

TRANSFORMER, COIL, WIRE AND PRODUCING METHOD THEREFOR

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☒ Description : paged ...1... to paged ...-.....	
☒ Claim(s) : paged ... 24 ... to paged ...45.....	
☐ Drawing(s) : paged to paged	
☒ Abstract : paged ...44... to paged ...-.....	
DATE OF RECEIPT	

2-2201122

BACKGROUND OF THE INVENTION AND RELATED ART STATEMENT

The present invention relates to a transformer, an electromagnetic coil, a wire for the electromagnetic coil or before wound as the electromagnetic coil, and a producing method therefor.

JP-U-60-121620 discloses an electromagnetic coil in which an electrically insulating sheet is arranged between windings extending axially formed by a wire with an electrically insulating coating.

JP-A-59-43514 discloses another electromagnetic coil in which axial ends of the tube-shaped windings formed by the wire with an electrically insulating coating are covered by epoxy resin.

OBJECT AND SUMMARY OF THE INVENTION

An object of the present invention is to provide a transformer, an electromagnetic coil, a wire for the electromagnetic coil or before wound as the electromagnetic coil, and a producing method therefor, by which the wire can be wound uninterruptedly or continuously with sufficient insulating strength of the wire and high manufacturing efficiency from a relatively radially-inner winding to a relatively radially-outer winding without inserting an electrically insulating sheet between the relatively radially-inner winding and

the relatively radially-outer winding.

Another object of the present invention is to provide an electromagnetic coil and a producing method therefor, by which an axial end of the tube-shaped
5 windings formed by the wire with an electrically insulating coating can be easily with improved manufacturing efficiency sealed up in comparison with the prior art.

A wire for a coil, according to the present
10 invention, comprises,

an electrically conductive wire body having first and second body surface portions substantially opposed to each other, and third and fourth body surface portions substantially opposed to each other, and

15 an electrically insulating layer having inner and outer layer surfaces substantially opposed to each other, inner layer surface covering at least partially the first, second, third and fourth body surface portions, and the outer layer surface being exposed to
20 an outside of the wire,

wherein a thickness of a part of the electrically insulating layer on at least one of the first and second body surface portions is larger than a thickness of a part of the electrically insulating layer
25 on at least one of the third and fourth body surface portions before being wound as the coil.

Since the thickness of the part of the electrically insulating layer on the at least one of the

first and second body surface portions is larger than the thickness of the part of the electrically insulating layer on the at least one of the third and fourth body surface portions before being wound as the coil, the
5 coil with both a direction in which the thickness of the electrically insulating layer is relatively large and another direction in which the thickness of the electrically insulating layer is relatively small so that an insulating strength in the direction is larger
10 than that in the another direction, is easily and uninterruptedly formed, without inserting a tube-shaped electrically insulating sheet between a relatively radially-inner substantially tube-shaped wire winding and a relatively radially-outer substantially tube-
15 shaped wire winding. The substantial tube-shape of the wire winding may be disturbed in accordance with an outer shape of a previously formed wire winding on which the wire is further wound and stacked.

A total amount of the thickness of the part of
20 the electrically insulating layer on the first body surface portion and the thickness of the part of the electrically insulating layer on the second body surface portion may be larger than a total amount of the thickness of the part of the electrically insulating
25 layer on the third body surface portion and the thickness of the part of the electrically insulating layer on the fourth body surface portion before being wound as the coil. It is preferable that the first and

second body surface portions are opposed to each other substantially in a radial direction of the coil, and the third and fourth body surface portions are opposed to each other substantially in an axial direction of the coil when the wire is wound and stacked axially to form a first substantially tube-shaped wire winding around an axis of the coil after being wound and stacked axially to form a second substantially tube-shaped wire winding of relatively radial inside of the first imaginary substantially tube-shaped wire winding. The substantial tube-shape of the wire windings may be disturbed in accordance with an outer shape of a previously formed wire winding on which the wire is further wound and stacked axially.

15 The one of the first and second layer surfaces may be adhered to the third and fourth body surface portions. The electrically insulating layer may include a main electrically insulating layer, and a supplemental electrically insulating layer between the at least one of the first and second body surface portions and the main electrically insulating layer. The electrically conductive wire body may be substantially rectangular with a substantially flat shape of the first, second, third and fourth body surface portions. The electrically conductive wire body may be substantially cycloid or elliptical with a curved shape of the first, second, third and fourth body surface portions.

When the electrically conductive wire body has

at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, it is preferable for preventing or restraining
5 a dielectric breakdown at the at least one body corner portion or a peak thereof that a thickness of a part of the electrically insulating layer extending over the at least one body corner portion is larger than the thickness of the part of the electrically insulating
10 layer on the at least one of the third and fourth body surface portions, and/or that a thickness of a part of the electrically insulating layer over a central position (substantially equal to the peak) of the at least one body corner portion on an imaginary radial
15 plane substantially perpendicular to the axial direction is larger than the thickness of the part of the electrically insulating layer on the at least one of the third and fourth body surface portions.

When the electrically insulating layer
20 includes an inner electrically insulating film which extends continuously between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and an outer electrically insulating film which covers a
25 part of the inner electrically insulating film on the at least one of the first and second body surface portions, and the electrically conductive wire body has at least one body corner portion between the at least one of the

first and second body surface portions and the at least one of the third and fourth body surface portions, it is preferable for preventing or restraining the dielectric breakdown at the at least one body corner portion or the peak thereof that the outer electrically insulating film extends over a part of the inner electrically insulating film on the at least one body corner portion, and/or extends over a part of the inner electrically insulating film on the at least one of the third and fourth body.

10 When the electrically insulating layer includes an inner electrically insulating film which extends continuously between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and an outer electrically insulating film which covers a part of the inner

15 electrically insulating film on the at least one of the first and second body surface portions, and the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the

20 third and fourth body surface portions, it is preferable for preventing or restraining the dielectric breakdown at least one body corner portion or the peak thereof that the outer electrically insulating film extends over

25 a part of the inner electrically insulating film on a central position of the at least one body corner portion on an imaginary radial plane substantially perpendicular to the axial direction.

When the electrically insulating layer includes an inner electrically insulating film which covers the at least one of the first and second body surface portions, and an outer electrically insulating film which covers continuously both the at least one of the third and fourth body surface portions and a part of the inner electrically insulating film on the at least one of the first and second body surface portions, and the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, it is preferable for preventing or restraining the dielectric breakdown at the at least one body corner portion or the peak thereof that the inner electrically insulating film extends on the at least one body corner portion, that the inner electrically insulating film reaches the at least one of the third and fourth body surface portions, and/or that the inner electrically insulating film extends on a central position of the at least one body corner portion on an imaginary radial plane substantially perpendicular to the axial direction.

The electrically insulating layer may include a first electrically insulating film which covers the first and second body surface portions and one of the third and fourth body surface portions, and a second electrically insulating film which covers another one of the third and fourth body surface portions and a part of

the first electrically insulating film on the first and second body surface portions.

The outer electrically insulating film may be prevented from contacting a part of the inner electrically insulating film over the at least one body corner portion, from contacting a part of the inner electrically insulating film over the central position of the at least one body corner portion, and/or from contacting a part of the inner electrically insulating film on the at least one of the first and second body surface portions.

The outer electrically insulating film may reach or contact a part of the inner electrically insulating film over the at least one body corner portion, a part of the inner electrically insulating film over the central position of the at least one body corner portion, and/or a part of the inner electrically insulating film on the at least one of the first and second body surface portions.

The supplemental electrically insulating layer may be adhered to the at least one of the first and second body surface portions, and the main electrically insulating layer may be adhered to the supplemental electrically insulating layer. The electrically insulating layer may be a prepreg member.

A method for producing a wire for a coil or for producing the coil, according to the present invention, comprises the steps of :

feeding an electrically conductive wire body

having first and second body surface portions substantially opposed to each other, and third and fourth body surface portions substantially opposed to each other,

5 covering at least one of the first and second body surface portions and one of the third and fourth body surface portions by an inner electrically insulating layer, and

covering a part of the inner electrically
10 insulating layer on the at least one of the first and second body surface portions and another one of the third and fourth body surface portions by an outer electrically insulating layer.

By this method, the wire with both a direction
15 in which the thickness of the electrically insulating layer is relatively large and another direction in which the thickness of the electrically insulating layer is relatively small so that an insulating strength in the direction is larger than that in the another direction,
20 is easily and continuously formed.

Both of the first and second body surface portions may be covered by the inner electrically insulating layer, and the part of the inner electrically insulating layer on the at least one of the first and
25 second body surface portions may be covered by the outer electrically insulating layer. One of the first and second body surface portions may be covered by the inner electrically insulating layer, and a part of the inner

electrically insulating layer on the one of the first and second body surface portions and another one of the first and second body surface portions may be covered by the outer electrically insulating layer. Both of the
5 first and second body surface portions may be covered by the inner electrically insulating layer, and a part of the inner electrically insulating layer on the both of the first and second body surface portions may be covered by the outer electrically insulating layer.

10 A method for producing a coil, according to the present invention, comprises the steps of :

preparing a wire comprising an electrically conductive wire body having first and second body surface portions substantially opposed to each other,
15 and third and fourth body surface portions substantially opposed to each other, and an electrically insulating layer covering the electrically conductive wire body, a thickness of a part of the electrically insulating layer on at least one the first and second body surface
20 portions being larger than a thickness of a part of the electrically insulating layer on at least one of the third and fourth body surface portions,

thereafter winding and stacking axially the wire along a substantially tube-shaped imaginary face
25 around an axis of the coil, and

further winding and stacking the wire axially along another substantially tube-shaped imaginary face of relatively radial outside of the substantially tube-

shaped imaginary face while the first and second body surface portions are opposed to each other substantially in a radial direction of the coil, and the third and fourth body surface portions are opposed to each other
5 substantially in an axial direction of the coil.

Since the wire comprising an electrically conductive wire body having first and second body surface portions substantially opposed to each other, and third and fourth body surface portions substantially
10 opposed to each other, and an electrically insulating layer covering the electrically conductive wire body, a thickness of a part of the electrically insulating layer on at least one the first and second body surface portions being larger than a thickness of a part of the
15 electrically insulating layer on at least one of the third and fourth body surface portions is prepared before being wound and stacked to be changed to the coil, the coil with both of a direction in which the thickness or electrical insulating strength of the
20 electrically insulating layer is relatively large and another direction in which the thickness or electrical insulating strength of the electrically insulating layer is relatively small, is easily and uninterruptedly formed without inserting the insulating sheet between
25 the wound and stacked wire mass or arrays.

A wire before changed to a coil, according to the present invention, comprising, an electrically conductive wire body having first and second body

surface portions substantially opposed to each other,
and third and fourth body surface portions substantially
opposed to each other, and an electrically insulating
layer covering the electrically conductive wire body,
5 wherein a total amount of a thickness of a part of the
electrically insulating layer on the first body surface
portion and a thickness of a part of the electrically
insulating layer on the second body surface portion is
larger than a total amount of a thickness of a part of
10 the electrically insulating layer on the third body
surface portion and a thickness of a part of the
electrically insulating layer on the fourth body surface
portion, is significantly useful for easy and uninter-
rupted formation of the coil without inserting the
15 insulating sheet between the wound and stacked wire
massses or arrays.

According to the present invention, a coil
comprises, a wire wound and stacked in axial and radial
directions of the coil so that a tube-shaped wire body
20 is formed, and a silicone rubber layer covering at least
one of axial ends of the tube-shaped wire body.

Since the silicone rubber layer has high
flexibility in comparison with epoxy resin, a thermal
stress in the wire body cover at the coil axial end
25 caused by a temperature distribution or variation
between a radial inside of the coil and a radial outside
thereof is reduced so that a breakage of the wire body
cover is securely prevented. Therefore, the axial end

of the tube-shaped wire winding formed by the wire with an electrically insulating coating can be easily sealed up in comparison with the prior art.

The silicone rubber layer may include therein
5 electrically-insulating solid grains so that an amount of silicone in the wire body cover is decreased and a hardness thereof is increased. The electrically-insulating solid grains may comprise quartz.

According to the present invention, a method
10 for producing a coil, comprises the steps of:

winding and stacking in axial and radial
directions of the coil a wire on an inner tube so that a tube-shaped wire body is formed, the inner tube including a thermosetting resin, for example, epoxy
15 resin, which is before being cured,

covering an outer periphery of the tube-shaped wire body by an outer tube including the thermosetting resin, for example, epoxy resin, which is before being cured,

20 covering at least one of axial ends of the tube-shaped wire body by a silicone rubber layer which is a thermosetting type before being cured, and

thereafter heating simultaneously the inner and outer tubes and the silicone rubber layer to be
25 cured.

Since the at least one of axial ends of the tube-shaped wire body is covered by a silicone rubber layer before being cured, an axial end cover of the

silicone rubber layer before being cured is not deformed or does not flow significantly largely when heating it. Therefore, the axial end of the tube-shaped wound-and-stacked-wire masses formed by the wire with an
5 electrically insulating coating can be easily sealed up in comparison with the prior art.

The inner and outer tubes may be prepreg members including the thermosetting resin, for example, epoxy resin.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a partial cross sectional view showing a wire of the present invention.

Fig. 2 is a partial cross sectional view showing a coil of the present invention.

15 Fig. 3 is a partial cross sectional view showing another wire of the present invention.

Fig. 4 is a partial cross sectional view showing another wire of the present invention.

20 Fig. 5 is a partial cross sectional view showing another wire of the present invention.

Fig. 6 is a partial cross sectional view showing another wire of the present invention.

Fig. 7 is a schematic oblique projection view showing a method and apparatus for producing a wire,
25 according to the present invention.

Fig. 8 is a schematic oblique projection view showing a method and apparatus for producing a coil,

according to the present invention.

Fig. 9 is a schematic oblique projection view showing a transformer with the coil or wire of the present invention.

5 Fig. 10 is a partial cross sectional view showing another coil of the present invention.

Fig. 11 is a partial cross sectional view showing a method and apparatus for producing a coil, according to the present invention

10 Fig. 12 is a schematic oblique projection view showing a method and apparatus for producing a coil, according to the present invention.

Fig. 13 is a schematic oblique projection view showing a method and apparatus for producing a coil,
15 according to the present invention.

Fig. 14 is a partial-cross-sectional and oblique-projection view showing another coil of the present invention.

Fig. 15 is a partial-cross-sectional and
20 oblique-projection view showing another wire of the present invention.

Each of Figs. 16-23 is a partial cross sectional view showing another wire of the present invention.

25 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 is a sectional view of a wire used for a dry transformer coil according to an embodiment of the

present invention.

As shown in the figure, a continuous sheet of paper is used as first insulating paper 2a, and encloses three sides of a rectangular conductor 1 in U-shape,
5 over which a continuous sheet of paper as second insulating paper 2b encloses opposite three sides in reversed U-shape.

Thus, since the conductor is wound by and enclosed in the first and second insulating paper,
10 coating thickness of the insulating paper differs depending on the directions of the conductor 1.

When it is assumed that the longitudinal direction of the conductor shown in the figure is x direction, while the lateral direction is y direction,
15 the coating thickness differs in the x and y directions. The ratio of insulating coating thickness in the x and y directions is $\alpha_1 : \alpha_2 = 1 : 2$.

When such wire is formed into a coil by a coil winding machine, winding is started from one end of the
20 lowest layer, ended at the other end, radially raised by one layer and overlapped to form the next layer in the same manner. The procedure is repeated to the outermost layer. Thus, it is determined that one end to the other end is the width direction of the coil, while the raised
25 and overlapped direction is the laminating direction.

If it is assumed that the coil width direction is x direction, while the coil laminating direction is y direction, the insulating coating thickness in the y

direction is thicker than that in the x direction, and $\alpha_1 : \alpha_2 = 1 : 2$, whereby insertion of inter-layer paper, which requires complicated operation, becomes unnecessary, and insulation can be attained between layers only
5 with the conductor coating.

Fig. 2 is a sectional view of essential parts of a coil which is formed by winding the wire of Fig. 2.

In Fig. 2, material of insulating paper used for coating the conductor may be any insulation material
10 with low permittivity including polyamide (PA), polyethylene naphthalete (PEN), polyimide (PI), polyetherimide (PEI), polyphenylene sulfide (PPS), polyethylene telephthalete (PET), and prepreg insulating material.

15 As described in Fig. 2, the coil in this embodiment has a tubular shape. Besides it has an inner insulating layer at the inside of the tubular shape, and an outer insulating layer at the outside of the tubular shape. The wire is wound so as to form a plurality of
20 conductor layers between the inner insulating layer and the outside insulating layer.

The wire has first surface facing inside in a radial direction of the coil and second surface facing outside in a radial direction of the coil and third and
25 fourth surface facing an axial direction of the coil. The surface insulating layer has larger thickness at a portion facing the radial direction of the coil than at portions facing the axial direction of the coil. Since

the wire is formed as such, and a plurality of conductor layers are integrated in radial direction of the coil, total amount of the surface insulating layer in the radial direction of said coil is larger than total
5 amount of the surface insulating layer in the axial direction of the coil.

In this embodiment, the first surface of innermost conductor layer forms the inner insulating layer, and the second surface of the outermost conductor
10 layer forms the outer insulating layer.

In general, voltage between adjacent wires in adjacent layer is higher than that between adjacent wires in the same layer. Also in Fig. 2, the voltage between adjacent wires in adjacent layer ΔV_1 is higher
15 than the voltage between adjacent wires in the same layer ΔV_2 . So, higher insulating capacity is required in the radial direction of the coil than in the axial direction of the coil. The present Invention solves this requirement without using a sheet-like insulating
20 material between the layers.

Moreover, in Fig. 2, if potential voltage difference in the transformer is ΔV_1 and ΔV_2 at the indicated portions, it is desirable that the insulating coating thickness α_1 in the coil width direction and
25 insulating coating thickness α_2 in the coil laminating direction correspond to the ratio of allotted potential ΔV_1 and ΔV_2 in the respective directions. $\alpha_1 : \alpha_2 = 1 : 2$ in Fig. 1 of Embodiment 1, so that the thickness of

insulating paper can be made thicker than necessary particularly in the coil width direction.

Another embodiment of the present invention is described by referring to Figs. 3 and 4.

5 Fig. 3 is a sectional view of a wire used for a dry transformer coil according to another embodiment of the present invention. Fig. 4 is a sectional view of a wire used for a dry transformer coil according to still another embodiment of the present invention.

10 Fig. 3 shows a wire in which insulating paper 2C (thickness β) is included on one side of the conductor 1 in the coil laminating direction. Fig. 4 shows a wire in which the insulating paper 2C (thickness $\beta/2$) is placed on both sides of the conductor. When
15 such wire is used, any ratio of allotted potential in the laminating direction and the width direction can be accommodated by combination of insulating paper 2a (thickness γ), 2b (thickness γ), and 2C (thickness β or $\beta/2$) having different thickness. A dry transformer coil
20 can be constituted by winding these wires shown in Figs. 3 and 4 with a coil winding machine.

Still another embodiment of the present invention is described by referring to Fig. 5.

At section A of Embodiment 1 shown in Fig. 2,
25 since a corner of one of the conductor 1a and 1b is positioned opposite to the other conductor, thickness of the insulating paper may become thinner between both conductors.

Fig. 5 is a sectional view of a wire used for a dry transformer coil according to still another embodiment of the present invention. When, in Fig. 5, the continuous insulating paper 2a and 2b are extended
5 and returned over the corners of the conductor 1 to surely enclose it, the thickness of the insulating paper can be maintained on the diagonal between the conductors so that insulating performance of the wire can be also improved. A coil can be formed by using this wire and
10 winding it with a coil winding machine.

Still another embodiment of the present invention is described by referring to Fig. 6.

Fig. 6 is a sectional view of a wire used for a dry transformer coil according to still another
15 embodiment of the present invention. Fig. 6 shows a case where the wider side of wire is wound toward the radial direction of the coil.

The shorter side of the wire 1 is lapped with continuous insulating paper 2a and 2b in double layers.
20 Thus, insulating performance of the wire can be also improved, and a coil using this wire can be manufactured.

Still another embodiment of the present invention is described by referring to Fig. 7.

25 Fig. 7 is a schematic view illustrating a method for manufacturing a dry transformer coil according to still another embodiment of the present invention.

As shown in the figure, it comprises a conductor supply step 6, a coating mounting step 7, and a coil winding step 8.

In the conductor supply step 6, the conductor 1 is a copper or aluminum wire, and supplied as a bare wire.

In the coating mounting step 7, coating mounting jigs j_1 and j_2 are disposed on each side of the conductor 1 to sequentially place the insulating paper 2a and 2b along each side of the supplied conductor 1 in U-shape. Each of the jigs j_1 and j_2 is designed to have an opening at one side, to form the remaining three sides in U-shape, and to be gradually narrowed down for its sectional area along the feeding direction of the insulating paper 2a and 2b drawn from a roll paper supply so that the insulating paper 2a and 2b are placed along the conductor 1.

The jig j_1 places the insulating paper 2a along the side of the conductor 1 in U-shape. Then, the jig j_2 places reversed U-shape the insulating paper 2b on the conductor 1 and the insulating paper 2a placed along it in U-shape from the side opposite to the U-shape to form an insulation coated coil.

Then, in the coil winding step 8, the conductor is wound on a roll 8. If the roll 8 is a coil winding machine, coil winding can be performed as is.

Still another embodiment of the present invention is described by referring to Fig. 8.

Fig. 8 is a schematic view showing a dry transformer coil according to still another embodiment of the present invention.

Fig. 8 shows a fixing method of the dry
5 transformer coil specifically using a prepreg material with self-fusion as the conductor coating.

The prepreg material is a fiber aggregate impregnated with resin in uncured or semi-cured state. These characteristics are utilized. When the uncured
10 resin is heated, adhesive resin flows out, fills in gaps between each prepreg material, and cures. Then, when pressure is externally applied, the gap in the prepreg material is further reduced and further stiffly adhered.

Generally, when a rectangular coil is wound,
15 good adherence of the prepreg material is obtained at the corners or bending portions of the coil because radial force is generated here to cause external force, while fixing with external force cannot be expected at the linear portions.

20 Then, as shown in Fig. 8, after the coil is wound, a contracting tube 10 filled with liquid in the outermost section is wound and heated around the wound coil 9, whereby adherence of the prepreg material can be enhanced by curing of the prepreg material and pressure
25 on the wound coil 9 due to expansion of the liquid filled in the tube 10.

Thus, it is possible to form a dry transformer coil with improved adherence of the prepreg material.

Still another embodiment of the present invention is described by referring to Fig. 9.

Fig. 9 is a schematic view showing a dry transformer according to still another embodiment of the present invention.

Fig. 9 is appearance of a transformer with a tap changer using a coil of an embodiment according to the present invention.

As shown, the transformer T with a tap changer has wound coils 9 in phase (three phases in the figure) on a cradle 12, a tap changer 13 mounted thereon, and a clamping cradle 14 for clamping them. The clamping cradle 14 is provided with terminals 15.

The wound coil 9 is characterized in that a resin molding operation after completion of winding is eliminated, and the windings are fixed through self-fusion, whereby a stripes 11 are formed in the circumferential direction. Thus, a dry transformer not causing interlayer defect can be manufactured.

A resin mold coil of another embodiment comprises, as shown in Figs. 10 - 13, a coil 111 formed substantially in a form of prism, prepreg sheets 118 covering the inner and outer surfaces 112 and 113 of the coil 111, and thermosetting silicon resin 119 covering both end surfaces 114 of the coil 111.

In manufacturing the resin mold coil, as shown in Fig. 11, a winding frame 122 substantially in a form of prism is mounted on a rotating shaft 121a of the coil

winding machine 121. Subsequently, an insulating prepreg sheet 118 is wound around the outer surface of the winding frame 122. The insulating prepreg sheet 118 is glass fiber cloth impregnated with epoxy resin. A
5 wire material is wound around an imaginary winding axis 125 coaxial with the rotating shaft 121a of the coil winding machine 121 in the direction of winding axis S while rotating the winding frame 122 by driving the coil winding machine 121. When the first layer is completed,
10 an interlayer insulating sheet (not shown) is applied on its outer surface, and the wire material is wound on its outer surface to form the second layer. On its outer surface the interlayer insulating sheet is also applied. The coil 111 is thus formed by repeating the above
15 processes to wind the wire material in a number of layers in the direction of layer R separating from the winding axis 125. When the coil 111 is formed, the insulating prepreg sheet 118 is also wound around the outer surface 113 of the coil 111. Here, the coil 111
20 on the inner and outer surfaces 112 and 113 of which the insulating prepreg sheet 118 is applied is called a resin mold coil intermediate product 110.

In the resin mold coil intermediate product 110, the length of insulating prepreg sheet 118 on the
25 inner and outer surfaces in the direction of winding axis S is longer than the length of coil 111 in the direction of winding axis S. The end surfaces 114 of the coil 111 and the insulating prepreg sheets 118 on

the inner and outer surfaces form a recess A.

Then, the thermosetting silicon resin 119 is filled in the recess A at the end of resin mold coil intermediate product 110 by using a resin injection gun 123 as shown in Fig. 12. Here, the thermosetting silicon resin 119 is filled while rotating the resin mold coil intermediate product 110 by driving the coil winding machine 121.

Then, the resin mold coil intermediate products 110a completed for filling of the thermosetting silicon resin are sequentially dismounted together with the winding frame 122 from the coil winding machine 121, and laid down on a drying plate 126 on which a separating sheet 127 of Teflon is spread. The resin mold coil intermediate product 110a can be laid down because the thermosetting silicon resin has viscosity at the room temperature preventing it from draping from the recess A of the resin mold coil intermediate product 110a, and the viscosity is not lowered as in epoxy resin in the subsequent thermosetting process. When predetermined number of resin mold coil intermediate products 110a has been laid down, the Teflon separating sheet 127 is spread over them, and the resin mold coil intermediate products 110a are placed thereon. As described, a plurality of resin mold coil intermediate products 110a are stacked on the drying plate 126 in a plurality of stages. Then, all of them are placed in a drying furnace, heated to about 130 - 150°C so that the

thermosetting silicon resin 119 filled in the ends of coil 111 is cured together with the insulating prepreg sheets 118 placed on the inner and outer surfaces of the coil 111. Thus, since a plurality of resin mold coils 110a filled with the thermosetting silicon resin can be stacked in a plurality of stages and cured all at once, it is possible to efficiently use the drying furnace.

Once the insulating prepreg sheets 118 and the thermosetting silicon resin 119 are cured, the winding frame 122 is removed to complete the resin mold coil shown in Fig. 10 through a shaping operation. In the shaping operation, the corners at the end of coil are chamfered by a cutter.

As described above, in manufacturing the resin mold coil, since the resin can be filled in the end surfaces 114 of the coil 111 at once, and the thermosetting silicon resin 119 filled in the ends 114 of the coil 111 can be cured together with the insulating prepreg sheets 118 placed on the inner and outer surfaces 112 and 113 of the coil 111 in one process, it is possible to reduce the number of processes and to shorten the period of time for manufacture. In addition, since the silicon resin retains viscosity even in curing and contracting not to generate internal residual stress, and to cause a problem such as crack, it is possible to attain curing and annealing in a short period of time. The period of time for manufacture can be also shortened in this aspect.

In addition, since the thermosetting silicon resin 119 is harmless to the human body, there is no particular consideration for preventing the resin from contacting the skin. Moreover, since the burr removing
5 operation with a grinder is eliminated, measures for collecting duct becomes unnecessary. Thus, the safety measures are easy to be provided for each process, whereby the manufacturing cost can be also reduced.

In addition, while the thermosetting silicon
10 resin 119 has viscosity so that it does not drape even if it is filled in the recess A at the ends of resin mold coil 110 while laying down it, the viscosity is lower than that of epoxy resin, so that the resin injection gun 123 can be used for filling the resin to
15 make the filling operation easy, and also to automate the filling operation.

Furthermore, a chemical synthetic film such as of polyester film (polyethylene telephthalete) or polyethylene naphthalete may be used as a wire
20 insulating material covering the outer surface of conductor and an interlayer insulating material for insulating the layers of coil 111 each other. In such a case, deterioration may be accelerated by an acid anhydride curing agent added in epoxy resin. However,
25 when silicon resin is used, it is harmless to such film, and very advantageous to insulation deterioration over a long period of time.

When the thermosetting silicon resin 119 is

used as the filler for the end surface 114 of the coil 111 rather than conventional epoxy resin, although various advantages are provided as described above, currently, there is shortcomings that the thermosetting 5 silicon resin 119 is more expensive than epoxy resin. Furthermore, since the cured silicon resin is rubber-like and soft, there may be a case the user feels some misgivings due to its tactile feel. Then, it is preferable to reduce amount of use of the relatively 10 expensive thermosetting silicon resin 119 for reducing the manufacturing cost and improving its tactile feel by adding an inexpensive material harder than the silicon resin and having fire-resistance and insulation property as an extender to the thermosetting silicon resin 119.

15 Specifically, quartz powder of 80 wt.% is preferably added to the thermosetting silicon resin 119 as an extender. The quartz powder currently costs about 1/2 of silicon resin so that the manufacturing cost can be sufficiently reduced.

20 Experiment using silicon resin added with 80 wt.% quartz powder revealed that, while viscosity was increased to some extent, the filling operation was satisfactorily performed by the resin injection gun 123. In addition, predetermined characteristics could be 25 obtained for curing time of 3 - 5 hours at 110 - 120°C. Furthermore, hardness of the cured resin added with quartz powder was higher than that of the cured resin without quartz powder added, and its Shore hardness

obtained was 80° or more. Furthermore, when a test was conducted according to the fire-resistance method (Method A) which was commonly used as index of fire-resistance described in JIS K6911 (1979) "General
5 Testing Method for Thermosetting Plastics," the material added with 80 wt.% quartz powder exhibited burning time of 0 second and burning distance of 5 mm, and was classified as fire-resistant. In comparison, similar fire-resistant test on cured epoxy resin added with a
10 typical acid anhydride curing agent and crystalline quartz powder exhibited burning time of 12 - 14 seconds and burning distance of 11 - 14 mm. These fire-resistant tests classified both materials as fire-resistant, but it can be said that the silicon resin
15 added with 80 wt.% quartz powder is improved for fire-resistance over the epoxy resin.

Now, a resin mold coil as an embodiment according to the present invention is described by referring to Figs. 14 and 15.

20 In this embodiment, as shown in Fig. 15, a wire material 115 forming a coil 111a comprises a conductor 116 which is the body of the wire material 115, an insulating material 117a for interlayer insulation adjacent to part of the outer surface of the
25 conductor 116 and along the longitudinal direction of the conductor 116, and an insulating resin sheet 117b wound around the outer surface of the conductor 116 on which the insulating material 117a for interlayer

insulation is applied.

When the conductor 116 is repeatedly wound around an imaginary winding axis 125 in the direction of winding axis S to which the winding axis 125 extends, the insulating resin sheet 117a assures insulation between the conductors 116 adjacent in the direction of winding axis S. In addition, when the conductor 116 is wound around the imaginary winding axis 125 in a plurality of layers in the direction of lamination R separating from the winding axis 125, the insulating material 117a for interlayer insulation assures insulation between the conductors 116 adjacent in the lamination direction R. In the coil 111a, since potential difference is higher between the conductors adjacent in the lamination direction R than between the conductors adjacent in the direction of winding axis S, the insulating material 117a for interlayer insulation provides higher insulation than the insulating resin sheet 117b. In this embodiment, both the insulating resin sheet 117b and the insulating material 117b for interlayer insulation are formed by a prepreg sheet.

In this embodiment, the coil 111a is formed by using the wire material 115 described above, by repeatedly winding the wire material 115 around a winding frame (not shown) in the direction of winding axis S in such a manner that the side applied with the insulating material 117b for interlayer insulation is directed toward the radial direction R, and by winding

the wire material 115 in the radial direction R in a plurality of layers. Thus, by using the wire material 115 previously applied with the insulating material 117b for interlayer insulation, it is possible to eliminate
5 the operation for providing an interlayer insulating sheet between each layer after it is formed in the coil forming process.

As shown in Fig. 16, the conductive wire body 1 may be covered by an electrically insulating layer or
10 film 2 on first and second body surface portions opposed to each other, and one of third and fourth body surface portions opposed to each other. As shown in Fig. 17, the conductive wire body 1 may be covered by an electrically insulating layer or film 2 which comprise a
15 first electrically insulating film covering first and second body surface portions, and third and fourth body surface portions; and a second electrically insulating film covering the first electrically insulating film portions on the first body surface portion and the third
20 body surface portion. As shown in Fig. 18, the conductive wire body 1 may be covered by an electrically insulating layer or film 2 which covers the first and second body surface portions, the third and fourth body surface portions, and a portion of the electrically
25 insulating layer or film 2 on the first body surface portion.

As shown in Fig. 19, the circular conductive wire body 1 may be covered by an electrically insulating

layer or film 2 which comprises an inner electrically insulating film covering first and second body surface portions and a third body surface portion, an inner electrically insulating film on the first and second
5 body surface portions, and an outer electrically insulating film covering a fourth body surface portion, overlapping extent of the outer and inner electrically insulating films being preferably 60 degrees or more. As shown in Fig. 20, the circular conductive wire body 1
10 may be covered by an electrically insulating layer or film 2 on first and second body surface portions opposed to each other, and one of third and fourth body surface portions opposed to each other. The extent of the portion of conductive wire body 1 not covered by the
15 electrically insulating layer or film 2 is preferably 60 degrees or less.

As shown in Fig. 21, the oval conductive wire body 1 may be covered by an electrically insulating layer or film 2 on first and second body surface
20 portions opposed to each other, and one of third and fourth body surface portions opposed to each other. As shown in Fig. 22, the oval conductive wire body 1 may be covered by an electrically insulating layer or film 2 which covers first and second body surface portions,
25 third and fourth body surface portions, and a portion of the electrically insulating layer or film 2 on the first body surface portion. As shown in Fig. 23, the oval conductive wire body 1 may be covered by an electrically

insulating layer or film 2 which comprises an inner electrically insulating film covering first and second body surface portions and third and fourth body surface portions, and an outer electrically insulating film
5 covering the inner electrically insulating film on the first and second body surface portions and the third body surface portion.

**WHAT IS CLAIMED IS:**

1. A coil comprising, a wire including an electrically conductive wire body and an electrically insulating layer on the electrically conductive wire body,

wherein the wire has first and second body surfaces opposed to each other substantially in a radial direction of the coil, and third and fourth body surfaces opposed to each other substantially in a axial direction of the coil, and

a thickness of a part of the electrically insulating layer on the first or second body surface is larger than that on the third or fourth body surface.

2. A coil according to claim 1, wherein a total amount of thicknesses of the parts of the electrically insulating layer on the first and second body surfaces is larger than that on the third and fourth body surfaces.

3. A coil according to claim 1, wherein the part of the electrically insulating layer on the first body surface faces to a radial outside of the coil as a radial inside insulating layer, and the part of the electrically insulating layer on the second body surface faces to a radial inside of the coil as a radial outside insulating layer.

4. A coil according to claim 1, wherein the electrically insulating layer has a main electrically insulating layer and a supplemental electrically





insulating layer on the first or second body surface.

5. A transformer, comprising,
a coil including, a wire including an electrically conductive wire body and an electrically insulating layer on the electrically conductive wire body,

wherein the wire has first and second body surfaces opposed to each other substantially in a radial direction of the coil, and third and fourth body surfaces opposed to each other substantially in a axial direction of the coil, and

a thickness of a part of the electrically insulating layer on the first or second body surface is larger than that on the third or fourth body surface.

6. A wire for a coil, comprising,
an electrically conductive wire body having first and second body surface portions substantially opposed to each other, and third and fourth body surface portions substantially opposed to each other, and

an electrically insulating layer having inner and outer layer surfaces substantially opposed to each other, the inner layer surface covering at least partially the first, second, third and fourth body surface portions, and the outer layer surface being exposed to an outside of the wire,

wherein a thickness of a part of the electrically insulating layer on at least one of the first and second body surface portions is larger than a

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thickness of a part of the electrically insulating layer on at least one of the third and fourth body surface portions before being wound as the coil.

7. A wire according to claim 6, wherein a total amount of the thickness of the part of the electrically insulating layer on the first body surface portion and the thickness of the part of the electrically insulating layer on the second body surface portion is larger than a total amount of the thickness of the part of the electrically insulating layer on the third body surface portion and the thickness of the part of the electrically insulating layer on the fourth body surface portion before being wound as the coil.

8. A wire according to claim 6, wherein the first and second body surface portions are to be opposed to each other substantially in a radial direction of the coil, and the third and fourth body surface portions are to be opposed to each other substantially in an axial direction of the coil when the wire is wound and stacked axially to form a first wire winding around an axis of the coil after being wound and stacked axially to form a second wire winding of relatively radial inside of the first wire winding.

9. A wire according to claim 6, wherein the one of the first and second layer surfaces is adhered to the third and fourth body surface portions.

10. A wire according to claim 6, wherein the electrically insulating layer includes a main





electrically insulating layer, and a supplemental electrically insulating layer between the at least one of the first and second body surface portions and the main electrically insulating layer.

11. A wire according to claim 6, wherein the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and a thickness of a part of the electrically insulating layer extending over the at least one body corner portion is larger than the thickness of the part of the electrically insulating layer on the at least one of the third and fourth body surface portions.

12. A wire according to claim 6, wherein the electrically conductive wire body is substantially rectangular with a substantially flat shape of the first, second, third and fourth body surface portions.

13. A wire according to claim 6, wherein the electrically conductive wire body is substantially cycloid or elliptical with a curved shape of the first, second, third and fourth body surface portions.

14. A wire according to claim 6, wherein the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and a thickness of a part of the electrically insulating layer over a

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central position of the at least one body corner portion on an imaginary radial plane substantially perpendicular to the axial direction is larger than the thickness of the part of the electrically insulating layer on the at least one of the third and fourth body surface portions.

15. A wire according to claim 6, wherein the electrically insulating layer includes an inner electrically insulating film which extends continuously between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and an outer electrically insulating film which covers a part of the inner electrically insulating film on the at least one of the first and second body surface portions, the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and the outer electrically insulating film extends over a part of the inner electrically insulating film on the at least one body corner portion.

16. A wire according to claim 6, wherein the electrically insulating layer includes an inner electrically insulating film which extends continuously between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and an outer electrically insulating film which covers a part of the inner

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electrically insulating film on the at least one of the first and second body surface portions, the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and the outer electrically insulating film extends over a part of the inner electrically insulating film on a central position of the at least one body corner portion on an imaginary radial plane substantially perpendicular to the axial direction.

17. A wire according to claim 6, wherein the electrically insulating layer includes an inner electrically insulating film which covers the at least one of the first and second body surface portions, and an outer electrically insulating film which covers continuously both the at least one of the third and fourth body surface portions and a part of the inner electrically insulating film on the at least one of the first and second body surface portions, the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and the inner electrically insulating film extends on the at least one body corner portion.

18. A wire according to claim 6, wherein the electrically insulating layer includes an inner

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electrically insulating film which covers the at least one of the first and second body surface portions, and an outer electrically insulating film which covers continuously both the at least one of the third and fourth body surface portions and a part of the inner electrically insulating film on the at least one of the first and second body surface portions, the electrically conductive wire body has at least one body corner portion between the at least one of the first and second body surface portions and the at least one of the third and fourth body surface portions, and the inner electrically insulating film extends on a central position of the at least one body corner portion on an imaginary radial plane substantially perpendicular to the axial direction.

19. A wire according to claim 6, wherein the electrically insulating layer includes a first electrically insulating film which covers the first and second body surface portions and one of the third and fourth body surface portions, and a second electrically insulating film which covers another one of the third and fourth body surface portions and a part of the first electrically insulating film on the first and second body surface portions.

20. A wire according to claim 15, wherein the outer electrically insulating film is prevented from contacting a part of the inner electrically insulating film over the at least one body corner portion.

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21. A wire according to claim 16, wherein the outer electrically insulating film is prevented from contacting a part of the inner electrically insulating film over the central position of the at least one body corner portion.

22. A wire according to claim 15 or 16, wherein the outer electrically insulating film is prevented from contacting a part of the inner electrically insulating film on the at least one of the first and second body surface portions.

23. A wire according to claim 15, wherein the outer electrically insulating film reaches a part of the inner electrically insulating film over the at least one body corner portion.

24. A wire according to claim 16, wherein the outer electrically insulating film reaches a part of the inner electrically insulating film over the central position of the at least one body corner portion.

25. A wire according to claim 15 or 16, wherein the outer electrically insulating film reaches a part of the inner electrically insulating film on the at least one of the first and second body surface portions.

26. A wire according to claim 10, wherein the supplemental electrically insulating layer is adhered to the at least one of the first and second body surface portions, and the main electrically insulating layer is adhered to the supplemental electrically insulating layer.

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27. A wire according to claim 6, wherein the electrically insulating layer is a prepreg member.

28. A method for producing a wire for a coil, comprising the steps of :

feeding an electrically conductive wire body having first and second body surface portions substantially opposed to each other, and third and fourth body surface portions substantially opposed to each other,

covering at least one of the first and second body surface portions and one of the third and fourth body surface portions by an inner electrically insulating layer, and

covering a part of the inner electrically insulating layer on the at least one of the first and second body surface portions and another one of the third and fourth body surface portions by an outer electrically insulating layer.

29. A method according to claim 28, wherein both of the first and second body surface portions are covered by the inner electrically insulating layer, and the part of the inner electrically insulating layer on the at least one of the first and second body surface portions is covered by the outer electrically insulating layer.

30. A method according to claim 28, wherein one of the first and second body surface portions is covered by the inner electrically insulating layer, and a part of

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the inner electrically insulating layer on the one of the first and second body surface portions and another one of the first and second body surface portions are covered by the outer electrically insulating layer.

31. A method according to claim 28, wherein both of the first and second body surface portions are covered by the inner electrically insulating layer, and a part of the inner electrically insulating layer on both of the first and second body surface portions is covered by the outer electrically insulating layer.

32. A method for producing a coil, comprising the steps of :

preparing a wire comprising an electrically conductive wire body having first and second body surface portions substantially opposed to each other, and third and fourth body surface portions substantially opposed to each other, and an electrically insulating layer covering the electrically conductive wire body, a thickness of a part of the electrically insulating layer on at least one the first and second body surface portions being larger than a thickness of a part of the electrically insulating layer on at least one of the third and fourth body surface portions,

thereafter winding and stacking axially the wire to form a wire winding around an axis of the coil, and

further winding and stacking the wire axially to form another wire winding of relatively radial

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outside of the face while the first and second body surface portions are opposed to each other substantially in a radial direction of the coil, and the third and fourth body surface portions are opposed to each other substantially in an axial direction of the coil.

33. A wire before changed to a coil, comprising,
an electrically conductive wire body having first and second body surface portions substantially opposed to each other, and third and fourth body surface portions substantially opposed to each other, and

an electrically insulating layer covering the electrically conductive wire body, wherein

a total amount of a thickness of a part of the electrically insulating layer on the first body surface portion and a thickness of a part of the electrically insulating layer on the second body surface portion is larger than a total amount of a thickness of a part of the electrically insulating layer on the third body surface portion and a thickness of a part of the electrically insulating layer on the fourth body surface portion.

34. A coil comprising,

a wire wound and stacked in axial and radial directions of the coil so that a tube-shaped wire winding is formed, and

a silicone rubber layer covering at least one of axial ends of the tube-shaped wire winding.

35. A coil according to claim 34, wherein the





silicone rubber layer includes therein electrically-insulating solid grains.

36. A coil according to claim 35, wherein the electrically-insulating solid grains comprise quartz.

37. A method for producing a coil, comprising the steps of:

winding and stacking in axial and radial directions of the coil a wire on an inner tube so that a tube-shaped wire winding is formed, the inner tube including a thermosetting resin which is before being cured,

covering an outer periphery of the tube-shaped wire winding by an outer tube including the thermosetting resin which is before being cured,

covering at least one of axial ends of the tube-shaped wire winding by a silicone rubber layer which is a thermosetting type before being cured, and

thereafter heating simultaneously the inner and outer tubes and the silicone rubber layer to be cured.

38. A method according to claim 37, wherein the inner and outer tubes are prepreg members.

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