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(54) **YARN AND FABRIC**

(57) Provided is a yarn containing a potential-generating filament. The yarn is characterized in that the yarn has a specific permittivity of 4.5 or less. Also provided is a fabric that is characterized by containing the yarn.

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Description

Background of the Invention

1. Field of the Invention

[0001] The present invention relates to a yarn, more specifically, a yarn capable of forming an electric field by surface charge, more specifically, capable of generating a potential. The present invention also relates to a fabric, more specifically, a fabric containing the above-mentioned yarn.

2. Description of the Related Art

[0002] Many proposals have heretofore been made as fibrous materials having antibacterial properties (for example, JP-B2-3281640, JP-A-7-310284, JP-B2-3165992, JP-B2-1805853, JP-A-8-226078, JP-A-9-194304, JP-A-2004-300650, and JP-B2-6428979).

Summary of the Invention

[0003] The present inventors have found that conventional fibrous materials having antibacterial properties have problems to overcome, and have found that there is a need to make improvements thereon.
Specifically, the present inventors have found that there are the following problems.

[0004] As a conventional fibrous material having antibacterial properties, in particular, an antibacterial yarn containing a plurality of charge-generating fibers that generate charges by external energy, e.g., external force such as tension is known (for example, JP-B2-6428979). Such an antibacterial yarn is characterized in that the state of spaces between the plurality of charge-generating fibers is not uniform, and thereby the antibacterial yarn exhibits antibacterial properties by generating a bias in electrical characteristics and forming a locally strong electric field.

[0005] However, according to the research by the present inventors, it has been found that the electric field that can be formed has a decreased electric field intensity depending on the state of spaces between charge-generating fibers, especially the physical properties such as permittivity of the dielectric existing between the charge-generating fibers, and antibacterial properties may not be obtained. In addition, physical property values from which antibacterial properties can be easily confirmed were also unknown.

[0006] The present invention has been devised in view of such problems, and a main object of the present invention is to find a physical property value with which antibacterial properties can be more reliably obtained and provide a yarn capable of being used as an antibacterial yarn. It is also an object of the present invention to provide a fabric containing the above-mentioned yarn.

[0007] As a result of intensive research, the present inventors have focused on a permittivity, especially a "specific permittivity", as physical properties of a yarn containing charge-generating fibers (in other words, fibers or filaments capable of generating a potential and forming an electrical field by generating charges (hereinafter, referred to as a "potential-generating filament" or an "electric field-forming filament") as described in more detail below), and they have found that when the value of the permittivity is "about 4.5 or less", antibacterial properties are more reliably obtained and the yarn can be successfully used as an antibacterial yarn. As a result, the present inventors have accomplished the invention of a yarn that has achieved the main object described above.

[0008] The present invention provides a yarn comprising a potential-generating filament, wherein the yarn has a specific permittivity of about 4.5 or less. The present invention also provides a fabric comprising the yarn.

[0009] According to the present invention, it is possible to provide products such as a yarn capable of more reliably exhibiting antibacterial properties (more preferably, an antibacterial yarn), and a fabric containing such a yarn (more preferably, an antibacterial fabric).

Brief Description of the Drawings

[0010]

Fig. 1(A) is a diagram illustrating the configuration of a yarn 1 (S yarn), Fig. 1(B) is a cross-sectional view taken along line A-A of Fig. 1(A), and Fig. 1(C) is a cross-sectional view taken along line B-B of Fig. 1(A);
Figs. 2(A) and 2(B) are diagrams showing a relationship among a uniaxial drawing direction of polylactic acid, an electric field direction, and deformation of a potential-generating filament (or piezoelectric fiber) 10;
Fig. 3(A) is a diagram illustrating the configuration of a yarn 2 (Z yarn), Fig. 3(B) is a cross-sectional view taken along line A-A of Fig. 3(A), and Fig. 3(C) is a cross-sectional view taken along line B-B of Fig. 3(A);

Fig. 4 is a cross-sectional view schematically illustrating a cross section of a yarn of the present disclosure having a dielectric 100 around the potential-generating filament 10;

Fig. 5 is a graph showing a relationship between a specific permittivity (ε) of a dielectric and an electric field intensity (V/μm);

Fig. 6 is a schematic view briefly illustrating a method of measuring the impedance of a yarn of the present disclosure using an LCR meter;

Fig. 7 is a graph showing a relationship between an interval d (μm) between potential-generating filaments and an electric field intensity (V/μm);

Fig. 8 shows a result of a preliminary test for confirming an antibacterial action by electrical stimulation;

Fig. 9(a) is a photograph showing the state of Trichophyton before and after voltage application for a sample of 20 V × 5 Hz in the table of Fig. 8, and Fig. 9(b) is a photograph showing a sample of 50 V × 5 Hz in the table of Fig. 8;

Fig. 10 is a photograph showing the Trichophyton used in the preliminary test;

Fig. 11 is a schematic view schematically illustrating a method of preparing a yarn bundle sample;

Fig. 12 is a photograph illustrating one example of a method of measuring the specific permittivity of a yarn with a yarn bundle sample; and

Fig. 13 is a schematic view schematically illustrating a method of measuring the specific permittivity of a yarn in a yarn bundle sample.

Detailed Description of the Invention

[0011] Hereinafter, a yarn according to one embodiment of the present invention (hereinafter, sometimes briefly referred to as "yarn of the present disclosure" or simply "yarn") will be described in detail. Although the description will be made with reference to the drawings as necessary, elements in the drawings are merely schematically and exemplarily shown for understanding of the present invention, and appearance, dimensional ratios, and the like may differ from actual ones.

[0012] The yarn of the present disclosure contains a "potential-generating filament", and is characterized in that the "specific permittivity" as a physical property thereof is "about 4.5 or less". With such a configuration and characteristic, the yarn of the present disclosure can more reliably exhibit "antibacterial property" described in detail below, and can be used as an "antibacterial yarn".

[0013] The numerical ranges referred to herein are intended to include the lower and/or upper numerical limits themselves, unless otherwise noted, such as "less than" or "more than/greater than". That is, taking the numerical range of 1 to 10 as an example, it can be interpreted as including the lower limit value "1" and the upper limit value "10".

[0014] In addition, some numerical values may be attached with "about", and the term "about" means that the numerical values may include variations of several percent, for example, ± 9%, ± 4%, ± 2%, or ± 1%.

[0015] Hereinafter, [basic configuration of yarn] and [characteristics of yarn] will be described in detail.

[Basic configuration of yarn]

[0016] The yarn of the present disclosure contains, for example, a plurality of "potential-generating filaments" or "electric field-forming filaments". The number of the potential-generating filaments or the electric field-forming filaments is not particularly limited, and for example, 2 or more, 2 to 500, preferably 10 to 350, and more preferably about 20 to 200 potential-generating filaments may be included in the yarn of the present disclosure.

[0017] In the present disclosure, a "potential-generating filament" or an "electric field-forming filament" means a fiber (or filament) capable of generating a potential and forming an electric field by generating charges by external energy (hereinafter, it may be referred to as "charge-generating fiber" or "charge-generating filament" or "electric field-forming fiber").

[0018] The term "potential-generating filament" can be used substantially synonymously with "electric field-forming filament".

[0019] Examples of the "external energy" which the potential-generating filament can receive include force from outside (hereinafter, sometimes referred to as "external force"), specifically, force which makes a yarn or filament to have deformation or strain and/or a force which is applied in the axial direction of a yarn or filament, more specifically, tension (e.g., tension in the axial direction of a yarn or filament) and/or stress or strain force (tensile stress or tensile strain applied to a yarn or filament) and/or external force such as force applied in the transverse direction of a yarn or filament.

[0020] The dimension (length, thickness (diameter), and the like) and the shape (cross-sectional shape and the like) of the potential-generating filament are not particularly limited. The yarn of the present disclosure containing such a potential-generating filament may contain a plurality of potential-generating filaments differing in thickness. Therefore, the yarn of the present disclosure may or may not have a constant diameter in the length direction.

[0021] The potential-generating filament may be a long fiber or may be a short fiber. The potential-generating filament may have a length (or dimension) of, for example, 0.01 mm or more, preferably 0.1 mm or more, more preferably 1 mm or more, even more preferably 10 mm or more, or 20 mm or more, or 30 mm or more. The length may be appropriately chosen according to a desired application. The upper limit value of the length is not particularly limited, and is, for example, 10,000 mm, 100 mm, 50 mm, or 15 mm.

[0022] The thickness of the potential-generating filament, that is, the single fiber diameter is not particularly limited, and may be the same (or constant) or may not be the same along the length of the potential-generating filament. The potential-generating filament may have a single fiber diameter of, for example, 0.001 μm (1 nm) to 1 mm, preferably 0.01 μm to 500 μm, more preferably 0.1 μm to 100 μm, and particularly 1 μm to 50 μm, such as 10 μm or 30 μm. The single fiber diameter may be appropriately chosen according to a desired application.

[0023] The shape, especially, cross-sectional shape of the potential-generating filament is not particularly limited, and may have, for example, a circular, elliptical, or profiled cross section. It is preferable to have a circular cross-sectional shape.

[0024] The potential-generating filament preferably contains a material having a photoelectric effect, a material having a pyroelectric effect, or a material having a piezoelectric effect (polarization phenomenon due to external force) or piezoelectricity (the property of generating a voltage when a mechanical strain is applied or, conversely, generating a mechanical strain when a voltage is applied) (hereinafter, sometimes referred to as a "piezoelectric material" or a "piezoelectric substance"). Among them, it is particularly preferable to use a fiber containing a piezoelectric material (hereinafter, sometimes referred to as "piezoelectric fiber"). Since the piezoelectric fiber can form an electric field by piezoelectricity, more specifically, can generate a potential, a power supply is unnecessary, and there is no risk of electric shock. In addition, the life of the piezoelectric material that can be contained in the piezoelectric fiber lasts longer than the antibacterial effect by a chemical agent or the like. Such piezoelectric fibers are less likely to cause allergic reactions.

[0025] As the "piezoelectric material", any material having a piezoelectric effect or piezoelectricity can be used without particular limitation, and may be an inorganic material such as piezoelectric ceramics or may be an organic material such as a polymer.

[0026] The "piezoelectric material" (or "piezoelectric fiber") preferably contains a "piezoelectric polymer".

[0027] Examples of the "piezoelectric polymer" include a "piezoelectric polymer having pyroelectricity" and a "piezoelectric polymer having no pyroelectricity".

[0028] "Piezoelectric polymer having pyroelectricity" generally means a piezoelectric material composed of a polymeric material that has pyroelectricity and is capable of generating charges on its surface upon application of temperature changes. Examples of such a piezoelectric polymer include polyvinylidene fluoride (PVDF). In particular, one capable of generating electric charges on the surface thereof by thermal energy from a human body is preferable.

[0029] "Piezoelectric polymer having no pyroelectricity" generally means a piezoelectric polymer (hereinafter, sometimes referred to as "polymeric piezoelectric substance") composed of a polymer material (polymeric material or resin material) and excluding the "piezoelectric polymer having pyroelectricity" described above. Examples of such a piezoelectric polymer include polylactic acid (PLA).

[0030] As the polylactic acid (PLA), poly-L-lactic acid (PLLA), in which an L-form monomer is polymerized, (in other words, a polymer composed substantially only of repeating units derived from L-lactic acid monomers), poly-D-lactic acid (PDLA), in which a D-form monomer is polymerized, (in other words, a polymer composed substantially only of repeating units derived from D-lactic acid monomers), and mixtures thereof are known.

[0031] As the polylactic acid (PLA), a copolymer of L-lactic acid and/or D-lactic acid with a compound copolymerizable with the L-lactic acid and/or D-lactic acid may be used.

[0032] A mixture of "polylactic acid (a polymer substantially composed of repeating units derived from a monomer selected from the group consisting of L-lactic acid and D-lactic acid)" and "a copolymer of L-lactic acid and/or D-lactic acid and a compound copolymerizable with L-lactic acid and/or D-lactic acid" may also be used.

[0033] In the present disclosure, the polymer containing polylactic acid is referred to as a "polylactic acid-based polymer". In other words, the "polylactic acid-based polymer" means "polylactic acid (a polymer substantially composed of repeating units derived from a monomer selected from the group consisting of L-lactic acid and D-lactic acid)", a "copolymer of L-lactic acid and/or D-lactic acid and a compound copolymerizable with L-lactic acid and/or D-lactic acid", and mixtures thereof.

[0034] Among polylactic acid-based polymers, "polylactic acid" is particularly preferable, and it is most preferable to use a homopolymer of L-lactic acid (PLLA) and a homopolymer of D-lactic acid (PDLA).

[0035] The polylactic acid-based polymer may have a crystalline portion, or at least a part of the polymer may be crystallized. As the polylactic acid-based polymer, it is preferable to use a polylactic acid-based polymer having piezoelectricity, in other words, a piezoelectric polylactic acid-based polymer, especially a piezoelectric polylactic acid.

[0036] Besides the polylactic acid-based polymer, for example, optically active polymers, such as polypeptide-based polymers (e.g., poly(γ-benzyl glutarate) and poly(γ-methyl glutarate)), cellulose-based polymers (e.g., cellulose acetate and cyanoethylcellulose), polybutyric acid-based polymers (e.g., poly(β-hydroxybutyric acid)), and polypropylene oxide-based polymers, and derivatives thereof may be used as a polymeric piezoelectric substance.

[0037] The yarn of the present disclosure may contain a potential-generating filament (or a charge-generating fiber) having a configuration in which a conductor is used as a core yarn, an insulator is wound around the conductor, and a voltage is applied to the conductor to generate charges or a potential.

[0038] The yarn of the present disclosure may be a yarn obtained by simply paralleling a plurality of potential-generating filaments (a paralleled yarn or a non-twisted yarn), or may be a yarn provided with twist (a co-twisted yarn or a twisted yarn), or may be a yarn provided with crimp (a crimped yarn or a false twisted yarn).

[0039] For example, as illustrated in Fig. 1(A), the yarn 1 can be configured by co-twisting a plurality of potential-generating filaments 10. In an aspect illustrated in Fig. 1(A), the yarn 1 is a left-twisted yarn (hereinafter, referred to as "S yarn") in which the potential-generating filament 10 is twisted to the left, but may be a right-twisted yarn (hereinafter, referred to as "Z yarn") in which the potential-generating filament 10 is twisted to the right (see, e.g., yarn 2 of Fig. 3(A)). Thus, in the case of a co-twisted yarn, the yarn of the present disclosure may be either an "S yarn" or a "Z yarn".

[0040] In the yarn of the present disclosure, the distance between potential-generating filaments 10 is about 0 μm to about 10 μm, typically about 5 μm. When the interval between the potential-generating filaments 10 is 0 μm, it means that the potential-generating filaments are in contact with each other. When being within the above range, in the yarn of the present disclosure, the targeted value of specific permittivity of "about 4.5 or less" described in detail below is suitably obtained, and an antibacterial property can be more reliably exhibited.

[0041] Herein, the specific permittivity of the yarn of the present disclosure means the ratio of the permittivity of the yarn of the present disclosure to the permittivity of a vacuum ([the specific permittivity of the yarn of present disclosure] = [the permittivity of the yarn of present disclosure]/[the permittivity of vacuum]). The specific permittivity is a dimensionless numerical value, and may be referred to as a relative permittivity or a dielectric constant.

[0042] The specific permittivity of the yarn of the present disclosure can be determined, for example, by measuring a capacitance by passing the yarn through a parallel plate capacitor, calculating a capacitance of the yarn from a difference between the measured capacitance and a capacitance attained when the yarn is not passed, determining a permittivity of the yarn of the present disclosure by using the capacitance of the yarn and the volume of the yarn, and then calculating the specific permittivity based on the above formula using a permittivity of a vacuum.

[0043] The method for determining the specific permittivity of the yarn is not limited to the method described above. For example, as described in detail with reference to the photograph of Fig. 12, especially Fig. 12(B), and the like, the specific permittivity of the yarn of the present disclosure may be directly measured using a measuring instrument such as an LCR meter (e.g., Precision LCR Meter (model: E4980A) manufactured by Agilent Technologies, Inc.). In this case, the specific permittivity of the yarn can be directly measured using a yarn bundle (sample) formed by collecting the yarns of the present disclosure (see Figs. 11 to 13).

[0044] The measured value of the specific permittivity in the yarn bundle shows substantially the same result as the calculated value of the specific permittivity of the yarn (one yarn) of the present disclosure based on the capacitance described above.

[0045] Hereinafter, in order to describe the yarn of the present disclosure in detail, the yarn of the present disclosure will be described in more detail with reference to Figs. 1 to 3 by taking an aspect in which a piezoelectric material is contained as a potential-generating filament and the piezoelectric material is "polylactic acid" as an example.

[0046] Polylactic acid (PLA), which can be used as a piezoelectric material, is a chiral polymer, and a main chain thereof has a spiral structure. Polylactic acid can exhibit piezoelectricity when it is uniaxially stretched and molecules thereof are oriented. The piezoelectric constant may be increased by further performing heat treatment to increase the crystallinity. In other words, the "piezoelectric constant" can be increased according to the "crystallinity" (see "A Study of Mechanism of High Piezoelectric Performance Poly(lactic acid) Film Manufactured by Solid-State Extrusion", Journal of the Institute of Electrostatics Japan, 40, 1 (2016) 38-43).

[0047] The optical purity of polylactic acid (PLA) as a piezoelectric material is a value calculated by the following formula.

$$\text{Optical purity (\%)} = \{|\text{the amount of L-form} - \text{the amount of D-form}|/(\text{the amount of L-form} + \text{the amount of D-form})\} \times 100$$

[0048] For example, with both of the D-form and the L-form, the optical purity is 90% by weight or more, preferably 95% by weight or more, more preferably 98% by weight or more and 100% by weight or less, even more preferably 99.0% by weight or more and 100% by weight or less, and particularly preferably 99.0% by weight or more and 99.8% by weight or less. As the amount of the L-form and the amount of the D-form of polylactic acid (PLA), for example, values obtained by a method using high performance liquid chromatography (HPLC) can be used.

[0049] The crystallinity of polylactic acid (PLA) is, for example, 35% or more (specifically, 35% or more and 45% or less, and more specifically, 42% or more and 44% or less), more preferably 50% or more, and even more preferably 55% or more and 100% or less. The crystallinity can be determined by a measurement method such as a method using a differential scanning calorimetry (DSC) (e.g., DSC 7000X manufactured by Hitachi High-Tech Science Corporation) and X-ray diffraction (XRD) (e.g., an X-ray diffraction method using ultraX 18 manufactured by Rigaku Corporation). When the crystallinity is within the above range, the charge and potential that can be generated in the yarn can be more appropriately controlled.

[0050] As illustrated in Fig. 1(A), the potential-generating filament (or piezoelectric fiber) 10 containing uniaxially drawn polylactic acid has tensor components of d_{14} and d_{25} as piezoelectric strain constants where a thickness direction is defined as a first axis, a drawing direction 900 is defined as a third axis, and a direction orthogonal to both the first axis and the third axis is defined as a second axis.

[0051] Therefore, polylactic acid can most efficiently generate charges or a potential when strain occurs in a direction of 45 degrees with respect to the uniaxially drawn direction.

[0052] The number average molecular weight (Mn) of polylactic acid is, for example, 6.2×10^4, and the weight average molecular weight (Mw) is, for example, 1.5×10^5. The molecular weight is not limited to these values.

[0053] Figs. 2(A) and 2(B) are diagrams showing the relationship among the uniaxial drawing direction of polylactic acid, the electric field direction, and the deformation of the potential-generating filament (or piezoelectric fiber) 10.

[0054] As illustrated in Fig. 2(A), when the filament 10 contracts in the direction of a first diagonal line 910A and expands in the direction of a second diagonal line 910B orthogonal to the first diagonal line 910A, an electric field can be generated in a direction from the back side toward the front side of the diagram. That is, the filament 10 can generate negative charges or a potential on the front side of the diagram. As illustrated in Fig. 2(B), the filament 10 can generate charges even when expanding in the direction of the first diagonal line 910A and contracting in the direction of the second diagonal line 910B, but the polarity is reversed, and an electric field can be generated in a direction from the front side of the diagram toward the back side of the diagram. That is, the filament 10 can generate positive charges or a potential on the front side of the diagram.

[0055] Polylactic acid can have piezoelectricity due to molecular orientation processing by drawing, crystallinity, etc., and thus does not need to be subjected to poling processing unlike other piezoelectric polymers such as polyvinylidene fluoride (PVDF) or piezoelectric ceramics. The uniaxially drawn polylactic acid has a piezoelectric constant of about 5 to 30 pC/N, and has a very high piezoelectric constant among polymers. Furthermore, the piezoelectric constant of polylactic acid does not vary with time and is extremely stable.

[0056] The potential-generating filament 10 is preferably a fiber having a circular cross section. The potential-generating filament 10 can be manufactured by, for example, a method of extruding and molding a piezoelectric polymer to form a fiber, a method of melt-spinning a piezoelectric polymer to form a fiber (examples thereof including a spinning-drawing method in which a spinning step and a drawing step are separately performed, a direct drawing method in which a spinning step and a drawing step are connected, a POY-DTY method in which false twisting step can also be performed simultaneously, or an ultrahigh speed spinning method with an increased speed), a method of forming a fiber from a piezoelectric polymer by a dry or wet spinning method (examples thereof including a phase separation method or a dry-wet spinning method in which a feed polymer is dissolved in a solvent and the solution is extruded through a nozzle to form a fiber, a gel-spinning method of uniformly forming a fiber in a gel state with a solvent contained, or a liquid crystal spinning method of forming a fiber using a liquid crystal solution or a liquid crystal melt), or a method of forming a fiber from a piezoelectric polymer by electrostatic spinning. The cross-sectional shape of the potential-generating filament 10 is not limited to a circular shape.

[0057] For example, the yarn 1 illustrated in Fig. 1 may be a yarn obtained by twisting a plurality of such potential-generating filaments 10 containing polylactic acid (multifilament yarn) (S yarn). The number of filaments 10 constituting the yarn 1 is not particularly limited. The drawing direction 900 of each potential-generating filament 10 coincides with the axial direction of each potential-generating filament 10. Therefore, the drawing direction 900 of the potential-generating filament 10 is inclined to the left with respect to the axial direction of the yarn 1. The angle may depend on the number of twists.

[0058] When a tension is applied to the yarn 1, which is such an S yarn, negative charges or a potential is generated on the surface of the yarn 1, and positive charges or a potential can be generated on the inner side thereof.

[0059] The yarn 1 can form an electric field by a potential difference that can be generated by the charge. This electric field leaks also into a space in the vicinity and can form a combined electric field with other portions. Furthermore, when a potential that can be generated in the yarn 1 is brought close to a prescribed potential, for example, an object having a prescribed potential (including a ground potential) such as a human body, the potential can also generate an electric field between the yarn 1 and the object.

[0060] Next, referring to Fig. 3, since the yarn 2 is a Z yarn, the drawing direction 900 of the potential-generating filament (or piezoelectric fiber) 10 is inclined to the right with respect to the axial direction of the yarn 2. The angle can depend on the number of twists of the yarn. The number of filaments 10 constituting the yarn 2 is also not particularly limited.

[0061] When a tension is applied to the yarn 2, which is such a Z yarn, a positive charge or potential is generated on the surface of the yarn 2, and a negative charge or potential can be generated on the inner side thereof.

[0062] The yarn 2 also can form an electric field by a potential difference that can be generated by the charge. This electric field leaks also into a space in the vicinity and can form a combined electric field with other portions. Furthermore, when a potential that can be generated in the yarn 2 is brought close to a prescribed potential, for example, an object having a prescribed potential (including a ground potential) such as a human body, the potential can also generate an electric field between the yarn 2 and the object.

[0063] Furthermore, when the yarn 1, which is an S yarn, and the yarn 2, which is a Z yarn, are brought close to each other, an electric field or potential can be generated between the yarn 1 and the yarn 2.

[0064] The polarities of charges or potentials that can be generated in the yarn 1 and the yarn 2 are different from each other. The potential difference at each position can be defined by an electric field coupled circuit formed by complexly entangling the fibers with each other or a circuit formed by an electric current path that is formed by accident in the yarn by the action of moisture or the like.

[0065] The yarn of the present disclosure should not be construed as limited to the above aspects. The method for manufacturing the yarn of the present disclosure is also not particularly limited, and is not limited to the manufacturing method described above.

[0066] Furthermore, the yarn of the present disclosure may be provided with a "dielectric" on at least a part of a periphery of the potential-generating filament, for example on at least a part of a surface in the longitudinal axial direction and/or the circumferential direction of the filament.

[0067] For example, as schematically illustrated in the cross-sectional view of Fig. 4, a dielectric 100 can be provided around the potential-generating filament (or piezoelectric fiber) 10.

[0068] In the yarn of the present disclosure, the "dielectric" is an arbitrary constituent, and is not an essential constituent of the invention.

[0069] In the present disclosure, the "dielectric" means a material or a substance containing a material or a substance having a dielectric property (a property of being electrically polarized by an electric field) and/or conductivity (a property of passing electricity), and for example, can accumulate charges on a surface thereof.

[0070] The specific permittivity of the yarn of the present disclosure may be more appropriately adjusted within a range of "about 4.5 or less", for example, a range of "about 1 to about 4.5" by providing a "dielectric" on a surface of the yarn or the potential-generating filament of the present disclosure, for example, on a surface of the potential-generating filament in a cross-sectional view or a radial cross section. For example, an electric field having a larger electric field intensity (for example, 0.1 V/μm or more) can be formed by lowering the specific permittivity to, for example, close to 1. In other words, at least a part of the yarn or the potential-generating filament of the present disclosure may be covered with a dielectric such that the specific permittivity of the yarn is about 1 to about 4.5.

[0071] The dielectric may be present, for example, in the longitudinal axial direction and the circumferential direction of the potential-generating filament, and may completely or partially cover the potential-generating filament.

[0072] Therefore, the dielectric may be provided entirely or partially in the longitudinal axial direction of the potential-generating filament. In addition, the dielectric may be provided entirely or partially in the circumferential direction of the potential-generating filament.

[0073] In addition, the dielectric may be uniform or non-uniform in thickness (see, e.g., Fig. 4). The thickness of the dielectric may be larger or smaller than the fiber diameter of the potential-generating filament. The thickness of the dielectric is preferably smaller than the fiber diameter of the potential-generating filament (see Fig. 4).

[0074] The dielectric may be provided in layer on a surface of the yarn or the potential-generating filament of the present disclosure, for example, on at least a part of a surface of the yarn or the potential-generating filament of the present disclosure in a cross-sectional view or a radial cross-section of the potential-generating filament. The dielectric may also be present between potential-generating filaments, and in this case, there may be a part where the dielectric is not present between the potential-generating filaments. In addition, bubbles or cavities may be present in the dielectric.

[0075] The dielectric is not particularly limited as long as it contains a material or a substance having dielectric properties, conductivity, and the like. As the dielectric, a dielectric material (for example, an oil agent, an antistatic agent, and the like) known to be usable mainly as a surface treating agent (or a fiber treating agent) in the fiber industry may be used.

[0076] In the yarn of the present disclosure, the dielectric preferably contains an oil agent. As the oil agent, an oil agent usable as a surface treating agent (or a fiber treating agent) usable in the manufacture of the potential-generating filament can be used. In addition, an oil agent usable as a surface treating agent (or a fiber treating agent) usable in a step of manufacturing fabric (for example, knitting, weaving, and the like) and an oil agent usable as a surface treating agent (or a fiber treating agent) usable in a finishing step can also be used. Here, as a representative example, a filament manufacture step, a fabric manufacture step, and a finishing step have been mentioned, but the present invention is not limited to these steps. As the oil agent, it is preferable to use a surface treating agent (or a fiber treating agent) such as an oil agent usable particularly for reducing friction of the potential-generating filament.

[0077] Examples of the oil agent include DELION series manufactured by TAKEMOTO OIL & FAT Co., Ltd., MARPOZOL series and MARPOZIES series manufactured by Matsumoto Yushi-Seiyaku Co., Ltd., and Paralatex series manufactured by MARUBISHI OIL CHEMICAL CO., LTD.

[0078] The oil agent may be present entirely or at least partially along the potential-generating filament. After the potential-generating filament is processed into a yarn, part of the oil agent may fall off from the potential-generating filament by washing.

[0079] In addition, the dielectric usable to reduce friction of the potential-generating filament may be a surfactant such as a detergent or a softener that can be used during washing.

[0080] Examples of the detergent include Attack series manufactured by Kao Corporation, TOP series manufactured by Lion Corporation, and ARIEL series manufactured by Procter & Gamble Japan K.K.

[0081] Examples of the softener include Humming series manufactured by Kao Corporation, SOFLAN series manufactured by Lion Corporation, and LENOR series manufactured by Procter & Gamble Japan K.K.

[0082] The dielectric may have conductivity (property of passing electricity), and in this case, the dielectric preferably contains an antistatic agent. As the antistatic agent, an antistatic agent usable as a surface treating agent (or a fiber treating agent) usable in the manufacture of the potential-generating filament can be used. As the antistatic agent, it is preferable to use an antistatic agent that can be used particularly for reducing the loosening of the potential-generating filament.

[0083] By containing at least one selected from the group consisting of surface treating agents (or fiber treating agents) such as oil agents and antistatic agents, detergents, softeners, and the like as a dielectric, a specific permittivity adjusted within a range of about 1.0 or more and about 4.5 or less can be imparted to the yarn.

[0084] Examples of the antistatic agent include Capron series manufactured by NISSIN KAGAKU KENKYUSHO CO.,LTD., NICEPOLE series and DEATRON series manufactured by NICCA CHEMICAL CO., LTD. Among them, NICEPOLE series manufactured by NICCA CHEMICAL CO., LTD. is preferable, and those containing an ester-based polymer such as a polyester-based polymer, especially a PEG-modified polyester-based polymer are preferable (for example, NICEPOLE PR-99). By using such an antistatic agent, a specific permittivity adjusted within a range of about 1.0 or more and about 4.5 or less can be imparted to the yarn.

[0085] As the antistatic agent, a surface treating agent (or a fiber treating agent) capable of imparting water absorbency and/or SR property (soil removability) together with an antistatic effect may be used. Examples of such an antistatic agent include Water absorbent/SR agent series manufactured by Takamatsu Oil & Fat Co., Ltd. (e.g., SR-1800 containing a polyester-based polymer); and QUEENSTAT series manufactured by Kotani Chemical Industry Co., Ltd. (e.g., QUEENSTAT NW-E conc, which contains a urethane-based polymer, especially, a crosslinkable hydrophilic urethane-based polymer and can impart a water absorbent SR property and an antistatic effect). By using such an antistatic agent, a specific permittivity adjusted within a range of about 1.0 or more and about 4.5 or less can be imparted to the yarn.

[0086] The antistatic agent may be present entirely or at least partially along the potential-generating filament, for example, on the longitudinal axial and/or the circumferential surface of the potential-generating filament. After the potential-generating filament is processed into a yarn, part of the antistatic agent may fall off from the potential-generating filament by washing.

[0087] In the yarn of the present disclosure, the dielectric may be a "metal oxide". As the metal oxide, it is preferable to use a metal oxide having conductivity (property of passing electricity). For example, at least one of a metal oxide selected from the group consisting of titanium oxide, tungsten oxide, zinc oxide, zirconium oxide, niobium oxide, antimony oxide, tin oxide, indium oxide, cerium oxide, aluminum oxide, silicon oxide, magnesium oxide, yttrium oxide, ytterbium oxide, and tantalum oxide, or a composite oxide thereof can be used.

[0088] The metal oxide may be present entirely or at least partially along the potential-generating filament, for example, on the longitudinal axial and/or the circumferential surface of the potential-generating filament.

[0089] By using such a metal oxide, a specific permittivity adjusted within a range of about 4.5 or less, preferably about 3.0 or more and about 4.0 or less can be imparted to the yarn.

[0090] The dielectric preferably contains titanium oxide (TiO_2) as a metal oxide because such a dielectric can exhibit not only conductivity but also antibacterial properties by photocatalysis.

[0091] The amount of a surface treating agent (or a fiber treating agent) such as an oil agent or an antistatic agent, a detergent, a softener, a metal oxide, or the like adhering to the potential-generating filament is not particularly limited as long as the above-described specific permittivity can be achieved.

[0092] In the case of a surface treating agent (or a fiber treating agent) such as an oil agent or an antistatic agent, a detergent, or a softener, the amount of adhesion to the potential-generating filament is, for example, 1% by weight or more and 20% by weight or less, preferably 1% by weight or more and 15% by weight or less, and more preferably 4% by weight or more and 15% by weight or less based on 100% by weight of the potential-generating filament.

[0093] In the case of a metal oxide, the amount of adhesion to the potential-generating filament is, for example, 0.1% by weight or more and 5% by weight or less, preferably 0.1% by weight or more and 1% by weight or less, and more preferably 0.1% by weight or more and 0.5% by weight or less based on 100% by weight of the potential-generating filament.

[0094] In addition, a surface treating agent (or a fiber treating agent) such as the above-described oil agent or antistatic agent, a detergent, a softener, a metal oxide, or the like may not be present around the potential-generating filament. That is, the potential-generating filament, and thus the yarn of the present disclosure may not contain a surface treating agent or the like. In such a case, air that may be present between or in gaps between the potential-generating filaments and/or around the filaments may function as a dielectric. Thus, in this case, the dielectric contains air or an air layer.

[0095] When a surface treating agent (or a fiber treating agent) such as the oil agent or the antistatic agent described above, a detergent, a softener, a metal oxide, or the like is not present around the potential-generating filament, in other words, when the potential-generating filament is untreated or unprocessed, the potential-generating filament may have a specific permittivity adjusted within a range of, for example, about 1.0 or more and about 3.0 or less, preferably about 1.0 or more and about 2.6 or less, and more preferably about 1.0 or more and about 2.0 or less.

[0096] In the present disclosure, when a surface treating agent (or a fiber treating agent) such as the oil agent or the antistatic agent described above, a detergent, a softener, a metal oxide, or the like is not present around the potential-generating filament, in other words, when only an air layer is present around the filament, the presence of an extremely small amount of component that can be unavoidably or accidentally mixed during the manufacture of the yarn or the filament can be permitted.

[0097] The thickness of the dielectric (or the interval between the potential-generating filaments) is about 0 μm to about 10 μm, preferably about 0.5 μm to about 10 μm, more preferably about 2.0 μm to about 10 μm, and typically about 5 μm. When being within such a range, in the yarn of the present disclosure, the targeted value of specific permittivity of "about 4.5 or less" described in detail below is suitably obtained, and an antibacterial property can be more reliably exhibited.

[0098] In the yarn of the present disclosure, the "dielectric" can have a specific permittivity (ε) of about 1.0 to about 5.0, preferably a specific permittivity (ε) of about 2.0 to about 5.0, more preferably about 3.0 to about 5.0, even more preferably about 3.5 to about 5.0, and particularly preferably about 4.0 to about 5.0 (Fig. 5). When being within such a range, in the yarn of the present disclosure, the targeted value of specific permittivity of "about 4.5 or less" described in detail below is suitably obtained, and an antibacterial property can be more reliably exhibited.

[0099] Regarding the specific permittivity of a yarn, for example, the yarn is sandwiched between a pair of electrodes of an LCR meter or the like, a potential is applied between the two electrodes, an electrostatic capacitance is calculated from the amount of charge generated in the electrodes and the applied potential, and the specific permittivity of the yarn can be calculated from the electrostatic capacitance, the area of the electrodes, and the distance between the electrodes.

[Characteristics of yarn]

[0100] The yarn of the present disclosure has, as a physical property thereof, a specific permittivity of about 4.5 or less, for example, about 1.0 or more and about 4.5 or less.

[0101] The lower limit value of the specific permittivity may be about 1.5, about 2.0, about 2.5, about 2.6, about 3.0, about 3.5, or about 4.0.

[0102] The upper limit value of the specific permittivity may be about 4.0, about 3.5, about 3.0, about 2.6, about 2.5, about 2.0, or about 1.5.

[0103] As the upper limit and the lower limit of the specific permittivity, the above values may be combined, as necessary.

[0104] With such physical property values, antibacterial properties can be obtained more reliably in the present invention. It has become apparent for the first time from the research by the present inventors that the antibacterial property can be more reliably obtained based on physical property values of the yarn such as the specific permittivity. The mechanism and the background of the research that led to the discovery of such physical properties and antibacterial property will be described in detail below.

(Mechanism)

[0105] As a result of intensive research by the present inventors, for example, when a yarn is viewed in a cross-sectional view or a radial cross section, it has been previously found that the strength of the electric field that can be formed in the yarn decreases depending on the state of the space and/or gap between the potential-generating filaments, particularly the permittivity of the dielectric (including the air layer) that can be present between the potential-generating filaments and/or the physical properties such as dielectric constant of the yarn itself, and for example, a desired or a certain (level) antibacterial property may not be obtained.

[0106] In addition, as demonstrated in the preliminary test of the following Examples (Fig. 8), etc., the research by the present inventors has revealed that the value of "voltage (or potential)" is more dominantly involved in the antibacterial action than the value of electric current.

[0107] Here, briefly explaining a germ to be taken as a target, bacteria and fungi, particularly fungi, are composed of elongated hyphae and spores having a basically circular shape. In addition, it is known that spores proliferate by germination, and when they float in the air or the like and adhere to parasites, they form hyphae and reproduce both sexually and asexually ("Textbook of Modern Dermatology", 2nd edition, written by Hiroshi SHIMIZU, page 469). The size of spores that contribute to such proliferation is generally about 2 μm to about 10 μm ("Window of Food Sanitation", the website of Bureau of Social Welfare and Public Health, Tokyo Metropolitan Government).

[0108] Next, briefly explaining the antibacterial action by electrical stimulation, it has been conventionally known that proliferation of germs can be suppressed by an electric field (see, for example, Tetsuaki Tsuchido, Hiroki Kourai, Hideaki Matsuoka, and Junichi Koizumi "Microbial Control-Science and Engineering": Kodansha; and see for example, Koichi Takaki "Agricultural and Food Processing Applications of High-Voltage and Plasma Technologies", J. HTSJ, Vol. 51, No. 216).

[0109] In addition, it has also been known that: by virtue of a potential that generates such an electric field, a current may flow through a current path formed by moisture or the like or a circuit that can be formed by a local micro discharge phenomenon or the like, and germs are weakened by such an electric current and the proliferation of germs can be suppressed.

[0110] Furthermore, in relation to such electrical stimulation, an electroporation method has been known as one of the mechanisms of cell membrane destruction (Mechanism of electroporation : Basis of electric-pulse mediated gene transfer., written by Michio KASAI and Hiroko INABA, page 1595).

[0111] According to the above document, the condition under which electroporation that destroys cell membranes of germs and the like occurs is generally that a potential difference (or voltage) of "about 1.0 V" is applied to cells, and the present inventors have considered that, for example, in a case where the size of a spore is about 2 μm to about 10 μm, when an electric field or potential having an electric field intensity of about 0.1 V/μm or more is generated, a potential difference (or voltage) of about 1.0 V or more can be applied even in the case of a spore having a size of about 10 μm at the maximum, so that cell membranes may be destroyed due to the occurrence of electroporation, or an electron transfer system for life support may be hindered, leading to weakening, killing, or reduction of cells.

[0112] Based on such considerations, the present inventors first studied the relationship of the electric field intensity (V/μm) of an electric field with the permittivity, e.g., the permittivity of a dielectric, which is considered to affect the antibacterial property; especially, the relationship with the "specific permittivity (ε)" of the dielectric.

[0113] As a result, it has been revealed that: as shown for example in the graph of Fig. 5, if for example the value of the specific permittivity (ε) of a dielectric that can be provided on a piezoelectric fiber is within a range of about 1.0 to about 5.0, preferably about 3.5 to about 5.0, and more preferably about 4.0 to about 5.0, when an external force, e.g., a tension of about 0.15%, e.g., a tensile strain (in other words, a tension in the axial direction of the fiber and a tensile stress applied to the fiber) is applied, an electric field having an electric field intensity of about 0.1 V/μm or more can be formed.

[0114] Here, regarding Fig. 5, the value (V/μm) of the electric field intensity for the specific permittivity (ε) of the dielectric at each filament interval (X: 0.5 μm, Y: 2 μm, Z: 5 μm) is more specifically as shown in the following table. The graph shown in Fig. 5 merely exemplifies the relationship between the specific permittivity of the dielectric and the electric field intensity.

[Table 1]

		Filament interval		
		X 0.5 μm	Y 2 μm	Z 5 μm
Specific permittivity (ε)	1	0.133802	0.14448	0.150119
	3	0.105362	0.113549	0.111665
	5	0.091435	0.096983	0.09158
	7	0.081765	0.085222	0.078101
	9	0.074336	0.076186	0.068243

[0115] As a result of further research, it has been found that the specific permittivity of the yarn similarly affects the antibacterial property. Then, it has been found that when the specific permittivity of the yarn is about 4.5 or less, preferably in a range of about 1.0 to about 4.5, an electric field or potential having an electric field intensity of about 0.1 V/μm or more can be formed when external energy such as external force, for example, external energy such as tensile force or tensile strain of at least 0.15% is applied.

[0116] Here, the electric field intensity can be measured by using, for example, a scanning probe microscope, a surface electrometer, or the like.

[0117] Specifically, first, using a scanning probe microscope, displacement of a minute probe due to electric attractive force or repulsive force caused by bringing the probe to which a weak voltage is applied close to an object is detected. Next, using a surface electrometer, a voltage for canceling the electric attractive force or the repulsive force applied to the minute probe is measured, whereby the value of the surface potential of the object or the value of the electric field intensity can be obtained.

[0118] The measurement with a scanning probe microscope and a surface electrometer may be performed using an electric force microscope (for example, Model 1100TN manufactured by TREK, INC.) having functions of both the instruments.

[0119] Thus, when the "specific permittivity" is a value of "about 4.5 or less" as a physical property of the yarn, an electric field having an electric field intensity of "about 0.1 V/μm or more" can be formed. As a result, when such an electric field is formed in a germ such as a fungus having a spore size of about 2 μm to about 10 μm, a potential difference of 1.0 V or more can be applied even when the spore size is 10 μm at the maximum, and for example, it is possible to destroy cell membranes by electroporation to weaken, kill, or reduce germs. In other words, the antibacterial property can be more reliably exhibited.

[0120] When the value of the "specific permittivity" of the yarn is a value of about 1.0 or more (desirably 4.5 or less), an electric field or potential having an electric field intensity of about 0.1 V/μm or more can be formed in the same manner as described above, which is favorable.

[0121] The filament interval (or the thickness of the dielectric) of the yarn of the present disclosure is typically about 5 μm, and at this time, the "specific permittivity" of the yarn is about 1.0 to about 2.6, and about 2.0 to about 2.6. Also in this case, an electric field having an electric field intensity of 0.1 V/μm or more can be formed, which is favorable.

[0122] Thus, the yarn of the present disclosure can form an electric field or potential having an electric field intensity of "about 0.1 V/μm or more" due to having a "specific permittivity" of "about 4.5 or less" as a unique physical property and a value thereof (a physical property value) found for the first time by the present inventors. By the direct action of such an electric field or potential, defects are caused in cell membranes of germs or in an electron transfer system for the life support of germs, and generation and proliferation of germs can be suppressed. Thus, it is possible to weaken germs or reduce or kill germs.

[0123] Therefore, in the present disclosure, the "antibacterial property" means that at least the generation and proliferation of germs is suppressed or prevented by an electric field or potential having an electric field intensity of about 0.1 V/μm or more that can be formed by the yarn of the present disclosure. Furthermore, the term "antibacterial property" as used in the present disclosure may also include weakening of germs and reduction and killing of germs.

[0124] The antibacterial effect may be indirectly exerted by a potential, electric field, or electric current that can be generated by the yarn of the present disclosure, and by an active oxygen species to which the oxygen that may be contained in moisture is changed, and a radical species generated by the interaction or the catalytic action of an additive that can be contained in a fiber, or other antibacterial chemical species (amine derivatives, and the like). In addition, oxygen radicals may be generated in cells of germs by a stress environment due to the presence of a potential or an electric field or an electric current that can be generated by the yarn of the present disclosure, and such oxygen radicals may indirectly exert antibacterial properties. Conceivable radicals include superoxide anion radicals (active oxygen) and hydroxy radicals.

[0125] Such weakening, killing, or reduction of germs due to the action of such active oxygen species, radical species, antibacterial chemical species, oxygen radicals, and the like can also be included in the definition of "antibacterial property" as an antibacterial effect.

[0126] In the present disclosure, "germ" means all germs such as bacteria and fungi and is not particularly limited as long as the "antibacterial property" is obtained therewith, and is a concept including microorganisms such as mites and fleas and/or viruses. A target germ is preferably a "fungus". A fungus is a type of eukaryotic microorganism having a cell wall, and is a living organism that parasitizes some organic bodies because it does not perform photosynthesis or exists in nature in the form of spore. Among fungi, it is preferable to target dermatophytes, and it is particularly preferable to target Trichophyton.

[0127] The yarn of the present disclosure has "antibacterial properties" against "germs", and thus may be referred to as an "antibacterial yarn".

(Other features)

[0128] The yarn (or antibacterial yarn) of the present disclosure may further have the following physical properties (impedance, resistivity, etc.) and values thereof (physical property values). The following physical properties and physical property values are also suitable because antibacterial properties can be obtained more reliably. The following physical properties and physical property values were found for the first time by the present inventors through earnest research.

(Impedance)

[0129] In the yarn of the present disclosure, the impedance is about 4.0×10^6 Ωm or more, preferably about 4.0×10^6 Ωm to about 1.8×10^7 Ωm, and typically about 7.0×10^6 Ωm.

[0130] When the impedance of the yarn of the present disclosure is within the above range, an electric field or potential having an electric field intensity of about 0.1 V/μm or more can be formed, and the antibacterial property can be more reliably achieved.

[0131] In the present disclosure, the "impedance" means an impedance Z per unit volume. For example, as schematically illustrated in Fig. 6, the impedance Z can be measured by sandwiching a yarn between two measurement electrodes and connecting the two measurement electrodes to an LCR meter (or impedance measuring instrument).

[0132] The method of measuring the impedance Z is not limited to the method illustrated in Fig. 6.

[0133] When the yarn of the present disclosure is regarded as an ideal dielectric, and its capacitance is C and frequency is 1 kHz, the impedance Z per unit volume of the yarn of the present disclosure can be expressed by the following formula:

$$Z = 1/C \times 1.6 \times 10^{-4} \Omega$$

wherein C represents a capacitance.

[0134] Since the capacitance C is proportional to the "specific permittivity" of the yarn of the present disclosure, the impedance Z is inversely proportional to the "specific permittivity" of the yarn of the present disclosure.

[0135] Therefore, the lower limit value of the impedance Z, that is "4.0×10^6 Ωm", can correspond to the upper limit value of the specific permittivity of the yarn of the present disclosure, that is "4.5". The upper limit value of the impedance Z, that is "1.8×10^7 Ωm", can correspond to the lower limit value of the specific permittivity of the yarn of the present disclosure, that is "1.0".

[0136] Thus, the value of the impedance of the yarn can be converted from the specific permittivity of the yarn.

[0137] A typical impedance value of the yarn of the present disclosure, that is "7.0×10^6 Ωm", can correspond to a typical value of the "specific permittivity" of the yarn of the present disclosure, that is "2.6".

(Resistivity)

[0138] In the yarn of the present disclosure, the resistivity is about 1.4×10^4 Ωm or more, and preferably about 1.4×10^4 Ωm to about 2.3×10^{15} Ωm.

[0139] When the resistivity of the yarn of the present disclosure is within the above range, an electric field or potential having an electric field intensity of about 0.1 V/μm or more can be formed, and the antibacterial property can be more reliably achieved.

[0140] Reference is now made to Fig. 7. Fig. 7 shows the relationship between the "interval d (μm) between the potential-generating filaments" (hereinafter, sometimes referred to as a "filament interval d") and the "electric field intensity (V/μm)" in the yarn of the present disclosure. The "filament interval d" indicates the shortest distance (μm) between the surfaces of two potential-generating filaments adjacent to each other. The filament interval d may also correspond to the thickness of the "dielectric" that may be present between the filaments.

[0141] Typically, the resistivity of the "dielectric" is less than the resistivity of the "potential-generating filament" (for example, the resistivity of the antistatic agent: about 1×10^3 Ωm). The resistivity of the yarn of the present disclosure tends to decrease as the "filament interval d" increases.

[0142] Regarding the yarn of the present disclosure as an ideal resister, for example, when the "filament interval d" is "5 μm" (the filament interval of the yarn of the present disclosure (or the thickness of the dielectric) is typically about 5 μm), the "electric field intensity" is "about 0.1 V/μm" as illustrated in Fig. 7, and the "resistivity" of the yarn of the present disclosure in this case is "about 1.4×10^4 Ωm", which can correspond to the lower limit value (about 1.4×10^4 Ωm). When the "filament interval d" is "0 μm", the "resistivity" of the yarn of the present disclosure is maximum, and the value thereof is "about 2.3×10^{15} Ωm", which can correspond to the above upper limit value (about 2.3×10^{15} Ωm).

[0143] Thus, the value of the resistivity of the yarn can also be calculated from the electric field intensity of the yarn.

[0144] Here, as to Fig. 7, the electric field intensity (V/μm) versus the filament interval d (μm) is more specifically as shown in the following table.

[Table 2]

d [μm]	Electric field intensity [V/μm]
1	0.1016814
2	0.1044287
3	0.1041357
4	0.1025711
5	0.1004682

(continued)

d [μm]	Electric field intensity [V/μm]
6	0.09817822
7	0.09577033
8	0.09339429
9	0.091025
10	0.08868541

[0145] In the yarn of the present disclosure, the resistivity can be measured with, for example, an insulation resistance meter.

[0146] In the yarn (or antibacterial yarn) of the present disclosure, the physical properties and the values (physical property values) thereof at which the antibacterial property can be more reliably obtained are not limited to the "specific permittivity", "impedance", and "resistivity" described above.

[Use of yarn]

[0147] The yarn of the present disclosure contains, as potential-generating filaments (or potential-generating fibers or charge-generating fibers or electric field-forming fibers), fibers capable of generating potential and forming an electric field by generating charges by external energy (for example, the application of external energy such as tensile force or tensile strain of at least 0.15%). Therefore, an electric field or potential is formed in the vicinity of the yarn or the yarn can generate an electric field between yarns or even when the yarn is brought close to an object having a prescribed potential (including a ground potential) such as a human body. As described above, the antibacterial property can be directly exhibited by such a potential or electric field.

[0148] Furthermore, the yarn of the present disclosure can also allow an electric current to flow when the yarn approaches another adjacent fiber or an object having a prescribed potential such as a human body via moisture such as sweat. The antibacterial property may be exhibited also by this electric current.

[0149] Therefore, when the yarn of the present disclosure is applied to an article that can be used in proximity to an object having a prescribed potential such as a human body, for example, the yarn can exhibit the antibacterial property as described above by the action of the generated potential, electric field or electric current, particularly the direct action of the potential or electric field.

[0150] The article or product to which the yarn of the present disclosure can be applied is not particularly limited, and examples thereof include clothing (general), footwear (general), and medical supplies (general) such as masks. More specifically, the following applications are conceivable.

[0151] For example, clothing items in general, particularly, underwear (especially, socks), towels, footwear in general, for example, insoles for shoes and boots, sportswear in general, hats, bedding (including duvets, mattresses, sheets, pillows, pillows covers, and the like), toothbrushes, flosses, various filters (filter and the like of water purifier, air conditioner, or air purifier), stuffed animals, pet-related products (mat for pet, clothing for pet, and inner of clothing for pet), various mat products (foot, hand, toilet seat, or the like), curtains, kitchen utensils (sponges, cloths, or the like), seats (seats of cars, trains, airplanes or the like), cushioning materials for motorbike helmets and exterior materials thereof, sofas, medical items in general, including bandages, gauzes, masks, sutures, clothes for doctors and patients, and supporters, sanitary items, sporting goods (inner of wear and glove, gauntlet used in martial arts, or the like), packaging materials, and the like can be cited.

[0152] Of the clothing items, in particular, socks (or supporters) always expand and contract along joints due to movement such as walking, and thus the yarn of the present disclosure can generate charges or a potential with high frequency. In addition, socks absorb moisture such as sweat and serve as a hotbed for the proliferation of germs and the like, but since the yarn of the present disclosure can suppress the proliferation of germs, it can produce a remarkable effect for antibacterial purposes for odor prevention.

[0153] The yarn of the present disclosure is considered to be suitable for all applications requiring antibacterial properties, and the applications are not particularly limited to the above applications.

(Fabric)

[0154] The yarn of the present disclosure can be processed into a fabric, for example, for the above applications. Therefore, such a fabric contains the yarn of the present disclosure, and can be used for the above-mentioned applications and the like as the above-mentioned "antibacterial fabric" having the above-described antibacterial property. Examples of the fabric of the present disclosure include woven fabrics, knitted fabrics, and nonwoven fabrics. These can be manufactured by appropriately processing the yarn of the present disclosure by a method well known in the art, or the like.

[0155] Hereinafter, the yarn and the fabric of the present disclosure will be described in more detail by way of examples.

Examples

<Preliminary test for confirming antibacterial action by electrical stimulation>

[0156] A preliminary test for confirming the antibacterial action by electrical stimulation was performed based on the following procedures (1) to (4).

(1) Using Trichophyton (fungus) as a germ, a suspension of Trichophyton was prepared by suspending Trichophyton in a state of germ tube in pure water.
(2) A voltage was applied to the suspension of Trichophyton under the following conditions.
(3) The state of Trichophyton after the voltage application is shown in the photograph of Fig. 8.
(4) As representative examples of the state change of Trichophyton before and after the voltage application, photographs of the state change of Trichophyton are shown in Figs. 9(a) and 9(b) for 20 V x 5 Hz and 50 V × 5 Hz, respectively.

[0157]

- Distance between electrodes
  50μm
- Voltage

  Condition A: 10V
  Condition B: 20V
  Condition C: 30V
  Condition D: 40V
  Condition E: 50V

- Frequency

  1Hz
  5Hz
  10Hz

- Number of measurements
  n = 3

(Results)

[0158] The voltage value was increased by changing the voltage every 10 V from 10 V to 50 V (conditions A to E). As a result, it became clear that Trichophyton deforms with an increase in voltage, and plasma streaming stops in some cases. Figs. 9 (a) and 9 (b) are representative photographs of the deformation of Trichophyton before and after voltage application, and the deformation of spores and that of hyphae were confirmed, respectively. In particular, it was confirmed that the plasma streaming of Trichophyton stopped under voltage conditions D and E.

[0159] On the other hand, it was found that even when the electric current value was increased by changing the frequency to 1 Hz, 5 Hz, and 10 Hz, the plasma streaming of Trichophyton might not stop in some cases.

[0160] From the facts described above, it was found that the value of voltage is dominantly involved in the antibacterial action rather than the value of electric current.

[0161] In addition, the size of spores of Trichophyton used in the preliminary test was about 5 μm as shown in the photograph of Fig. 10, and it has been found that when a voltage with an electric field intensity of about 0.2 V/μm or more is applied, a voltage of about 1.0 V or more is applied from one end of a spore to the other and Trichophyton is killed or reduced.

[0162] From the above, since the size of spores of germs, particularly fungi, is about 2 μm to about 10 μm ("Window of Food Sanitation", the website of Bureau of Social Welfare and Public Health, Tokyo Metropolitan Government), it can be found from the above results that when a voltage of about 0.1 V/μm or more is applied, a voltage of about 1.0 V or more is applied corresponding to spores having a size of up to 10 μm, and such germs can be killed or reduced.

[0163] The above preliminary test is merely an example, and is not intended to limit the present invention.

(Example 1)

Preparation of yarn A

[0164] Yarn A composed of potential-generating filaments (the number of filaments: 24) containing poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%). The potential-generating filaments contained in the yarn A each contained therearound an oil agent as a dielectric. It was found that part of the oil agent was removed from the potential-generating filaments by washing after the manufacture of the yarn.

Measurement of specific permittivity of yarn A

[0165] The specific permittivity of the yarn A was determined by measuring a capacitance by passing the yarn A through a parallel plate capacitor, calculating a capacitance of the yarn A from a difference between the measured capacitance and a capacitance attained when the yarn A was not passed, determining a permittivity of the yarn A by use of the measured capacitance and the volume of the yarn, and further determining the specific permittivity of the yarn A by calculation based on a formula: [specific permittivity of the yarn A] = [permittivity of the yarn A]/[permittivity of vacuum] using the permittivity of a vacuum. As a result, the specific permittivity of the yarn A was found to be about 1.4 (measurement temperature: room temperature (25°C)).

Measurement of electric field intensity of electric field formed by yarn A

[0166] Since the yarn A contains PLLA (optical purity (L-form): 99% or more, crystallinity: 42 to 44%), it has been found that an electric field or potential is generated by applying external energy such as a tensile strain of at least 0.15%. Furthermore, since the specific permittivity of the yarn A is 1.4, the electric field formed by the yarn A was measured using an electric force microscope (for example, Model 1100TN manufactured by TREK, INC.) including a scanning probe, a surface electrometer, and the like, and has been found to have an electric field intensity exceeding about 0.1 V/μm.

[0167] In the measurement of the electric field intensity, first, using a scanning probe, displacement of a minute probe due to electric attractive force or repulsive force caused by bringing the probe to which a weak voltage was applied close to the yarn A was detected. Next, using a surface electrometer, a voltage for canceling the electric attractive force or the repulsive force applied to the minute probe was measured, whereby the value of the electric field intensity of the yarn A was measured.

Antibacterial property

[0168] From the facts described above, since the yarn A has an electric field intensity exceeding about 0.1 V/μm, it has been found that the yarn A exhibits a sufficient antibacterial property against Trichophyton of about 10 μm, for example.

(Example 2)

Preparation of yarn B

[0169] Yarn B composed of potential-generating filaments (the number of filaments: 24) containing poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%). The potential-generating filaments contained in the yarn B each contained therearound an antistatic agent as a dielectric. It was found that part of the antistatic agent was removed from the potential-generating filaments by washing after the manufacture of the yarn.

Measurement of specific permittivity of yarn B

[0170] The specific permittivity of the yarn B was measured in the same manner as the yarn A, and it was found to be about 1.4 (measurement temperature: room temperature (25°C)).

Measurement of electric field intensity of electric field formed by yarn B

[0171] Since the yarn B contains PLLA (optical purity (L-form): 99% or more, crystallinity: 42 to 44%), it has been found that an electric field or potential is generated by applying external energy such as a tensile strain of at least 0.15%. Furthermore, since the specific permittivity of the yarn B was about 1.4, the electric field formed by the yarn B was measured in the same manner as the yarn A, and was found to have an electric field intensity exceeding about 0.1 V/μm.

Antibacterial property

[0172] From the facts described above, since the yarn B has an electric field intensity exceeding about 0.1 V/μm, it has been found that the yarn B exhibits a sufficient antibacterial property against Trichophyton of about 10 μm, for example.

(Example 3)

Preparation of yarn C

[0173] Yarn C composed of potential-generating filaments (the number of filaments: 24) containing poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%). The potential-generating filaments contained in the yarn C did not contain any surface treating agent, and only an air layer as a dielectric was present therearound.

Measurement of specific permittivity of yarn C

[0174] The specific permittivity of the yarn C was measured in the same manner as the yarn A, and it was found to be about 1.1 (measurement temperature: room temperature (25°C)).

Measurement of electric field intensity of electric field formed by yarn C

[0175] Since the yarn C contains PLLA (optical purity (L-form): 99% or more, crystallinity: 42 to 44%), it has been found that an electric field or potential is generated by applying external energy such as a tensile strain of at least 0.15%. Furthermore, since the specific permittivity of the yarn C was about 1.1, the electric field formed by the yarn C was measured in the same manner as the yarn A, and was found to have an electric field intensity exceeding about 0.1 V/μm.

Antibacterial property

[0176] From the facts described above, since the yarn C has an electric field intensity exceeding about 0.1 V/μm, it has been found that the yarn B exhibits a sufficient antibacterial property against Trichophyton of about 10 μm, for example.

(Example 4)

Preparation of yarn D

[0177] Yarn D composed of potential-generating filaments (the number of filaments: 24) made of poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (degreased non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%).

Measurement of specific permittivity of yarn bundle of yarn D

[0178] The yarn D was set on a bobbin, and the yarn D was laterally aligned through a yarn path guide such that the yarn D did not overlap in the thickness direction on a winding cylinder having a diameter of 45 mm using a yarn winding machine manufactured by Murata Manufacturing Co., Ltd., and the yarn D was wound on the cylinder (rotation speed: 60 rpm, 1 minute) (see Fig. 11(A)).

[0179] The yarn D was cut along the axial direction of the winding cylinder to separate the yarn D from the winding cylinder, thereby affording a yarn bundle sample (yarn D) having a width of about 1 cm (see Fig. 11(B)). Both the upper and lower ends in the longitudinal direction of the yarn bundle sample were fixed at the time of cutting.

[0180] The yarn sample (yarn D) was set in a jig (vise) and fixed with Kapton (registered trademark) tape (see Fig. 12(A) (the photograph shows merely one example of a measurement method, and the yarn contained in the yarn bundle sample is different from the yarn D)).

[0181] The yarn bundle sample (yarn D) was disposed to overlap (thickness: about 50 μm) between two circular measurement electrodes of an LCR meter (Precision LCR Meter (model: E4980A) manufactured by Agilent Technologies, Inc.) connected to a fixture (Dielectric Test Fixture (model: 16451B) manufactured by Agilent Technologies, Inc.), and the yarn bundle sample was sandwiched and fixed by the two measurement electrodes (see Fig. 12(B) (the photograph shows merely one example of a measurement method, and the yarn contained in the yarn bundle sample is different from the yarn D)).

[0182] Here, the relationship between the measurement electrodes of the LCR meter and the yarn bundle sample is illustrated in Fig. 13. In the case of the yarn bundle sample illustrated in this schematic diagram, since the yarns D are sandwiched between the measurement electrodes and adjacent to each other, it was assumed that there was no gap between a yarn D and another yarn D.

[0183] The sum of the areas S1 and S2 illustrated in Fig. 13 was multiplied by 4, and calculation was performed with the product taken as the area of the yarn bundle sample (hereinafter, referred to as "sample area").

[0184] As a result of measuring the specific permittivity of the yarn D over such a sample area with the LCR meter, the value was about 2.1 (temperature: room temperature (25°C), frequency: 1 kHz). Details of the measurement are shown in the following Table 3.

(Example 5)

Preparation of yarn E

[0185] Yarn E composed of potential-generating filaments (the number of filaments: 24) made of poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (degreased non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%).

Measurement of specific permittivity of yarn bundle of yarn E

[0186] As a result of measuring the specific permittivity of the yarn E with an LCR meter in the same manner as in the yarn D of Example 4, the value of the specific permittivity was about 1.9. Details of the measurement are shown in the following Table 3.

(Example 6)

Preparation of yarn F

[0187] A yarn composed of potential-generating filaments (the number of filaments: 24) made of poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%).

[0188] About 0.1 mL of a surface treating agent (NICEPOLE PR-99 (NICEPOLE series manufactured by NICCA CHEMICAL CO., LTD.), an antistatic agent containing a PEG-modified polyester-based polymer) was applied to that yarn and dried, and thus yarn F (non-twisted yarn) was prepared (weight before application: 0.207 g, dry weight after application: 0.219 g, adhesion weight: 0.012 g, adhesion amount: 5.4% by weight).

Measurement of specific permittivity of yarn bundle of yarn F

[0189] A yarn bundle sample of the yarn F was prepared in the same manner as in Example 4 (see Fig. 11).

[0190] The yarn bundle sample (yarn F) was set in a jig (vise) and fixed with Kapton (registered trademark) tape (see Fig. 12(A) (the photograph shows merely one example of a measurement method, and the yarn contained in the yarn bundle sample is different from the yarn F)).

[0191] In the same manner as in Example 4, the yarn bundle sample (yarn F) was disposed to overlap (thickness: about 50 μm) between two circular measurement electrodes of an LCR meter (Precision LCR Meter (model: E4980A) manufactured by Agilent Technologies, Inc.) connected to a fixture (Dielectric Test Fixture (model: 16451B) manufactured by Agilent Technologies, Inc.), and the yarn bundle sample was sandwiched and fixed by the two measurement electrodes (see Fig. 12(B) (the photograph shows merely one example of a measurement method, and the yarn contained in the yarn bundle sample is different from the yarn F)).

[0192] In the case of this yarn bundle sample, since the surface treating agent was applied to the yarn F, the filaments contained in the yarn gathered and a space was generated between a yarn F and another yarn F.

[0193] In such a case, for example, a value obtained by subtracting the area of the space from a value obtained by multiplying the sum of the areas S1 and S2 illustrated in Fig. 13 by 4 (in other words, the value of the area in an ideal state) was calculated as a sample area. The area of the space was calculated by actually measuring the interval between a yarn F and another yarn F, preferably calculating the average of the total gaps, and integrating over the width direction (the electrode diameter direction) of the yarn bundle sample with a width of 1 cm arranged on a measurement electrode (see Fig. 13).

[0194] As a result of measuring the specific permittivity of the yarn F over such a sample area with the LCR meter, the value was about 4.5 (temperature: room temperature (25°C), frequency: 1 kHz). Details of the measurement are shown in the following Table 4.

(Example 7)

Preparation of yarn G

[0195] A yarn composed of potential-generating filaments (the number of filaments: 24) made of poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%).

[0196] About 0.1 mL of a surface treating agent (SR-1800 (Water absorbent/SR agent series manufactured by Takamatsu Oil & Fat Co., Ltd.), a surface treating agent containing a polyester-based polymer and being capable of imparting water absorbency/SR property (stain removability or anti-soiling property)/antistatic effect) was applied to that yarn and dried, and thus yarn G (non-twisted yarn) was prepared (weight before application: 0.203 g, dry weight after application: 0.213 g, adhesion weight: 0.010 g, adhesion amount: 4.7% by weight).

Measurement of specific permittivity of yarn bundle of yarn G

[0197] As a result of measuring the specific permittivity of the yarn G with an LCR meter in the same manner as in the yarn F of Example 6, the value of the specific permittivity was about 4.5. Details of the measurement are shown in the following Table 4.

(Example 8)

Preparation of yarn H

[0198] A yarn composed of potential-generating filaments (the number of filaments: 24) made of poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%).

[0199] About 0.1 mL of a surface treating agent (QUEENSTAT NW-E conc (QUEENSTAT series manufactured by Kotani Chemical Industry Co., Ltd.), a surface treating agent containing a crosslinkable hydrophilic urethane-based polymer and being capable of imparting water absorbency/SR property (stain removability or anti-soiling property)/antistatic effect) was applied to that yarn and dried, and thus yarn H (non-twisted yarn) was prepared (weight before application: 0.205 g, dry weight after application: 0.234 g, adhesion weight: 0.029 g, adhesion amount: 12% by weight).

Measurement of specific permittivity of yarn bundle of yarn H

[0200] As a result of measuring the specific permittivity of the yarn H with an LCR meter in the same manner as in the yarn F of Example 6, the value of the specific permittivity was about 4.4. Details of the measurement are shown in the following Table 4.

(Example 9)

Preparation of yarn I

[0201] A yarn composed of potential-generating filaments (the number of filaments: 24) made of poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%).

[0202] About 0.1 mL of a liquid containing a metal oxide (titanium oxide (TiO_2) spray liquid (photocatalyst TiO2 anti-bacterial and deodorization spray available from TRUSCO Nakayama Corporation)) was applied to that yarn and dried, and thus yarn I (non-twisted yarn) was prepared (weight before application: 0.206 g, dry weight after application: 0.207 g, adhesion weight: 0.001 g, adhesion amount: 0.48% by weight).

Measurement of specific permittivity of yarn bundle of yarn I

[0203] As a result of measuring the specific permittivity of the yarn I with an LCR meter in the same manner as in the yarn F of Example 6, the value of the specific permittivity was about 3.3. Details of the measurement are shown in the following Table 5.

(Example 10)

Preparation of yarn J

[0204] A yarn composed of potential-generating filaments (the number of filaments: 24) made of poly-L-lactic acid (PLLA) as a piezoelectric material was prepared (non-twisted yarn) (optical purity (L-form) measured and calculated by high performance liquid chromatography (HPLC): 99% or more, crystallinity measured by ultraX 18 manufactured by Rigaku Corporation: 42 to 44%).

[0205] About 0.1 mL of a liquid containing a metal oxide (titanium oxide (TiO_2) spray liquid (photocatalyst TiO_2 anti-bacterial and deodorization spray available from TRUSCO Nakayama Corporation)) was applied to that yarn and dried, and thus yarn J (non-twisted yarn) was prepared (weight before application: 0.213 g, dry weight after application: 0.213 g, adhesion weight: less than 0.001 g, adhesion amount: less than 0.47% by weight).

Measurement of specific permittivity of yarn bundle of yarn J

[0206] As a result of measuring the specific permittivity of the yarn J with an LCR meter in the same manner as in the yarn F of Example 6, the value of the specific permittivity was about 3.5. Details of the measurement are shown in the following Table 5.

[Table 3]

Yarn bundle sample	Example 4	Example 5
Yarn	D (Non-twisted yarn)	E (Non-twisted yarn)
Thickness [m]	5.00E - 05	5.00E - 05
Cp [F]	1.69E - 10	1.50E - 10
Area of electrode [m^2]	0.001134115	0.001134115
Area of sample [m^2]	0.000438149	0.000438149
Permittivity of vacuum	8.85E - 12	8.85E - 12
Specific permittivity	About 2.1	About 1.9

[Table 4]

Yarn bundle sample	Example 6	Example 7	Example 8
Yarn	F (Non-twisted yarn)	G (Non-twisted yarn)	H (Non-twisted yarn)

(continued)

Yarn bundle sample	Example 6	Example 7	Example 8
Thickness [m]	2.6E - 04	2.8E - 04	2.9E - 04
Cp [F]	4.39E - 11	4.14E - 11	3.96E - 11
Area of electrode [m^2]	0.001134115	0.001134115	0.001134115
Area of sample [m^2]	0.000281082	0.000287416	0.000291216
Permittivity of vacuum	8.85E - 12	8.85E - 12	8.85E - 12
Specific permittivity	About 4.5	About 4.5	About 4.4

[Table 5]

Yarn bundle sample	Example 9	Example 10
Yarn	I (Non-twisted yarn)	J (Non-twisted yarn)
Thickness [m]	9.0E - 05	1.0E - 04
Cp [F]	1.44E - 10	1.39E - 10
Area of electrode [m^2]	0.001134115	0.001134115
Area of sample [m^2]	0.000438149	0.000438149
Permittivity of vacuum	8.85E - 12	8.85E - 12
Specific permittivity	About 3.3	About 3.5

Measurement of electric field intensity of electric field formed by yarns D to J

[0207] Since the yarns D to J contain PLLA (optical purity (L-form): 99% or more, crystallinity: 42 to 44%), it has been found that an electric field is generated by applying external energy such as a tension or tensile strain of at least 0.15%. Furthermore, since the yarns D to J have a specific permittivity of about 4.5 or less, the electric fields formed by the yarns D to J were found to have an electric field intensity exceeding about 0.1 V/μm as in the cases of the yarns A to C.

Antibacterial property

[0208] From the facts described above, the yarns D to J were found to have an electric field intensity exceeding about 0.1 V/μm and exhibit a sufficient antibacterial property against Trichophyton of about 10 μm.
[0209] As a result of measuring the specific permittivity of the yarn A of Example 1 and the yarn B of Example 2 in the form of a yarn bundle in the same manner as the yarn F of Example 6, the specific permittivity was about 1.4 with both the yarns, and there were consistent with the results measured in Examples 1 and 2.
[0210] As a result of measuring the specific permittivity of the yarn C of Example 3 in the form of a yarn bundle in the same manner as the yarn D of Example 4, the specific permittivity of the yarn C was about 1.1, which was consistent with the result measured in Example 3.

(Comparative Example 1)

[0211] Since the non-piezoelectric polylactic acid (PLA) polymer (TERRAMAC (registered trademark) manufactured by Unitika Ltd., crystallinity: 34%) does not have piezoelectricity, it has been found that the polymer does not generate charges and does not exhibit antibacterial properties.
[0212] The above-described Examples 1 to 10 merely exemplify the yarn of the present disclosure, and particularly merely exemplify that the specific permittivity, the generated potential, and the like can be adjusted, and the yarn of the present disclosure is not limited to the embodiments shown in the above-described Examples. While Examples 1 to 10 are all directed to non-twisted yarns, by applying twist (for example, 45°), the electric field intensity can be further increased and furthermore the antibacterial property can be further enhanced.
[0213] Finally, aspects of the present invention will be additionally described. The invention described above includes, but is not limited to, the following aspects.

(Aspect 1)

[0214] A yarn comprising a potential-generating filament or an electric field-forming filament, wherein the yarn has a specific permittivity of 4.5 or less.

(Aspect 2)

[0215] The yarn according to Aspect 1, wherein the specific permittivity is 1.0 or more.

(Aspect 3)

[0216] The yarn according to Aspect 1 or 2, wherein the yarn has an impedance of 4.0×10^6 Ωm or more.

(Aspect 4)

[0217] The yarn according to Aspect 3, wherein the impedance is 1.8×10^7 Ωm or less.

(Aspect 5)

[0218] The yarn according to any one of Aspects 1 to 4, wherein the yarn has a resistivity of 1.4×10^4 Ωm or more.

(Aspect 6)

[0219] The yarn according to Aspect 5, wherein the resistivity is 2.3×10^{15} Ωm or less.

(Aspect 7)

[0220] The yarn according to any one of Aspects 1 to 6, wherein the potential-generating filament comprises a piezoelectric material.

(Aspect 8)

[0221] The yarn according to Aspect 7, wherein the piezoelectric material comprises poly-L-lactic acid (PLLA).

(Aspect 9)

[0222] The yarn according to Aspect 8, wherein the poly-L-lactic acid (PLLA) has a crystallinity of 35% or more.

(Aspect 10)

[0223] The yarn according to any one of Aspects 1 to 9, wherein a dielectric is provided on at least a part of a periphery of the potential-generating filament.

(Aspect 11)

[0224] The yarn according to Aspect 10, wherein the dielectric comprises an oil agent.

(Aspect 12)

[0225] The yarn according to Aspect 10 or 11, wherein the dielectric has conductivity.

(Aspect 13)

[0226] The yarn according to any one of Aspects 10 to 12, wherein the dielectric comprises an antistatic agent.

(Aspect 14)

[0227] The yarn according to Aspect 10, wherein the dielectric comprises air.

(Aspect 15)

[0228] The yarn according to Aspect 10, wherein the dielectric comprises a polymer.

(Aspect 16)

[0229] The yarn according to Aspect 15, wherein the polymer comprises at least one selected from the group consisting of ester-based polymers and urethane-based polymers.

(Aspect 17)

[0230] The yarn according to Aspect 10, wherein the dielectric comprises a metal oxide.

(Aspect 18)

[0231] The yarn according to Aspect 17, wherein the metal oxide is titanium oxide.

(Aspect 19)

[0232] The yarn according to any one of Aspects 1 to 9, wherein the yarn is free of a surface treating agent.

(Aspect 20)

[0233] The yarn according to any one of Aspects 1 to 19, wherein the yarn is an antibacterial yarn.

(Aspect 21)

[0234] A fabric comprising the yarn according to any one of Aspects 1 to 20.
[0235] The present invention can be used for various products. For example, the present invention can be suitably used as a yarn or a fabric generally in daily products, industrial products, and especially clothing products in which yarns are used.

Claims

1. A yarn comprising a potential-generating filament,
wherein the yarn has a specific permittivity of 4.5 or less.

2. The yarn according to claim 1, wherein the specific permittivity is 1.0 or more.

3. The yarn according to claim 1 or 2, wherein the yarn has an impedance of 4.0×10^6 Ωm or more.

4. The yarn according to claim 3, wherein the impedance is 1.8×10^7 Ωm or less.

5. The yarn according to any one of claims 1 to 4, wherein the yarn has a resistivity of 1.4×10^4 Ωm or more.

6. The yarn according to claim 5, wherein the resistivity is 2.3×10^{15} Ωm or less.

7. The yarn according to any one of claims 1 to 6, wherein the potential-generating filament comprises a piezoelectric material.

8. The yarn according to claim 7, wherein the piezoelectric material comprises poly-L-lactic acid (PLLA).

9. The yarn according to claim 8, wherein the poly-L-lactic acid (PLLA) has a crystallinity of 35% or more.

10. The yarn according to any one of claims 1 to 9, wherein a dielectric is provided on at least a part of a periphery of the potential-generating filament.

11. The yarn according to claim 10, wherein the dielectric comprises an oil agent.

12. The yarn according to claim 10 or 11, wherein the dielectric has conductivity.

13. The yarn according to any one of claims 10 to 12, wherein the dielectric comprises an antistatic agent.

14. The yarn according to claim 10, wherein the dielectric comprises air.

15. The yarn according to claim 10, wherein the dielectric comprises a polymer.

16. The yarn according to claim 15, wherein the polymer comprises at least one selected from a group consisting of an ester-based polymer and an urethane-based polymer.

17. The yarn according to claim 10, wherein the dielectric comprises a metal oxide.

18. The yarn according to claim 17, wherein the metal oxide is a titanium oxide.

19. The yarn according to any one of claims 1 to 9, wherein the yarn is free of a surface treating agent.

20. The yarn according to any one of claims 1 to 19, wherein the yarn is an antibacterial yarn.

21. A fabric comprising the yarn according to any one of claims 1 to 20.

Fig.1

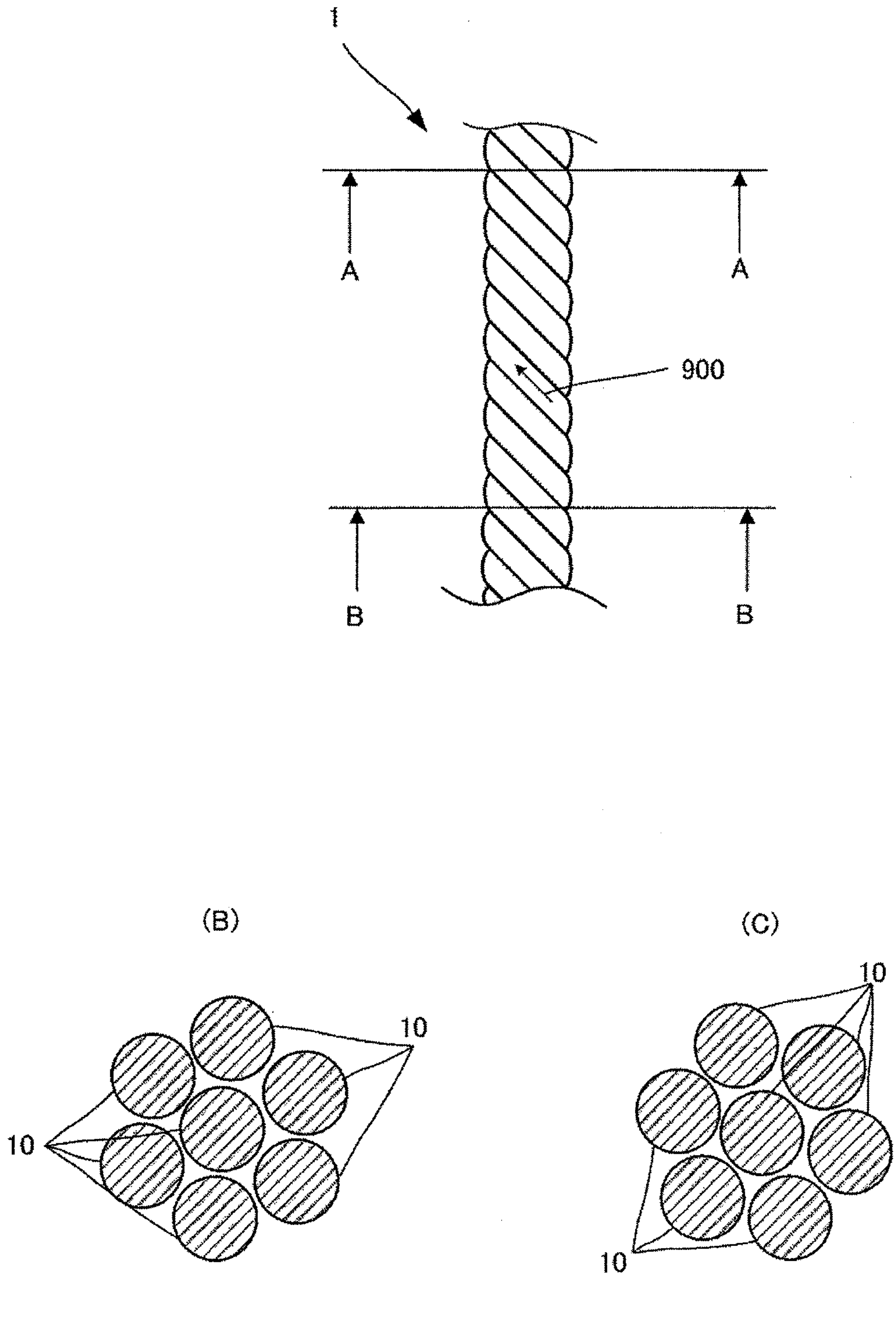


Fig.2

(A)

(B)

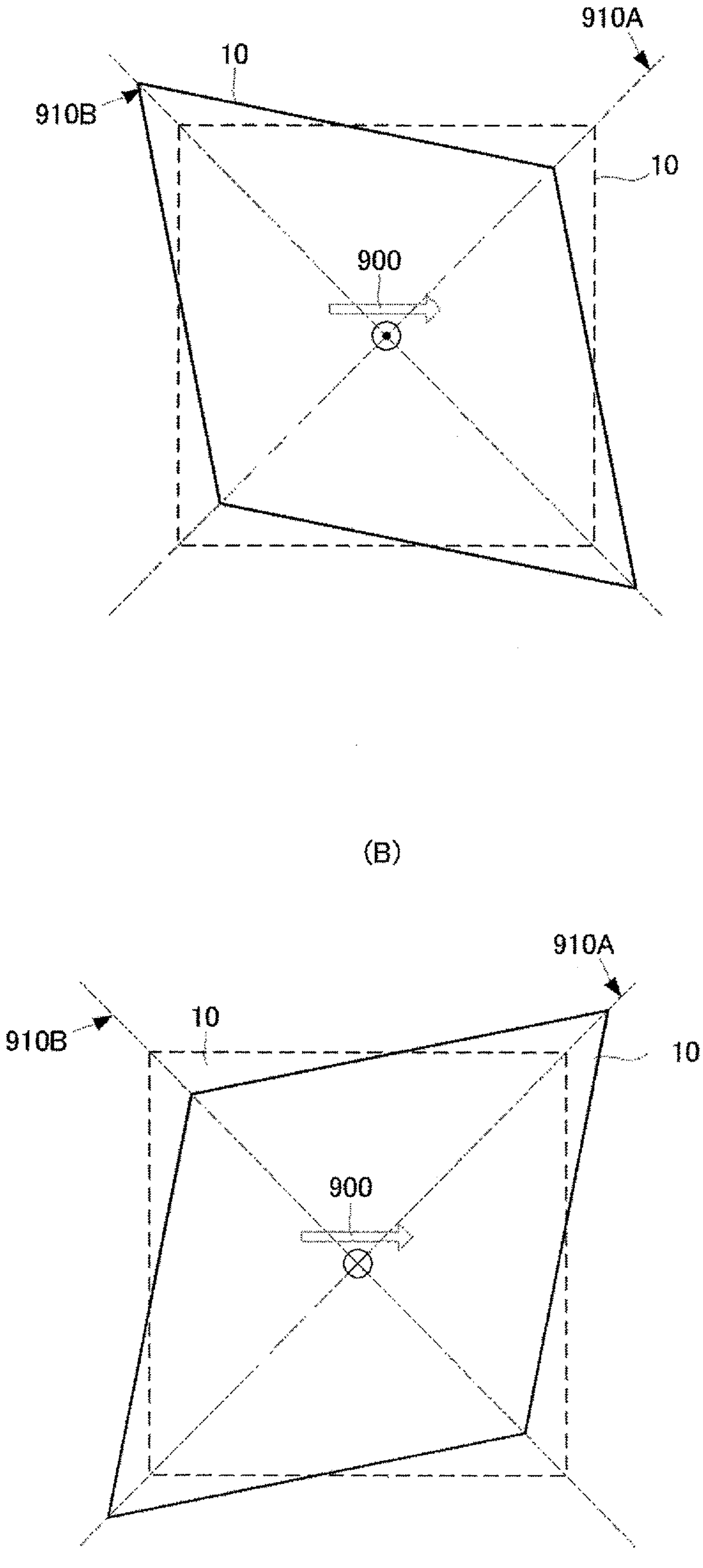


Fig.3

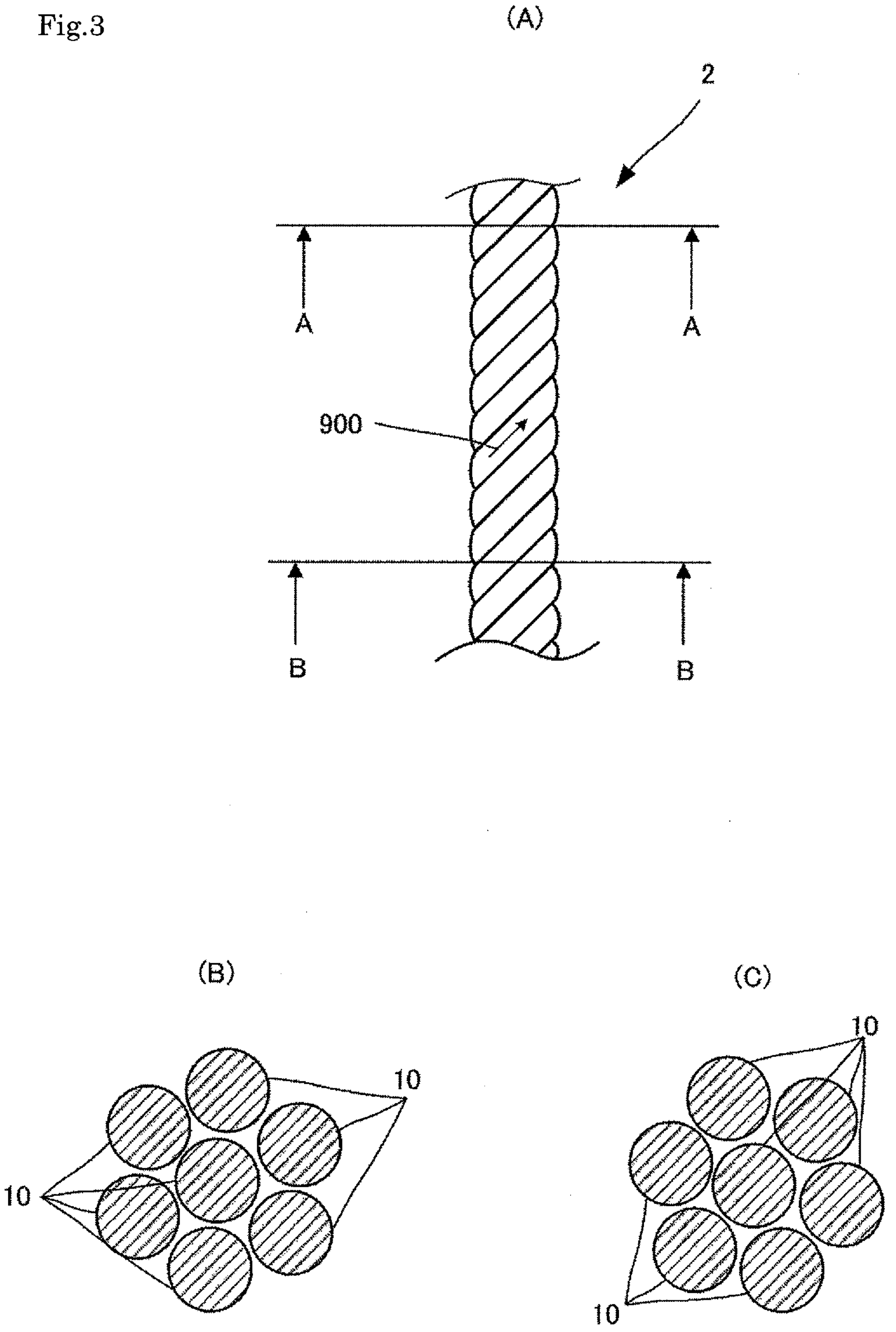


Fig.4

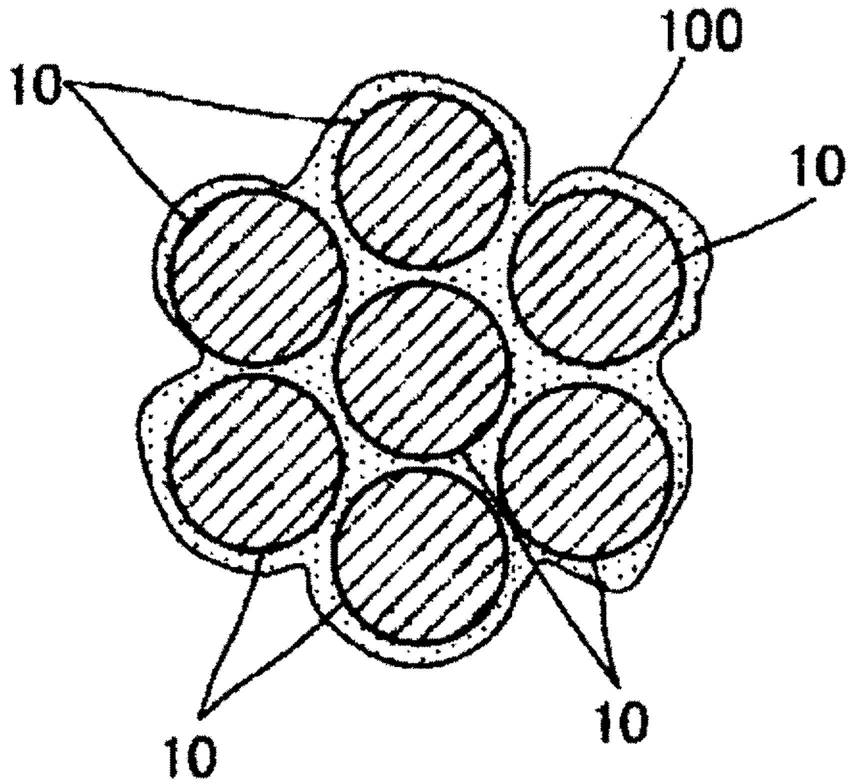


Fig.5

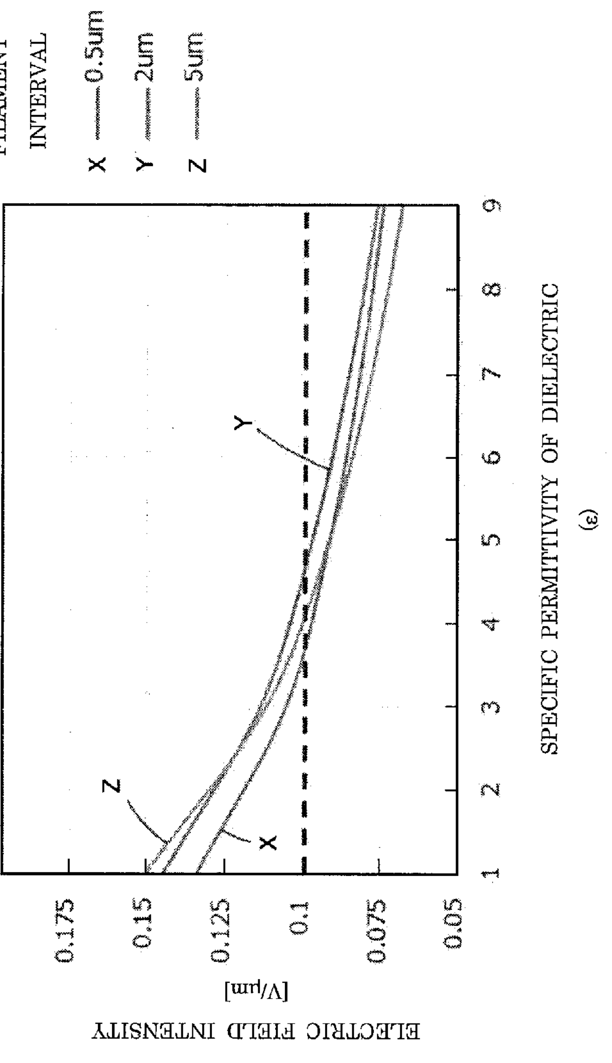
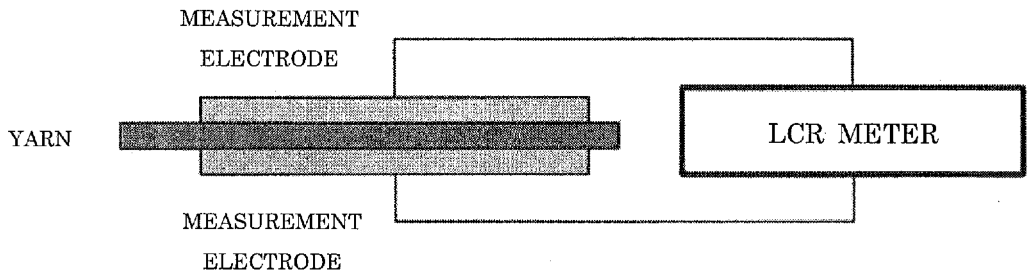

FILAMENT INTERVAL
X 0.5um
Y 2um
Z 5um
ELECTRIC FIELD INTENSITY [V/μm]
0.175
0.15
0.125
0.1
0.075
0.05
1
2
3
4
5
6
7
8
9
X
Y
Z
SPECIFIC PERMITTIVITY OF DIELECTRIC
(ε)

Fig.6


MEASUREMENT
ELECTRODE
YARN
LCR METER
MEASUREMENT
ELECTRODE

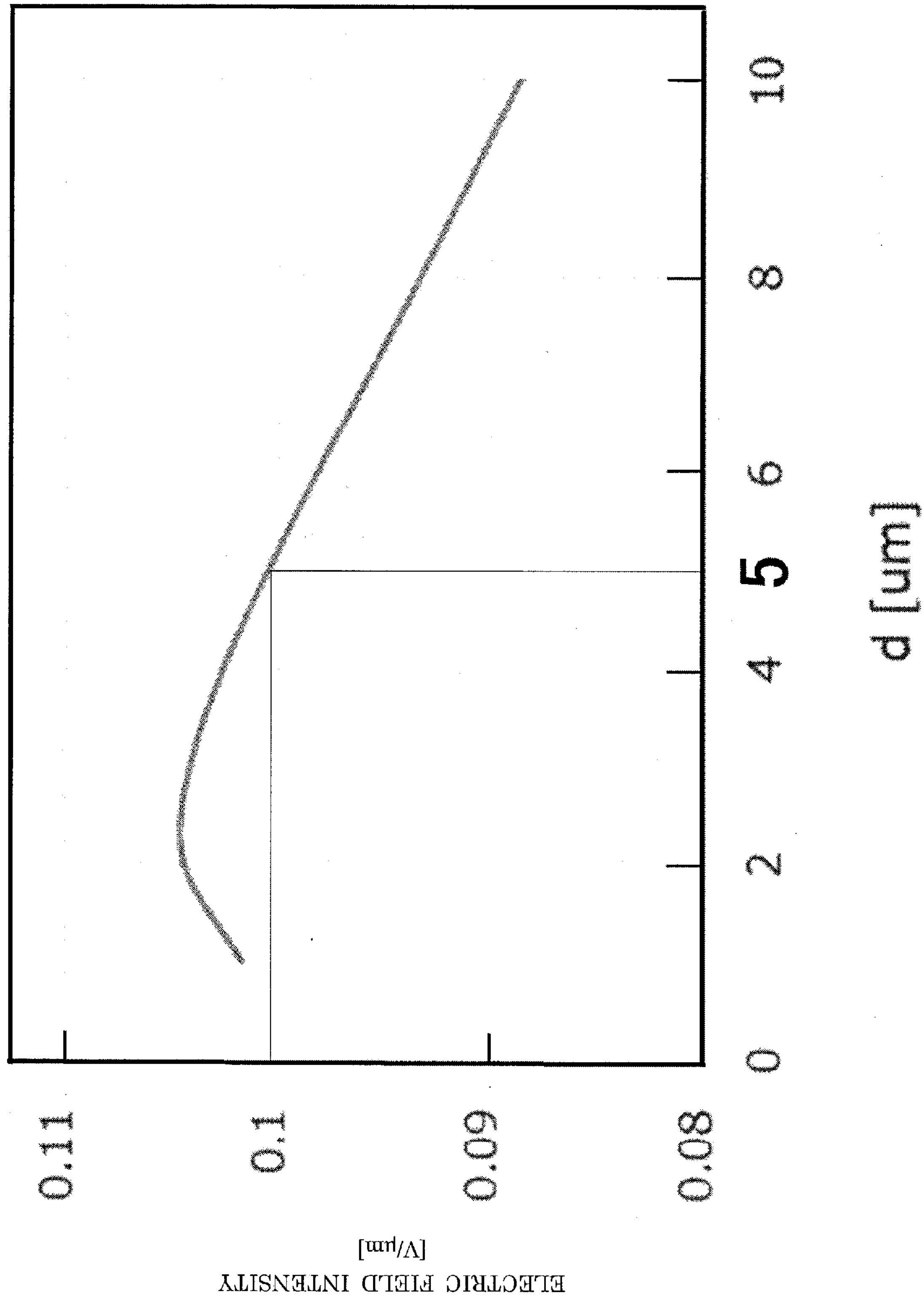
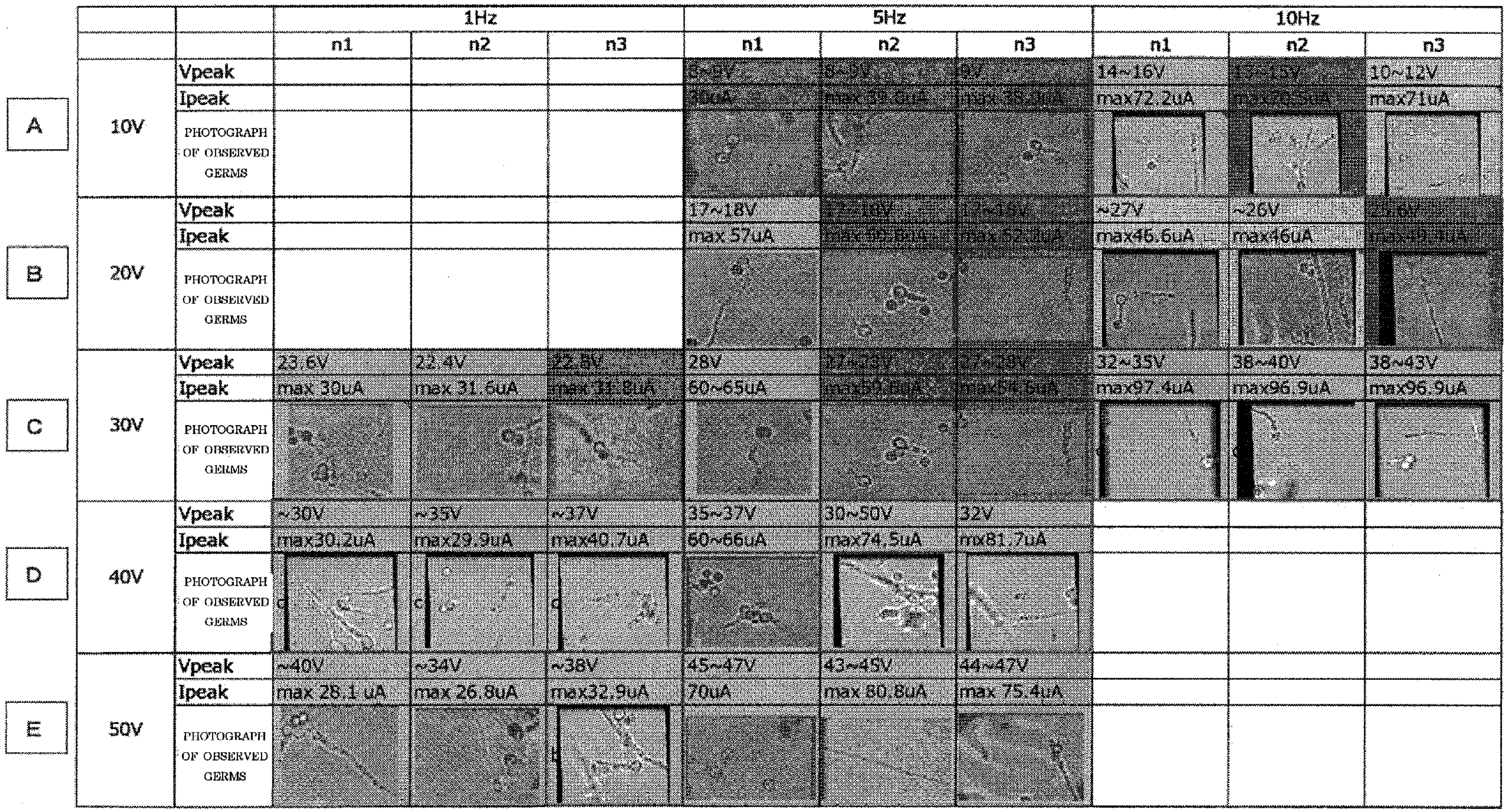


Fig.7

Fig.8



ELECTRIC CURRENT: SMALLER → ELECTRIC CURRENT: LARGER

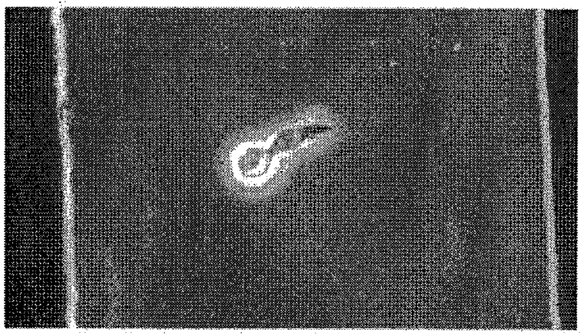
VOLTAGE: SMALLER → VOLTAGE: LARGER

			1Hz			5Hz			10Hz		
			n1	n2	n3	n1	n2	n3	n1	n2	n3
A	10V	Vpeak				8~9V	8~9V	9V	14~16V	13~15V	10~12V
		Ipeak				30uA	max 39.0uA	max 38.[illegible]uA	max72.2uA	max70.5uA	max71uA
		PHOTOGRAPH OF OBSERVED GERMS									
B	20V	Vpeak				17~18V	17~18V	17~18V	~27V	~26V	25.6V
		Ipeak				max 57uA	max 55.6uA	max 52.[illegible]uA	max46.6uA	max46uA	max49.4uA
		PHOTOGRAPH OF OBSERVED GERMS									
C	30V	Vpeak	23.6V	22.4V	22.8V	28V	27~28V	27~28V	32~35V	38~40V	38~43V
		Ipeak	max 30uA	max 31.6uA	max 31.8uA	60~65uA	max59.6uA	max54.6uA	max97.4uA	max96.9uA	max96.9uA
		PHOTOGRAPH OF OBSERVED GERMS									
D	40V	Vpeak	~30V	~35V	~37V	35~37V	30~50V	32V			
		Ipeak	max30.2uA	max29.9uA	max40.7uA	60~66uA	max74.5uA	mx81.7uA			
		PHOTOGRAPH OF OBSERVED GERMS									
E	50V	Vpeak	~40V	~34V	~38V	45~47V	43~45V	44~47V			
		Ipeak	max 28.1 uA	max 26.8uA	max32.9uA	70uA	max 80.8uA	max 75.4uA			
		PHOTOGRAPH OF OBSERVED GERMS									

Fig.9

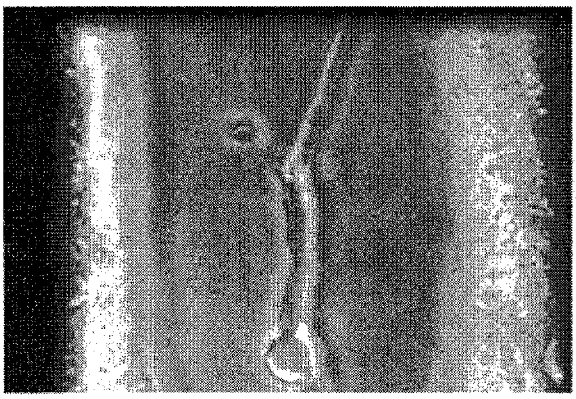
(a) 20V×5Hz

BEFORE VOLTAGE APPLICATION

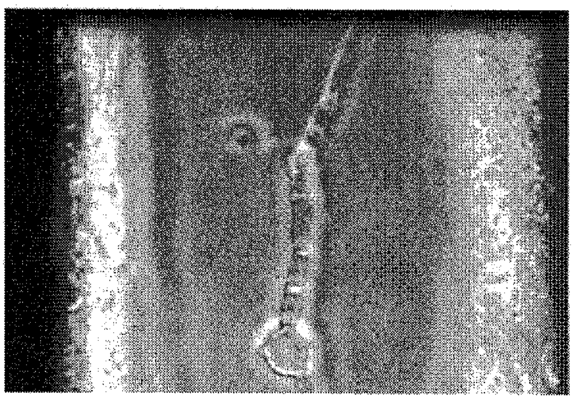


AFTER VOLTAGE APPLICATION

(b) 50V×5Hz



BEFORE VOLTAGE APPLICATION

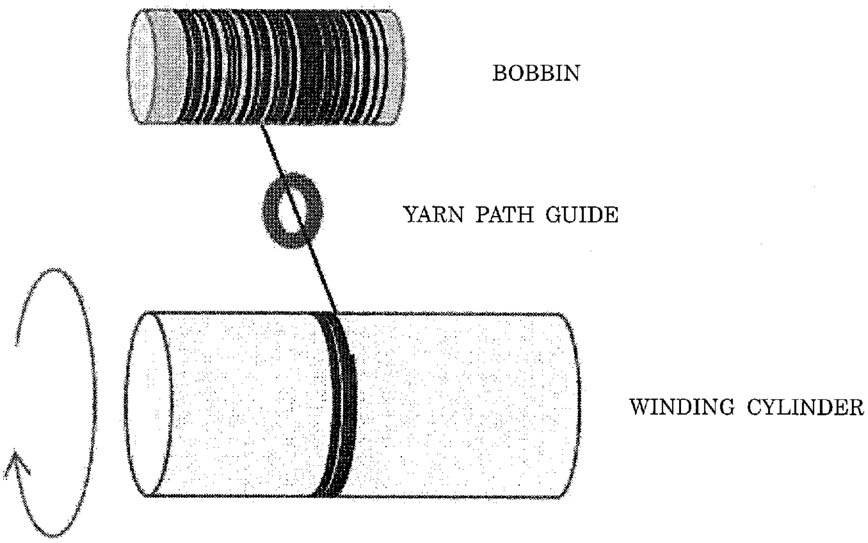


AFTER VOLTAGE APPLICATION

Fig.10

Fig.11

(A)


BOBBIN
YARN PATH GUIDE
WINDING CYLINDER

(B)

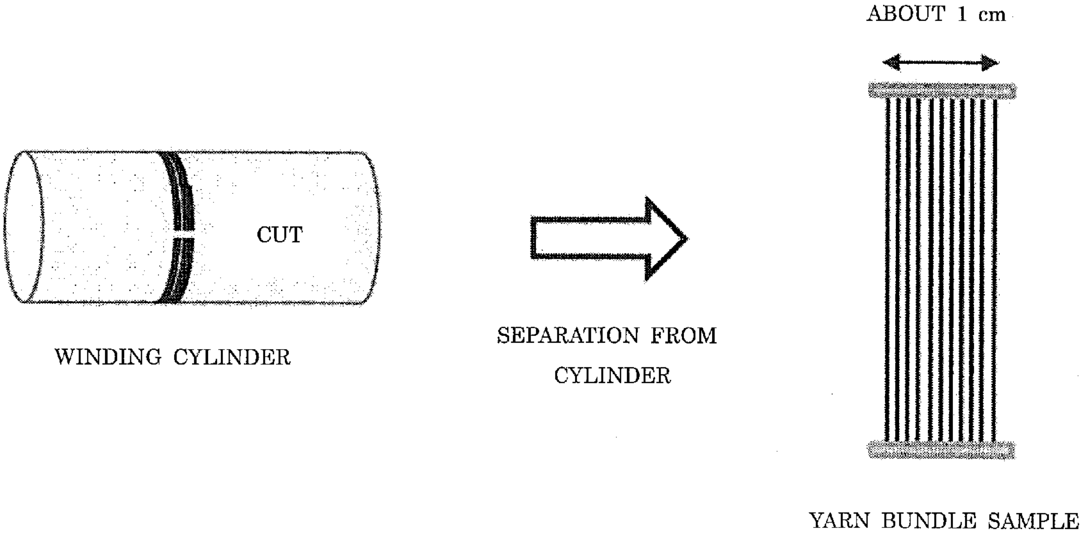
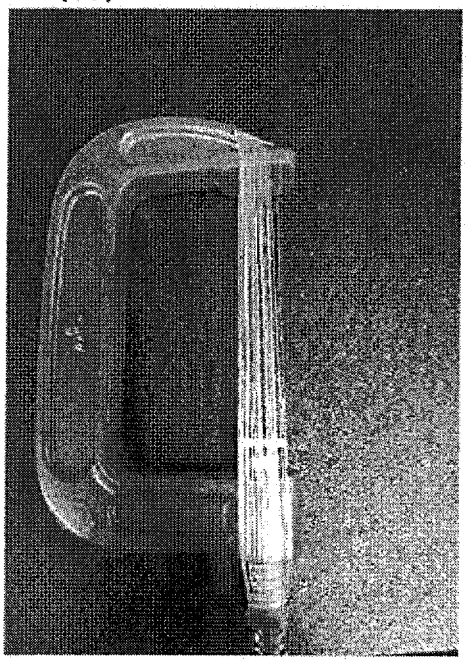

ABOUT 1 cm
CUT
WINDING CYLINDER
SEPARATION FROM
CYLINDER
YARN BUNDLE SAMPLE

Fig.12

(A)



(B)

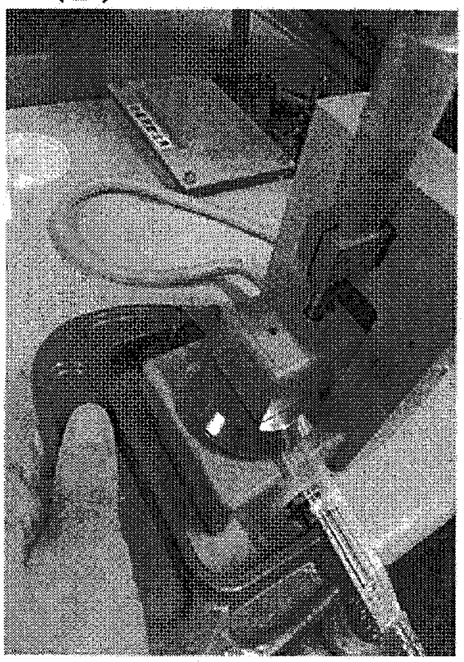
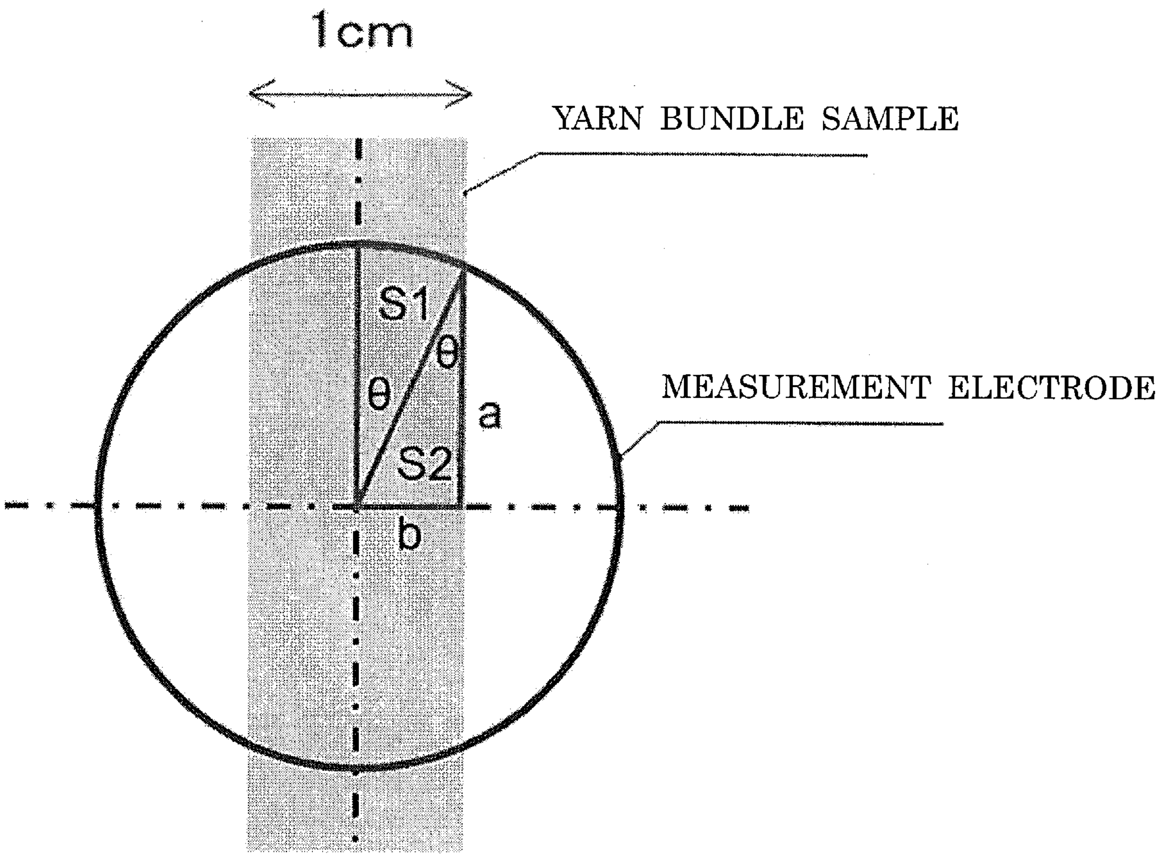


Fig.13



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2021/000385

A. CLASSIFICATION OF SUBJECT MATTER
D02G 3/02(2006.01)i; D06M 11/46(2006.01)i; D06M 15/507(2006.01)i; D06M 15/564(2006.01)i; D06M 101/32(2006.01)n
FI: D02G3/02; D06M11/46; D06M15/507; D06M15/564; D06M101:32

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)
D02G1/00-3/48; D02J1/00-13/00; D06M10/00-16/00; D06M19/00-23/18; D01F1/00-9/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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	WO 2018/221332 A1 (TEIJIN FRONTIER CO., LTD.) 06 December 2018 (2018-12-06) claims, paragraphs [0079]-[0081]	1-10, 14, 19-21 1-13, 15-21
Y	JP 2009-13553 A (TAKEMOTO OIL & FAT CO., LTD.) 22 January 2009 (2009-01-22) claims, examples 110-146	1-11, 13, 20, 21
Y	JP 2001-40529 A (SHIMADZU CORPORATION) 13 February 2001 (2001-02-13) claims	1-10, 15, 16, 20, 21
Y	JP 2006-225821 A (KUROSAWA LACE KK) 31 August 2006 (2006-08-31) claims, paragraphs [0015]-[0017]	1-10, 12, 15-21
A	WO 2018/211817 A1 (MURATA MANUFACTURING CO., LTD.) 22 November 2018 (2018-11-22) claims	1-21

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

* Special categories of cited documents:
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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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 March 2021 (16.03.2021)	30 March 2021 (30.03.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/000385

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
WO 2018/221332 A1	06 Dec. 2018	EP 3633088 A1 claims, paragraphs [0078], [0079], table 1 US 2020/0157709 A1 CN 110709544 A TW 201903228 A	
JP 2009-13553 A	22 Jan. 2009	US 2008/0302079 A1 claims, test examples 110-146 CN 101324028 A TW 200907138 A	
JP 2001-40529 A	13 Feb. 2001	EP 1054085 A1 claims US 6399197 B1 ID 26074 A KR 10-2001-0049377 A CN 1274771 A TW 270587 B SG 87108 A	
JP 2006-225821 A	31 Aug. 2006	(Family: none)	
WO 2018/211817 A1	22 Nov. 2018	EP 3626872 A1 claims JP 2019-44325 A JP 2020-73747 A US 2019/0038787 A1 CN 109287121 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 7310284 A **[0002]**
- JP 3165992 B **[0002]**
- JP 1805853 B **[0002]**
- JP 8226078 A **[0002]**
- JP 9194304 A **[0002]**
- JP 2004300650 A **[0002]**
- JP 6428979 B **[0002] [0004]**

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- Textbook of Modern Dermatology. Hiroshi SHIMIZU, 469 **[0107]**
- Window of Food Sanitation. Bureau of Social Welfare and Public Health **[0107] [0162]**
- **TETSUAKI TSUCHIDO ; HIROKI KOURAI ; HIDEAKI MATSUOKA ; JUNICHI KOIZUMI.** *Microbial Control-Science and Engineering* **[0108]**
- **KOICHI TAKAKI.** Agricultural and Food Processing Applications of High-Voltage and Plasma Technologies. *J. HTSJ,* vol. 51 (216 **[0108]**
- Mechanism of electroporation : Basis of electric-pulse mediated gene transfer. Michio KASAI and Hiroko INABA, 1595 **[0110]**