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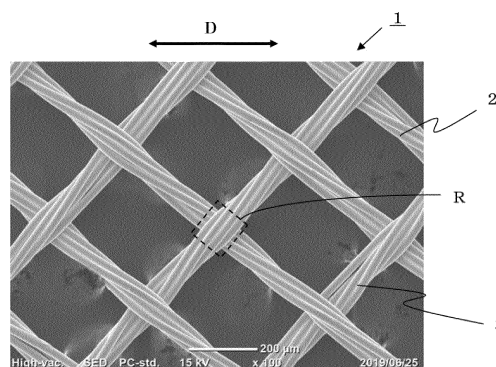
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(54) **CONDUCTIVE MESH FABRIC**

(57) The invention comprises a conductive mesh fabric comprising a twisted yarn consisting of synthetic fiber filaments as warp and weft with a metal film formed covering the warp and the weft, having an opening ratio of 40-80%, and having recesses on the surface of the warp

where that surface is in contact with the weft and recesses on the surface of the weft where that surface is in contact with the warp at the portions where the warp and the weft intersect.

[FIG. 1]



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Description**Technical Field**

5 **[0001]** The present invention relates to a conductive mesh fabric. In detail, the present invention relates to a conductive mesh fabric in which variation in conductivity in the bias direction is suppressed even under repeated bending or repeated torsional deformation.

Background Art

10 **[0002]** Conventionally, conductive mesh fabrics are known in which a metal film is formed on a mesh fabric made of fibers. Conductive mesh fabrics are used as electromagnetic shielding members or as conductive members for grounding inside electronic equipment housings, and are often used as sensor electrodes or the like.

15 **[0003]** The applicant of the present invention has proposed in Patent Document 1 a conductive tape that is thinner having excellent grounding properties and high adhesiveness capable of using as an electromagnetic shielding gasket. The conductive tape uses a conductive mesh fabric having a metal film on its surface, and has an adhesive film made of an adhesive only at the openings thereof. The metal film is exposed on both sides of the conductive mesh fabric without being covered with the adhesive film, and at least some of the threads constituting the conductive mesh fabric include thermoplastic synthetic fiber monofilament yarns.

20 **[0004]** Patent Document 2 discloses inserting a mesh-like extensible conductive knitted fabric into a mold during injection molding to form a conductive molded body having electromagnetic shielding properties. The conductive knitted fabric has an opening ratio of 20% or more and 80% or less, and is imparted with conductivity by electroless plating the entire knitted fabric made of a fibrous material such as polyester fiber or the like.

25 **[0005]** Patent Document 3 describes an invention relating to a capacitive sensor using a conductive cloth in which a mesh cloth having openings made of twisted wires is plated with metal, as a capacitive detection electrode placed on the surface of a sheet-like base material.

Prior Art Documents**[Patent Document]****[0006]**

Patent Document 1: Jpn. Pat. Laid-Open Publication No.2013-018956

35 Patent Document 2: Jpn. Pat. Laid-Open Publication No. 2007-175970

Patent Document 3: Jpn. Pat. Laid-Open Publication No. 2021-082573

Disclosure of the Invention**Problems to be Solved by the Invention**

40 **[0007]** In the case of the conductive tape described in Patent Document 1, once it is pasted inside the housing of an electronic device, then it is not accompanied by deformation. The conductive knitted fabric of Patent Document 2 exhibits excellent moldability due to its extensibility during injection molding, but is not deformed after being integrated with resin. On the other hand, when a conductive mesh fabric is used as part of a member that is flexible and is accompanied by repeated deformation during use, variation in conductivity due to deformation particularly in the bias direction of the conductive mesh fabric may become a problem.

45 **[0008]** The conductive mesh fabric described in Patent Document 1 and the conductive knitted fabric described in Patent Document 2 are unrelated to the problem of variation in conductivity due to repeated deformation, and naturally there is no suggestion of a solution to the problem. The detection electrode described in Patent Document 3 is made of a conductive cloth in which a mesh cloth is plated with metal, but it is necessary to further improve the effect of suppressing variation in conductivity.

50 **[0009]** The present invention has focused on this problem and aims to provide a conductive mesh fabric that can suppress variation in conductivity even through under repeated deformation. Specifically, the present invention provides a conductive mesh fabric in which variation in conductivity in the bias direction is suppressed even when it is subjected to repeated bending deformation and/or repeated twisting deformation.

Means for Solving the Problems

[0010] The present invention relates to a conductive mesh fabric comprising a twisted yarn consisting of synthetic fiber filaments as warp and weft with a metal film formed covering the warp and the weft, having an opening ratio of 40-80%, and having recesses on the surface of the warp where that surface is in contact with the weft and recesses on the surface of the weft where that surface is in contact with the warp at the portions where the warp and the weft intersect.

[0011] According to the above-mentioned present invention, it is possible to obtain a conductive mesh fabric in which variation in conductivity in the bias direction due to repeated bending deformation and repeated torsional deformation can be suppressed.

[0012] It is preferable that one or more of the recesses are formed on the surface of a filament constituting the warp (hereinafter referred to as a warp filament) that is in contact with a filament constituting the weft (hereinafter referred to as a weft filament), and one or more recesses are formed on the surface of a weft filament that is in contact with a warp filament.

[0013] It is preferable that at least one of the recesses formed on the surface of the warp filament and the recesses formed on the surface of the warp filament is substantially circular having a diameter of "[warp filament diameter] + [80 pm]" or less and/or a diameter of "[weft filament diameter] + [80 pm]" or less, and having the depth of 4 to 20 μm .

[0014] It is preferable that the recesses have the diameter of 20 to 80 μm and the depth of 4 to 20 μm .

[0015] It is preferable that, at a portion where the warp and the weft intersect, a recess on the surface of the warp that is in contact with the weft and a recess on the surface of the weft that is in contact with the warp are engaged with each other.

[0016] It is preferable that the number of twists of the twisted yarn is 300 to 2,000 T/m. When the number of twists of the twisted yarn is within the range of 300 to 2,000 T/m, it is possible to obtain a conductive mesh fabric in which variation in conductivity due to repeated deformation can be further suppressed.

[0017] It is preferable that the coefficient of variation of the resistance value in the bias direction measured at 0.33 second intervals during a repeated bending test using a bending tester with a bending radius of 2.5 mm, a bending angle of $\pm 135^\circ$, a bending speed of 60 cycles/min and a total number of bends of 1,000 cycles is 5.0% or less.

[0018] It is preferable that the coefficient of variation of the resistance value in the bias direction measured at 0.33 second intervals during a repeated twisting test using a twisting tester with a twisting angle of $\pm 90^\circ$, a twisting speed of 60 cycles/min and a total number of twists of 1,000 cycles is 5.0% or less.

[0019] The conductive mesh fabric of the present invention can be manufactured by a method including a weaving process of producing a mesh fabric using a twisted yarn made of synthetic fiber filaments as warp and weft, a heat treatment process of heat-treating the mesh fabric obtained by the weaving process, and a metal film forming process of forming a metal film on the heat-treated mesh fabric.

[0020] In said manufacturing method, the number of twists of the twisted yarn is preferably 300 to 2,000 T/m. It is also preferable that the heat treatment process is carried out at a tentering ratio of 1.0 to 8.0% in the warp direction and/or weft direction. It is also preferable that the temperature condition in the heat treatment process is 150 to 220°C.

Effect of the Invention

[0021] According to the present invention, it is possible to extremely effectively suppress misalignment of the warp and weft yarns constituting the conductive mesh fabric at the portion where the warp and the weft intersect (hereinafter referred to as the "intersecting portion"), thereby making it possible to obtain a conductive mesh fabric in which variation in conductivity in the bias direction under repeated bending deformation and repeated torsional deformation are suppressed. By incorporating it into a flexible member that undergoes deformation during use, it is possible to provide a conductive mesh fabric capable of providing conductivity that can withstand repeated bending and twisting.

Brief Description of Drawings

[0022]

[FIG.1]

FIG. 1 shows an enlarged photograph of one embodiment of the conductive mesh fabric of the present invention.

[FIG.2]

FIG. 2 shows an enlarged photograph of a warp yarn taken out from one embodiment of the conductive mesh fabric of the present invention and observed.

[FIG.3]

FIG. 3 shows a schematic diagram indicating a state in which recesses of the warp and weft are engaged with each other in the conductive mesh fabric of the present invention.

[FIG.4]

FIG. 4 shows an enlarged photograph of a warp yarn taken out from the conductive mesh fabric obtained in Example 1 and observed.

[FIG.5]

FIG. 5 is a graph indicating the results of measuring the surface unevenness of the warp of the conductive mesh fabric obtained in Example 1.

[FIG.6]

FIG. 6 is an enlarged photograph in which a warp yarn taken out from the fabric obtained in Comparative Example 1 and observed.

[FIG.7]

FIG. 7 is a graph indicating the results of measuring the surface unevenness of the warp of the fabric obtained in Comparative Example 1.

Modes for Carrying Out the Invention

1. Twisted Yarn

[0023] The conductive mesh fabric of the present invention comprises a twisted yarn made of synthetic fiber filaments as warp and weft. Examples of synthetic fibers include fibers made of polyesters such as polyethylene terephthalate and polybutylene terephthalate, fibers made of polyamides such as nylon 6 and nylon 66, fibers made of polyolefins such as polyethylene and polypropylene, polyacrylonitrile fibers, polyvinyl alcohol fibers and polyurethane fibers. Among them, polyester fibers and polyamide fibers are preferably used from the viewpoint of strength, versatility, and chemical resistance.

[0024] A plurality of filaments made of the above-mentioned synthetic fibers are bundled and twisted together to obtain a twisted yarn to use as the warp and weft. The number of filaments is preferably 2 to 20, more preferably 4 to 10.

[0025] The single yarn fineness of the filament is preferably 3 to 50 dtex, more preferably 4 to 20 dtex. Or, the diameter of the filament is preferably 20 to 45 μm , more preferably 23 to 28 μm .

[0026] The total fineness of the twisted yarn made by bundling a plurality of filaments is preferably 22 to 84 dtex, more preferably 33 to 55 dtex. Or, the diameter of the twisted yarn is preferably 45 to 90 μm , more preferably 55 to 75 μm .

[0027] The number of twists of the warp and weft is preferably 300 to 2,000 T/m, more preferably 500 to 1,000 T/m, respectively. When the number of twists of the synthetic fiber filament is within the range of 300 to 2,000 T/m, gentle unevenness (for example, having the depth of about 20 μm or less) are formed on the surface of the yarn. Due to the presence of this unevenness, it is possible to suppress misalignment of the warp and weft at the intersecting portion between the warp and the weft.

2. Mesh Fabric

[0028] The mesh fabric can be woven by a normal weaving method using the warp and the weft. Examples of weaving methods include a method using a water jet loom, an air jet loom, a rapier loom, or the like.

[0029] The mesh fabric is a fabric in which adjacent warp yarns and adjacent weft yarns are spaced apart from each other respectively, and the fabric structure thereof has relatively large voids, that is, openings (see FIG. 1).

[0030] Although the thickness of the resulting mesh fabric is not particularly limited because it may vary depending on the thickness of the twisted yarn used or the like, it is preferably 80 to 180 μm , more preferably 90 to 140 μm .

3. Opening Ratio

[0031] In the present invention, the ratio of the area of openings per unit area when the mesh fabric is projected onto a plane is referred to as an opening ratio. It is important for the present invention that the finally obtained conductive mesh fabric has an opening ratio of 40 to 80%, preferably 50 to 70%.

[0032] When the conductive mesh fabric has an opening ratio in the range of 40 to 80%, high followability to bending and torsional deformation can be acquired, and the effect of suppressing variation in conductivity in the bias direction of the conductive mesh fabric can be improved.

[0033] The opening ratio according to the present invention can be calculated using the following formula (Mathematical Formula 1). In the Mathematical Formula 1, calculated values obtained by viewing the mesh fabric in plan with a microscope manufactured by HIROXCO., LTD. (140 $\times$ magnification), and measuring by an image processing software are used as the opening area and the fiber area respectively.

<Mathematical Formula 1>

$$[\text{Opening Ratio (\%)}] = [\text{Opening Area}] / ([\text{Opening Area}] + [\text{Fiber Area}])$$

4. Metal film

[0034] According to the conductive mesh fabric of the present invention, a metal film is formed to cover the warp and the weft. Examples of metal types constituting the metal film include gold, silver, copper, platinum, nickel, zinc, tin and the like. It can also be an alloy containing a plurality of metals selected from these metal types. It is more preferable to use copper and/or nickel as the metal type constituting the metal film.

[0035] The total amount of metal applied to form the metal film is preferably 5 to 20 g/m² to the mesh fabric. When the total amount of metal applied is within this range, a conductive mesh fabric with an excellent balance between flexibility and conductivity can be obtained. The thickness of the metal film is preferably 0.5 to 2.0 μm.

[0036] Examples of methods for forming the metal film include known methods such as vapor deposition, sputtering, electroplating and electroless plating. Among these, electroless plating and/or electroplating are preferred from the viewpoint that a uniform metal film can be formed in all directions.

[0037] It is more preferable to form the metal film into a multilayer structure by first performing electroless plating and then performing electroplating. Preferable examples of metals used for electroless plating include copper, nickel and silver. Preferable examples of metals used for electroplating include gold, silver, nickel and tin. More specifically, it is preferable to perform first electroless copper plating and then electric nickel plating.

[0038] The amount of metal applied by electroless plating is preferably 5 to 25 g/m² to the mesh fabric. The amount of metal applied by electroplating is preferably 0.5 to 3.0 g/m² to the mesh fabric.

[0039] Performing electroless plating or electroplating has an advantage of forming a uniform metal film without defects even on the intersecting portion, regardless of its complicated shape.

[0040] In the present invention, a metal film may be formed on a yarn before weaving a mesh fabric, or a metal film may be formed on a mesh fabric after weaving. Preferably, a metal film can be formed on a mesh fabric after weaving. As a result, plating can be performed while the contact pressure between the warp and weft is ensured, thereby the contact pressure at the contact point between the warp and weft (at the intersecting portion) can be further improved. Especially, a mesh fabric to which electroless copper plating has been applied can be covered with a nickel film by further applying electric nickel plating, which enables to suppress oxidation of the copper plating film and also to improve conductivity at the contact point between the warp and weft.

[0041] According to the conductive mesh fabric of the present invention, it is important that the conductivity in the bias direction can be maintained at a high level even after repeated deformation. The bias direction means a direction in the plane of the conductive mesh fabric which is not parallel to either the warp extending direction or the weft extending direction. In general terms, it can be said that the bias direction is diagonal to the weave structure of the conductive mesh fabric, or can be said that an acute angle to the longitudinal directions of the warp and the weft is approximately 45°, respectively. An example of the bias direction is shown in FIG. 1 (D).

[0042] When considering the conductivity of the conductive mesh fabric in the bias direction, the electrical connections at the intersecting portions are important. In the mesh fabric, as described above, since adjacent warp yarns and adjacent weft yarns are spaced apart from each other respectively, the intersecting portions greatly contribute to conductivity in the bias direction.

[0043] Therefore, if a defect occurs in the metal film at the intersecting portion (or intersection), the conductivity of the conductive mesh fabric in the bias direction will vary significantly. When misalignment of the yarns occurs at the intersecting portion caused by repeated deformation, the metal film formed at the intersecting portion might be destroyed or torn, resulting in defects.

[0044] According to the present invention, by using a twisted yarn as the warp and the weft, misalignment of the yarns can be suppressed because of gentle unevenness formed on the surface thereof. Preferably, by using a twisted yarn having a specific number of twists, the effect of suppressing misalignment of yarns be enhanced. Furthermore, by forming recesses as described below at the intersecting portions, the effect of suppressing misalignment of yarns can be remarkably improved.

5. Recesses

(1) Structure of Recesses

[0045] In order to further suppress misalignment of yarns at the intersecting portion, the conductive mesh fabric of the present invention has recesses on the surface of the warp where that surface is in contact with the weft and has recesses on the surface of the weft where that surface is in contact with the warp at the portion where the warp and the weft intersect.

[0046] It is preferable that one or more of the recesses are formed on the surface of a filament constituting the warp (a warp filament) that is in contact with the filament constituting the weft (a weft filament), and one or more of the recesses are formed on the surface of the weft filament that is in contact with the warp filament.

<Substantially Circular Recess>

[0047] The recess can be formed by intersecting or crossing of one filament with the other filament, or one warp filament with one weft filament, and has a substantially circular shape (hereinafter referred to as "substantially circular recess"). Theoretically, the substantially circular recesses can be generated on the surface of a filament in the longitudinal direction thereof as many as the number of the other crossing filaments.

[0048] For example, when using a multifilament twisted yarn consisting of six monofilaments, the substantially circular recesses can be formed on the warp filament up to the number of weft filaments. Therefore, a maximum of six substantially circular recesses can be formed on the warp filament in this case.

[0049] Therefore, the substantially circular recesses according to the present invention can be formed in the longitudinal direction of the surface of the warp filament or the weft filament so that the number of the other intersecting filaments is the maximum number of recesses formed. The substantially circular recesses thus formed are preferably formed in parallel in the longitudinal direction of the surface of the filament (see FIG. 2) .

[0050] The substantially circular recess is not always required to be a complete circle, and may be a modified substantially circular recess that has a longitudinal direction and a lateral direction.

<Substantially Elliptical Recess>

[0051] A plurality of substantially circular recesses formed close to each other in the longitudinal direction of the surface of the warp filament or the weft filament can be integrated with each other. In that case, the plurality of substantially circular recesses may be integrated to form one recess, and the integrated recess may have a nearly oval shape or a substantially elliptical shape (hereinafter referred to as a substantially elliptical recess) along the longitudinal direction of the filament. The substantially elliptical recess formed in this manner can also be counted as one of the recesses of the present invention.

[0052] When a plurality of substantially circular recesses formed in the longitudinal direction of the surface of the filament are integrated, all of the plurality of substantially circular recesses formed in parallel in the longitudinal direction may be integrated, or only part of said plurality of substantially circular recesses may be integrated.

[0053] For example, when using a multifilament twisted yarn consisting of six monofilaments, only three out of the six substantially circular recesses formed at the intersecting portion can be integrated to form a substantially elliptical recess and the others can be left as a substantially circular recess respectively.

<Integrated Recess>

[0054] In the case of a yarn in which a plurality of monofilaments (warp filaments or weft filaments) with substantially elliptical recesses being formed are bundled together, the substantially elliptical recesses formed in adjacent filaments may be integrated with each other to form a larger substantially circular recess ("an integrated substantially circular recess"). In another case, substantially circular recesses formed over a plurality of adjacent filaments may be integrated with each other to form a circular or elliptical integrated recess.

(2) Size of Recesses

[0055] At least one of the substantially circular recesses formed on the surface of one warp filament and/or on the surface of one warp filament has the upper limit of a diameter which is preferably "[the thickness of a filament consisting a warp and/or a weft (= diameter; 25 to 45 μm)] + (plus) [50 to 90 pm] ", more preferably "[the thickness of a filament (= diameter; 25 to 45 μm)] +(plus) [80 μm]" .

[0056] The lower limit of a diameter of the substantially circular recess is preferably "[the thickness of a filament] -(minus) [5 to 25 pm]" , more preferably "[the thickness of a filament] -(minus) [20 pm]" .

[0057] The depth of the substantially circular recess is preferably smaller than the thickness of a twisted yarn (= the thickness of a conductive mesh fabric; 90 to 140 μm), more preferably smaller than the above-described thickness of a filament, still more preferably 5 to 20 μm , particularly preferably 8 μm to 15 μm .

[0058] The depth of the recess according to the present invention refers to the depth of the farthest (or the deepest) point from the surface of a twisted yarn constituting the mesh fabric. Preferably, it refers to the depth of the farthest (or the deepest) point from the surface of a filament constituting the twisted yarn.

[0059] Regarding the substantially elliptical recess formed by integrating a plurality of substantially circular recesses, the upper and lower limits of the length in the shorter side direction thereof is the same as the size of the above-mentioned substantially circular recess. That is, the upper limit is preferably "[the thickness of a filament] + [50 to 90 μm]", more preferably "[the thickness of a filament] + [80 μm]", and the lower limit is preferably "[the thickness of a filament] - [5 to 25 μm]", more preferably "[the thickness of a filament] - [20 μm]".

[0060] Regarding the length in the longer side direction of the substantially elliptical recess, the upper limit thereof is preferably "[the thickness of a twisted yarn (= a yarn formed by bundling a plurality of the above-described filaments)] + [50 to 90 μm]", more preferably "[the thickness of a twisted yarn] + [80 μm]".

[0061] Although the lower limit is not particularly limited, it is preferably about "[the thickness of two filaments] - [10 μm]".

[0062] In the case of an integrated recess formed by integrating substantially elliptical recesses and/or substantially circular recesses formed over a plurality of filaments, the upper limit of the approximate diameter is preferably "[the thickness of a twisted yarn] + [50 to 90 μm]", more preferably "[the thickness of a twisted yarn] + [80 μm]". The lower limit is preferably "[the thickness of a filament (monofilament) - [5 to 25 μm]", more preferably about "[the thickness of a filament (monofilament) - [20 μm]".

[0063] FIG. 2 shows an example of an electron microscopic photograph of the intersecting portion of an arbitrary twisted yarn extracted from the conductive mesh fabric of the present invention and observed from the side where the twisted yarn has been in contact with the other twisted yarn intersecting.

[0064] FIG. 2 is an electron microscopic photograph of the vicinity of the intersecting portion R of the warp yarn 2 extracted from the conductive mesh fabric 1 and observed from the side where the weft yarn 3 has been in contact with.

[0065] It can be seen from FIG. 2 that a recess 4 (a substantially circular recess) is formed in a region corresponding to the above-described intersecting portion R where the warp yarn 2 has been in contact with the weft yarn 3. It is similar for the weft yarn 3, and a recess (a substantially circular recess) is formed in a region corresponding to the intersecting portion R where the weft yarn 3 has been in contact with the warp yarn 2.

[0066] According to FIG. 2, it can be seen that similar recesses are formed next to (on both sides of) the recess 4. These adjacent recesses can also be integrated with each other to form a substantially elliptical recess.

[0067] In the case of a yarn in which a plurality of filaments are bundled (a warp yarn 2), substantially circular recesses or substantially elliptical recesses formed on the adjacent warp filaments can also be further integrated with each other to form a larger substantially circular recess (an integrated substantially circular recess).

(3) Engagement

[0068] According to the present invention, it is desirable that, in a portion where the warp and the weft intersect, the recesses formed on the surface of the warp in contact with the weft and those formed on the surface of the weft in contact with the warp are engaged with each other.

[0069] In FIG. 2, for example, the recess 4 on the warp yarn 2 and the recess on the weft yarn 3 are contacted and engaged with each other at the intersecting portion R, thereby misalignment of the warp yarn 2 and the weft yarn 3 is effectively suppressed.

[0070] Accordingly, the present invention provides a conductive mesh fabric capable of extremely effectively suppressing misalignment between the warp and weft by engagement with each other and suppressing variation in conductivity in the bias direction caused by repeated bending deformation and repeated twisting deformation.

[0071] FIG. 3 shows an image diagram representing a state in which the recesses of the warp and weft yarns are to be engaged with each other at the intersecting portion according to the present invention. Said engaging state in the present invention means a relationship in which the recesses fit into each other. However, this engaging state is not necessarily the same as a mechanically precise fit. The recesses are not necessarily required to be in close contact or fixed to each other. It is preferable that the warp and weft yarns are loosely or firmly engaged with each other.

[0072] In Fig. 3, in order to make it easier to understand the engaging state, the twisted yarn composed of multiple filaments is represented as a cylinder (a single yarn) for convenience, and only one engaging part by the recesses is represented at the intersecting portion. Actually, as mentioned above however, at least one recess (one substantially circular recess) can be formed at each intersection between a monofilament constituting the warp twisted yarn and a monofilament constituting the weft twisted yarn, and therefore, the entire intersection consisting of the whole twisted yarn may have a plurality of recesses (substantially circular recesses) (see FIG. 2). Then, they fit into each other to form an engaging state unique to the present invention capable of exhibiting an effect of suppressing misalignment between

the warp and weft.

[0073] The recess 4 in FIG. 2 represents a state in which the surface of the warp filament constituting the warp yarn 2 is deformed and crushed (state in FIG. 2; formation of a substantially circular recess), but the present invention is not limited to this case.

[0074] For example, in the case of a yarn in which a plurality of filaments are bundled as described above, a plurality of substantially circular recesses 4 may be formed on the warp filaments constituting the warp yarn 2 by intersecting with the plurality of weft filaments constituting the weft yarn, and a substantially elliptical recess may also be formed by integrating them.

[0075] For the warp yarn 2 (a yarn in which a plurality of warp filaments are bundled), substantially circular recesses and/or substantially elliptical recesses formed on adjacent warp filaments may also be integrated to form a larger substantially circular recess or substantially elliptical recess (an integrated recess).

[0076] In such a case, the cross-sectional shape of the yarn as a whole may become crushed. That is, the thickness of the warp yarn 2 (the dimension in the thickness direction of the conductive mesh fabric 1) may be smaller at the intersection R depending on the arrangement state of the plurality of filaments in the warp yarn 2. For example, in the case where the yarn represented as a cylinder in FIG. 3 is a twisted yarn made of a plurality of monofilaments, the cross-sectional shape of the entire twisted yarn may be in a crushed state.

[0077] Taking FIG. 3 as an example, "a" and "b" in FIG. 3 both correspond to the diameter of the recess, and at least one of "a" and "b" is preferably 20 to 80 μm , more preferably 30 to 60 μm . Desirably, both "a" and "b" are preferably 20 to 80 μm , more preferably 30 to 60 μm .

[0078] In FIG. 3, "c" corresponds to the depth of the recess, specifically the depth of the farthest (deepest) point from the surface of the yarn. "c" is preferably 2 to 20 μm , more preferably 4 to 10 μm .

6. Manufacturing Method

[0079] A method for manufacturing the conductive mesh fabric of the present invention will be explained below.

[0080] First, a mesh fabric having twisted yarns made of synthetic fiber filaments as a warp yarn 2 and a weft yarn 3 is produced by a normal weaving method.

[0081] Next, a process for forming recesses 4 on the surface of the warp yarn 2 and the weft yarn 3 at the intersection R is performed.

[0082] Means for forming the recesses 4 include a method of performing calendering while heating and a method of performing heat setting treatment while applying tension in the direction of the warp yarn 2 and the direction of the weft yarn 3. Since the mesh fabric used for the present invention is composed of twisted yarns made of synthetic fiber filaments, the recesses 4 can be formed by applying a proper contact pressure to the intersection R while heating the fabric at a temperature range of a glass transition temperature or higher and a melting temperature or lower of the synthetic fiber filaments used.

[0083] For example, when the synthetic fiber filament is made of polyester fiber, since the glass transition temperature thereof is 69°C and the melting point is about 260°C usually, the heating temperature is preferably 150 to 220°C, more preferably 170 to 200°C.

[0084] Preferred conditions for calendering include a temperature of 90 to 180°C and a linear pressure of 15 to 40 kg/cm.

[0085] Examples of preferred methods in the present invention include a heat setting treatment in which heat is applied while applying constant tension in the warp and/or weft directions. Examples of means for applying tension include a method of adjusting a setting width of the heat setting processing device to a specific tentering ratio. At this time, tension is applied in the weft direction which is a set width direction, or a direction orthogonal to the take-up direction of the fabric. Preferred conditions for the heat setting treatment include a temperature of 150 to 220°C and a tentering ratio of 1.0 to 8.0%.

[0086] After the step of forming the recess 4, the step of forming a metal film is performed. The means for forming a metal film can be performed as described above, and electroless plating and electroplating are preferred. In particular, after forming a copper film by electroless copper plating, it is preferable to laminate a nickel film thereon by electric nickel plating.

[0087] Recesses having the above-mentioned characteristic shapes can be formed at the intersecting portion of the conductive mesh fabric thus obtained.

[0088] Since the recess of the present invention is formed before the metal film is formed, the diameter of the filament (monofilament), which is the reference for the shape (size) of the recess, does not include the thickness of the metal film.

[0089] Since the warp and weft yarns are engaged with each other at the recess, a metal film is usually not formed on the recess surface of the conductive mesh fabric obtained after forming the metal film.

7. Physical Properties

[0090] When the resistance value in the bias direction of the conductive mesh fabric of the present invention is measured at 0.33 second intervals during a repeated bending test with a bending radius of 2.5 mm, a bending angle of $\pm 135^\circ$, a bending speed of 60 cycles/min, and a total number of bends of 1,000 cycles, the coefficient of variation of the resistance value is preferably 5.0% or less.

[0091] When the resistance value in the bias direction of the conductive mesh fabric of the present invention is measured at 0.33 second intervals during a repeated twisting test with a twisting angle of $\pm 90^\circ$, a twisting speed of 60 cycles/min, and a total number of twists of 1,000 cycles, the coefficient of variation of the resistance value is preferably 5.0% or less.

[0092] The bending tester and twisting tester used to measure the above-mentioned physical properties are not particularly limited, and general bending testers and twisting testers commonly used by those skilled in the art can be used.

[0093] In the above-mentioned bending test and twisting test, it is usually possible to obtain, for example, 3,000 resistance values in the bias direction respectively. Therefore, the average value and standard deviation of the obtained resistance value data can be determined to calculate the value "[standard deviation]/[average value] $\times$ 100" as the coefficient of variation (%).

[0094] A mesh fabric having the coefficient of variation of the resistance values in the bias direction during bending tests and/or twisting tests of 5.0% or less can be used for various purposes as a conductive mesh fabric capable of suppressing variation in conductivity in the bias direction even when deformed.

Examples

[Example 1]

[0095] A plain woven mesh fabric was produced using a twisted yarn made of polyester fiber filaments (33 dtex/6f, 800 T/m in a Z-twisting direction) for both the warp and weft, and using a water jet loom as the weaving method. The warp yarn density was 68 yarns/inch, and the weft yarn density was 88 yarns/inch.

[0096] Next, as a step for forming recesses at the intersections, a heat setting process was carried out in the weft direction of the fabric with a tentering ratio of 2.5% at a temperature of 185°C for 1 minute using a heat setting machine.

[0097] A catalyst for electroless plating was applied to the obtained mesh fabric using a colloidal solution of PdCl_2 and SnCl_2 , and then electroless copper plating and electric nickel plating were sequentially performed. In electroless copper plating, a plating solution containing CuCl_2 , formaldehyde, and sodium hydroxide was used.

[0098] In electric nickel plating, a plating solution containing $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ and sodium citrate was used. The amount of copper applied by electroless copper plating was 9.0 g/m², the amount of nickel applied by electric nickel plating was 1.4 g/m², and the total amount of metal applied was 10.4 g/m².

[0099] The opening ratio of the obtained conductive mesh fabric was 58.3%. The opening ratio in this example was calculated using the above calculation formula (Mathematical Formula 1). In Mathematical Formula 1, the opening area and the fiber area were calculated by viewing the mesh fabric in plan using a microscope manufactured by HIROX CO., LTD. (140x magnification), and measuring by an image processing software.

[0100] FIG. 4 shows an electron microscopic photograph of the intersecting portion of an arbitrary warp yarn extracted from this conductive mesh fabric and observed from the side where the warp yarn had been in contact with the weft yarn. The electron microscope used was the product name "S-3000N", manufactured by Hitachi, Ltd., and the magnification was 1000 times.

[0101] FIG. 5 shows a result of measuring the surface unevenness of a warp of the conductive mesh fabric as a graph. The measurement was performed along the cross section A-B in FIG. 4 using a surface unevenness measuring device (trade name "Laser Microscope VK-X3000", manufactured by KEYENCE CORPORATION).

[0102] In FIG. 5, the actual surface unevenness measurement result was represented by a solid line 5. Meanwhile, based on the photographed image of FIG. 4, the starting points of the recesses were connected with each other by a natural line estimated from the surface unevenness measurement results of forward and rearward of the intersection to draw an arc, and the arc thus obtained was represented as a dotted line 6 as a baseline.

[0103] As is clear from FIG. 5, there was a portion where the solid line 5 and the dotted line 6 diverged, and it was confirmed that a recess was formed. The divergence width at the location where the divergence width was maximum (7 in FIG. 5) was defined as the depth.

[0104] From FIGS. 4 and 5, it was confirmed that a recess was formed in the region of the warp that was in contact with the weft. As a result of measuring the size and depth of the recess using the graph shown in FIG. 5, the diameter in the longitudinal direction was 80 μm and the depth was 5 μm . The diameter in the lateral direction was measured using a surface unevenness measuring device (trade name "Laser Microscope VK-X3000", manufactured by KEYENCE CORPORATION), which was 20 μm .

[0105] In addition, the area near the intersecting portion was observed from the side where the weft was in contact

with the warp by the same method. As a result, it was confirmed that a similar recess was also formed in the area of the weft corresponding to said intersecting portion where the weft was in contact with the warp.

[0106] The conductivity of the obtained conductive mesh fabric in the bias direction during a repeated bending test was evaluated. A 15 cm × 8 mm ribbon-shaped test piece was cut out from the conductive mesh fabric in the bias direction (45 degrees to the warp) so that the longitudinal direction of the test piece was in the bias direction.

[0107] The test piece thus obtained was subjected to a repeated bending test with the number of repeated bending of 1000 cycles using a bending tester (trade name "TCDMLS-P150", manufactured by YUASA SYSTEM Co., Ltd.) under the conditions of a bending radius of 2.5 mm, a bending angle of $\pm 135^\circ$ and a bending speed of 60 cycles/min.

[0108] During the bending test, the resistance value between 12 cm in the bias direction of the conductive mesh fabric (the resistance value between two points arbitrarily selected at 12 cm intervals in the bias direction or the longitudinal direction of the cut test piece) was measured at 0.33 second intervals (= measured 3 times per second or at 1/3 second interval). A milliohm tester (trade name "RM-3545-02", manufactured by HIOKI E.E. CORPORATION) was used to measure the resistance value.

[0109] Similarly, the conductivity of the conductive mesh fabric thus obtained in the bias direction during a repeated twisting test was evaluated. A 15 cm × 8 mm ribbon-shaped test piece was cut out from the conductive mesh fabric in the bias direction (45 degrees to the warp) so that the longitudinal direction of the test piece was in the bias direction.

[0110] The test piece thus obtained was subjected to a repeated twisting test with the number of repeated twisting of 1000 cycles using a twisting tester (trade name "TCDMLH-FT", manufactured by YUASA SYSTEM Co., Ltd.) under the conditions of a twisting angle of $\pm 90^\circ$ and a twisting speed of 60 cycles/min.

[0111] During the twisting test, the resistance value between two points arbitrarily selected at 12 cm intervals in the bias direction of the conductive mesh fabric was measured at 0.33 second intervals. A milliohm tester (trade name "RM-3545-02", manufactured by HIOKI E.E. CORPORATION) was used to measure the resistance value.

[0112] In each of the above bending test and twisting test, 3,000 resistance values in the bias direction were obtained. The average value and standard deviation of the resistance value data thus obtained were determined, and the coefficient of variation was calculated using the following formula (Mathematical Formula 2). Table 1 shows the maximum value, minimum value, average value, standard deviation, and coefficient of variation (%) of the measured resistance values (Ω).

(Mathematical Formula 2)

$$[\text{Coefficient of Variation (\%)}] = [\text{Standard Deviation}] / [\text{Average Value}] \times 100$$

[Comparative Example 1]

[0113] Instead of the plain woven mesh fabric of Example 1, a plain woven fabric in which the warp and weft were made of untwisted polyester fiber filaments having 56 dtex/36f, and the warp density was 80 yarns/inch and the weft density was 61 yarns/inch was used. A heat treatment process and a metal film forming process were performed in the same manner as in Example 1 except for using said plain woven fabric, to obtain a conductive plain woven fabric.

[0114] The amount of copper applied by electroless copper plating was 23.6 g/m², the amount of nickel applied by electric nickel plating was 2.4 g/m², and the total amount of metal applied was 26.0 g/m².

[0115] The opening ratio of the conductive plain fabric thus obtained was 19.2%.

[0116] FIG. 6 shows an electron microscopic photograph of the intersecting portion of an arbitrary warp yarn extracted from this conductive plain fabric and observed from the side where the warp yarn had been in contact with the weft yarn. The electron microscope used was the product name "S-3000N", manufactured by Hitachi, Ltd., and the magnification was 1000 times. According to FIG. 6, no clear recesses were formed at the intersections of this conductive plain fabric.

[0117] FIG. 7 shows a result of measuring the surface unevenness of a warp of this conductive plain fabric as a graph. The measurement was performed along the cross section A'-B' in FIG. 6 using a surface unevenness measuring device (trade name "Laser Microscope VK-X3000", manufactured by KEYENCE CORPORATION).

[0118] In FIG. 7, the actual surface unevenness measurement result was represented by a solid line 5', and the baseline was represented by a dotted line 6'. It was confirmed that there was almost no divergence between the solid line 5' and the dotted line 6', and no recess was formed.

[0119] Table 1 shows the results of measuring the resistance values of the obtained conductive fabric during repeated deformation (bending and/or twisting) tests in the same manner as in Example 1.

[Table 1]

		Example 1	Comparative Example 1
	Opening Ratio (%)	58.3	19.2
Resistance Value during Repeated Bending Test	Maximum (Ω)	1.17	76.68
	Minimum (Ω)	1.05	5.55
	Average (Ω)	1.10	13.76
	Standard Deviation (Ω)	0.02	7.93
	Coefficient of Variation (%)	1.82	57.6
Resistance Value during Repeated Twisting Test	Maximum (Ω)	1.45	119.9
	Minimum (Ω)	1.22	17.93
	Average (Ω)	1.35	61.67
	Standard Deviation (Ω)	0.03	10.07
	Coefficient of Variation (%)	2.22	16.3

Explanation of Reference Letters

[0120]

- 1: Conductive mesh fabric
- 2: Warp
- 3: Weft
- 4: Recess
- 5, 5': Surface unevenness measurement results (solid line)
- 6, 6': Baseline (dotted line)
- 7: Depth (maximum divergence between solid line 5 and dotted line 6)
- D: Bias direction
- R: Intersecting portion
- a: Diameter of the recess in the schematic diagram
- b: Diameter of the recess in the schematic diagram
- c: Depth of recess in schematic diagram

Claims

1. A conductive mesh fabric comprising a twisted yarn consisting of synthetic fiber filaments as warp and weft with a metal film formed covering the warp and the weft, having an opening ratio of 40-80%, and having recesses on the surface of the warp where that surface is in contact with the weft and recesses on the surface of the weft where that surface is in contact with the warp at the portions where the warp and the weft intersect.
2. The conductive mesh fabric according to claim 1, wherein one or more of said recesses are formed on the surface of a filament constituting the warp that is in contact with a filament constituting the weft, and one or more of said recesses are formed on the surface of a filament constituting the weft that is in contact with a filament constituting the warp.
3. The conductive mesh fabric according to claim 1 or 2, wherein at least one of the recesses formed on the surface of said filament constituting the warp and the recesses formed on the surface of said filament constituting the weft is substantially circular having a diameter of "[warp filament diameter] + [80 μm]" or less and/or a diameter of "[weft filament diameter] + [80 μm]" or less, and having the depth of 4 to 20 μm .
4. The conductive mesh fabric according to any one of claims 1 to 3, wherein said recesses have the diameter of 20 to 80 μm and the depth of 4 to 20 μm .

5. The conductive mesh fabric according to any one of claims 1 to 4, wherein a recess on the surface of the warp that is in contact with the weft and a recess on the surface of the weft that is in contact with the warp are engaged with each other at a portion where the warp and the weft intersect.

5 6. The conductive mesh fabric according to any one of claims 1 to 3, wherein the number of twists of said twisted yarn is 300 to 2,000 T/m.

10 7. The conductive mesh fabric according to any one of claims 1 to 4, wherein the coefficient of variation of the resistance value in the bias direction measured at 0.33 second intervals during a repeated bending test using a bending tester with a bending radius of 2.5 mm, a bending angle of $\pm 135^\circ$, a bending speed of 60 cycles/min and a total number of bends of 1,000 cycles is 5.0% or less.

15 8. The conductive mesh fabric according to any one of claims 1 to 5, wherein the coefficient of variation of the resistance value in the bias direction measured at 0.33 second intervals during a repeated twisting test using a twisting tester with a twisting angle of $\pm 90^\circ$, a twisting speed of 60 cycles/min, and a total number of twists of 1,000 cycles is 5.0% or less.

20 9. A method for manufacturing a conductive mesh fabric which includes a weaving process of producing a mesh fabric using a twisted yarn made of synthetic fiber filaments as warp and weft, a heat treatment process of heat-treating the mesh fabric obtained by the weaving process, and a metal film forming process of forming a metal film on the heat-treated mesh fabric.

25 10. The method for manufacturing a conductive mesh fabric according to claim 9, wherein the number of twists of said twisted yarn is 300 to 2,000 T/m.

11. The method for manufacturing a conductive mesh fabric according to claim 9 or 10, wherein the heat treatment process is carried out at a tentering ratio of 1.0 to 8.0% in the warp direction and/or weft direction.

30 12. The method for manufacturing a conductive mesh fabric according to any one of claim 9 to 11, wherein the temperature condition in the heat treatment process is 150 to 220°C.

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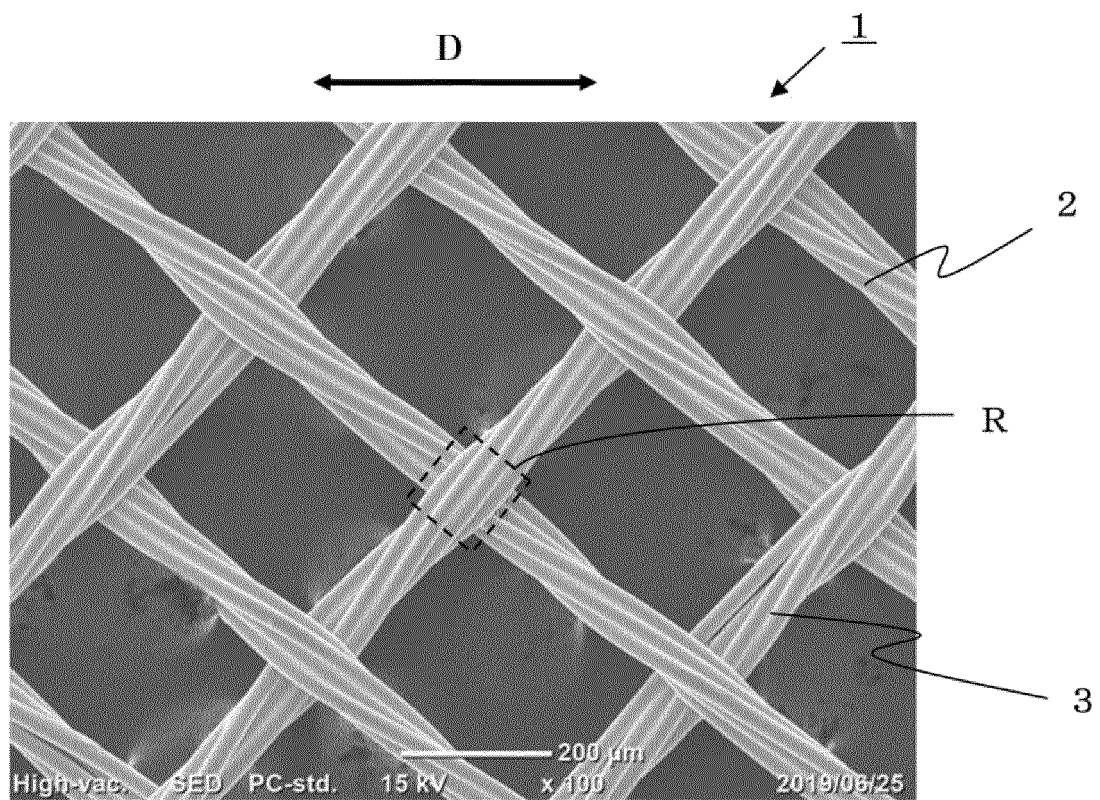
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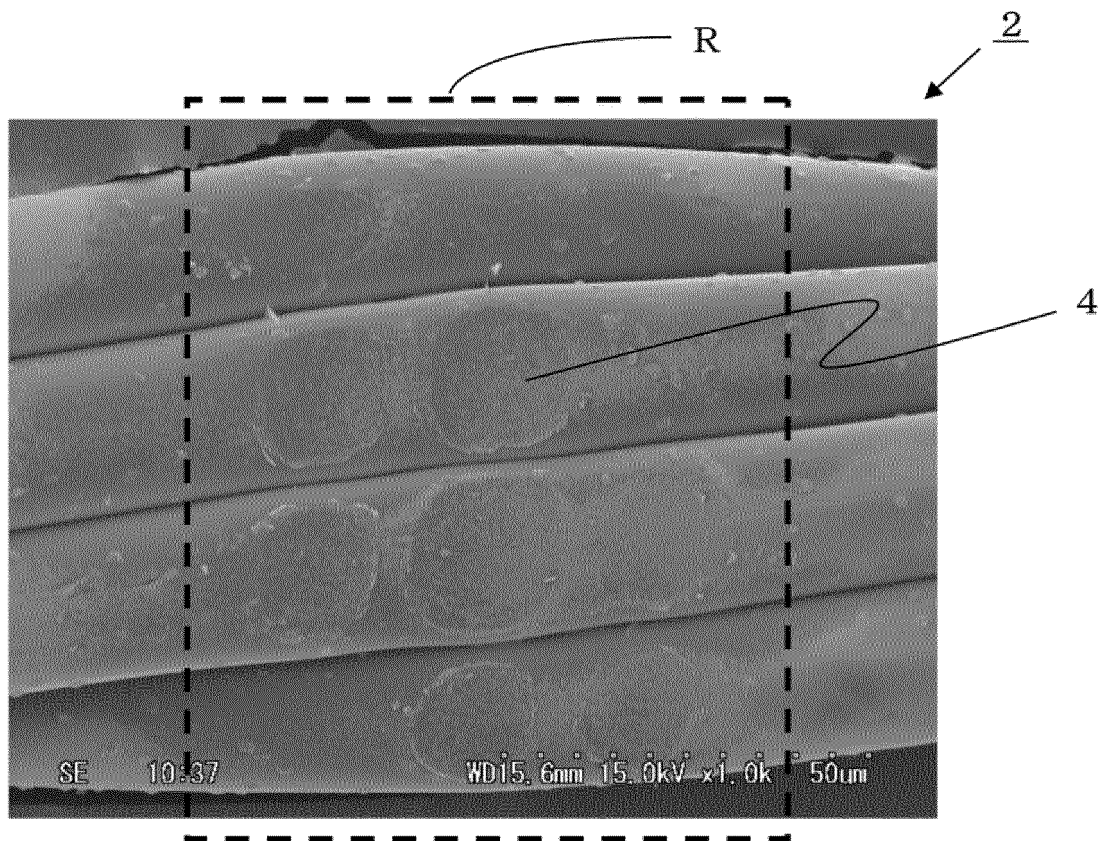
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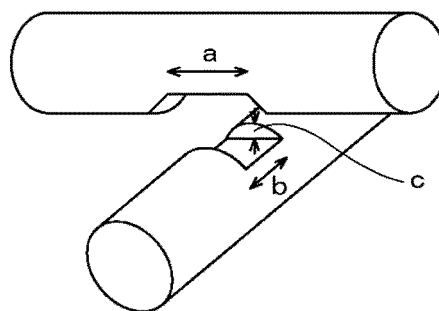
[FIG. 1]



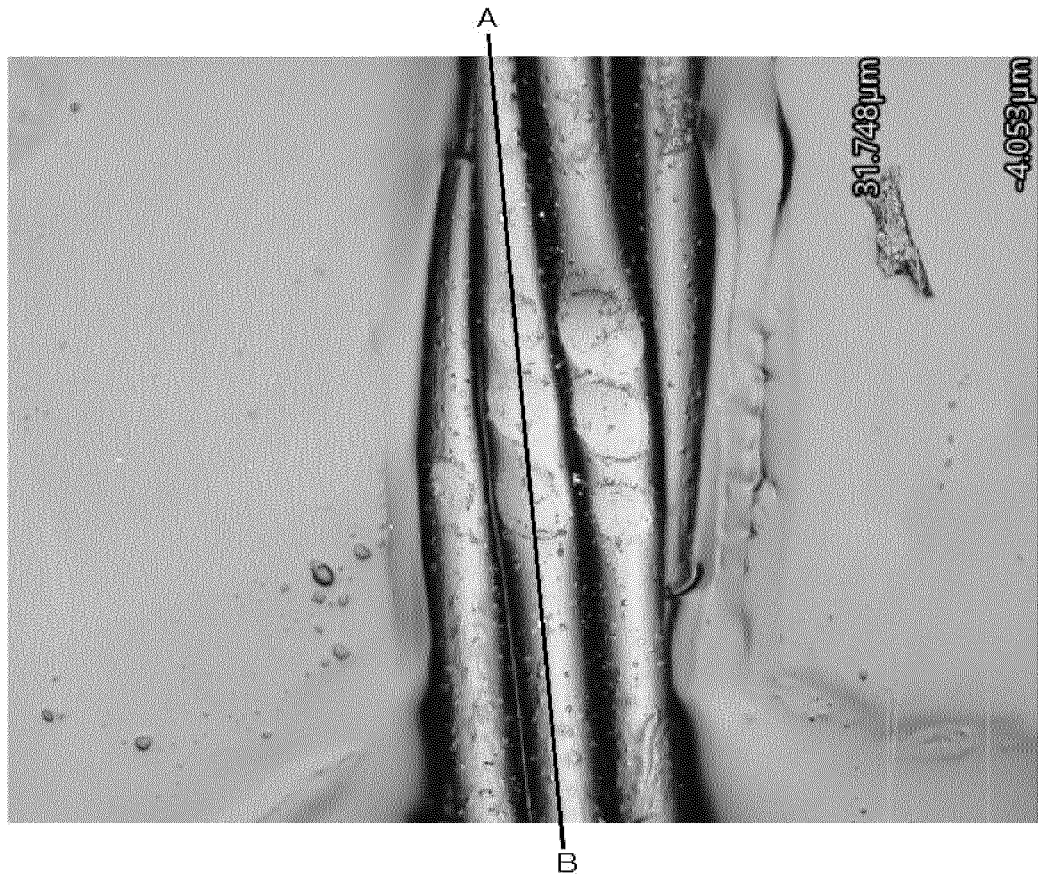
[FIG.2]



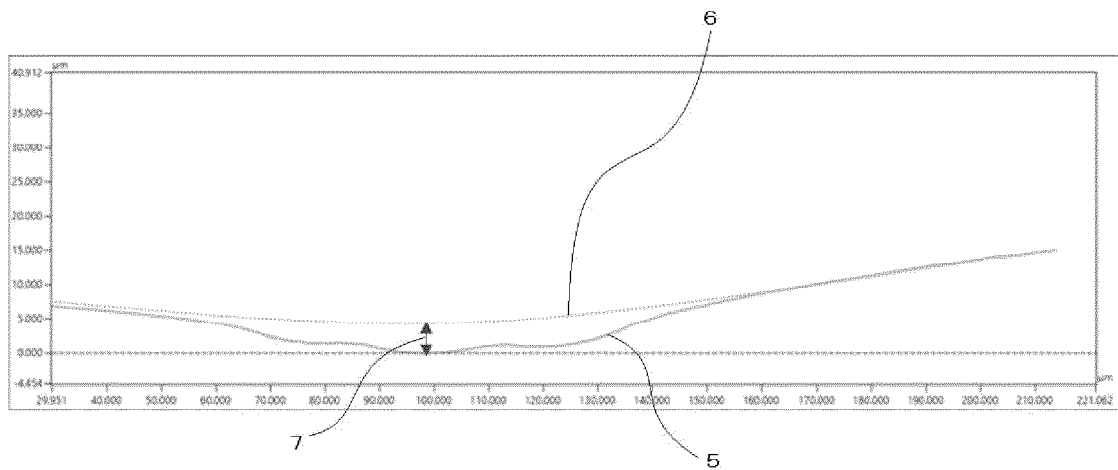
[FIG.3]



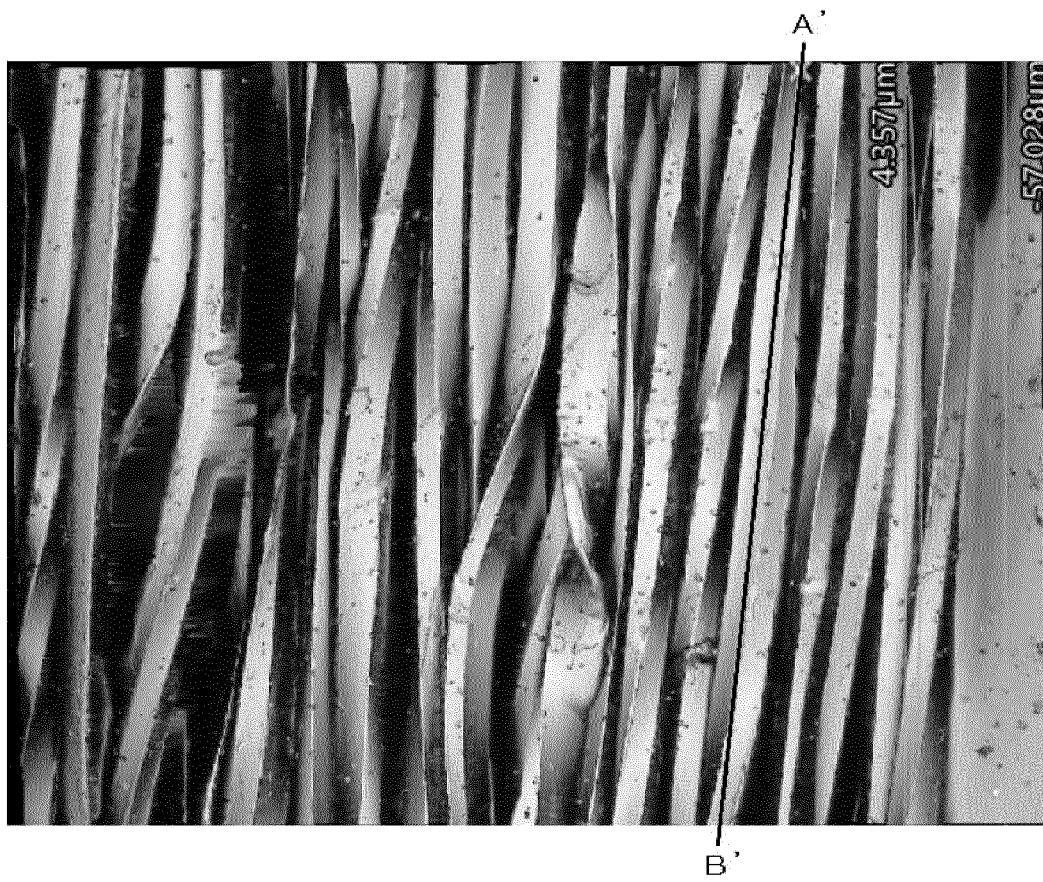
[FIG. 4]



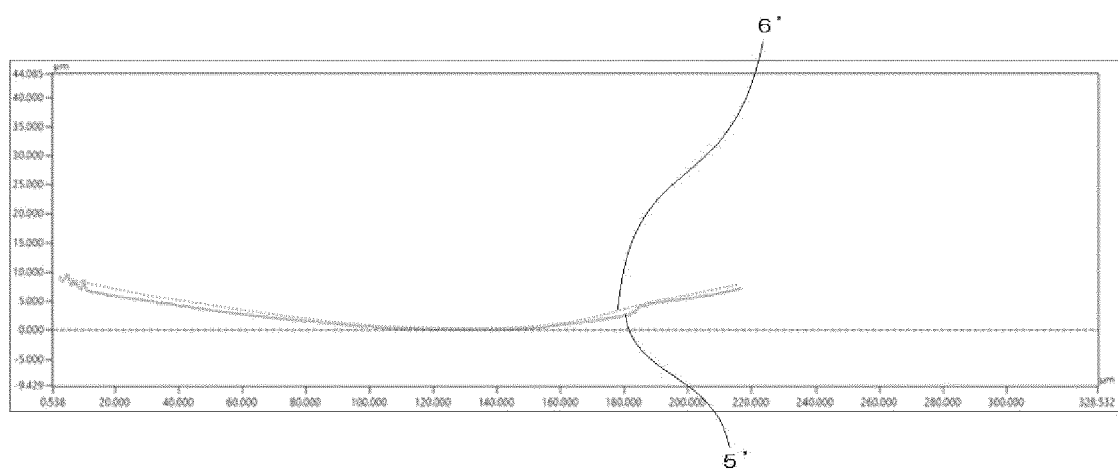
[FIG. 5]



[FIG. 6]



[FIG. 7]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/024523

A. CLASSIFICATION OF SUBJECT MATTER

D03D 15/533(2021.01)i; **D03D 9/00**(2006.01)i; **D03D 15/20**(2021.01)i; **D03D 15/41**(2021.01)i; **D06M 11/83**(2006.01)i
 FI: D03D15/533; D03D9/00; D03D15/20 100; D03D15/41; D06M11/83

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)

D03D1/00-27/18; D06M11/83

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 1971-2022
 Registered utility model specifications of Japan 1996-2022
 Published registered utility model applications of Japan 1994-2022

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	JP 2021-82573 A (PANASONIC IP MAN CORP) 27 May 2021 (2021-05-27) claim 1, paragraphs [0078]-[0079], [0107]-[0110]	9-10, 12
A		1-8, 11
A	WO 2008/001958 A1 (SEIREN CO., LTD.) 03 January 2008 (2008-01-03)	1-12
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A	CN 211106114 U (JIANGSU SUZHOU LIHUA TEXTILE CO., LTD.) 28 July 2020 (2020-07-28)	1-12

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

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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

12 August 2022

Date of mailing of the international search report

23 August 2022

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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/024523

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2021082573 A [0006]