material of at least one type selected from a group consisting of (1) to (8) hereinbelow can be used.

(1) a coating material comprising a dye;
(2) a coating material comprising an antibacterial agent and/or a deodorant;
(3) a coating material comprising a water and oil repellent;
(4) a coating material comprising a flame retardant;
(5) a coating material comprising a bleaching agent;
(6) a coating material comprising a softener;
(7) a coating material comprising a sizing agent; and
(8) a coating material comprising an anti-fouling agent.

[0072] A device to be used in the fiber material feed mechanism in the apparatus for processing a fiber material of the present invention is not particularly limited, provided that an arrangement is obtained such that the fiber material comprising the electrolyte solution can be moved to the spray target for the electrospray sprayer. For example, a roller conveyor or a belt conveyor can be used.

[0073] Other features of the apparatus for processing a fiber material of the present invention are not particularly

limited, but it is preferred that the apparatus be configured such that the distance between the electrospray sprayer and the fiber material which is the spraying object, or the spraying direction of the electrospray sprayer could be changed. By enabling such changes, it is possible to adapt the apparatus to various processing applications and processing conditions.

[0074] It is also preferred that a power source (voltage-controlled device) that generates an electric field between the electrospray sprayer and the fiber material which is the spraying object have a variable application voltage. Where the application voltage can be changed, it is possible to adapt the apparatus to various processing applications and processing conditions.

[0075] It is also preferred that a shutter be provided for blocking the application of the sprayed coating material to the fiber material. By providing the shutter, it is possible to adjust precisely the amount of the coating material to be applied and perform more sophisticated dyeing, etc.

EXAMPLES

[0076] The present invention will be explained hereinbelow in greater detail on the basis of examples and comparative examples, but the present invention can be changed, as appropriate, without departing from the spirit thereof. Therefore, the scope of the invention should not be interpreted as being limited to the below-described specific examples.

<Example 1>

[0077] A cotton yarn (material: cotton, thickness: No. 4 single yarn) manufactured by ASAHIBO CO., LTD. was immersed in an aqueous solution of sodium carbonate (concentration: 5% by mass) to prepare a cotton yarn comprising the aqueous solution of sodium carbonate.

[0078] An electrospray sprayer having a nozzle in the form of a glass capillary (opening diameter 0.1 mm) with an electrode attached to the tip thereof and the cotton yarn comprising the aqueous solution of sodium carbonate were each connected to a high-voltage power source device (the nozzle electrode was connected to the positive electrode, the cotton yarn was connected to the negative electrode, a reference electrode was grounded). The cotton yarn was then positioned on the spraying direction of the nozzle, and the nozzle tip and cotton yarn were fixed such that the shortest distance therebetween was 30 mm. Spraying of ethanol toward the cotton yarn was started by applying an electric potential of +3.0 kV to the nozzle electrode and -1.4 kV (reference potential: ground) to the cotton yarn. A photograph illustrating the state of spraying is shown in Fig. 4(A).

<Comparative Example 1>

[0079] Ethanol was sprayed toward the cotton yarn in the same manner as in Example 1, except that the cotton yarn was not immersed in the aqueous solution of sodium carbonate (concentration: 5% by mass). A photograph illustrating the state of spraying is shown in Fig. 4(B).

[0080] As clearly follows from Figs. 4(A) and 4(B), when the cotton yarn was immersed in the electrolyte solution, the droplets focused to the cotton yarn, whereas when the cotton yarn was not immersed in the electrolyte solution, the droplets diffused within a wide range. The charged droplets apparently focused to the cotton yarn because when the cotton yarn was immersed in the electrolyte solution, the cotton yarn became an electric conductor and an electric field was formed between the nozzle and cotton yarn.

<Example 2>

[0081] The lower end of a cotton yarn (material: cotton, thickness: No. 4 single yarn) with a total length of 2 m or more which was manufactured by ASAHIBO CO., LTD. was fixed to a winding roll, and the cotton yarn, electrospray sprayer, immersion liquid tank, and electrodes for voltage application, etc., were disposed as shown in the conceptual diagram in Fig. 5 (in Fig. 5, the reference numeral 501 stands for a cotton yarn, 502 - an electrospray sprayer, 503 - a sprayed dye solution, 504 - a sodium carbonate solution, 505 - an immersion liquid tank, 506 - a roller, 507 - electrodes for voltage application, and 508 - a winding roll). A stainless steel nozzle with an opening diameter of the spraying port of 0.1 mm was used for the electrospray sprayer. The cotton yarn was then positioned on the spraying direction (horizontal direction) of the nozzle, and the nozzle tip and cotton yarn were fixed such that the shortest distance therebetween was 30 mm. The electrospray sprayer was loaded with a dye solution (Remazol RED RU-N, concentration: 0.5% by mass, manufactured by DyStar Japan Ltd.).

[0082] In the present arrangement, the preparation step in which the cotton yarn is immersed in the electrolyte solution and the spraying step in which the dye solution is sprayed toward the cotton yarn with the electrospray sprayer are performed continuously by winding the cotton yarn. The preparation step and spraying step will be described hereinbelow

in greater detail.

(Preparation step)

[0083] An aqueous solution of sodium carbonate (concentration: 5% by mass) was loaded into the immersion liquid tank. The cotton yarn was immersed for about 5 sec into the aqueous solution of sodium carbonate, and the cotton yarn was then wound such as to move to the spray target for the electrospray sprayer (the content of the aqueous solution of sodium carbonate on the cotton yarn: 400% by mass).

(Spraying step)

[0084] The loaded dye solution was sprayed from the electrospray sprayer toward the cotton yarn which passed through the aqueous solution of sodium carbonate. The spraying was performed by applying 5.0 kV to the nozzle electrode and grounding the cotton yarn. A photograph illustrating the state of spraying the dye solution is shown in Fig. 6.

[0085] As clearly follows from Fig. 6, the dye solution sprayed from the electrospray sprayer was focused to the cotton yarn. Droplets that deviated from the cotton yarn were also focused to the cotton yarn such as to be guided by and comprised in the electric field. The dye solution utilization efficiency was calculated from the results obtained in measuring the mass and concentration of the sprayed dye solution and the concentration of the dye eluate from the dyed yarn. The calculation result indicated that 37% by mass of the dye solution was used for application to the cotton yarn. Further, the droplets scattered without focusing could be collected behind the fiber material, and the amount thereof could be incinerated.

<Example 3>

[0086] A cotton yarn was dyed by spraying a dyeing solution in the same manner as in Example 2, except that dyeing solutions of two types were continuously sprayed using two electrospray sprayers as in the conceptual diagrams shown in Figs. 7(A) and 7(B) (in Fig. 7(A) and Fig. 7(B), the reference numeral 701 stands for a cotton yarn, 702 - an electrospray sprayer, 703 - a sprayed dye solution, 704 - an electrospray sprayer, 705 - a sprayed dye solution, 706 - a sodium carbonate solution, 707 - an immersion liquid tank, 708 - a roller, 709 - electrodes for voltage application, and 710 - a winding roll). A photograph illustrating the state of spraying the dye solution is shown in Fig. 7(C).

[0087] As clearly follows from Fig. 8, by using two or more electrospray sprayers, multicolor dyeing can be performed continuously with respect to one cotton yarn, and the processing such as gradation dyeing can be performed by adjusting the applied potential and the feed rate of the cotton yarn.

<Comparative Example 2>

[0088] A dye solution was sprayed toward a cotton yarn from an electrospray sprayer by the same method as in Example 2, except that the cotton yarn was not immersed in the solution of sodium carbonate (concentration: 5.0% by mass). A photograph illustrating the state of spraying the dye solution is shown in Fig. 9. When the cotton yarn was not immersed in the electrolyte solution, the dye solution sprayed from the electrospray sprayer diffused within a wide range and could not be sufficiently supplied to the cotton yarn.

<Example 4>

[0089] The lower end of a cotton yarn (material: cotton, thickness: No. 4 single yarn) with a total length of 2 m or more which was manufactured by ASAHIBO CO., LTD. was fixed to a winding roll, and the cotton yarn, electrospray sprayer, and immersion liquid tank, etc. were disposed as shown in the conceptual diagram in Fig. 10 (in Fig. 10, the reference numeral 1001 stands for a cotton yarn, 1002 - an electrospray sprayer, 1003 - a sprayed aqueous solution of silver nitrate, 1004 - an aqueous solution of ascorbic acid, 1005 - an immersion liquid tank, 1006 - a roller, 1007 - electrodes for voltage application, and 1008 - a winding roll). A stainless steel nozzle with an opening diameter of the spraying port of 0.1 mm was used for the electrospray sprayer. The cotton yarn was then positioned on the spraying direction (horizontal direction) of the nozzle, and the nozzle tip and cotton yarn were fixed such that the shortest distance therebetween was 20 mm. The electrospray sprayer was loaded with a silver nitrate solution (silver ion concentration: 0.1 mol/L, solvent: ethanol/water = 4/1 (volume ratio)).

[0090] In the present arrangement, the preparation step in which the cotton yarn is immersed in the electrolyte solution and the spraying step in which the aqueous solution of silver nitrate is sprayed toward the cotton yarn with the electrospray sprayer are performed continuously by winding the cotton yarn. The preparation step and spraying step will be described herein below in greater detail.

(Preparation step)

[0091] An ascorbic acid solution (ascorbic acid concentration: 0.1 mol/L, solvent: ethanol/water = 4/1 (volume ratio)) was loaded into the immersion liquid tank. The cotton yarn was immersed for about 2 sec into the aqueous solution of ascorbic acid, and the cotton yarn was then wound such as to move to the spray target for the electrospray sprayer at a rate of 1 m/min (the content of the aqueous solution of ascorbic acid on the cotton yarn: 400% by mass).

(Spraying step)

[0092] The loaded aqueous solution of silver nitrate was sprayed from the electrospray sprayer toward the cotton yarn which has passed through the solution of ascorbic acid. The spraying was performed by applying +6.0 kV to the nozzle electrode and -3.0 kV to the cotton yarn (reference potential: ground).

[0093] The cotton yarn subjected to spraying was recovered, washed with water (conditions: 12 yards of the cotton yarn was picked up and then washed with water while introducing into a pot of a dyeing testing device and rotating therein; cotton yarn : water = 1 : 20) in the device depicted in Fig. 11 and dried (conditions: constant-temperature drying at 60°C) (in Fig. 11, the reference numeral 1111 stands for a processed yarn, 1112 - a cotton yarn (for bath ratio adjustment), 1113 - a pot, 1114 - a sample fixing fixture, 1115 - washing water, and 1116 - hot solution (ethylene glycol)).

[0094] The photographs of the cotton yarn taken before and after the spraying are shown in Fig. 12(A), and the scanning electron micrograph of the cotton yarn taken after the spraying is shown in Fig. 12(B). As a result of impregnation with metallic silver particles, the cotton yarn is colored black, and it is clear that fine particles have been applied to the cotton yarn surface.

[0095] Further, silver was eluted from the cotton yarn with 1 N nitric acid, and the eluate was measured with an atomic absorption spectrometer. Silver ions were detected and it was confirmed that metallic silver was formed on the cotton yarn surface.

[0096] Thus, it was made clear that when the fiber material comprises a reducing agent (also acts as an electrolyte), such as ascorbic acid, and the coating material comprising metal ions, such as a silver nitrate solution, is sprayed, it is possible to generate metal particles in the fiber material.

<Impregnation capacity evaluation test for metallic silver particles>

[0097] Cotton yarns impregnated with metallic silver particles were prepared by the same method as in Example 4, except that the feed rate (winding rate) of the cotton yarn was changed, and the impregnated amount of the metallic silver particles was measured before and after washing with water. The impregnated amount of the metallic silver particles was determined by eluting silver with nitric acid and measuring the amount of silver ions in the solution with an atomic absorption spectrometer in the same manner as in Example 4. Fig. 14 shows the graph representing the relationship between the feed rate of the cotton yarn and the impregnated amount of the metallic silver particles. The impregnated amount of the metallic silver particles tends to decrease with the increase in the feed rate of the cotton yarn, but since the difference between the impregnated amount of the metallic silver particles before and after washing with water decreases, it can be supposed that the impregnation with excess metallic silver particles which can easily fall from the yarn is suppressed and that securely impregnated metallic silver particles are selectively formed. Further, it is clear that by using the application method of the present invention it is possible to impregnate the fiber material securely with the metallic silver particles, without using a binder (binding agent, joining agent). When a binder suitable for surface processing of fiber material is used, since the exposed surface area of the substance to be affixed, such as metallic silver particles, decreases, the effect thereof is considered to weaken. By contrast, since the application method of the present invention enables the "binder-free" application, it is possible to manufacture a fiber material with excellent antibacterial ability.

<Antibacterial ability evaluation test>

[0098] The antibacterial ability of the cotton yarn impregnated with metallic silver particles of Example 4 was evaluated. The antibacterial activity was evaluated by a method conforming to JIS L1902 (Bacterial liquid absorption methods). Staphylococcus aureus IFO12732 was used as bacteria.

[0099] More specifically, the cotton yarn, 0.15 g, was placed in a vial, and a test bacterial solution, 0.2 ml, was inoculated and cultured for 18 h at 35°C. The bacteria were then washed out from the cotton yarn by adding sterile water, 10 ml, the number of bacteria in the washout solution was measured by an emission measurement method (ATP method), and the bacteriostatic activity value and bactericidal activity value were calculated by the following formulas:

bacteriostatic activity value = {log (standard yarn, number of viable bacteria after culturing) - log (standard yarn, number of viable bacteria immediately after inoculation)} – {log (processed yarn, number of viable bacteria after culturing) - log (processed yarn, number of viable bacteria immediately after inoculation)};

bactericidal activity value = log (standard yarn, number of viable bacteria immediately after inoculation) - log (processed yarn, number of viable bacteria after culturing).

[0100] The bacteriostatic activity value is the logarithmic representation of a value obtained by dividing the number of viable bacteria in the standard yarn after culturing for 18 h by the number of viable bacteria in the processed yarn after culturing for 18 h. Where the bacteriostatic activity value is 2.0 or more, it is assumed that the antibacterial/deodorizing effect is demonstrated. The bactericidal activity value is the logarithmic representation of a value obtained by dividing the number of viable bacteria in the standard yarn immediately after the inoculation by the number of viable bacteria in the processed yarn after culturing for 18 h. Where the antibacterial activity value is 0 or more, it is assumed that the antibacterial effect is demonstrated.

[0101] The results are shown in Table 1. The results obtained with the cotton yarn for which the feed rate (winding rate) of the cotton yarn was changed from 1 m/min to 2 m/min (Example 5) and for the standard cotton yarn that has not been impregnated with the metallic silver particles (Comparative Example 3) are also shown in Table 1.

[0102] The results clearly indicate that the cotton yarn impregnated with the metallic silver particles excels in antibacterial ability.

Table 1

	Feed rate of cotton yarn	Number of viable bacteria [CFU/ml]		Bacteriostatic activity value	Bactericidal activity value
		Number of inoculated bacteria	After 18 h		
Example 4	1 m/min	3.1×10^5	0.59×10^5	2.07	0.72
Example 5	2 m/min	3.1×10^5	0.38×10^5	2.26	0.91
Comparatives Example 3	Standard cotton yarn	3.1×10^5	6.9×10^6		

<Example 6 (plant dyeing)>

[0103] The lower end of a silk yarn (material: silk, thickness: 120 Nm double-yarn) with a total length of 2 m or more which was manufactured by Jiangsu Spcc Silk Group Co., Ltd. was fixed to a winding roll, and the silk yarn, electrospray sprayer, immersion liquid tank, etc., were disposed as shown in the conceptual diagram in Fig. 15(A) (in Fig. 15(A), the reference numeral 1501 stands for a silk yarn, 1502 - an electrospray sprayer, 1503 - a sprayed dye solution, 1504 - an electrolyte solution, 1505 - an immersion liquid tank, 1506 - a roller, 1507 - electrodes for voltage application, and 1508 - a winding roll). An electrospray sprayer had a nozzle in the form of a glass capillary (opening diameter 0.1 mm) with an electrode attached to the tip thereof. The silk yarn was positioned on the spraying direction (horizontal direction) of the nozzle, and the nozzle tip and silk yarn were fixed such that the shortest distance therebetween was 20 mm. The electrospray sprayer was loaded with a liquid plant dye (sappanwood solution, sophora solution (TANAKANAO SENRYOTEN)), liquid plant dye : ethanol/water = 1/1 (volume ratio)).

[0104] A mordant solution (aqueous solution of potassium alum or iron (II) sulfate; concentration: 1% by mass) was loaded into the immersion liquid tank. The silk yarn was immersed for about 2 sec into the mordant solution, and the silk yarn was then wound at a rate of 1 m/min such as to move to the spray target for the electrospray sprayer (the content of the mordant solution in the silk yarn: 400% by mass).

[0105] The liquid plant dye was sprayed from the electrospray sprayer toward the silk yarn which passed through the mordant solution. The spraying was performed by applying +5.0 kV to the nozzle electrode and -3.0 kV to the silk yarn (reference potential: ground).

[0106] The silk yarn subjected to spraying was recovered, baked for 5 min at 90°C, washed with water (conditions: 12 yards of the silk yarn was picked up and then washed with water while introducing into a pot of a dyeing testing device and rotating therein: silk yarn : water = 1 : 20) in the device depicted in Fig. 11 and dried (conditions: constant-temperature drying at 60°C). A photograph of the silk yarn is shown in Fig. 15(B).

<Example 7 (gradation dyeing (cotton))>

[0107] The lower end of a cotton yarn (material: cotton, thickness: No. 20 single yarn) with a total length of 2 m or more which was manufactured by ASAHIBO CO., LTD. was fixed to a winding roll, and the cotton yarn, electrospray sprayer, and immersion liquid tank, etc. were disposed as shown in the conceptual diagram in Fig. 16(A) (in Fig. 16(A), the reference numeral 1601 stands for a cotton yarn, 1602 - an electrospray sprayer, 1603 - a sprayed dye solution, 1604 - an electrolyte solution, 1605 - an immersion liquid tank, 1606 - a roller, 1607 - electrodes for voltage application, 1608 - a winding roll, and 1609 - a filter paper shutter). Each of three electrospray sprayers had a nozzle in the form of a glass capillary (opening diameter 0.1 mm) with an electrode attached to the tip thereof. The cotton yarns were positioned in parallel on the spraying direction (horizontal direction) of the nozzle, and the nozzle tip and cotton yarns were fixed such that the shortest distance therebetween was 20 mm. Three electrospray sprayers were loaded with dye solutions of three colors (Remazol RED RU-N, concentration: 5% by mass, Remazol BLUE RU-N, concentration: 5% by mass, Remazol YELLOW RU-N, concentration: 5% by mass; manufactured by DyStar Japan Ltd.). The spray of the dyes from the electrospray sprayers was cut off with the filter paper shutter to obtain color gradation.

[0108] In the present arrangement, the preparation step in which the cotton yarn is immersed in the electrolyte solution and the spraying step in which the dye solutions are sprayed toward the cotton yarn with the electrospray sprayers are performed continuously by winding the cotton yarn. The preparation step and spraying step will be described hereinbelow in greater detail.

(Preparation step)

[0109] An aqueous solution of sodium carbonate (concentration: 5% by mass) was loaded into the immersion liquid tank. The cotton yarn was immersed for about 5 sec into the aqueous solution of sodium carbonate, and the cotton yarn was then wound such as to move to the spray target for the electrospray sprayer (the content of the aqueous solution of sodium carbonate on the cotton yarn: 400% by mass).

(Spraying step)

[0110] The loaded dye solutions of three colors were successively sprayed from the electrospray sprayers toward the cotton yarn which passed through the aqueous solution of sodium carbonate. The spraying was performed by applying +4.0 kV to the nozzle electrode and -3.7 kV to the cotton yarn. A photograph of the cotton yarn is shown in Fig. 16(B).

<Example 8 (gradation dyeing (silk))>

[0111] The lower end of a silk yarn (material: silk, thickness: 120 Nm double-yarn) with a total length of 2 m or more which was manufactured by Jiangsu Spcc Silk Group Co., Ltd. was fixed to a winding roll, and the silk yarn, electrospray sprayer, immersion liquid tank, etc., were disposed as shown in the conceptual diagram in Fig. 17(A) (in Fig. 17(A), the reference numeral 1701 stands for a silk yarn, 1702 - an electrospray sprayer, 1703 - a sprayed dye solution, 1704 - an electrolyte solution, 1705 - an immersion liquid tank, 1706 - a roller, 1707 - electrodes for voltage application, 1708 - a winding roll, and 1709 - a filter paper shutter). The three electrospray sprayers each had a nozzle in the form of a glass capillary (opening diameter 0.1 mm) with an electrode attached to the tip thereof. The silk yarns were positioned in parallel on the spraying direction (horizontal direction) of the nozzle, and the nozzle tip and cotton yarns were fixed such that the shortest distance therebetween was 20 mm. The three electrospray sprayers were loaded with dye solutions of three colors (Kayanol Milling Blue BW, concentration: 1% by mass, Kayanol Milling Red 3BW, concentration: 1% by mass, Kayanol Milling YELLOW BW, concentration: 1% by mass; manufactured by Nippon Kayaku Co., Ltd.). The spray of the dyes from the electrospray sprayers was cut off with the filter paper shutter to obtain color gradation.

[0112] In the present arrangement, the preparation step in which the silk yarn is immersed in the electrolyte solution and the spraying step in which the dye solutions are sprayed toward the silk yarn with the electrospray sprayers are performed continuously by winding the cotton yarn. The preparation step and spraying step will be described hereinbelow in greater detail.

(Preparation step)

[0113] An aqueous solution of ammonium acetate (concentration: 0.01 M) was loaded into the immersion liquid tank. The silk yarn was immersed for about 5 sec into the aqueous solution of ammonium acetate, and the silk yarn was then wound such as to move to the spray target for the electrospray sprayer (the content of the aqueous solution of ammonium acetate on the cotton silk: 400% by mass).

(Spraying step)

[0114] The loaded dye solutions of three colors were successively sprayed from the electrospray sprayers toward the silk yarn which has passed through the aqueous solution of ammonium acetate. The spraying was performed by applying +4.0 kV to the nozzle electrode and -3.7 kV to the silk yarn. A photograph of the silk yarn is shown in Fig. 17(B).

<Example 9 (dark dyeing)>

[0115] The lower end of a cotton yarn (material: cotton, thickness: No. 20 single yarn) with a total length of 2 m or more which was manufactured by ASAHIBO CO., LTD. was fixed to a winding roll, and the cotton yarn, electrospray sprayer, and immersion liquid tank, etc. were disposed as shown in the conceptual diagram in Fig. 18(A) (in Fig. 18(A), the reference numeral 1801 stands for a cotton yarn, 1802 - an electrospray sprayer, 1803 - a sprayed dye solution, 1804 - an electrolyte solution, 1805 - an immersion liquid tank, 1806 - a roller, 1807 - electrodes for voltage application, and 1808 - a winding roll). The three electrospray sprayers each had a nozzle in the form of a glass capillary (opening diameter 0.1 mm) with an electrode attached to the tip thereof. The cotton yarns were positioned in parallel on the spraying direction (horizontal direction) of the nozzle, and the nozzle tip and cotton yarns were fixed such that the shortest distance therebetween was 20 mm. The three electrospray sprayers were all loaded with the same dye solution (Remazol RED RU-N, concentration: 5% by mass; manufactured by DyStar Japan Ltd.).

[0116] In the present arrangement, the preparation step in which the cotton yarn is immersed in the electrolyte solution and the spraying step in which the dye solutions are sprayed toward the cotton yarn with the electrospray sprayers are performed continuously by winding the cotton yarn. The preparation step and spraying step will be described hereinbelow in greater detail.

(Preparation step)

[0117] An aqueous solution of sodium carbonate (concentration: 5% by mass) was loaded into the immersion liquid tank. The cotton yarn was immersed for about 5 sec into the aqueous solution of sodium carbonate, and the cotton yarn was then wound such as to move to the spray target for the electrospray sprayer (the content of the aqueous solution of sodium carbonate on the cotton yarn: 400% by mass).

(Spraying step)

[0118] The loaded dye solutions were successively sprayed from the electrospray sprayers toward the cotton yarn which passed through the aqueous solution of sodium carbonate. The spraying was performed by applying +4.0 kV to the nozzle electrode and -3.2 kV to the cotton yarn. A photograph of the cotton yarn is shown in Fig. 18(B).

<Example 10 (paper yarn dyeing)>

[0119] The lower end of a paper yarn (material: paper, thickness: 41 Nm single yarn) with a total length of 2 m or more which was manufactured by DAIGO FIBER LTD. was fixed to a winding roll, and the paper yarn, electrospray sprayer, immersion liquid tank, etc. were disposed as shown in the conceptual diagram in Fig. 5 (in Fig. 5, the reference numeral 501 stands for a cotton yarn, 502 - an electrospray sprayer, 503 - a sprayed dye solution, 504 - a sodium carbonate solution, 505 - an immersion liquid tank, 506 - a roller, 507 - electrodes for voltage application, and 508 - a winding roll). The electrospray sprayer had a nozzle in the form of a glass capillary (opening diameter 0.1 mm) with an electrode attached to the tip thereof. The paper yarns were positioned in parallel on the spraying direction (horizontal direction) of the nozzle, and the nozzle tip and paper yarns were fixed such that the shortest distance therebetween was 20 mm. The electrospray sprayer was loaded with a dye solution (Remazol RED RU-N, concentration: 5% by mass, manufactured by DyStar Japan Ltd.).

[0120] In the present arrangement, the preparation step in which the paper yarn is immersed in the electrolyte solution and the spraying step in which the dye solution is sprayed toward the paper yarn with the electrospray sprayer are performed continuously by winding the paper yarn. The preparation step and spraying step will be described hereinbelow

in greater detail.

(Preparation step)

[0121] An aqueous solution of sodium carbonate (concentration: 5% by mass) was loaded into the immersion liquid tank. The paper yarn was immersed for about 5 sec into the aqueous solution of sodium carbonate, and the paper yarn was then wound such as to move to the spray target for the electrospray sprayer (the content of the aqueous solution of sodium carbonate on the paper yarn: 400% by mass).

(Spraying step)

[0122] The loaded dye solution was sprayed from the electrospray sprayer toward the paper yarn which passed through the aqueous solution of sodium carbonate. The spraying was performed by applying 5.0 kV to the nozzle electrode and grounding the paper yarn. A photograph of the paper yarn is shown in Fig. 19.

[0123] Photographs of cotton yarn dyed using other reactive dyes are shown in Fig. 20. The application method of the present invention is clearly suitable for dyeing various fiber materials such as cotton, silk, and paper. The application method can be also used with various types of dyes.

INDUSTRIAL APPLICABILITY

[0124] The application method of the present invention enables efficient application of a coating material to a fiber material such as yarns, woven fabrics, nonwoven fabrics, and paper. Therefore, the application method can be used for dyeing, antibacterial/deodorizing treatment, water and oil repelling treatment, flame retardant treatment, bleaching treatment, softening treatment, and the like.

REFERENCE SIGNS LIST

[0125]

101 fiber material comprising an electrolyte solution
102 nozzle of electrospray sprayer
103 sprayed coating material
104 distance between the nozzle of the electrospray sprayer and the fiber material
201 fiber material comprising an electrolyte solution
202 electrospray sprayer
203 sprayed coating material
204 sprayed coating material of a type different from that of 203
301 fiber material
302 roller
303 electrospray sprayer
304 sprayed coating material
305 immersion liquid tank
306 electrolyte solution
307 spraying device for spraying an electrolyte solution
308 sprayed electrolyte solution
309 dropping device
310 dropped electrolyte solution
501 cotton yarn
502 electrospray sprayer
503 sprayed dye solution
504 sodium carbonate solution
505 immersion liquid tank
506 roller
507 electrode for voltage application
508 winding roll
701 cotton yarn
702 electrospray sprayer
703 sprayed dye solution

704 electrospray sprayer
705 sprayed dye solution
706 sodium carbonate solution
707 immersion liquid tank
708 roller
709 electrode for voltage application
710 winding roll
1001 cotton yarn
1002 electrospray sprayer
1003 sprayed aqueous solution of silver nitrate
1004 aqueous solution of ascorbic acid
1005 immersion liquid tank
1006 roller
1007 electrode for voltage application
1008 winding roll
1111 processed yarn
1112 cotton yarn (for bath ratio adjustment)
1113 pot
1114 sample fixing fixture
1115 water for washing
1116 hot solution (ethylene glycol)
1301 fiber material before processing
1302 tank containing electrolyte solution
1303 dyeing treatment step
1304 functional material addition (antibacterial/deodorizing treatment) step
1305 sizing step
1306 electrospray sprayer
1307 heating and drying device
1501, 1701 silk yarns
1502, 1602, 1702, 1802 electrospray sprayers
1503, 1603, 1703, 1803 sprayed dye solutions
1504, 1604, 1704, 1804 electrolyte solutions
1505, 1605, 1705, 1805 immersion liquid tanks
1506, 1606, 1706, 1806 rollers
1507, 1607, 1707, 1807 electrodes for voltage application
1508, 1608, 1708, 1808 winding rolls
1601, 1801 cotton yarns
1609, 1709 filter paper shutters.

Claims

1. A method for applying a coating material to a fiber material, the method comprising: a preparation step of preparing a fiber material comprising an electrolyte solution; and a spraying step of spraying the coating material onto the fiber material by electrospray.

2. The method for applying according to claim 1, wherein the electrolyte solution comprises at least one selected from a group consisting of alkali metal salts, alkaline earth metal salts, aluminum salts, ammonium salts, and transition metal salts.

3. The method for applying according to claim 1 or 2, wherein the preparation step comprises at least one selected from a group consisting of: immersing the fiber material into the electrolyte solution; spraying the electrolyte solution onto the fiber material; and dropping the electrolyte solution onto the fiber material.

4. The method for applying according to any one of claims 1 to 3, wherein the coating material comprises at least one selected from a group consisting of a dye, an antibacterial agent, a deodorant, a water and oil repellent, a flame retardant, a bleaching agent, a softener, a sizing agent, and an anti-fouling agent.

5. The method for applying according to any one of claims 1 to 4, wherein with the fiber material comprising a reducing agent and with the coating material being a solution that comprises a metal ion, when the coating material comprising the metal ion is sprayed onto the fiber material in the spraying step, the metal ion reacts with the reducing agent, and as a result a metal particle is generated in the fiber material.

6. The method for applying according to any one of claims 1 to 5, wherein the spraying step comprises spraying one or two or more types of coating materials by using two or more electrospray sprayers.

7. The method for applying according to claim 6, wherein the spraying step comprises spraying one or two or more types of coating materials continuously by moving the fiber material and/or the electrospray sprayers.

8. The method for applying according to any one of claims 1 to 7, wherein the preparation step and the spraying step are performed continuously by moving the fiber material comprising the electrolyte solution.

9. The method for applying according to any one of claims 1 to 8, wherein the fiber material is a yarn, woven fabric, nonwoven fabric, knitted fabric, paper, or a film.

10. A method for manufacturing a fiber material, comprising at least one step selected from a group consisting of (1) to (8) below:

(1) a dye treatment step comprising dyeing a fiber material by applying a coating material comprising a dye by the method for applying according to any one of claims 1 to 9;
(2) an antibacterial/deodorizing treatment step comprising imparting an antibacterial activity and/or a deodorizing activity to a fiber material by applying a coating material comprising an antibacterial agent and/or a deodorant by the method for applying according to any one of claims 1 to 9;
(3) a water and oil repelling treatment step comprising imparting a water and oil repelling activity to a fiber material by applying a coating material comprising a water and oil repellent by the method for applying according to any one of claims 1 to 9;
(4) a flame retardant treatment step of making a fiber material less flammable by applying a coating material comprising a flame retardant by the method for applying according to any one of claims 1 to 9;
(5) a bleaching treatment step comprising bleaching a fiber material by applying a coating material comprising a bleaching agent by the method for applying according to any one of claims 1 to 9;
(6) a softening treatment step comprising softening a fiber material by applying a coating material comprising a softener by the method for applying according to any one of claims 1 to 9;
(7) a sizing treatment step comprising sizing a fiber material by applying a coating material comprising a sizing agent by the method for applying according to any one of claims 1 to 9; and
(8) an anti-fouling treatment step comprising imparting an anti-fouling activity to a fiber material by applying a coating material comprising an anti-fouling agent by the method for applying according to any one of claims 1 to 9.

11. The method for manufacturing a fiber material according to claim 10, further comprising at least one step selected from a group consisting of a fiber forming step, a stretching step, a spinning step, a knitting and weaving step, and a scouring step.

12. An apparatus for processing a fiber material, comprising: an electrolyte solution contact mechanism performing at least one selected from a group consisting of immersing the fiber material into an electrolyte solution, spraying the electrolyte solution onto the fiber material, and dropping the electrolyte solution onto the fiber material; an electrospray sprayer that sprays a coating material toward the fiber material comprising the electrolyte solution; and a fiber material feed mechanism for moving the fiber material comprising the electrolyte solution to a spray target for the electrospray sprayer.

13. The apparatus for processing a fiber material according to claim 12, comprising two or more electrospray sprayers.

14. The apparatus for processing a fiber material according to claim 12 or 13, comprising an electrospray sprayer that sprays at least one coating material selected from a group consisting of (1) to (8) below as the electrospray sprayer:

(1) a coating material comprising a dye;
(2) a coating material comprising an antibacterial agent and/or a deodorant;
(3) a coating material comprising a water and oil repellent;

(4) a coating material comprising a flame retardant;
(5) a coating material comprising a bleaching agent;
(6) a coating material comprising a softener;
(7) a coating material comprising a sizing agent; and
(8) a coating material comprising an anti-fouling agent.

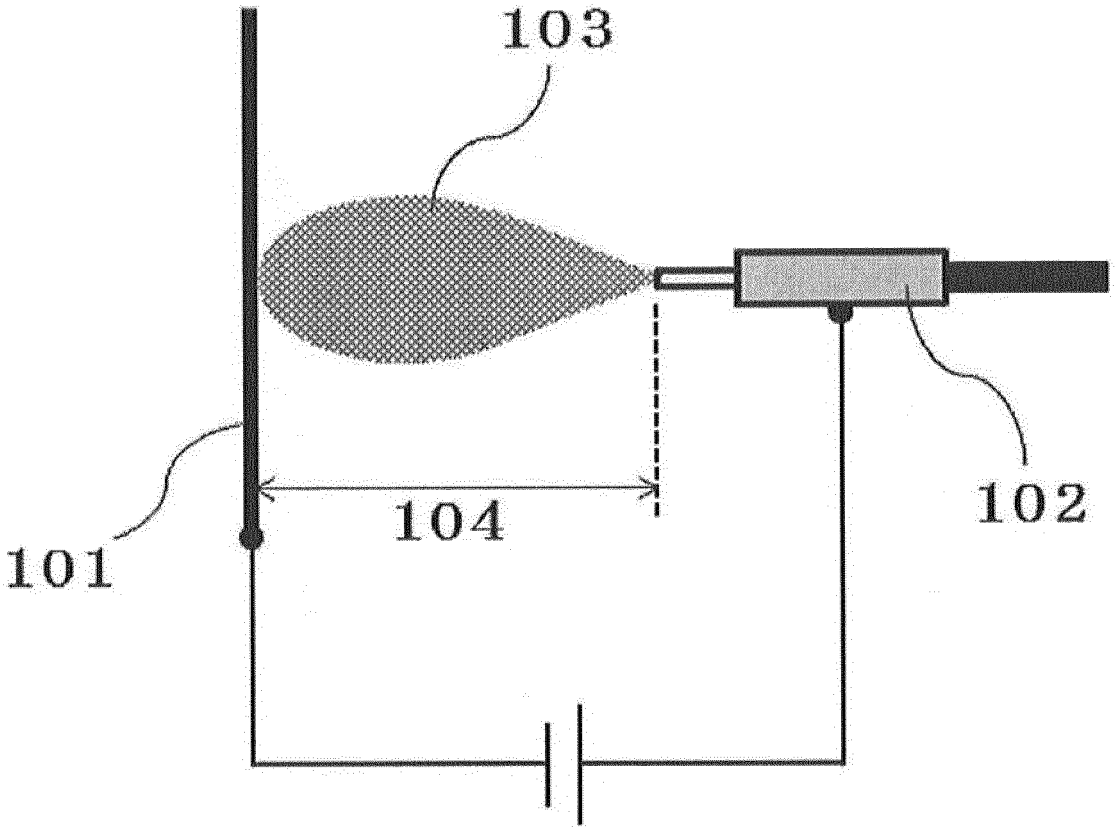

Fig.1

Fig.2(A)

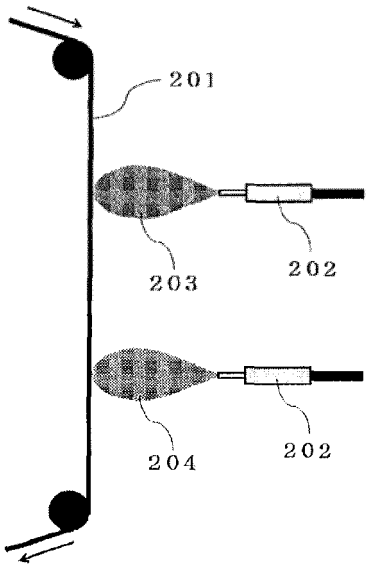

Fig.2(B)

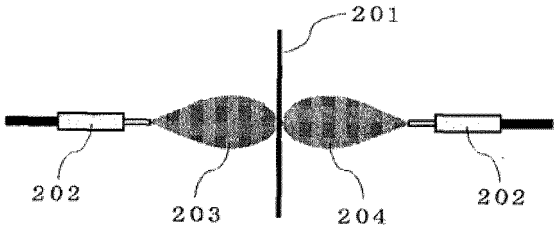

Fig.2(C)

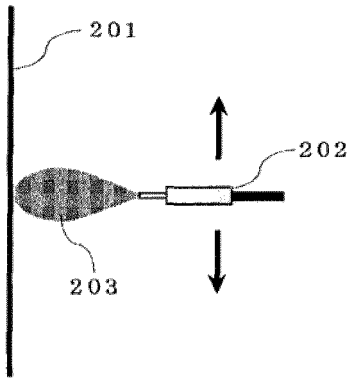

Fig.2

Fig.3(A)

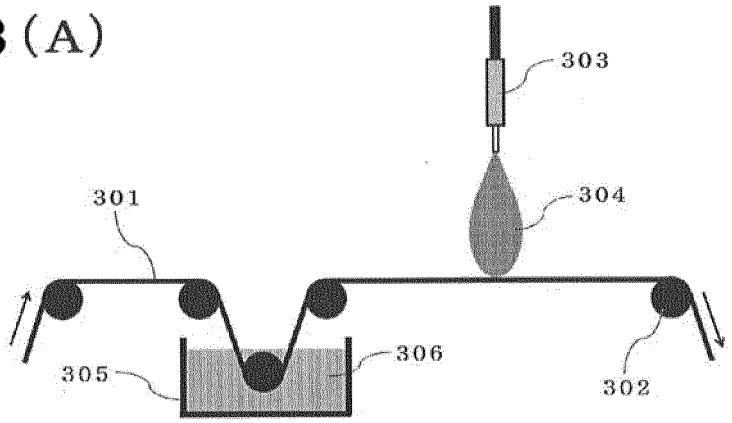

Fig.3(B)

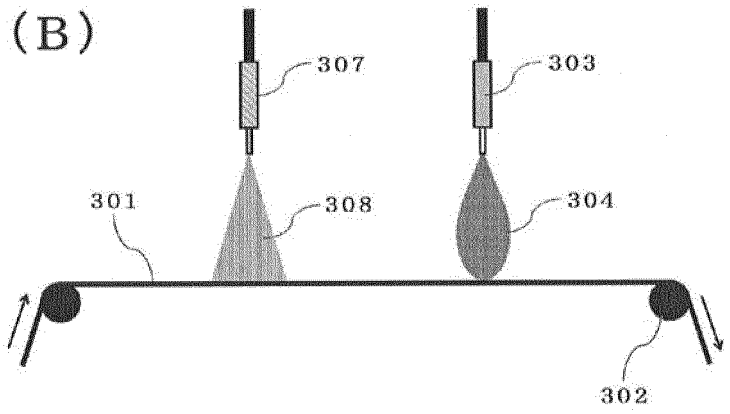

Fig.3(C)

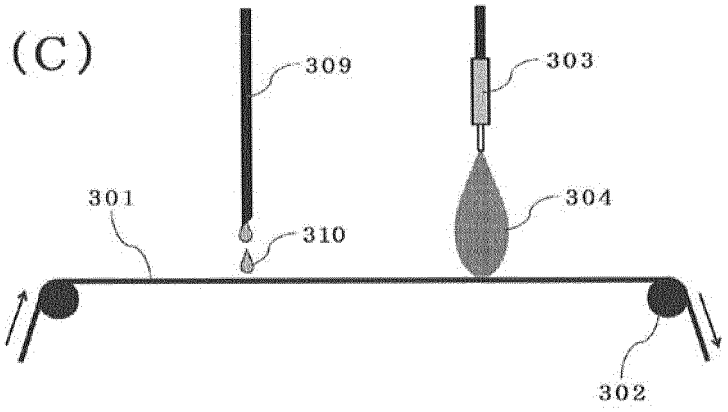

Fig.3

Fig.4(A)

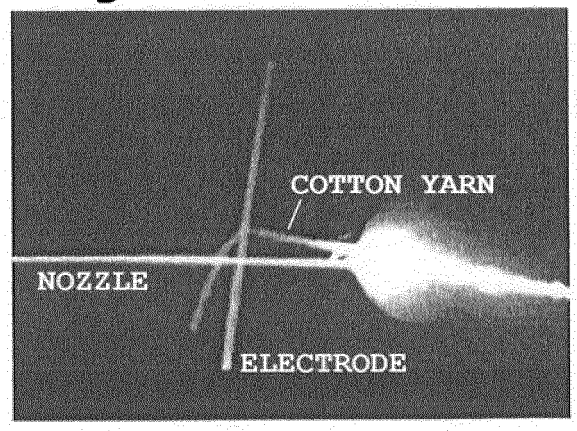

Fig.4(B)

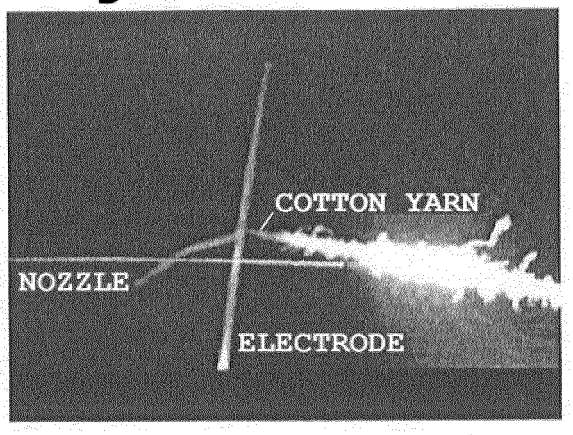

Fig.4(C)

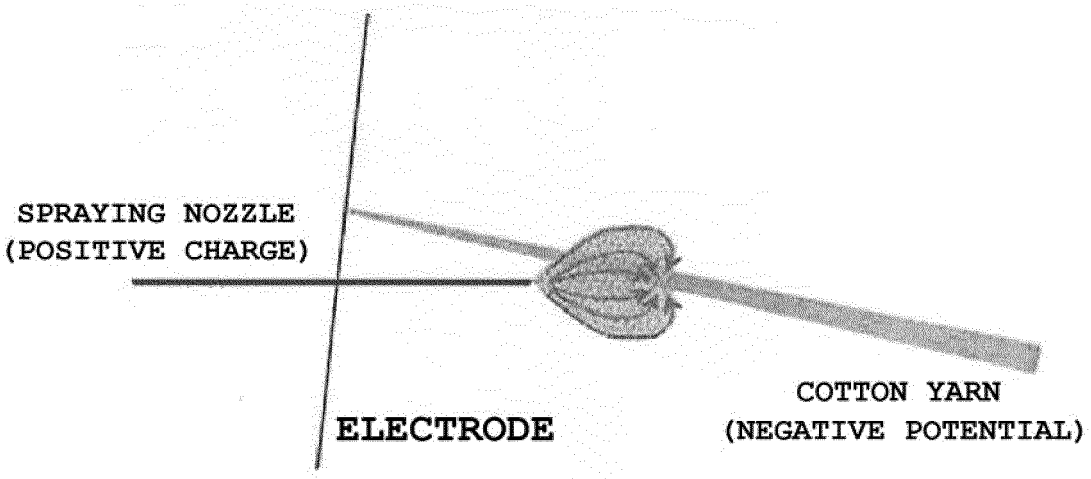

Fig.4

Fig.5 (A)

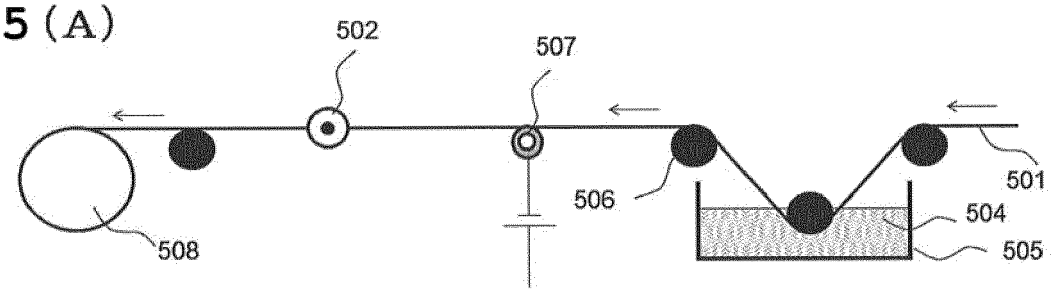

Fig.5 (B)

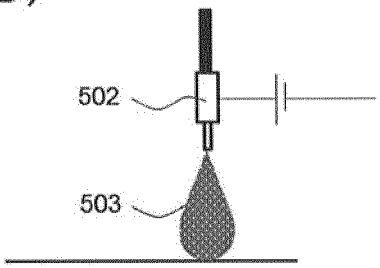

Fig.5

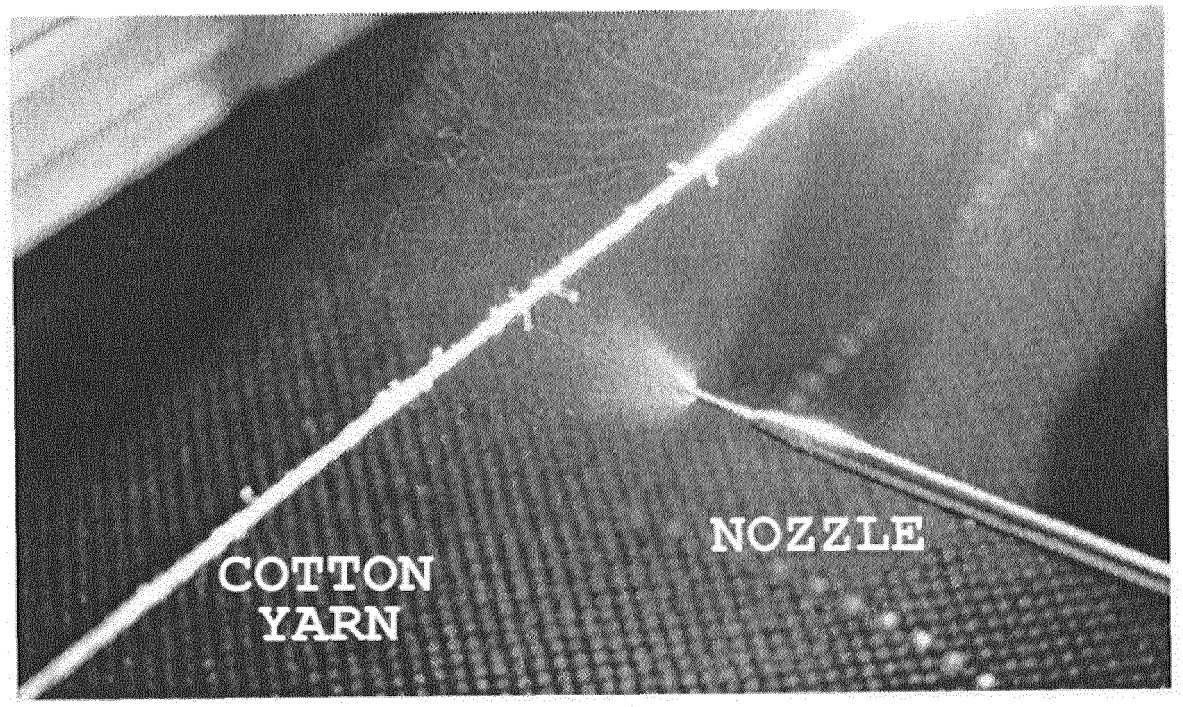

Fig.6

Fig.7(A)

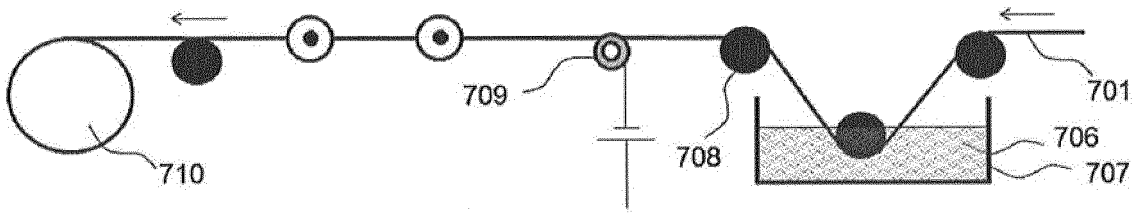

Fig.7(B)

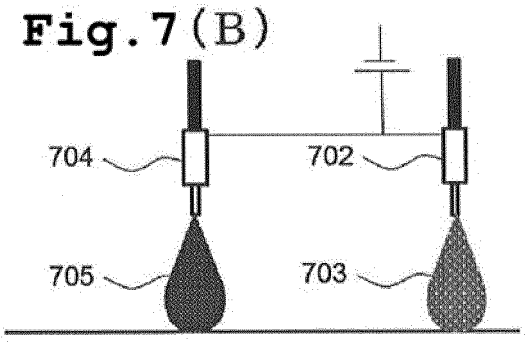

Fig.7(C)

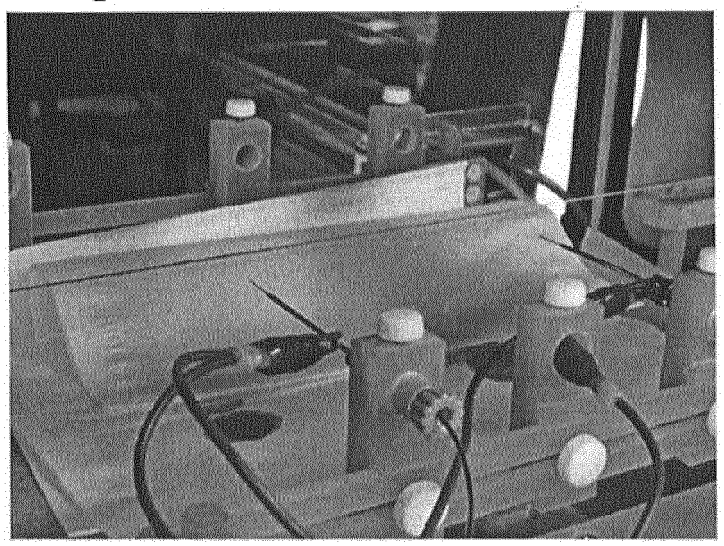

Fig.7

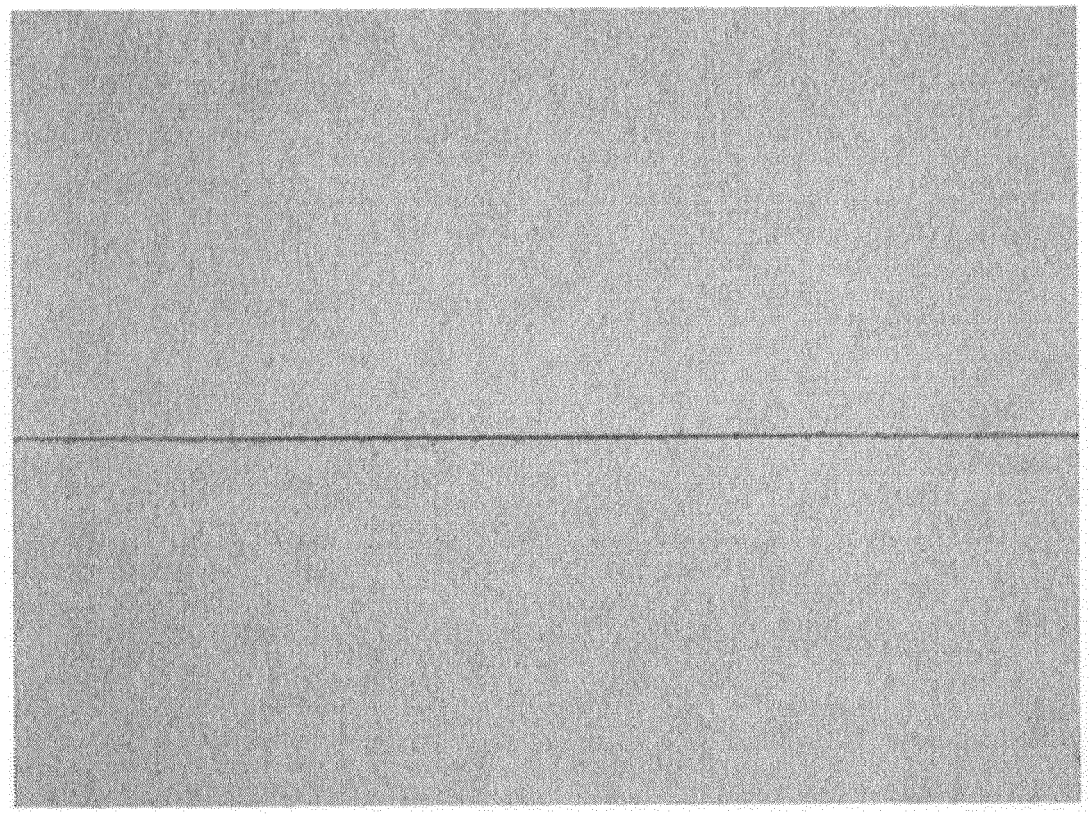

Fig.8

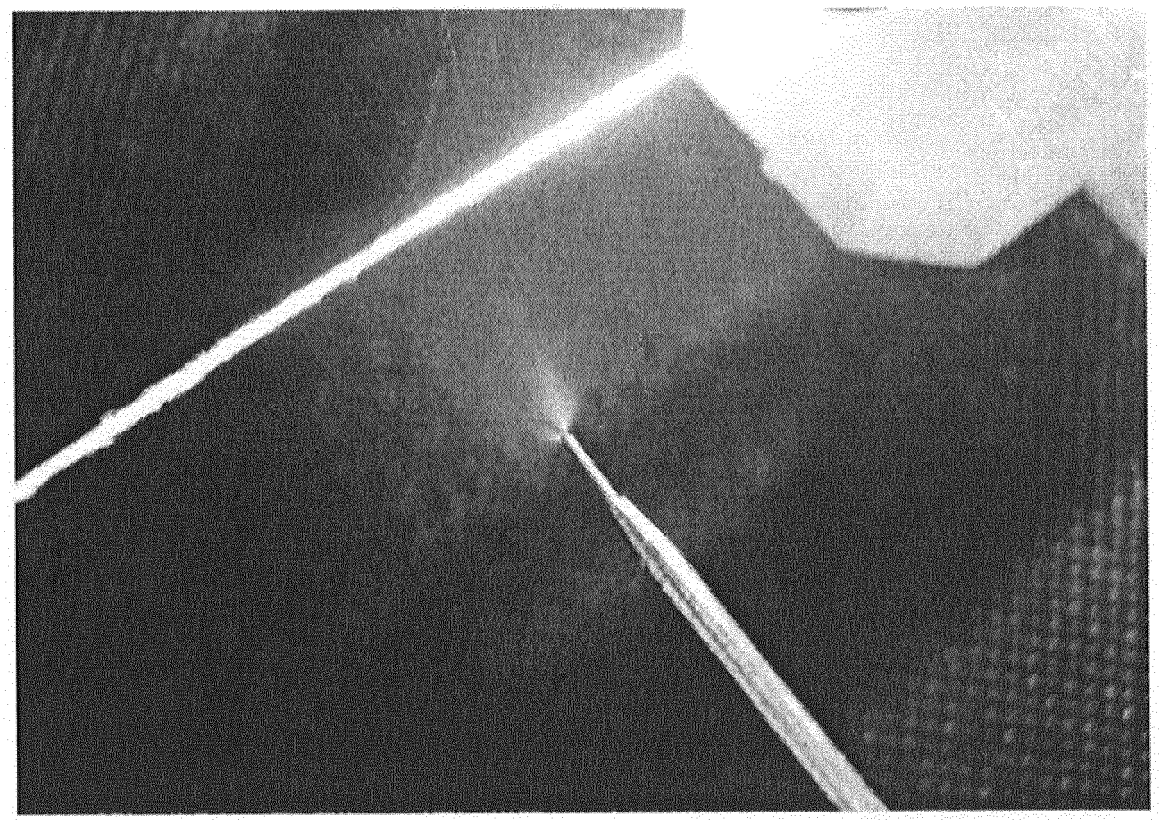

Fig.9

Fig.10 (A)

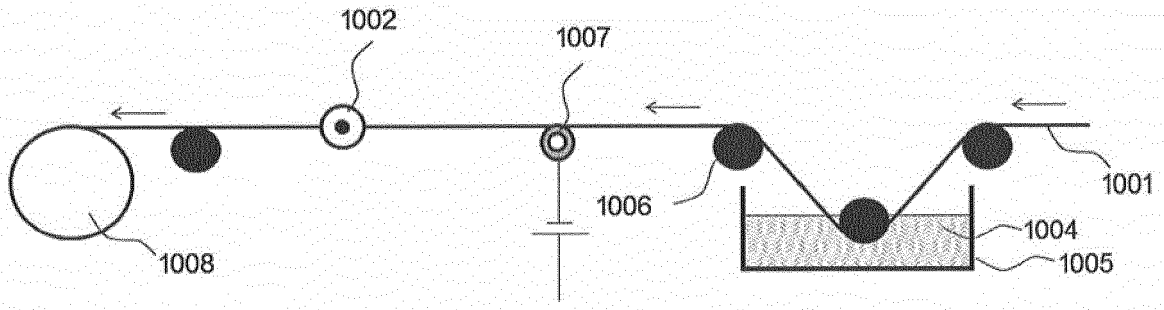

Fig.10 (B)

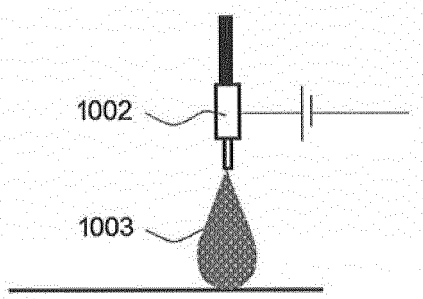

Fig.10

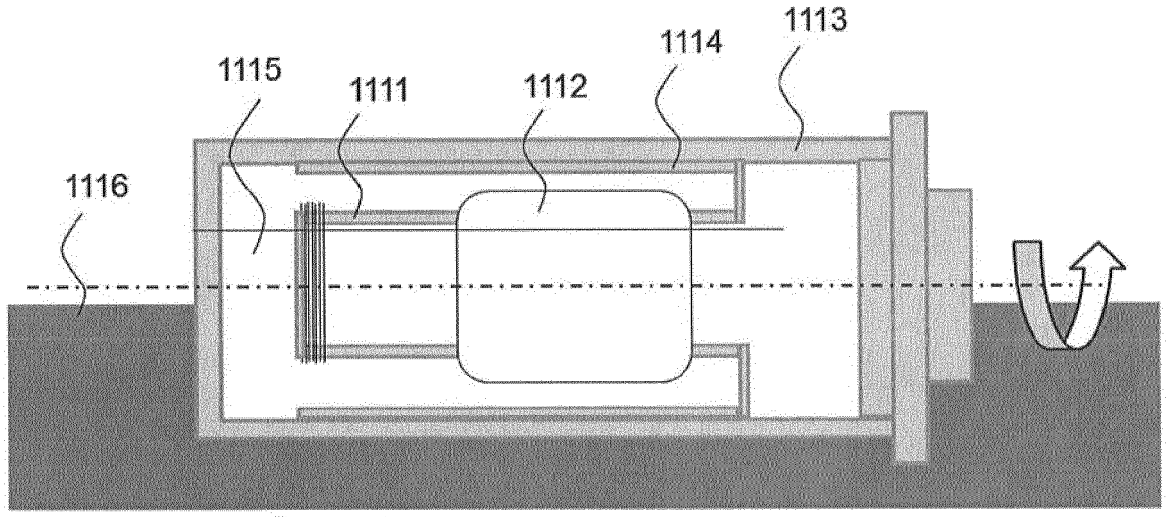

Fig.11

Fig.12 (A)

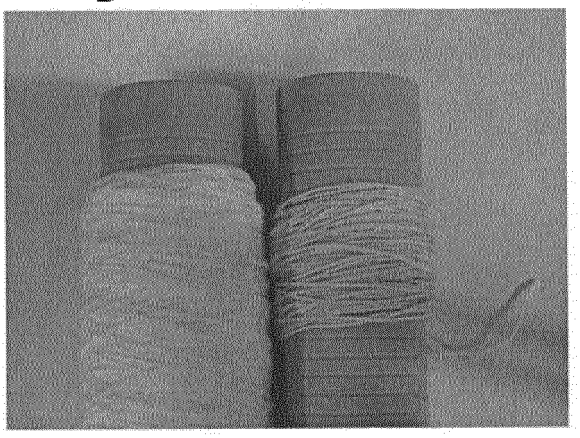

Fig.12 (B)

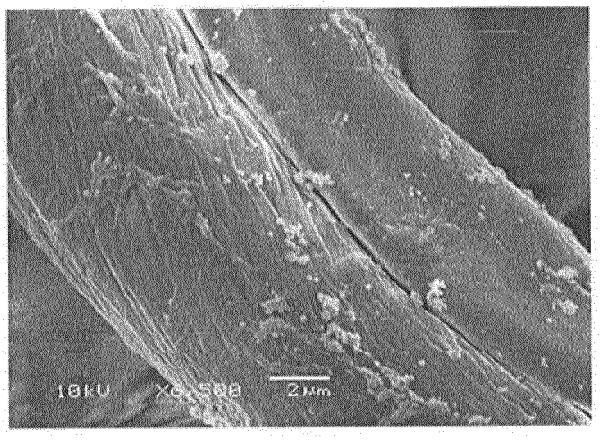

Fig.12

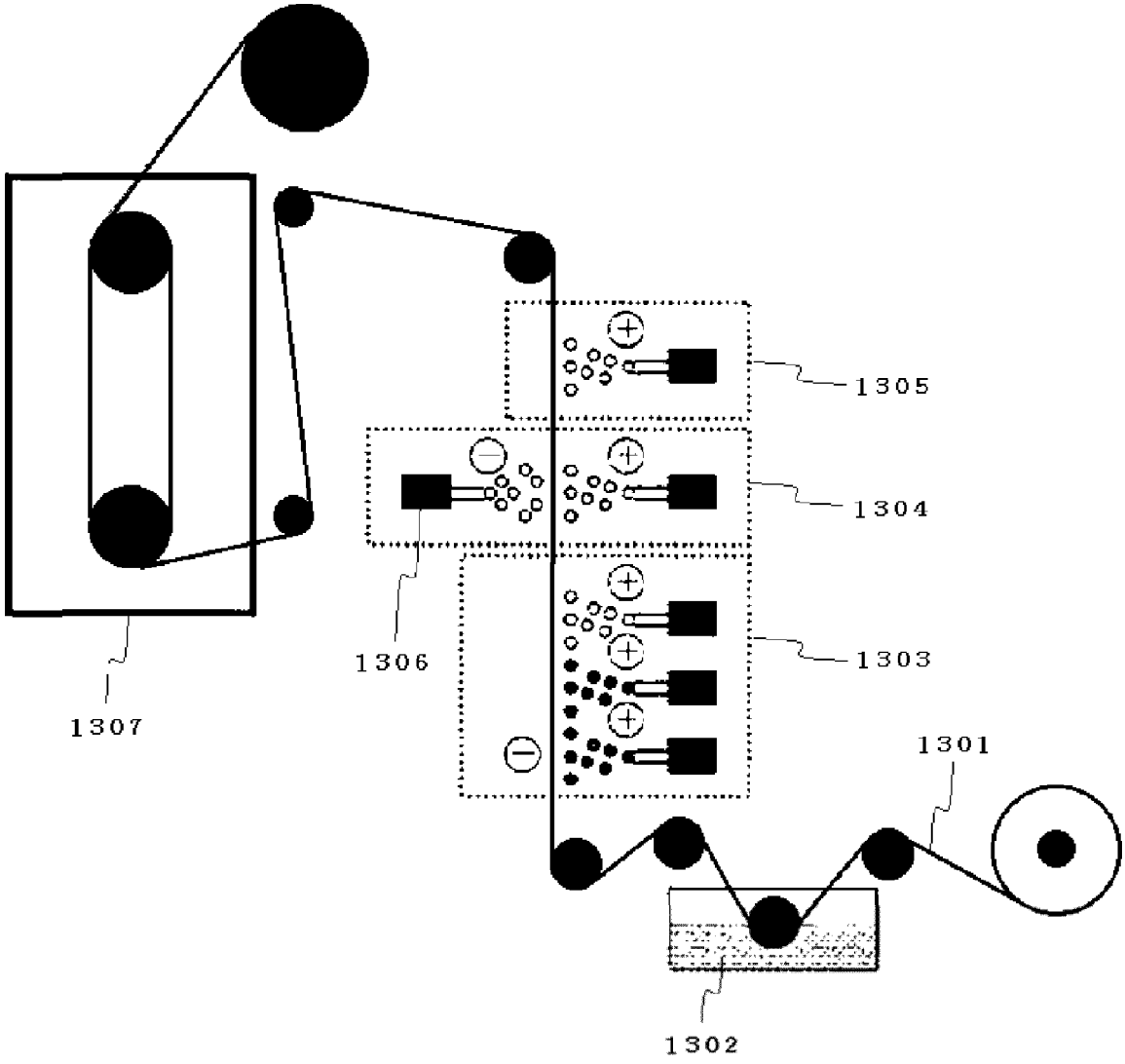

Fig.13

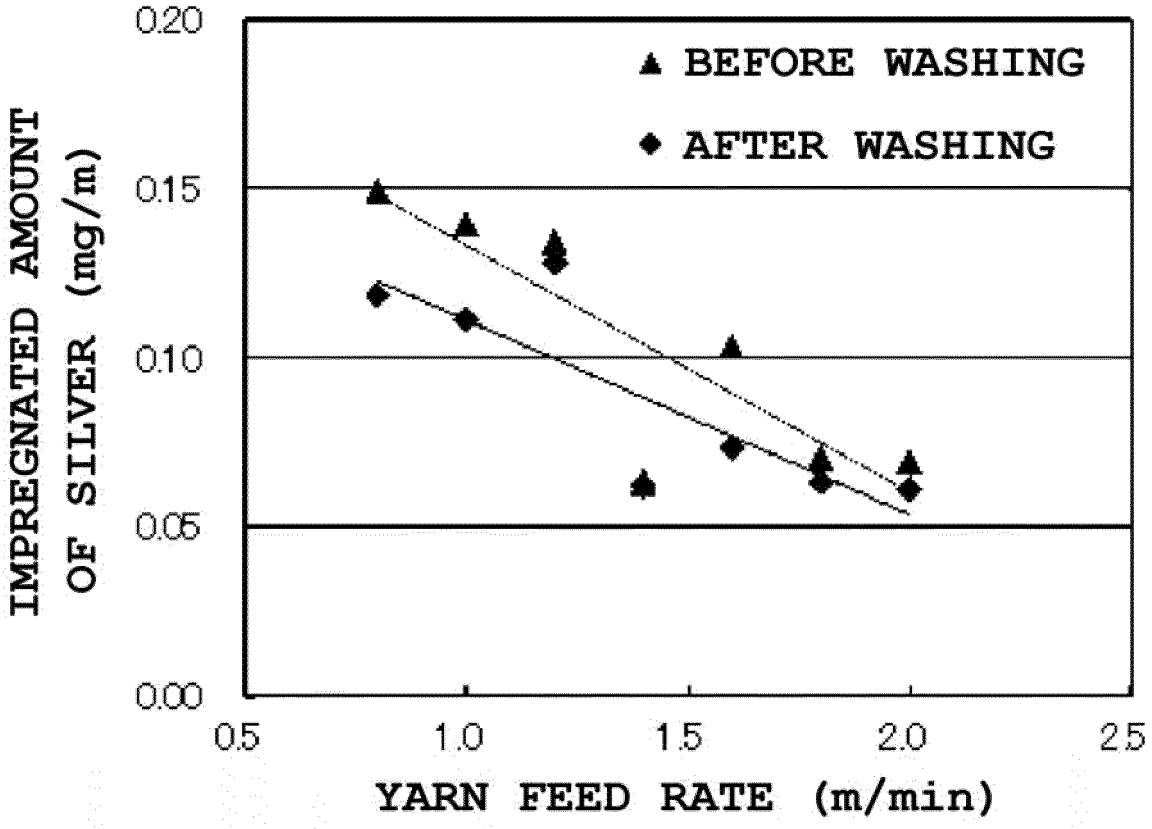
0.20
0.15
0.10
0.05
0.00
0.5
1.0
1.5
2.0
2.5
BEFORE WASHING
AFTER WASHING
IMPREGNATED AMOUNT OF SILVER (mg/m)
YARN FEED RATE (m/min)

Fig.14

Fig.15 (A)

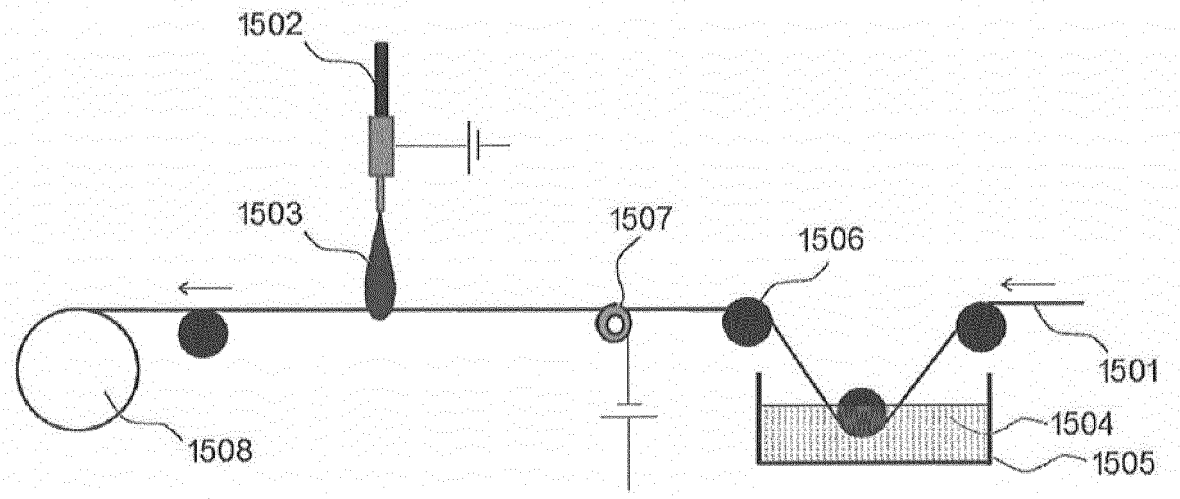

Fig.15 (B)

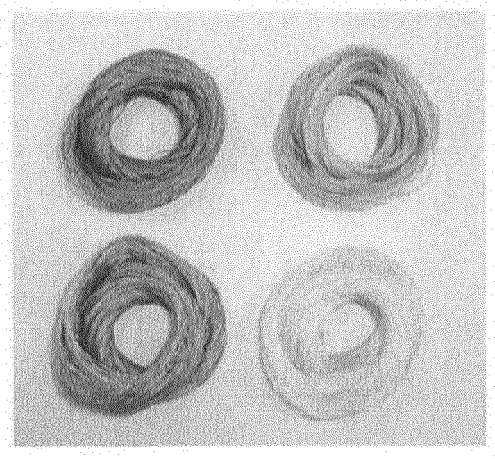

Fig.15

Fig.16 (A)

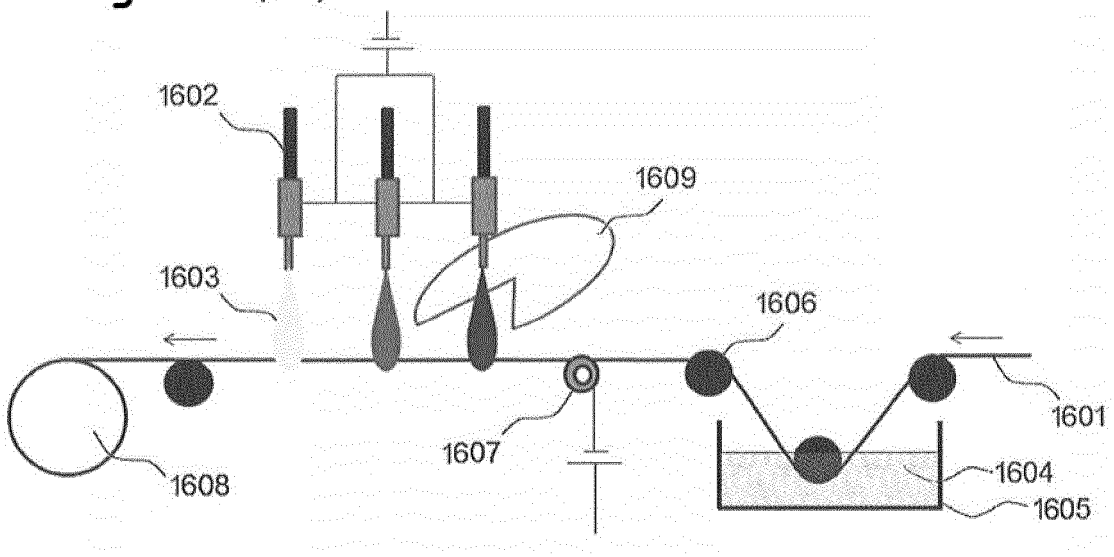

Fig.16 (B)

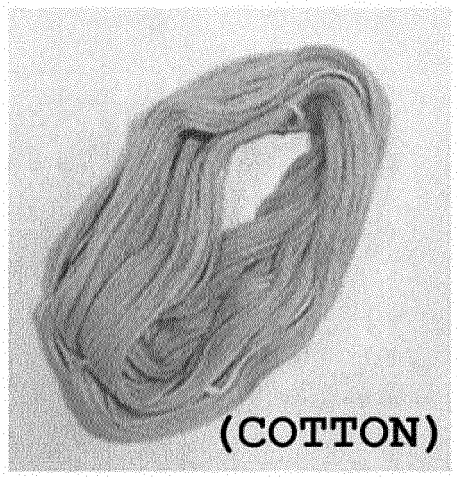

Fig.16

Fig.17(A)

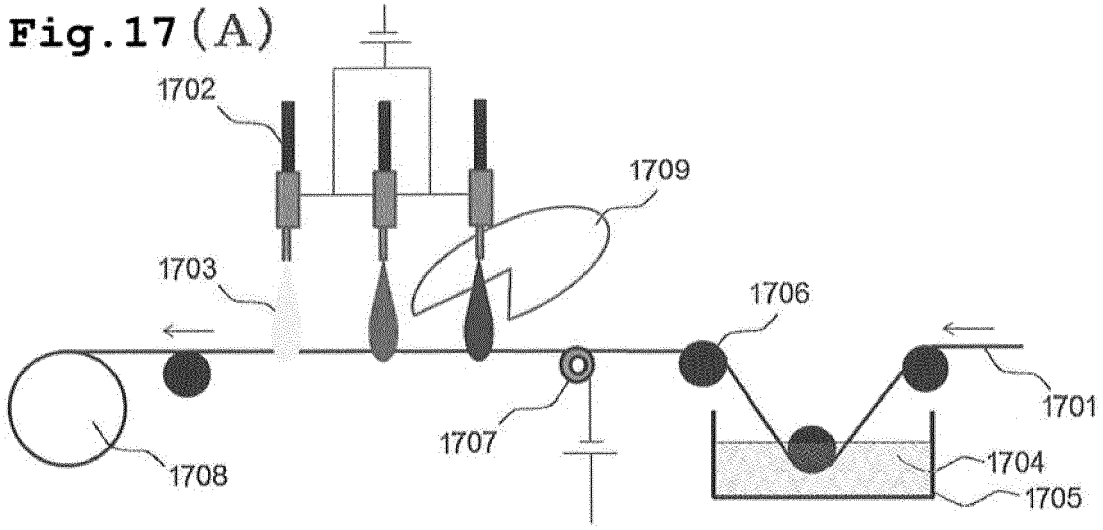

Fig.17(B)

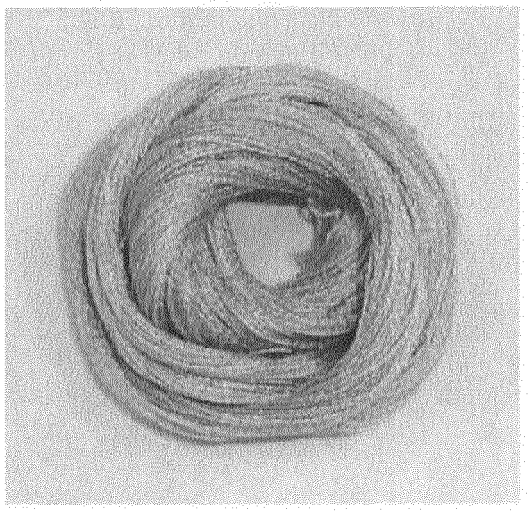

Fig.17

Fig.18 (A)

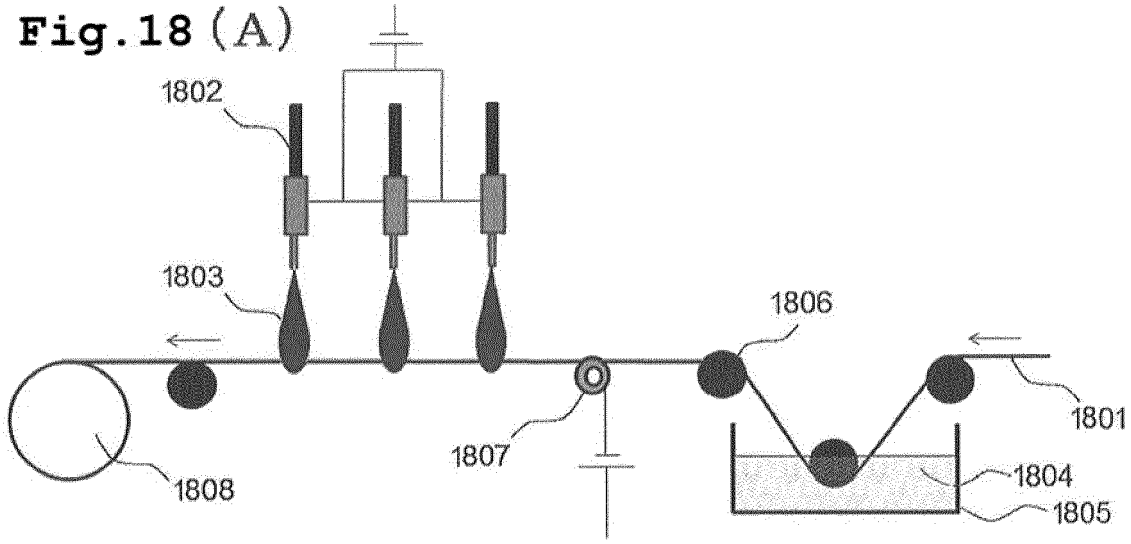

Fig.18 (B)

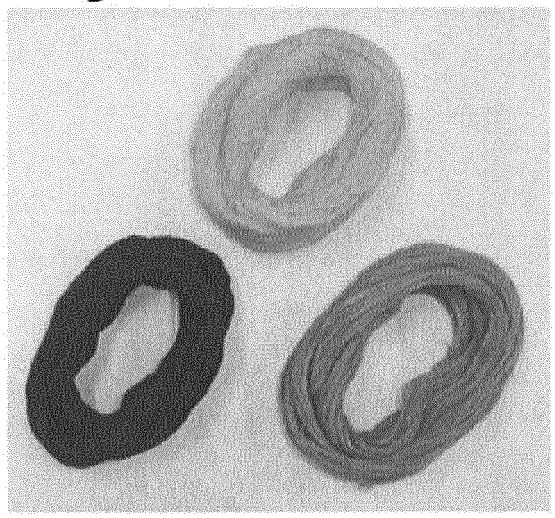

Fig.18

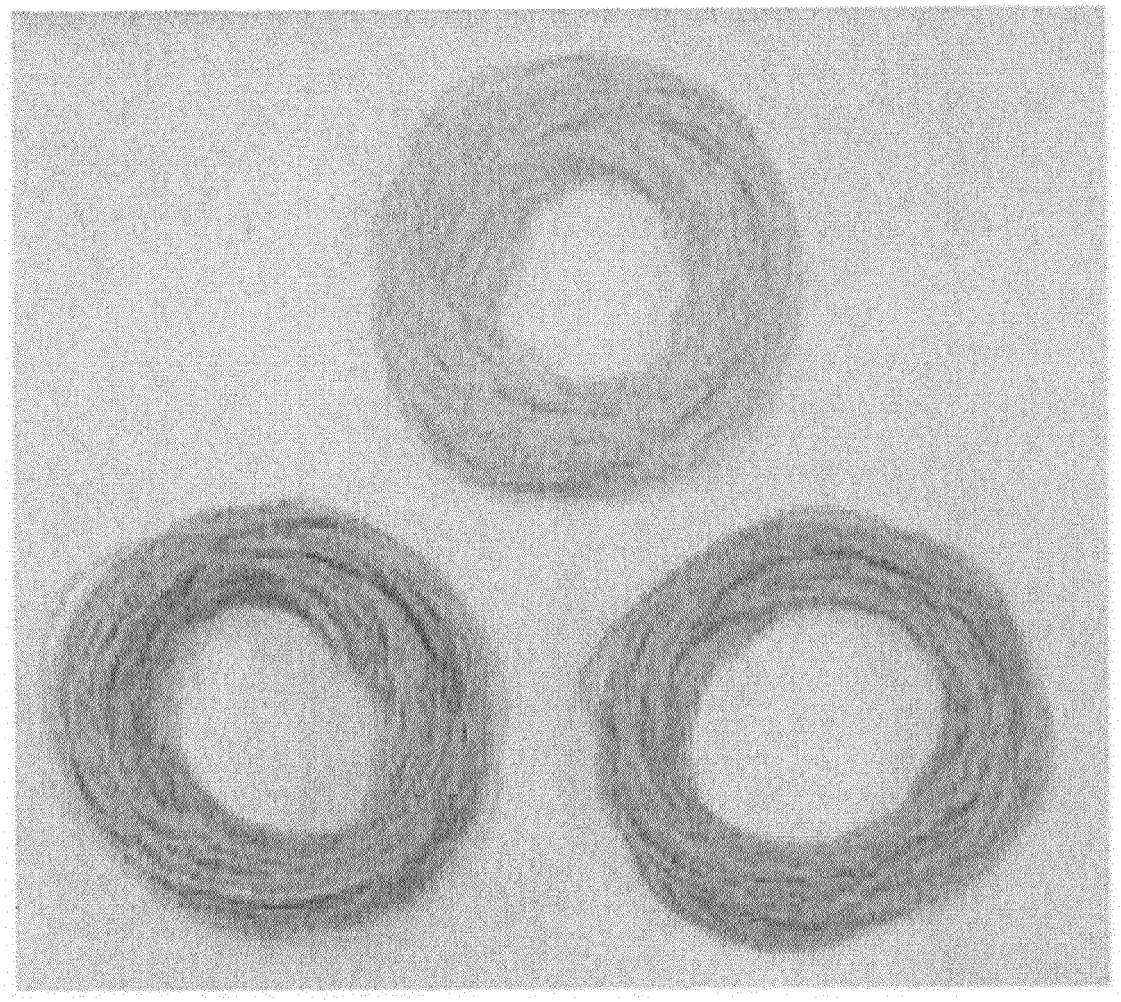

Fig.19

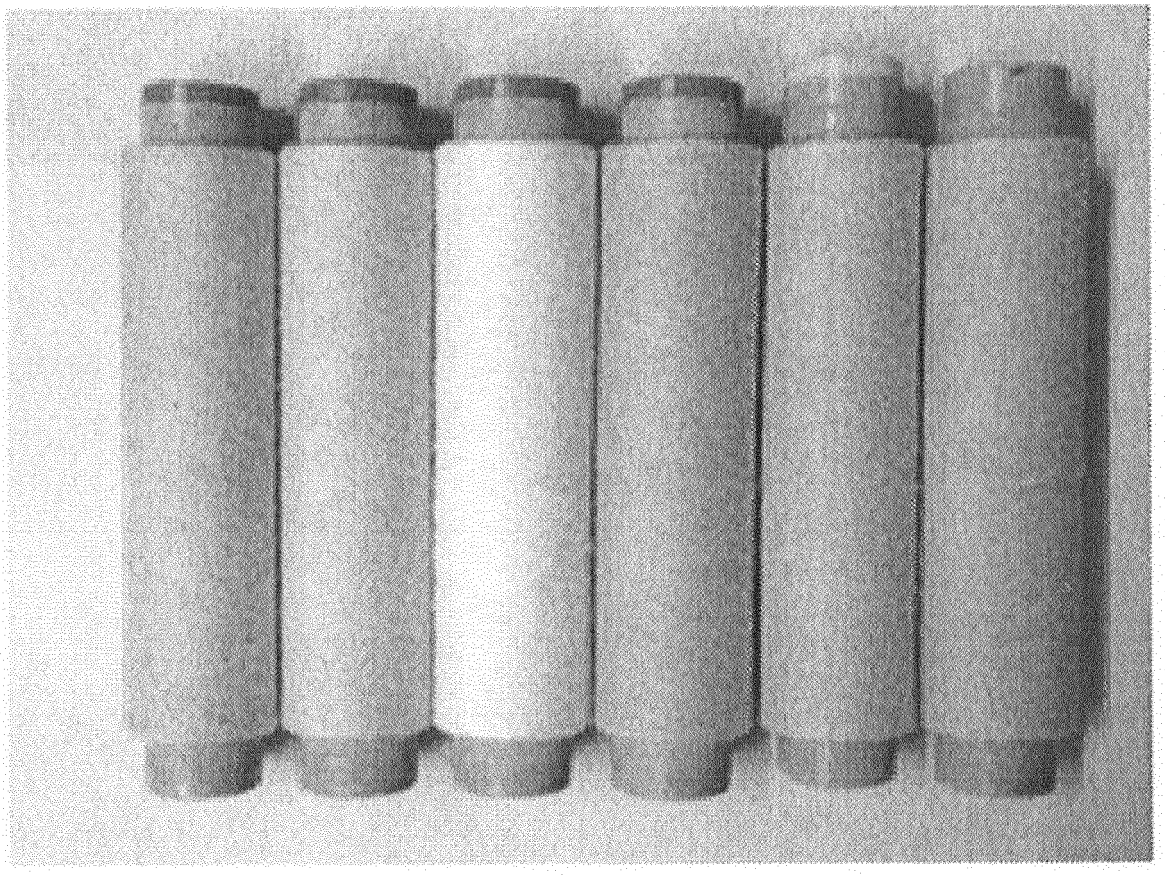

Fig.20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/078082

A. CLASSIFICATION OF SUBJECT MATTER
D06M11/76(2006.01)i, *B05D1/04*(2006.01)i, *B05D7/00*(2006.01)i, *B05D7/20*(2006.01)i, *D06M11/38*(2006.01)i, *D06M11/55*(2006.01)i, *D06M11/57*(2006.01)i, *D06M11/83*(2006.01)i, *D06P3/60*(2006.01)i, *D06P5/20*(2006.01)i
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D06M10/00-16/00, D06M19/00-23/18, B05D1/00-7/26, D06P1/00-7/00, B05B5/00-5/16, D06B1/00-23/30, D06C3/00-29/00, D06G1/00-5/00, D06H1/00-7/24, D06J1/00-1/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015
Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 30-003827 B1 (Director General, Agency of Industrial Science and Technology), 06 June 1955 (06.06.1955), entire text (Family: none)	1-3,6-9,12,13 4,10,11,14 5
X Y A	JP 07-290469 A (Unitika Ltd.), 07 November 1995 (07.11.1995), claims; paragraphs [0009], [0017], [0018] (Family: none)	1-3,6-9,12,13 4,10,11,14 5
Y A	JP 2001-098458 A (Shinshu Ceramics Co., Ltd.), 10 April 2001 (10.04.2001), claims 4, 5; paragraphs [0001], [0054] to [0065]; fig. 5 (Family: none)	4,10,11,14 1-3,5-9,12,13

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 January 2015 (16.01.15)	27 January 2015 (27.01.15)
Name and mailing address of the ISA/ Japan Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/078082

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 08-049161 A (NS Brain Co., Ltd.), 20 February 1996 (20.02.1996), claims; paragraphs [0001], [0020], [0021] (Family: none)	4,10,11,14 1-3,5-9,12, 13
Y A	JP 2009-235373 A (Chugoku Marine Paints, Ltd.), 15 October 2009 (15.10.2009), claims; paragraph [0068] (Family: none)	4,10,11,14 1-3,5-9,12, 13
A	JP 2006-283234 A (National Institute of Advanced Industrial Science and Technology), 19 October 2006 (19.10.2006), claims; paragraph [0012] (Family: none)	1-14
A	JP 01-207473 A (Mitsubishi Metal Corp.), 21 August 1989 (21.08.1989), page 2, upper left column, line 19 to upper right column, line 5 (Family: none)	1-14

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2013006174 A **[0004]**
- JP H06215729 B **[0004]**
- JP 2007070738 A **[0004]**