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Tsuruya

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(54) **FIXING UNIT AND IMAGE FORMING APPARATUS**

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CPC ***G03G 15/2053*** (2013.01); ***G03G 15/2017*** (2013.01); ***G03G 15/2064*** (2013.01)

(58) **Field of Classification Search**
CPC G03G 15/2017; G03G 15/2053; G03G 15/2064
See application file for complete search history.

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(57) **ABSTRACT**

A fixing unit includes a tubular film including a heat generating layer, a nip forming member including a sliding surface configured to be in sliding contact with an inner surface of the film, a heat generation mechanism configured to cause the film to generate heat, and a pressing member that is configured to be in contact with an outer surface of the film. The film includes a heat generating layer, an inner layer formed on an inner circumference side of the heat generating layer, and an outer layer formed on an outer circumference side of the heat generating layer. The sliding surface of the nip forming member includes a protruded portion that is protruded toward the pressing member in a third direction. A neutral axis of the film is positioned within the outer layer.

11 Claims, 18 Drawing Sheets

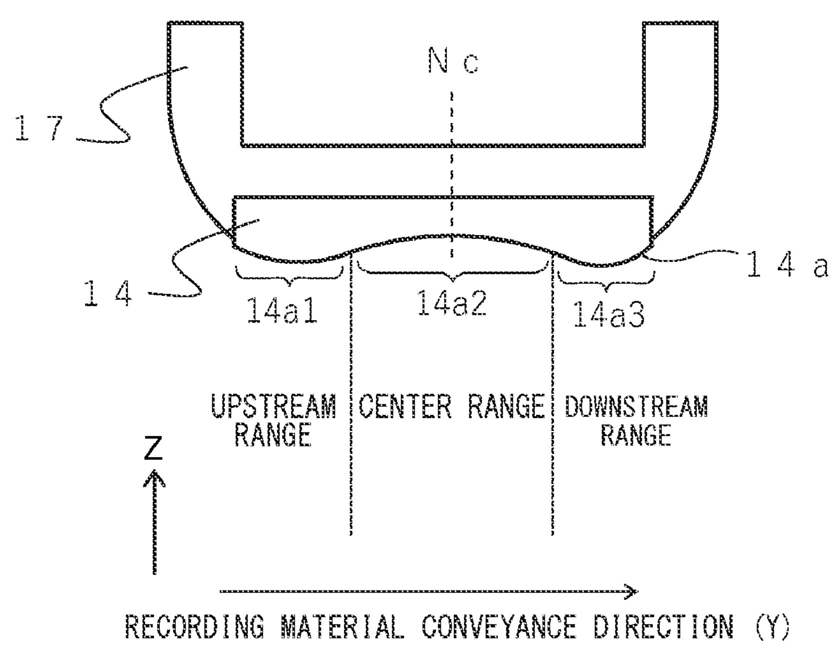


FIG.1

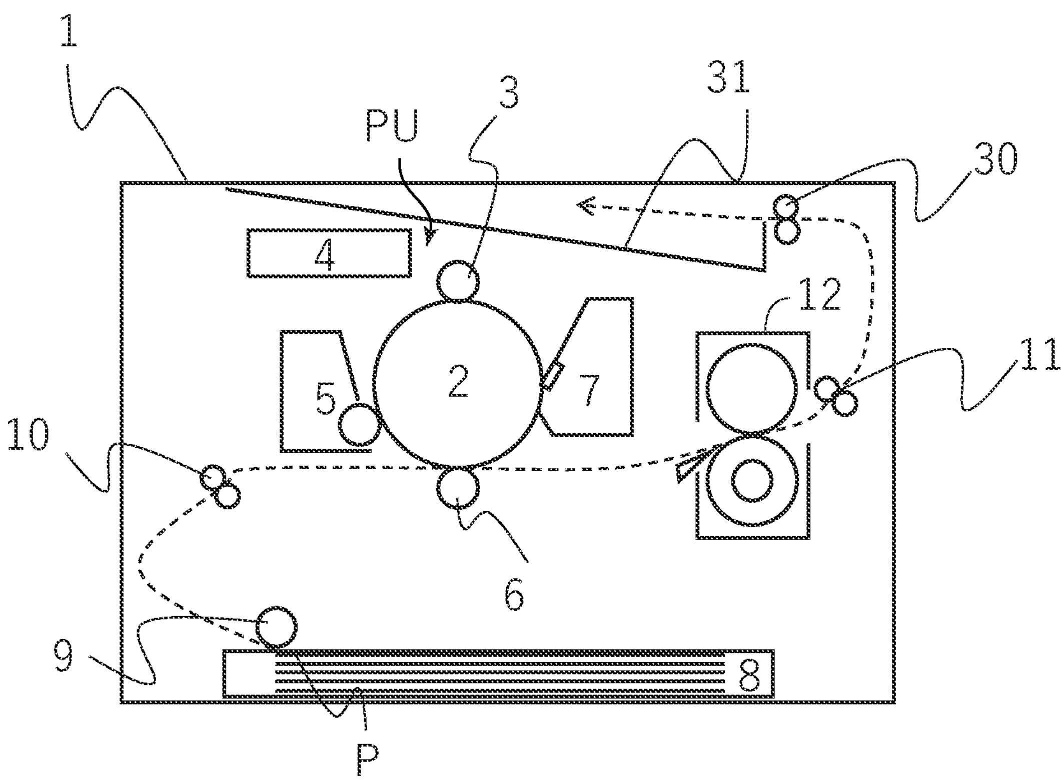


FIG.2

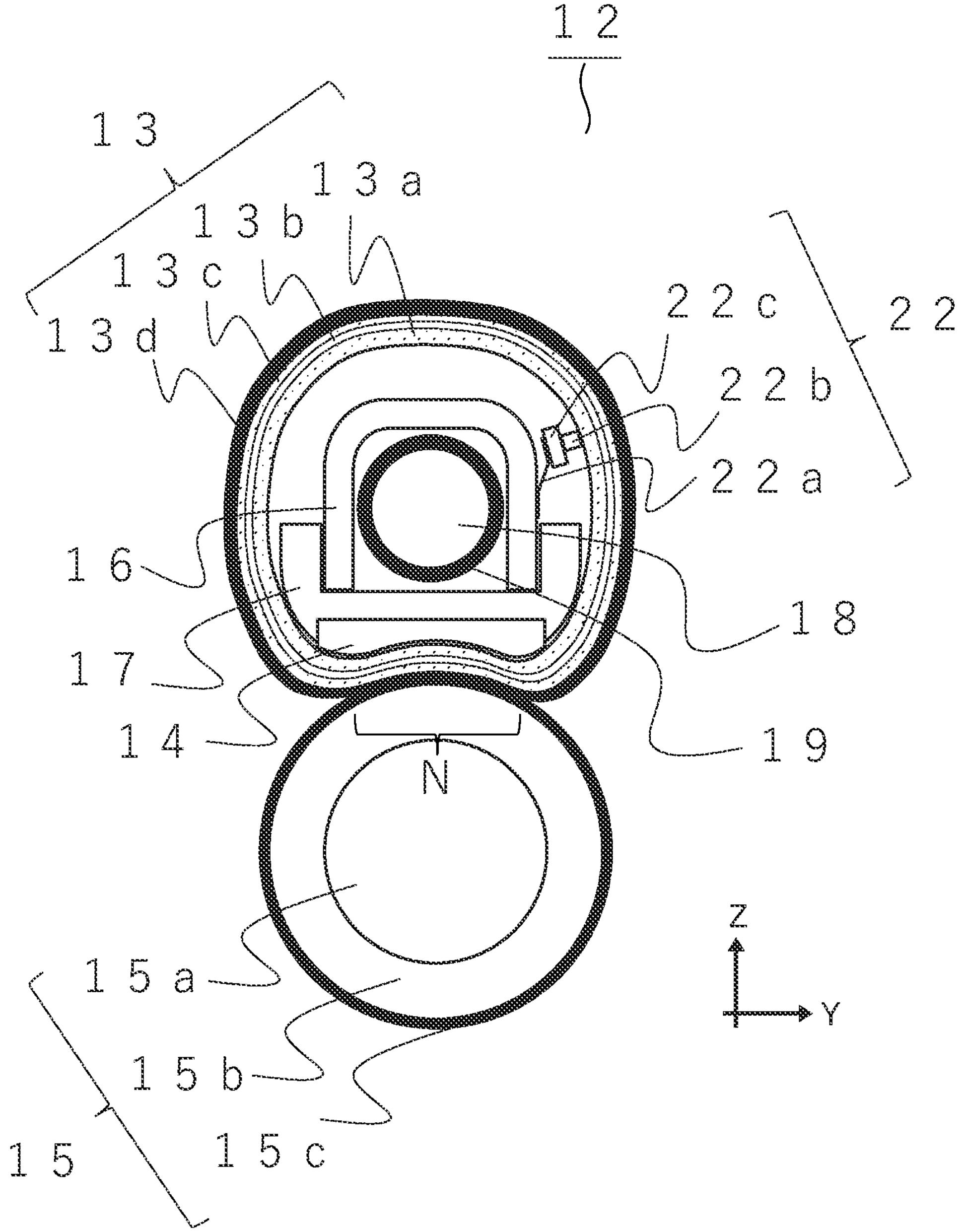

12
13
13a
13b
13c
13d
22c
22
22b
22a
16
18
17
14
19
N
15a
15b
15c
15
Z
Y

FIG.3

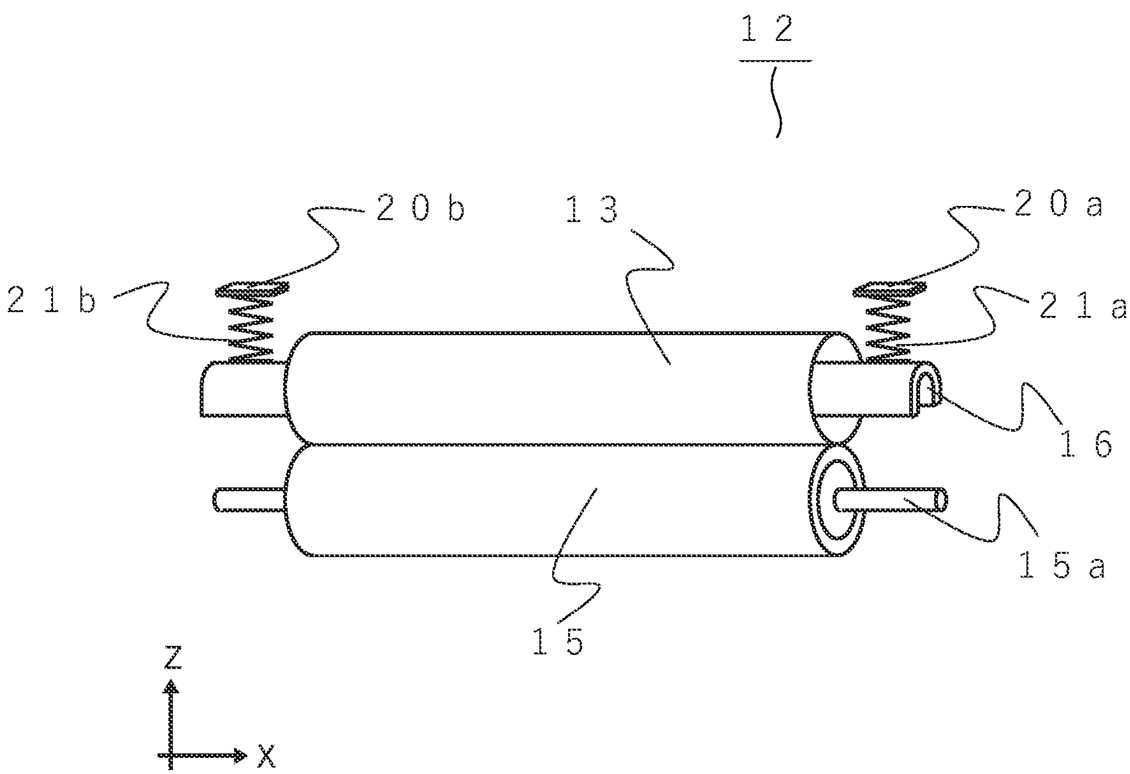


FIG.4

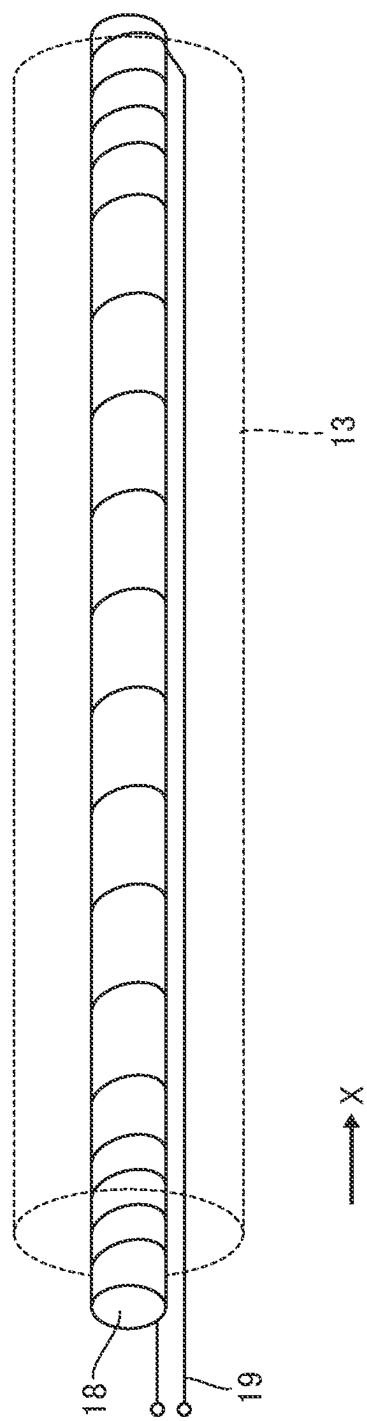


FIG.5

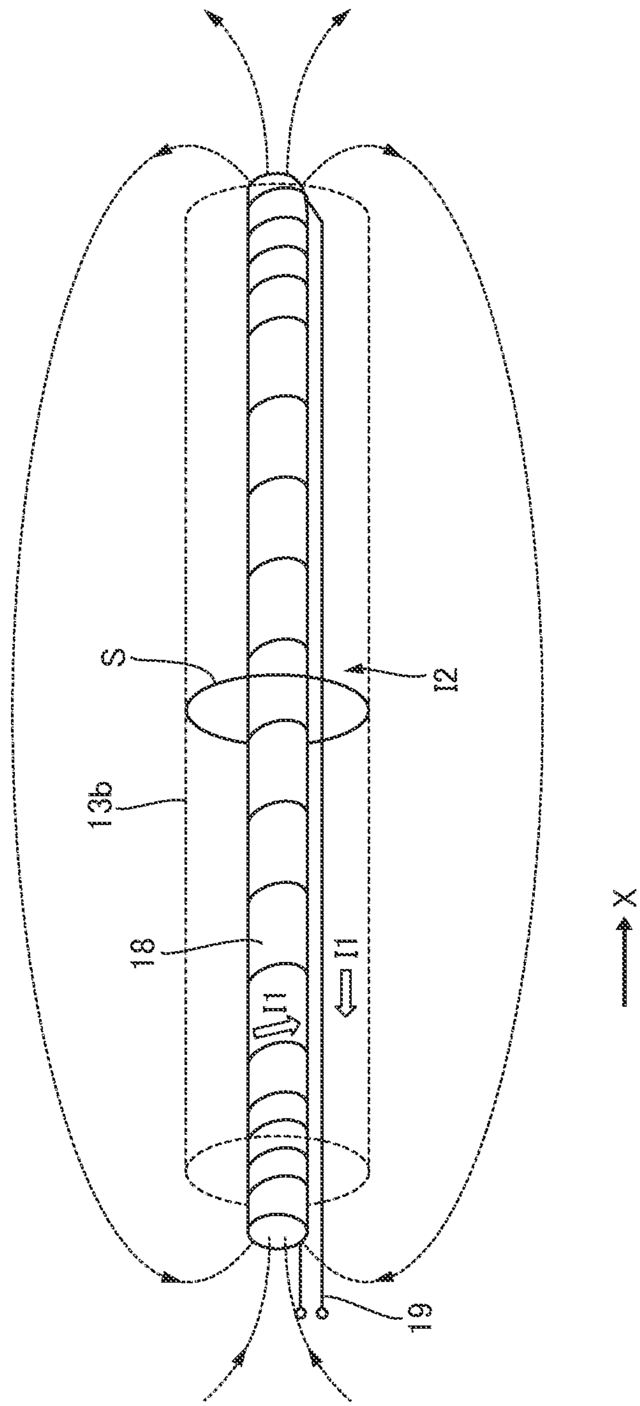


FIG.6

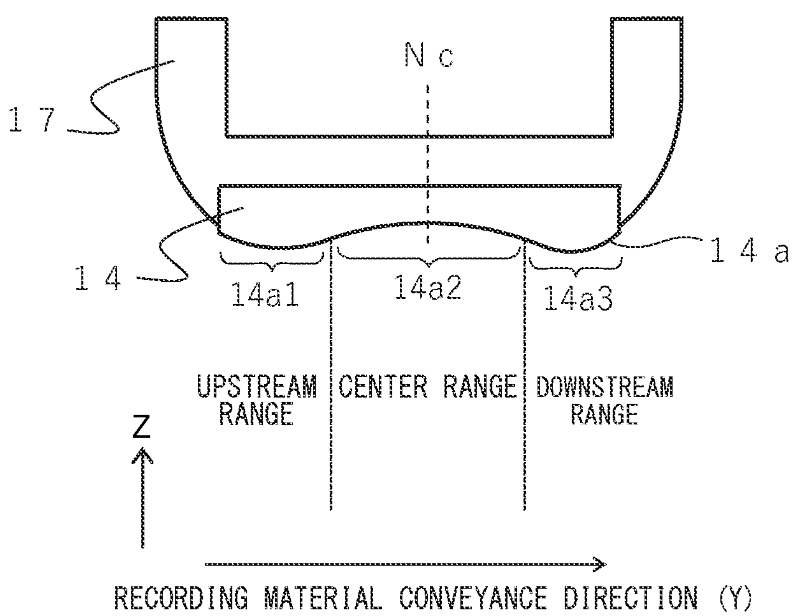

Nc
17
14
14a
14a1
14a2
14a3
UPSTREAM RANGE
CENTER RANGE
DOWNSTREAM RANGE
Z
RECORDING MATERIAL CONVEYANCE DIRECTION (Y)

FIG.7

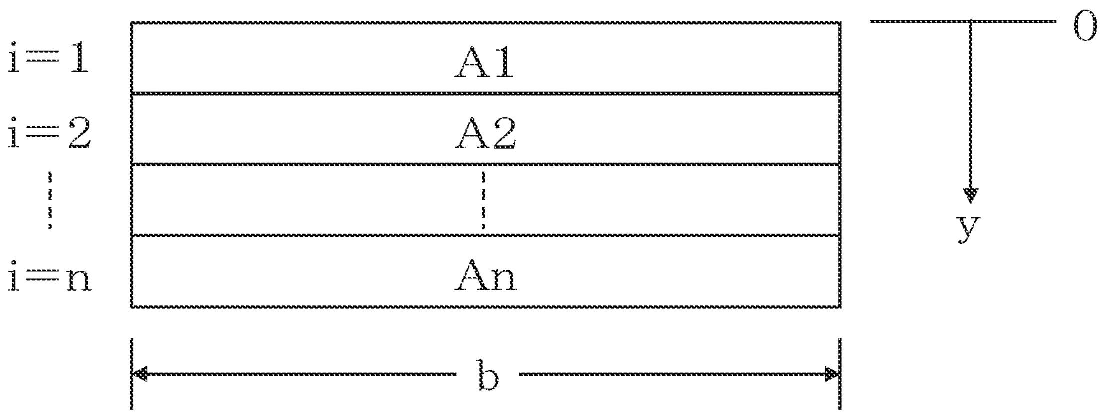


FIG.8

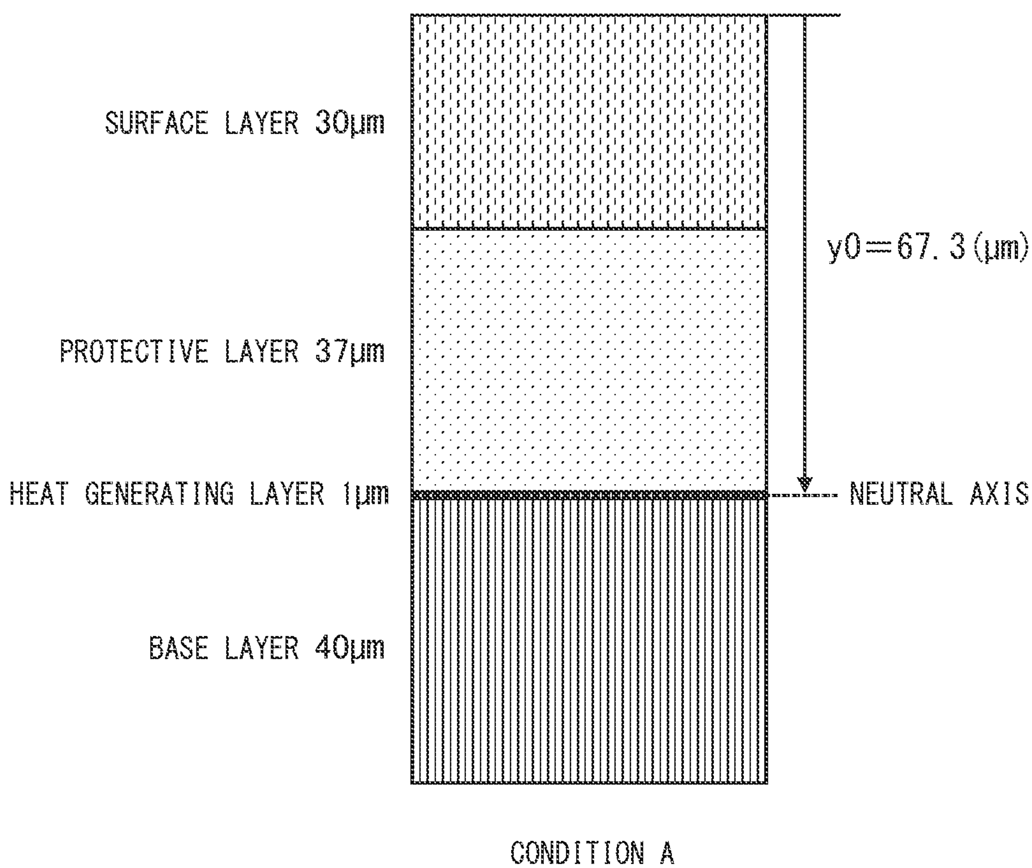
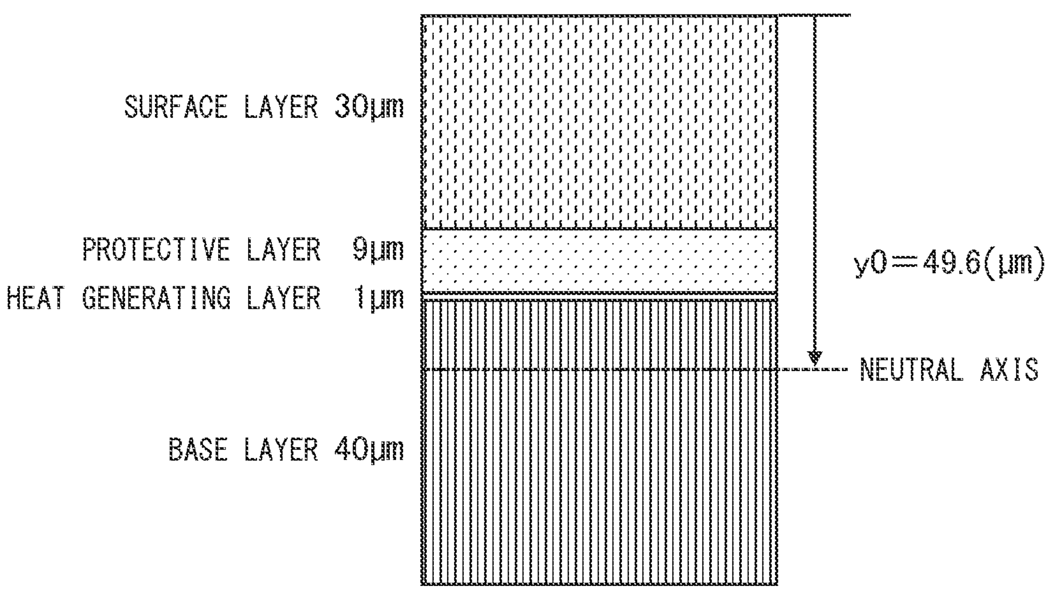
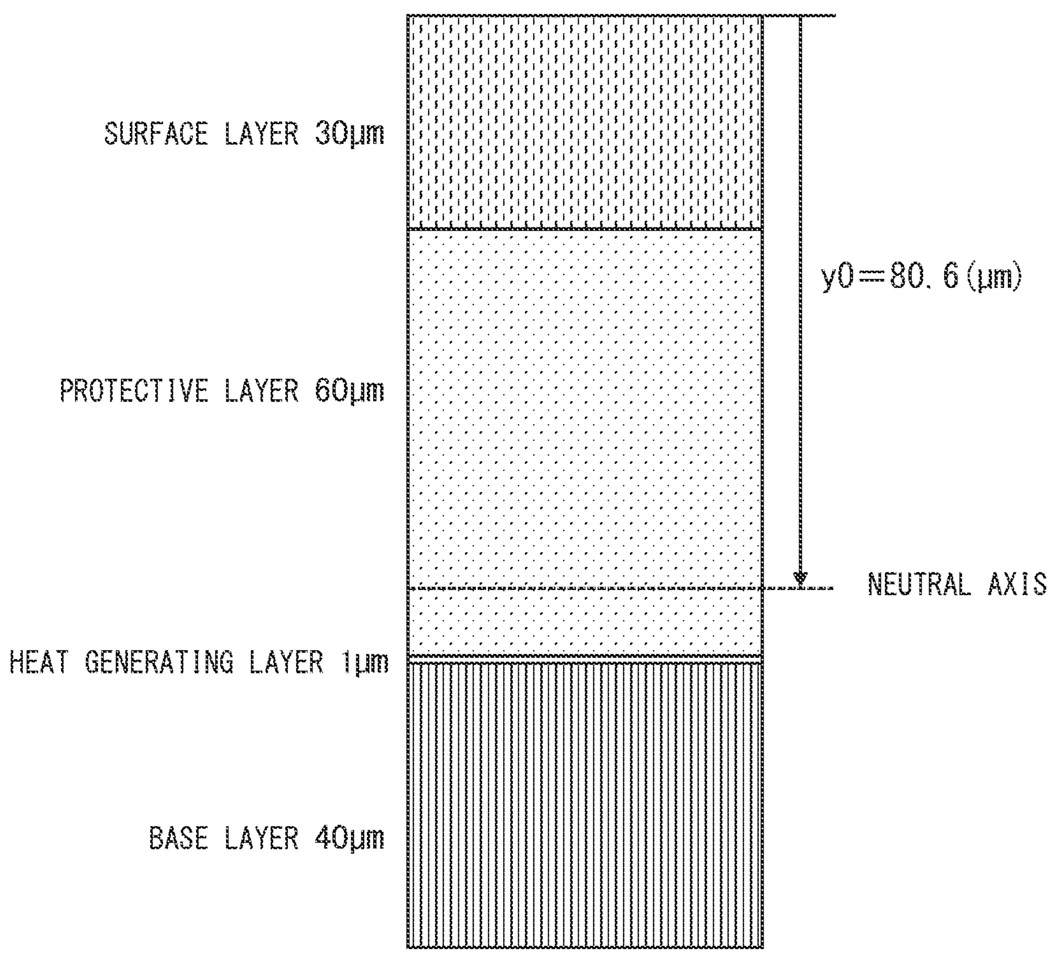

SURFACE LAYER 30μm
PROTECTIVE LAYER 37μm
HEAT GENERATING LAYER 1μm
BASE LAYER 40μm
y0=67.3(μm)
NEUTRAL AXIS
CONDITION A

FIG.9



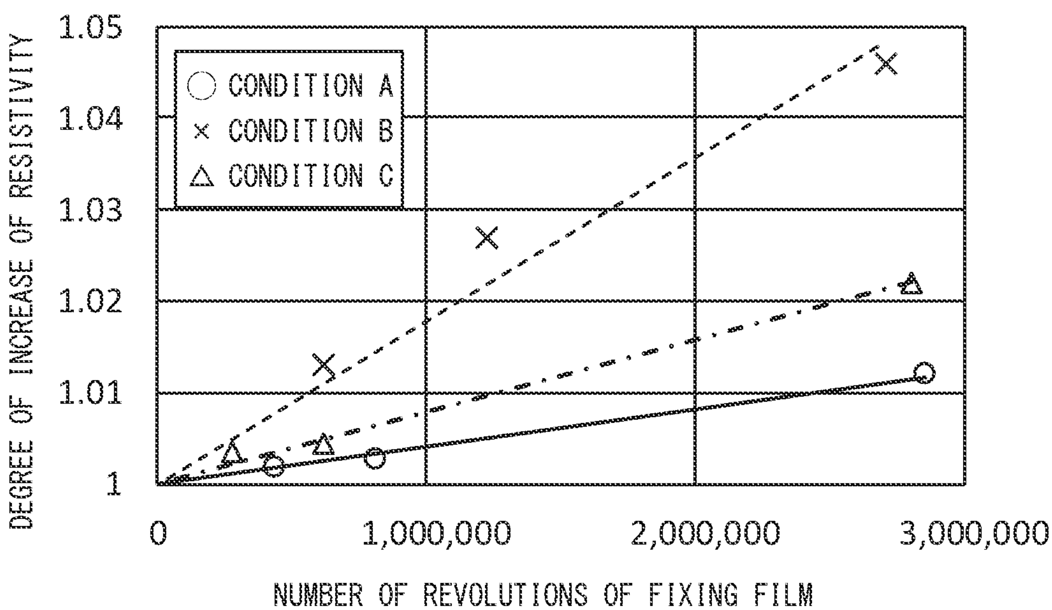
CONDITION B

FIG.10



CONDITION C

FIG.11



1.05
1.04
1.03
1.02
1.01
1
DEGREE OF INCREASE OF RESISTIVITY
CONDITION A
CONDITION B
CONDITION C
0
1,000,000
2,000,000
3,000,000
NUMBER OF REVOLUTIONS OF FIXING FILM

FIG.12

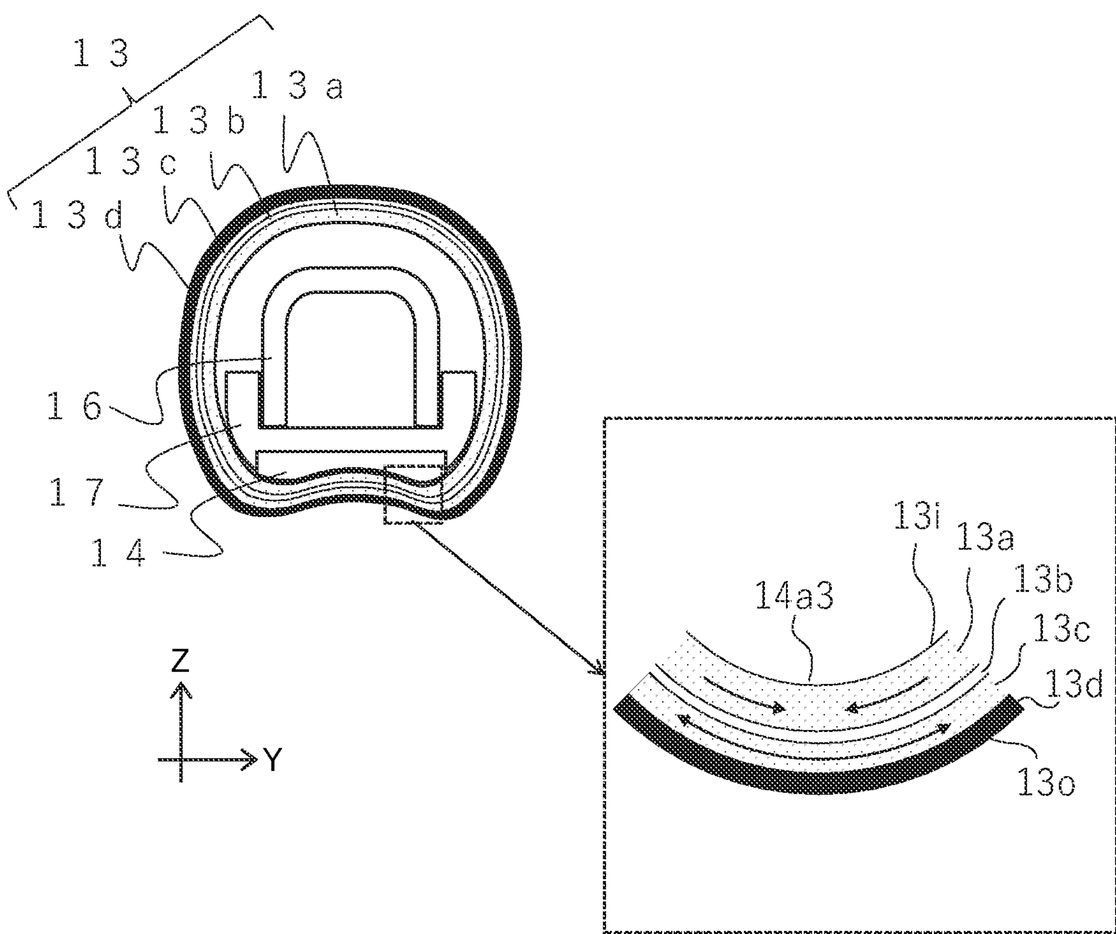
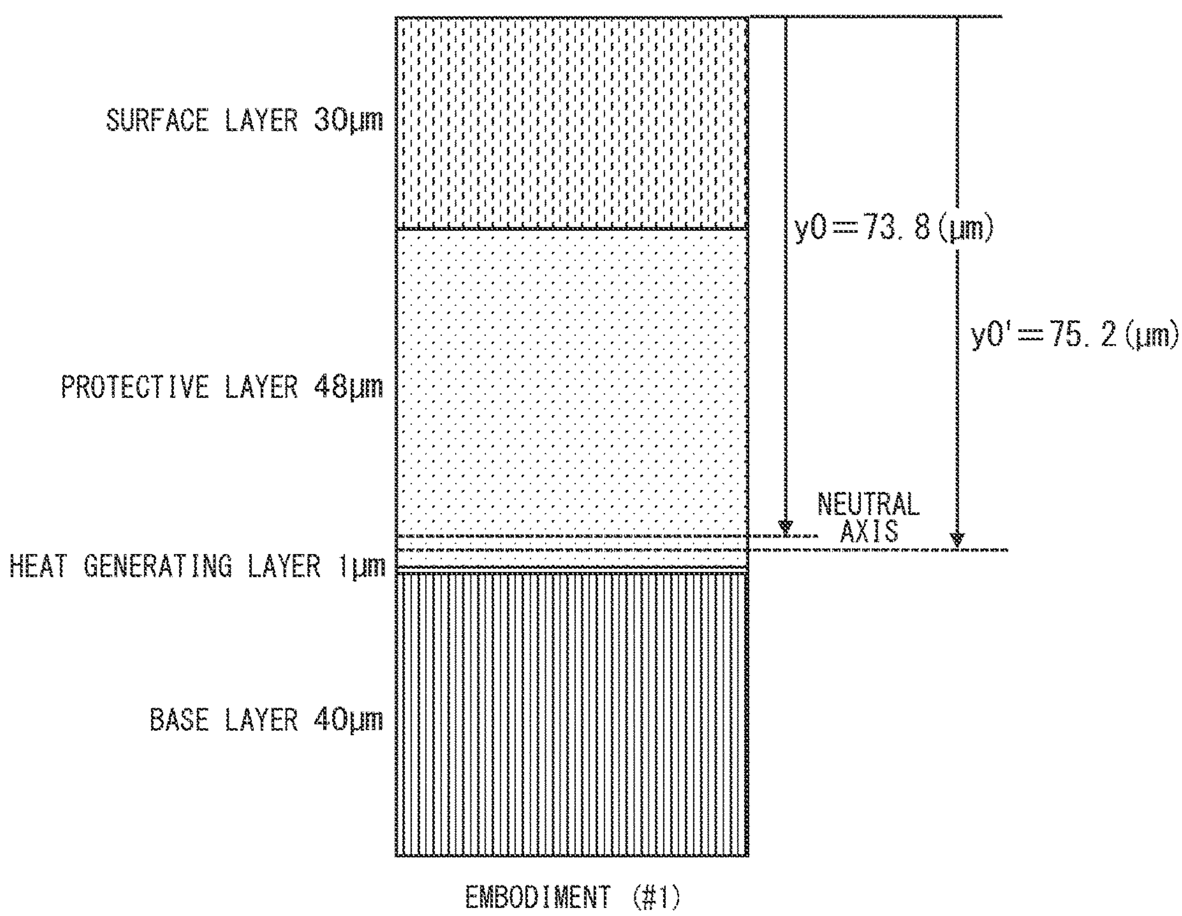
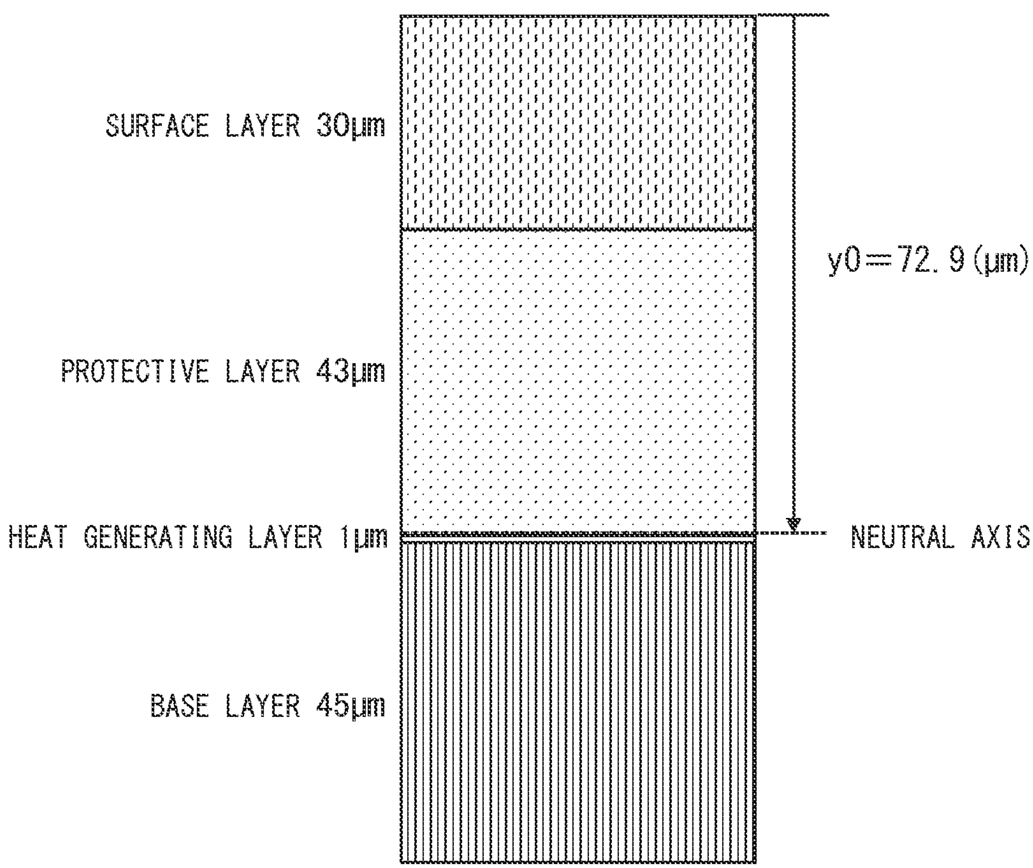


FIG.13



SURFACE LAYER 30μm
PROTECTIVE LAYER 48μm
HEAT GENERATING LAYER 1μm
BASE LAYER 40μm
y0=73.8(μm)
y0'=75.2(μm)
NEUTRAL AXIS
EMBODIMENT (#1)

FIG.14



EMBODIMENT (#2)

FIG.15

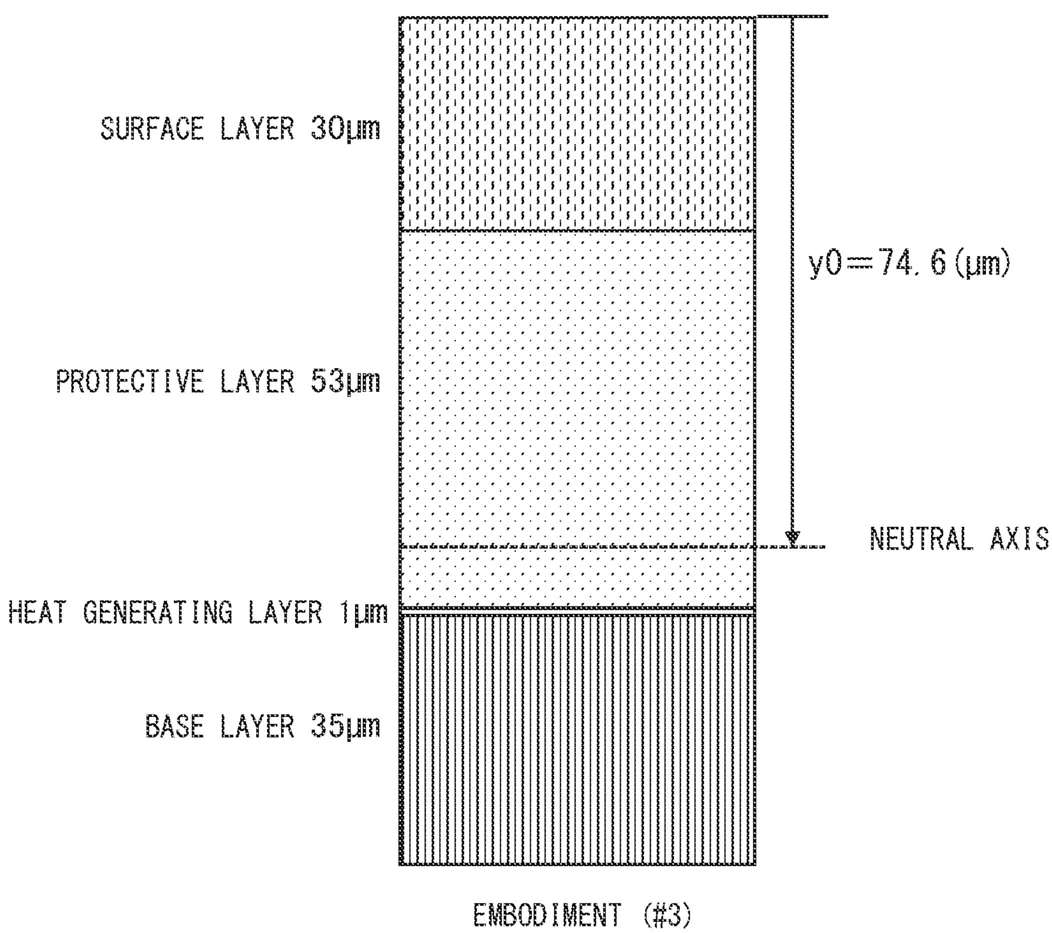
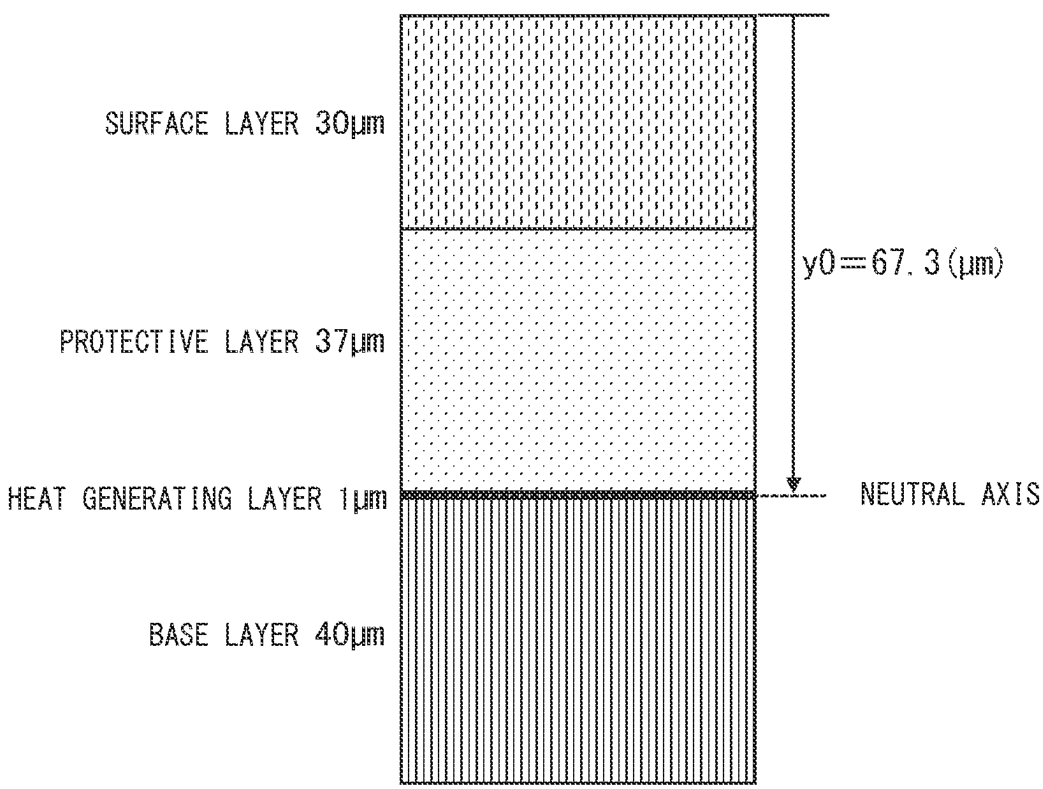

SURFACE LAYER 30μm
PROTECTIVE LAYER 53μm
HEAT GENERATING LAYER 1μm
BASE LAYER 35μm
y0=74.6(μm)
NEUTRAL AXIS
EMBODIMENT (#3)

FIG.16



COMPARATIVE EXAMPLE (#4)

FIG.17

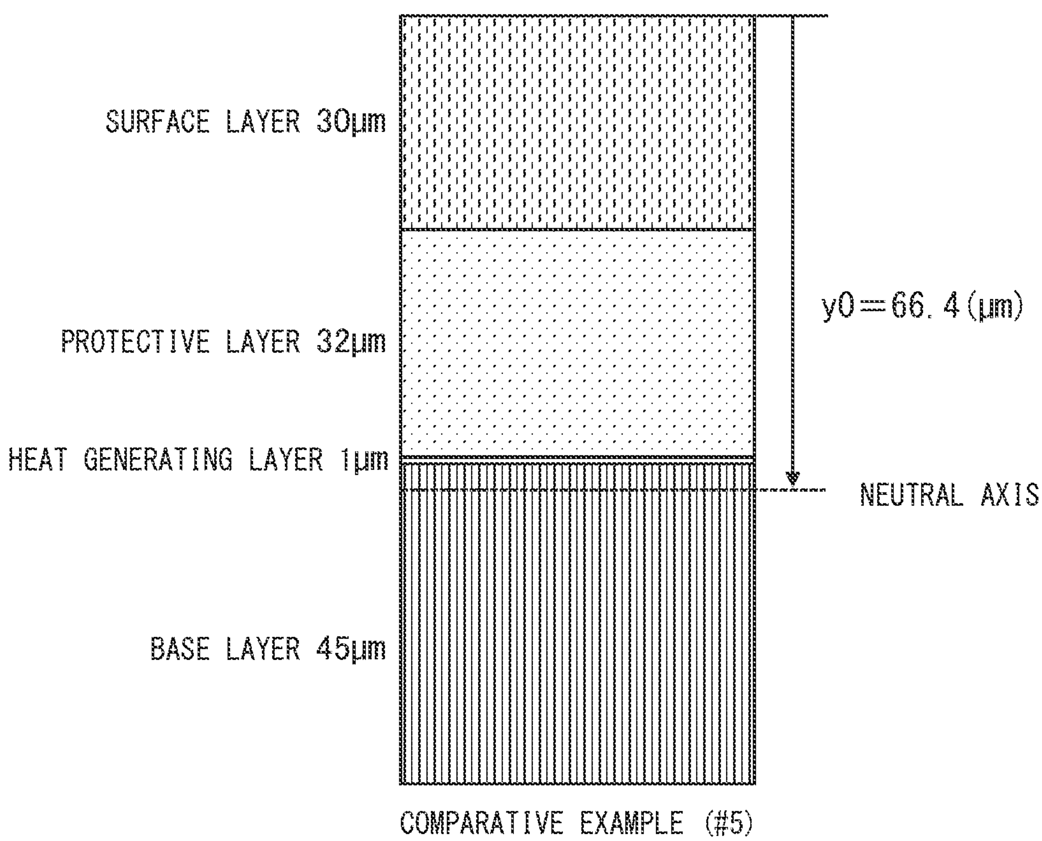
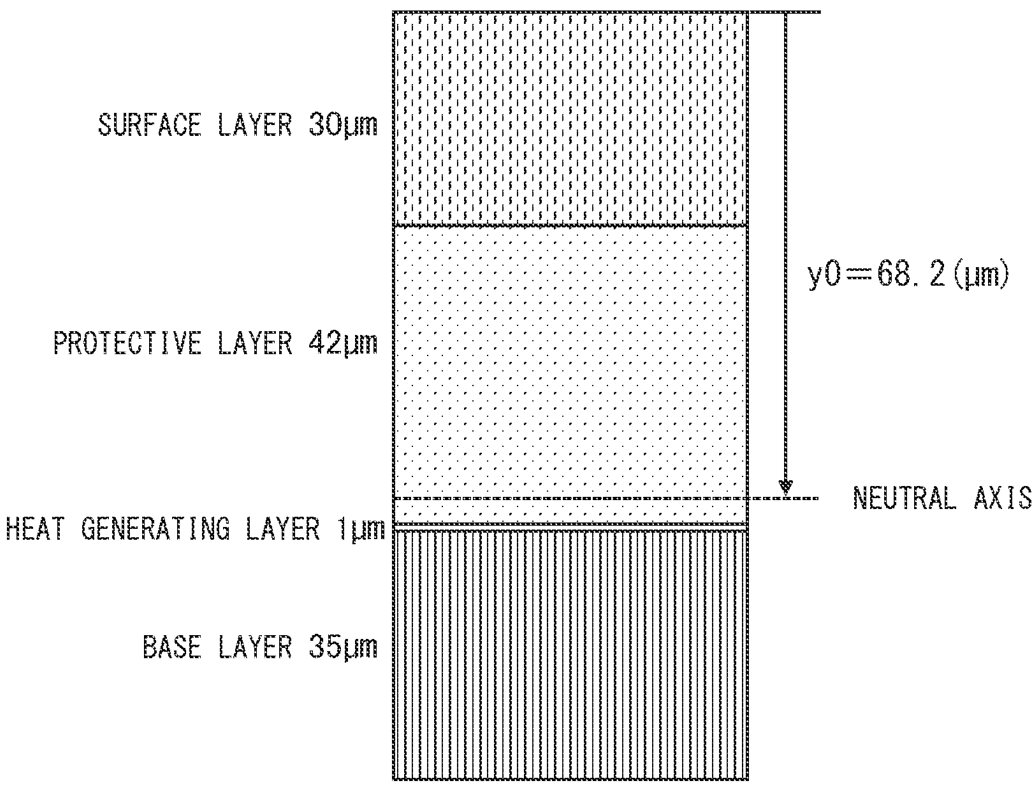

SURFACE LAYER 30μm
PROTECTIVE LAYER 32μm
HEAT GENERATING LAYER 1μm
BASE LAYER 45μm
y0=66.4(μm)
NEUTRAL AXIS
COMPARATIVE EXAMPLE (#5)

FIG.18



COMPARATIVE EXAMPLE (#6)

FIXING UNIT AND IMAGE FORMING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a fixing unit for fixing images on recording materials, and to an image forming apparatus for forming images on recording materials.

Description of the Related Art

A known configuration of a fixing unit for fixing images on recording materials in an image forming apparatus adopts a film having a heat generating layer, wherein a current is supplied to the heat generating layer to generate Joule heat and heat the film. Japanese Patent Application Laid-Open Publication No. 2011-253085 discloses supplying a current to the heat generating layer through a power feeding brush that is in contact with an end portion of a film, i.e., fixing belt. Japanese Patent Application Laid-Open Publication No. 2014-026267 discloses generating an alternating magnetic field by supplying an alternating current to a coil inserted to an inner space of a film, and causing a circulating current to flow through the heat generating layer based on the principle of electromagnetic induction.

However, if there is an area within a rotation track of the film where the film is bent with a large curvature, bending fatigue of the heat generating layer caused by bending deformation may occur. If cracking or permanent deformation of the heat generating layer occurs by the bending fatigue when the film has been used for a long period of time, electric resistance of the heat generating layer may rise, which may cause the heating value to drop and cause image fixing failures.

SUMMARY OF THE INVENTION

The present disclosure provides a fixing unit and an image forming apparatus having a film that is capable of exerting a stable performance for a long period of time.

According to one aspect of the invention, a fixing unit includes a tubular film including a heat generating layer and extending in a longitudinal direction f the film, a nip forming member including a sliding surface configured to be in sliding contact with an inner surface of the film, a heat generation mechanism configured to cause the film to generate heat, and a pressing member that is configured to be in contact with an outer surface of the film, and that is arranged to sandwich the film together with the nip forming member to form a nip portion between the film and the pressing member, wherein the film includes a heat generating layer configured to generate heat in a case where an electric current is passed in a circumferential direction of the film by the heat generation mechanism, an inner layer formed on an inner circumference side of the heat generating layer, and an outer layer formed on an outer circumference side of the heat generating layer, wherein, in a case where the longitudinal direction is referred to as a first direction, a recording material conveyance direction at the nip portion is referred to as a second direction, and a direction orthogonal to both the first direction and the second direction is referred to as a third direction, the sliding surface of the nip forming member includes a protruded portion that is protruded toward the pressing member in the third direction, and the sliding surface is formed such that a curvature of the film

when viewed in the first direction is maximum at a contact portion between the film and the protruded portion, and wherein as seen in the first direction, a neutral axis of the film is positioned within the outer layer.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an image forming apparatus according to an embodiment.

FIG. **2** is a cross-sectional view of a fixing unit according to the embodiment.

FIG. **3** is a perspective view of the fixing unit according to the embodiment.

FIG. **4** is a perspective view of an exciting coil and a magnetic core according to the embodiment.

FIG. **5** is a view illustrating a heating principle of the fixing unit according to the embodiment.

FIG. **6** is a view illustrating a shape of a sliding member according to the embodiment.

FIG. **7** is a view illustrating a neutral axis in a film-like member.

FIG. **8** is a view illustrating an example of a fixing film whose neutral axis is positioned within a heat generating layer.

FIG. **9** is a view illustrating an example of a fixing film whose neutral axis is positioned within a base layer.

FIG. **10** illustrates an example of a fixing film whose neutral axis is positioned within a protective layer.

FIG. **11** is a view in which degree of increase of resistivities according to respective examples illustrated in FIGS. **8** to **10** are compared.

FIG. **12** is a view illustrating deformation and stress in a fixing film at a protruded portion of a sliding member.

FIG. **13** is a view illustrating a layer configuration of a fixing film sample (#1) according to the embodiment.

FIG. **14** is a view illustrating a layer configuration of a fixing film sample (#2) according to the embodiment.

FIG. **15** is a view illustrating a layer configuration of a fixing film sample (#3) according to the embodiment.

FIG. **16** is a view illustrating a layer configuration of a fixing film sample (#4) according to a comparative example.

FIG. **17** is a view illustrating a layer configuration of a fixing film sample (#5) according to the comparative example.

FIG. **18** is a view illustrating a layer configuration of a fixing film sample (#6) according to the comparative example.

DESCRIPTION OF THE EMBODIMENTS

A preferred embodiment according to the present disclosure will be described below with reference to the drawings.

In the present disclosure, an "image forming apparatus" refers, not only to a single-function printer having only a printing function, but also to a wide variety of apparatuses for forming images on recording materials, such as a copying machine having a copying function, a multifunction machine having multiple functions, and a commercial large-scale printer.

Further, in the present disclosure, a "fixing unit" includes a wide variety of apparatuses, such as an image heating apparatus, for heating the image formed on the recording material through an electrophotographic process and fixing the image on the recording material. The fixing unit may also be a device arranged to heat the image that has already been fixed, i.e., primarily fixed, to the recording material in order to apply glossiness thereto.

1. Image Forming Apparatus

An overall configuration of an image forming apparatus according to an embodiment of the present disclosure will be described with reference to FIG. **1**. FIG. **1** is a cross-sectional view illustrating a schematic configuration of a laser beam printer, hereinafter referred to as printer **1**, serving as an example of an image forming apparatus. The printer **1** executes an image forming operation for forming an image on a recording material P based on an image information received from an external apparatus, such as a personal computer. Various sheet materials of various sizes and materials may be used as the recording material P, i.e., recording medium, such as paper including normal paper and thick paper, sheet materials such as a coated paper having a surface treatment applied thereto, sheet materials such as an envelope or an index paper having a special shape, plastic films, and cloths.

The printer **1** includes a process unit PU serving as an image forming unit or an image forming portion that forms an image on the recording material P by an electrophotographic process, and a fixing unit **12** for fixing the image on the recording material P.

The process unit PU includes a photosensitive drum **2** serving as an image bearing member, a charging roller **3** serving as a charging unit or a charging portion, a laser scanner unit **4** serving as an exposing unit or an exposing portion, and a developing unit **5** serving as a developing unit or a developing portion. Further, the process unit PU includes a transfer roller **6** serving as a transfer unit or a transfer portion, and a cleaning blade **7** serving as a cleaning unit or a cleaning portion. The photosensitive drum **2** is a photosensitive member that is formed in a cylindrical shape. The developing unit **5** is equipped with a container for storing toner serving as developer, and a developing roller for bearing and supplying toner to the photosensitive drum **2**.

In the image forming operation, the photosensitive drum **2** is driven to rotate, and the charging roller **3** charges the surface of the photosensitive drum **2** uniformly. The laser scanner unit **4** irradiates the photosensitive drum **2** with laser light to expose the photosensitive drum **2** based on a digital image signal generated according to the image information being entered by the image processing unit equipped in the printer **1**, and an electrostatic latent image corresponding to the image information is formed on the surface of the photosensitive drum **2**. The developing unit **5** supplies toner to the photosensitive drum **2** and develops the electrostatic latent image as a toner image.

Simultaneously with the creation of the toner image, the conveyance of the recording material P is performed. A cassette **8** is stored in a lower portion of the printer **1** in a manner capable of being drawn out therefrom. The recording material P is stored in a stacked manner in the cassette **8**. The recording material P stored in the cassette **8** is fed one sheet at a time by a feed roller **9** serving as a feeding unit or feeding portion, and conveyed to a transfer portion by a conveyance roller pair **10**.

The transfer roller **6** transfers the toner image from the photosensitive drum **2** to the recording material P at a transfer portion between the photosensitive drum **2** and the transfer roller **6**. Foreign substances such as transfer residual toner remaining on the photosensitive drum **2** without being transferred to the recording material P is removed by the cleaning blade **7**.

The recording material P having passed through the transfer portion is transferred to the fixing unit **12**. The fixing unit **12** heats and presses the image on the recording material P while conveying the recording material P to thereby fix the image on the recording material P. The details of the fixing unit **12** will be described later. The recording material P having passed through the fixing unit **12** is conveyed via a conveyance roller pair **11** to a sheet discharge roller pair **30**, and discharged by the sheet discharge roller pair **30** onto a sheet discharge tray **31**.

In the present embodiment, a direct transfer-type image forming unit, i.e., image forming portion, has been descried, but it is also possible to use an intermediate transfer-type image forming unit, i.e., image forming portion, in which a toner image is primarily transferred from an image bearing member to an intermediate transfer body such as an intermediate transfer belt, and then secondarily transferred from the intermediate transfer body to the recording material. Further, the image forming unit, or image forming portion, may form a color image using a plurality of colored toners.

2. Fixing Unit

The fixing unit **12** will be explained. The fixing unit **12** according to the present embodiment is an induction heating-type fixing unit. FIG. **2** is a cross-sectional view of the fixing unit **12**, and FIG. **3** is a perspective view of the fixing unit **12**.

As illustrated in FIGS. **2** and **3**, the fixing unit **12** includes a fixing film **13**, a sliding member **14**, a pressing roller **15**, a stay **16**, a holder **17**, a magnetic core **18**, an exciting coil **19**, and a temperature sensor **22**.

The fixing film **13** is formed of a tubular, or endless, film having flexibility. The fixing film **13** is an example of a heating member, i.e., rotating heating body, that heats the image on the recording material. The sliding member **14** is an example of a nip forming member that is in sliding contact with an inner surface of the fixing film **13**. The pressing roller **15** is an example of a pressing member that is abutted against the sliding member **14** interposing the fixing film **13** and that forms a nip portion N, i.e., fixing nip, with the sliding member **14**.

The exciting coil **19** and the magnetic core **18** are an example of a heat generation mechanism that supplies current to a heat generating layer **13***b* of the fixing film **13** and causes the heat generating layer **13***b* to generate heat. The exciting coil **19** and the magnetic core **18** serving as the heat generation mechanism according to the present embodiment generates an alternating magnetic field by having an alternating current supplied thereto, and functions as a magnetic field generation portion or magnetic field generation unit that induces a current flowing in a circumferential direction inside the heat generating layer **13***b* by the alternating magnetic field.

The holder **17** retains the sliding member **14** at a position opposed to the pressing roller **15** interposing the fixing film **13**. Further, the holder **17** has a function to be in contact with the inner surface of the fixing film **13** at an outer side of the nip portion N and to guide a rotation track of the fixing film **13**. The stay **16** is a metal member that enhances a stiffness of the fixing unit **12**. The temperature sensor **22** is a sensor that detects a temperature of the fixing film **13**.

The fixing unit **12** heats the fixing film **13** by passing an electric current through the exciting coil **19**, and heats the image on the recording material P by the fixing film **13** while nipping and conveying the recording material P by the fixing film **13** and the pressing roller **15** at the nip portion N.

In the following description and drawings, a bus line direction, i.e., longitudinal direction, of the fixing film **13** is referred to as a longitudinal direction X of the fixing unit **12**, or the longitudinal direction X. A direction of movement of the recording material P at the nip portion N is referred to as a recording material conveyance direction Y. The recording material conveyance direction Y is a direction orthogonal to the longitudinal direction X, and it is a direction in which the surface of the fixing film **13** and the pressing roller **15** move at the nip portion N. The direction orthogonal to both the longitudinal direction X and the recording material conveyance direction Y is referred to as a perpendicular direction Z.

The longitudinal direction X is an example of a first direction. The recording material conveyance direction Y is an example of a second direction. The perpendicular direction Z is an example of a third direction.

The fixing film **13** adopts a layer structure including a base layer **13***a*, the heat generating layer **13***b*, a protective layer **13***c*, and a surface layer **13***d*. The base layer **13***a*, the heat generating layer **13***b*, the protective layer **13***c*, and the surface layer **13***d* are laminated in the named order from an inner circumference side toward an outer circumference side in a thickness direction of the fixing film **13**. The base layer **13***a* is an example of an inner layer formed of synthetic resin on an inner circumference side of the heat generating layer **13***b*. The protective layer **13***c* is an example of an outer layer formed of synthetic resin on an outer circumference side of the heat generating layer **13***b*. The surface layer **13***d* is a layer, i.e., release layer, formed on an outermost circumference side of the fixing film **13**.

The base layer **13***a* desirably has a higher electrical resistivity than the heat generating layer **13***b* and a heat resisting property. The material of the base layer **13***a* is preferably an insulator, and for example, itis preferably an insulative heat-resistant resin such as polyimide, polyamide imide, polyether ether ketone (PEEK), and polyethersulfone (PES). The base layer **13***a* according to the present embodiment is a polyimide having an inner diameter of 30 mm, a length of 240 mm in the longitudinal direction X, and a thickness of approximately 40 μm.

The heat generating layer **13***b* is a layer of heating resistor that generates Joule heat in a case where an electric current is passed therethrough. The heat generating layer **13***b* is formed of a material having a lower electrical resistivity than the base layer **13***a* and the protective layer **13***c*. The material of the heat generating layer **13***b* is preferably a simple metal such as iron, copper, silver, aluminum, nickel, chromium, and tungsten, or an alloy having a low volume resistivity such as stainless steel (SUS304) and nichrome containing such simple metals. If the volume resistivity is sufficiently low, a conductive resin such as carbon fiber reinforced plastic (CFRP) and carbon nanotube resin may be used to form the heat generating layer **13***b*. The heat generating layer **13***b* may be formed by a known method, such as coating, plating sputtering and vapor deposition. The base layer **13***a*, the protective layer **13***c*, the surface layer **13***d*, and an elastic layer described later, other than the heat generating layer **13***b* may also be formed by a known film manufacturing method such as dipping spray-coating and inflation molding. The heat generating layer **13***b* according to the present embodiment is formed by plating copper through electroplating to a thickness of approximately 1 μm.

The protective layer **13***c* preferably has a higher electrical resistivity than the heat generating layer **13***b* and a higher heat resisting property. The material of the protective layer **13***c* is preferably an insulator, and for example, it is preferably an insulative heat-resistant resin such as polyimide, polyamide imide, polyether ether ketone (PEEK), and polyethersulfone (PES). The protective layer **13***c* may be formed of a same material as the base layer **13***a*. The protective layer **13***c* according to the present embodiment is formed of the same polyimide as the base layer **13***a*, and has a thickness of approximately 47 μm.

In the present embodiment, a position of a neutral axis of the fixing film **13** may be adjusted by adjusting the thickness of the protective layer **13***c* or other layers. The neutral axis of the fixing film **13** is a line of intersection where a surface, i.e., neutral plane, where distortion does not occur to the fixing film **13** when bending deformation deforming the cross-sectional shape viewed in the longitudinal direction X of the fixing film **13** occurs thereto intersects a virtual plane perpendicular to the longitudinal direction X. In the description, the term bending deformation refers to a deformation wherein the inner circumference surface of the fixing film **13** is compressed in the circumferential direction and the outer circumference surface of the fixing film **13** is elongated in the circumferential direction when viewed in the longitudinal direction X. The position of the neutral axis of the fixing film **13** may be computed based on a thickness and an elastic modulus of each layer of the fixing film **13**.

The surface layer **13***d* is preferably formed of a material having a high release property to toner and has a high heat resisting property. The surface layer **13***d* is preferably formed of a material having a good release property and heat resisting property, such as a fluororesin such as PFA, PTFE, and FEP. PFA is an abbreviation of tetrafluoroethylene-perfluorcalkylvinyl ether copolymer, PTFE is an abbreviation of polytetrafluoroethylene, and FEP is an abbreviation of tetrafluoroethylene-hexafluoropropylene copolymer. The surface layer **13***d* according to the present embodiment is an PFA resin tube having a thickness of approximately 30 μm.

According to the present embodiment, a configuration is described in which the surface layer **13***d* and the protective layer **13***c*, i.e., an outer circumference side layer of the heat generating layer **13***b*, or outer layer, are arranged adjacent to each other, but it is also possible to provide an elastic layer formed of an elastic material such as sponge or rubber between the surface layer **13***d* and the protective layer **13***c*. By providing the elastic layer, the surface layer **13***d* is made to follow the unevenness of the surface of the recording material and have a higher adhesiveness to the toner image, such that heating unevenness of the recording material and the toner image is reduced, and an image having a small unevenness of glossiness may be achieved. Further, a primer layer may be disposed with the aim to enhance the adhesiveness between the respective layers. Moreover, a layer constituting the inner surface of the fixing film **13** may be provided on the inner circumference side of the base layer **13***a*.

The sliding member **14** preferably has a superior sliding contact property with the inner surface of the fixing film **13** and a heat resisting property. The sliding member **14** according to the present embodiment is composed of a base material in which a surface layer is provided on a surface being in sliding contact with the fixing film **13**. The base material is preferably a heat-resistant resin such as polyimide, polyamide imide, PEEK, and PES having superior heat resisting property, or a metal such as aluminum and steel. In the present embodiment, a pure aluminum having a thickness of 0.8 mm is adopted as a base material. A surface layer of the present embodiment is a PTFE coating with a thickness of approximately 30 μm that has a low sliding fiction against the inner surface of the fixing film **13** and has superior heat resisting property and abrasion resistance. Further, a lubricant having a heat resisting property is disposed between the sliding member **14** and the fixing film

13 to further reduce the sliding fiction therebetween. A fluorine-based or silicone-based grease or oil is preferable as the lubricant. In the present embodiment, a fluorine grease containing fluorine oil as base and PTFE as thickener is used as the lubricant.

The sliding member **14** is retained by the holder **17**. The holder **17** includes a groove portion, i.e., recess portion, on the pressing roller **15** side in the perpendicular direction Z to which the sliding member **14** is fit. Further, the surface of the holder **17** opposite to the surface having the sliding member **14** in the perpendicular direction Z is supported by the stay **16**. The stay **16** is a metal member having a U-shaped cross section. The sliding member **14**, the holder **17**, and the stay **16** are each a member that is inserted to an inner space of the fixing film **13** and elongated in the longitudinal direction X.

The pressing roller **15** is a roller having an outer diameter of 30 mm including a core metal **15***a*, an elastic layer **15***b* that is coated concentrically to an outer circumference side of the core metal **15***a*, and a surface layer **15***c* serving as a surface layer. The elastic layer **15***b* is desirably formed of a material having a good heat resisting property, and for example, it is preferably formed of silicone rubber, fluororubber, or fluorosilicone rubber. The elastic layer **15***b* according to the present embodiment is a silicone rubber having a thickness of approximately 4 mm. The surface layer **15***c* is preferably formed of a material having good release property and heat resisting property, and fluororesin such as PFA, PTFE, and FEP are preferable. The surface layer **15***c* according to the present embodiment is a PFA resin having a thickness of approximately 50 μm. Both end portions of the core metal **15***a* are retained rotatably by conductive bearings that are attached to side panels which constitute a portion of the frame body of the fixing unit **12**.

Pressurizing springs **21***a* and **21***b* are respectively arranged between both end portions of the stay **16** and spring receiving members **20***a* and **20***b* disposed on the frame body of the fixing unit **12** (FIG. **3**). The stay **16**, the holder **17**, and the sliding member **14** are urged toward the pressing roller **15** in the perpendicular direction Z by urging force of the pressurizing springs **21***a* and **21***b*. In the present embodiment, a pressing force of a total pressure of approximately 100 N to 500 N, i.e., approximately 10 kgf to approximately 50 kgf is applied to the stay **16**. Thereby, the sliding member **14** and the pressing roller **15** are abutted against one another while sandwiching the fixing film **13** in between, and the nip portion N between the fixing film **13** and the pressing roller **15** is formed.

By receiving input of driving force from a motor serving as a driving source, the pressing roller **15** is driven to rotate in a direction of rotation along the recording material conveyance direction Y, i.e., clockwise direction of FIG. **2**. The fixing film **13** rotates in a counterclockwise direction of FIG. **2** following the movement of the pressing roller **15** by fictional force received from the pressing roller **15** at the nip portion N.

The magnetic core **18** and the exciting coil **19** are arranged in a space surrounded by the stay **16** having a U-shaped cross-sectional shape and the holder **17**. That is, the magnetic core **18** and the exciting coil **19**, i.e., magnetic field generation portion or magnetic field generation unit, serving as a heat generation mechanism according to the present embodiment is passed through the inner space of the fixing film **13**.

FIG. **4** is a perspective view illustrating the magnetic core **18** and the exciting coil **19** in schematic diagram. As illustrated in FIG. **4**, the exciting coil **19** is formed in a helical shape that extends along the longitudinal direction X, i.e., first direction. The exciting coil **19** according to the present embodiment is wound around an outer circumference of the magnetic core **18**. The magnetic core **18** has a columnar shape with end portions, and it is arranged approximately at a center, i.e., face center, of the fixing film **13** when viewed in the longitudinal direction X.

The magnetic core **18** has a function as a magnetic path forming member that induces lines of magnetic force, i.e., magnetic flux, of alternating magnetic field generated by the exciting coil **19** and forms a path, i.e., magnetic path, of the lines of magnetic force. The material of the magnetic core **18** is a magnetic body, and especially, a material having a small iron loss, i.e., hysteresis loss and eddy current loss, and a high relative permeability, such as a ferromagnetic body having a high permeability such as sintered ferrite or a ferrite resin, is preferred. The cross-sectional shape of the magnetic core **18** may be any shape that may be accommodated in a hollow portion of the fixing film **13**, and the shape preferably has a cross-sectional area that is as large as possible. The cross-sectional shape of the magnetic core **18** is not necessarily round, but it is preferably dose to a round shape, since the copper loss, i.e., coil current Joule loss, may be reduced if the length of a wire, i.e., winding wire, when winding the exciting coil **19** around the magnetic core **18** is shot. The magnetic core **18** of the present embodiment is a ferrite that has a round cross-sectional shape with a diameter of 10 mm, and a length of 280 mm.

The exciting coil **19** is formed by winding a copper wire rod, i.e., single lead wire, having a diameter of 1 to 2 mm that is coated with a polyamide imide having a heat resisting property around the magnetic core **18** in a helical shape. The number of turns is 24. A direction of a helical axis of the exciting coil **19** is a direction parallel to the axial direction of the magnetic core **18** and the bus line direction of the fixing film **13**, that is, the longitudinal direction X. When a high-frequency current is supplied to the exciting coil **19**, induced current flows to the heat generating layer **13***b* by the principle described below, and the heat generating layer **13***b* generates heat.

As illustrated in FIG. **2**, the temperature of the fixing film **13** is detected by the temperature sensor **22**. The temperature sensor **22** includes a leaf spring **22***a* having its first end fixed to the stay **16**, a thermistor **22***b* serving as a temperature detecting element disposed on a second end of the leaf spring **22***a*, and a sponge **22***c* interposed between the leaf spring **22***a* and the thermistor **22***b*. A surface of the thermistor **22***b* is covered with a polyimide tape having a thickness of 50 μm to ensure electric insulation. The sponge **22***c* functions as a heat insulating material for the thermistor **22***b* and also functions to fit the thermistor **22***b* flexibly to the fixing film **13** serving as the measurement target.

3. Heating Principle

FIG. **5** is a conceptual diagram illustrating a moment where current flowing along the exciting coil **19** toward the direction of arrow I1 has increased. In the fixing unit **12** according to the present embodiment, when a high-frequency current is flown through the exciting coil **19**, a magnetic field is formed where most, i.e., 90% or more, of the magnetic flux occurring from the first end of the magnetic core **18** passes through the external space of the fixing film **13** and returns to the second end of the magnetic core **18**. Induced current, i.e., circulating current, flows through the heat generating layer **13***b* of the fixing film **13** toward the direction of arrow **12**, i.e., direction cancelling out the variation of the magnetic field, within the circumferential direction of the fixing film **13**. In the drawing, S indicates a portion of the induced current flowing through the heat generating layer **13***b*. By having induced current flow through the heat generating layer **13***b*, the heat generating layer **13***b* generates heat by Joule heat.

The fixing unit **12** further comprises a power supply circuit that supplies high-frequency current to the exciting coil **19**, and a control unit for controlling the power supply circuit. The control unit controls the power supply circuit so that the temperature of the fixing film **13** is set to a predetermined target temperature, i.e., fixing temperature, based on a detection signal of a temperature sensor **20**. Thereby, the fixing film **13** is maintained at a temperature suitable for fixing the image.

As described, according to the present embodiment, a portion of the power supplied to the exciting coil **19** is converted to heat based on the principle of induction heating, and the fixing film **13** itself generates heat. The fixing unit **12** uses the heat to heat and fix the image on the recording material.

4. Shape of Sliding Member (Nip Forming Member)

A preferable shape of the sliding member **14** will be described. Since the main component of toner is thermoplastic resin, toner is softened along with the rising of temperature. Toner on the recording material P receives heat from the fixing film **13** at the nip portion N of the fixing unit **12**, and the temperature thereof rises. Therefore, the temperature of toner while passing through the nip portion N becomes highest at an exit, i.e., downstream end in the recording material conveyance direction Y, of the nip portion N.

Therefore, in order to press and deform toner to fix the toner to the recording material P, it is efficient to press toner strongly at the vicinity of the exit of the nip portion N where softening of toner advances. That is, pressure distribution where a peak position of pressure at the nip portion N is biased toward the downstream side in the recording material conveyance direction Y of the nip portion N is preferable.

Further, the toner temperature rises higher if the contact time between toner on the recording material and the fixing film **13** is longer. Therefore, in order to fix the toner to the recording material P, it is preferable that the width of the nip portion N in the recording material conveyance direction Y is wide.

FIG. **6** is an example of a shape of the sliding member **14**, i.e., nip forming member. FIG. **6** illustrates a cross-sectional shape of the sliding member **14** in a virtual plane perpendicular to the longitudinal direction X. In the following description, within the nip portion N, that is, contact range of the fixing film **13** and the pressing roller **15**, a center point in the recording material conveyance direction Y is referred to as a center position Nc of the nip portion N. The range including the center position Nc of the nip portion N is referred to as a center range of the nip portion N. A range including an upstream end of the nip portion N in the recording material conveyance direction Y is referred to as an upstream range of the nip portion N. A range including a downstream end of the nip portion N in the recording material conveyance direction Y is referred to as a downstream range of the nip portion N.

The sliding member **14** according to the present embodiment has a surface being in sliding contact with the fixing film **13** of the sliding member **14**, i.e., sliding surface **14***a*, formed as a curved surface, including an upstream-side projected portion **14***al*, a recess portion **14***a***2**, and a downstream-side projected portion **14***a***3**. The downstream-side projected portion **14***a***3** is an example of a protruded portion, and the upstream-side projected portion **14***al* is an example of a second protruded portion.

By forming the sliding surface **14***a* of the sliding member **14** to have a curved surface shape that is dented toward a side receding from the pressing roller **15** in the perpendicular direction Z, i.e., upper side in the drawing, the adhesiveness of the pressing roller **15** and the sliding member **14** may be enhanced. Further, by forming the sliding surface **14***a* to have a curved surface shape, the width of the nip portio N may be widened compared to a case where the sliding surface **14***a* of the sliding member **14** is formed to have a flat shape.

However, if the radius of curvature of the recess portion **14***a***2** is smaller than the radius of curvature of the outer circumference surface of the pressing roller **15**, a range in which the pressure applied at the nip portion N is weak, i.e., weakening of pressure, near the center of the recess portion **14***a***2** may occur. Therefore, the radius of curvature of the recess portion **14***a***2** is preferably equal to or greater than the radius of curvature of the outer circumference surface of the pressing roller **15**. Since the diameter of the pressing roller **15** according to the present embodiment is 30 mm, the radius of curvature thereof is 15 mm. Thus, the radius of curvature of the recess portion **14***a***2** according to the present embodiment is set to 20 mm. In this case, the width of the nip portion N may be widened without excessively increasing the deformation quantity of the pressing roller **15**.

Further according to the present embodiment, by providing the downstream-side projected portion **14***a***3** serving as a protruded portion to the sliding surface **14***a* of the sliding member **14**, a peak position of the pressure distribution at the nip portio N is set to be positioned within the downstream range of the nip portion N. The downstream-side projected portion **14***a***3** is a portion of the sliding surface **14***a*, and it is a protruded portion that is protruded toward the pressing roller **15** side in the perpendicular direction Z, i.e., downward in the drawing. An apex position of the downstream-side projected portion **14***a***3** in the perpendicular direction Z is positioned on the side having the pressing roller **15**, i.e., downward in the drawing, of an apex position of the upstream-side projected portion **14***al* in the perpendicular direction Z. According to this configuration, the peak position of the pressure distribution at the nip portio N may be positioned within the downstream range of the nip portion N, and the fixity of the toner image may be enhanced.

From the viewpoint of fixity, the radius of curvature of the downstream-side projected portion **14***a***3** should be set smaller to increase the peak pressure of the pressure distribution at the nip portion N, and deformation of toner may be caused more effectively. However, as the radius of curvature of the downstream-side projected portion **14***a***3** reduces, bending stress applied to the fixing film **13** that is rotated along a rotation track along the sliding surface **14***a* increases.

If a portion where the film is bent with a large curvature is included in the rotation track of the fixing film **13**, bending fatigue caused by bending deformation of the heat generating layer **13***b* occurs. If the apparatus is used for along period of time, the bending fatigue may cause cracking and permanent deformation to occur in the heat generating layer **13***b*, and the electric resistance of the heat generating layer **13***b* may increase, leading to deterioration of heating value and fixing failure of image accompanying the same.

Therefore, a minimum value of the radius of curvature of the downstream-side projected portion **14***a***3** according to the present embodiment is set to 6.0 mm. Meanwhile, a minimum value of the radius of curvature of the upstream-side projected portion **14***a*1 of the sliding surface **14***a* is greater than 6.0 mm. In other words, the minimum value of the radius of curvature of the downstream-side projected portion **14*a*3**, i.e., protruded portion, when viewed in the longitudinal direction X is smaller than the minimum value of the radius of curvature of the recess portion **14*a*2** and the minimum value of the radius of curvature of the upstream-side projected portion **14*al***, i.e., second protruded portion, when viewed in the longitudinal direction X. Thereby, the pressure at the downstream range in the nip portion N may be increased by the downstream-side projected portion **14*a*3**.

It is also possible to adopt a configuration where the minimum value of the radius of curvature of the downstream-side projected portion **14*a*3** and the minimum value of the radius of curvature of the upstream-side projected portion **14*al*** are the same, that is, there are two portions where the curvature of the fixing film **13** is maximum, which are the contact portion of the downstream-side projected portion **14*a*3** and the contact portion of the upstream-side projected portion **14*al***.

5. Neutral Axis of Fixing Film

Next, a neutral axis of the fixing film **13** will be described. A film-like member, i.e., belt-like member, composed of n layers as illustrated in FIG. **7** is assumed. An outer surface of the film-like member is set as reference (y=0), wherein a distance of the film-like member in a thickness direction is referred to as y, a cross-sectional area of an i-th layer from the outer surface is referred to as Ai, a width of the i-th layer is referred to as bi, and an elastic modulus, i.e., Young's modulus, is referred to as Ei. In this case, a distance (y0) from the outer surface of the film-like member to the neutral axis is defined by the following expression, Expression 1.

$$y_0 = \frac{\sum_i \left(E_i \int_{A_i} y dA_i\right)}{\sum_i (E_i A_i)} \quad \text{Expression 1}$$

In the expression, considering the range of a unit width (b=1), dAi=dyi is satisfied, and the distance (y0) from the outer surface of the film-like member to the neutral axis is expressed by the following expression.

$$y_0 = \frac{\sum_i \left(E_i \int_{A_i} y dy_i\right)}{\sum_i (E_i y_i)} \quad \text{Expression 2}$$

In order to confirm the relationship between the position of the neutral axis and the rising of resistance of the heat generating layer **13*b***, the fixing films **13** respectively satisfying three conditions, which are condition A (FIG. **8**), condition B (FIG. **9**), and condition C (FIG. **10**), wherein the thicknesses of the surface layer **13*d***, the heat generating layer **13*b***, and the base layer **13*a*** are the same but the thickness of the protective layer **13*c*** differ, were created. The Young's modulus of the respective layers is common among the three conditions, which is 60 kgf/mm^2 for the PFA of the surface layer **13*d***, 700 kgf/mm^2 for the polyimide of the protective layer, 13200 kgf/mm^2 for the copper of the beat generating layer **13*b***, and 700 kgf/mm^2 for the polyimide of the base layer **13*a***. The thicknesses of the respective layers according to the respective conditions are as shown in Table 1.

TABLE 1

	CONDITION A	CONDITION B	CONDITION C
SURFACE LAYER 13d	30 μm	30 μm	30 μm
PROTECTIVE LAYER 13c	37 μm	9 μm	60 μm
HEAT GENERATING LAYER 13b	1 μm	1 μm	1 μm
BASE LAYER13a	40 μm	40 μm	40 μm
NEUTRAL AXIS y0	67.3 μm	49.6 μm	80.6 μm

According to condition A, the position of approximately 67.3 μm from the outer surface is a neutral axis y0, and as shown in FIG. **8**, the neutral axis y0 is positioned approximately at a center of the heat generating layer **13*b***. According to condition B, the position of approximately 49.6 μm from the outer surface is the neutral axis y0, and as shown in FIG. **9**, the neutral axis y0 is deviated by approximately 10 μm from the center of the heat generating layer **13*b*** toward the base layer **13*a*** side, that is, the inner circumference side of the fixing film **13**. According to condition C, the position of approximately 80.6 μm from the outer surface is the neutral axis y0, and as shown in FIG. **10**, the neutral axis y0 is deviated by approximately 10 μm from the center of the heat generating layer **13*b*** toward the protective layer **13*c*** side, that is, the outer circumference side of the fixing film **13**.

The fixing films **13** according to the three conditions described above were attached to the fixing unit **12**, the pressing roller **15** and the fixing film **13** were rotated, and the increase rates of electrical resistivity, i.e., degree of increase of resistivity, with respect to the number of revolutions were measured. The electrical resistivity was calculated based on a current value that has been flown when an AC voltage of a fixed amplitude was applied to the exciting coil **19**. The results are shown in FIG. **11**. A horizontal axis of the graph denotes a number of revolutions, i.e., accumulated number of revolutions, of the fixing film **13**. A vertical axis of the graph denotes a degree of increase of resistivity in a case where an initial resistance value of the fixing film **13** was normalized to 1.

As can be recognized from the graph showing the magnitude correlation of the rising of resistance, the rising of resistance of condition A was smallest, the rising of resistance of condition C was second smallest, and the rising of resistance of condition B was greatest. In other words, according to condition A, the performance of the fixing film **13** was maintained for a long period of time, whereas according to condition B, the performance of the fixing film **13** was deteriorated most quickly.

In the example, though the amount of deviation of the neutral axis from the center of the heat generation layer **13*b*** was approximately the same level according to condition B and condition C, the degree of rising of resistance was smaller according to condition C. This result will be considered below.

The sliding member **14** adopted in the present embodiment includes the downstream-side projected portion **14*a*3** serving as a protruded portion that is protruded toward the pressing roller **15** side at the vicinity of the exit of the nip portion N. The downstream-side projected portion **14*a*3** is the area where the radius of curvature becomes minimum within the rotation track of the fixing film **13** when viewed in the longitudinal direction X. In other words, the sliding member **14** serving as the nip forming member is configured such that the curvature of the film when viewed in the first direction becomes maximum at the contact portion with the protruded portion.

Therefore, if the fixing film **13** rotates while being in sliding contact with the sliding member **14**, the fixing film **13** receives the maximum bending stress at the contact portion with the protruded portion, i.e., the downstream-side projected portion **14**_a_**3**, of the sliding member **14**.

As illustrated in FIG. **12**, the direction of bending deformation of the portion of the fixing film **13** that is in contact with the protruded portion, i.e., the downstream-side projected portion **14**_a_**3**, is a direction in which an other surface **13**_o_ of the fixing film **13** expands and an inner surface **13**_i_ of the fixing film **13** contracts. In other words, at the contact portion with the protruded portion, i.e., the downstream-side projected portion **14**_a_**3**, the stress applied on the cross section that crosses the fixing film **13** in the thickness direction and the longitudinal direction X is a tensile force at the outer circumference side of the fixing film **13** and a compressive force at the inner circumference side thereof with respect to the neutral axis.

In the case of condition A, the heat generating layer **13**_b_ is positioned on the neutral axis y0, such that neither tensile force nor compressive force are easily applied. Therefore, according to condition A, cracking and other problems will not easily occur to the heat generating layer **13**_b_ even if the number of revolutions of the fixing film **13** increases, and it is assumed that as a result, the degree of increase of resistivity was smallest.

According to condition B, the heat generating layer **13**_b_ is positioned on the outer circumference side of the neutral axis y0, such that at the contact portion with the protruded portion, i.e., the downstream-side projected portion **14**_a_**3**, tensile force acts on the heat generating layer **13**_b_. According to the induction heating method adopted in the present embodiment, the current flows in the circumferential direction of the fixing film **13**, such that the rising of resistance in the circumferential direction becomes a problem. In the case of condition B, when the heat generating layer **13**_b_ is elongated in the circumferential direction at the contact portion with the protruded portion, i.e., the downstream-side projected portion **14**_a_**3**, microscopic cracks may occur in the heat generating layer **13**_b_, and it is assumed that the rising of resistance became significant due to the growing or accumulating of the cracks accompanying the increase in the number of revolutions.

Meanwhile, according to condition C, the heat generating layer **13**_b_ is positioned on the inner circumference side of the neutral axis y0, such that at the contact portion with the protruded portion, i.e., the downstream-side projected portion **14**_a_**3**, compressive force acts on the heat generating layer **13**_b_. In that case, since the direction of the stress received by the heat generating layer **13**_b_ at the contact portion with the protruded portion, i.e., the downstream-side projected portion **143**, is the direction of compression, it is considered that microscopic cracks relatively unlikely to occur. Therefore, even if the degree of the stress received by the heat generating layer **13**_b_ is approximately the same level as condition B, it is assumed that condition C causes less damage of the heat generating layer **13**_b_ that leads to the rising of resistance of the fixing film **13** in the circumferential direction compared to condition B.

In other words, even if the heat generating layer **13**_b_ is deviated from the position of the neutral axis y0 of the fixing film **13**, it has been recognized that if the heat generating layer **13**_b_ is deviated toward the protected layer **13**_c_ i.e., outer circumference side, as in condition C, the damage of the heat generating layer **13**_b_ that leads to the deterioration of performance of the fixing film **13** is small. Meanwhile, if the heat generating layer **13**_b_ is deviated toward the base layer **13**_a_ side, i.e., inner circumference side, from the position of the neutral axis y0 of the fixing film **13**, it has been recognized that even if the amount of deviation is relatively small, microscopic cracks of the heat generating layer **13**_b_ that leads to the deterioration of performance of the fixing film **13** tends to occur.

As described, regarding the tendency of occurrence of damage of the heat generating layer **13**_b_ that may lead to the deterioration of performance of the fixing film **13**, it has been determined that there is an asymmetric property in the directions of positional deviation of the heat generating layer **13**_b_ from the neutral axis y0 of the fixing film **13**.

If the film thicknesses of the respective layers of the fixing film **13** may be created according to design values, it is preferable that the neutral axis y0 is positioned in the heat generating layer **13**_b_, but the film thicknesses of the respective layers may be varied according to fabrication tolerances. Especially, certain levels of dispersion may occur to the film thicknesses of the base layer **13**_a_ and the protective layer **13**_c_, which influence the position of the neutral axis y0 greatly.

Therefore, the present embodiment focuses on the asymmetry described above, and defines the positional relationship between the heat generating layer **13**_b_ and the neutral axis y0 so that the fixing film **13** exerts a stable performance through a long term of use even if the film thicknesses of the respective layers of the fixing film **13** are varied. Specifically, the film thicknesses of the respective layers of the fixing film **13** were set such that even if the film thicknesses of the base layer **13**_a_ and the protective layer **13**_c_ were varied due to fabrication tolerance, the heat generating layer **13**_b_ will not be positioned on the outer circumference side, that is, the side where tensile force acts at the contact portion with the protruded portion, of the neutral axis y0.

The dispersion of film thicknesses of the base layer **13**_a_ and the protective layer **13**_c_ during fabrication was confirmed, and it was recognized that a dispersion of approximately 5 μm occurred. Therefore, according to the present embodiment, a positional relationship is realized where the heat generating layer **13**_b_ is not positioned on the outer circumference side of the neutral axis y0 even if dispersion of approximately ±5 μm occurred to the film thicknesses of the base layer **13**_a_ and the protective layer **13**_c_.

FIG. **13** illustrates one example of the layer configuration according to the present embodiment. FIG. **13** illustrates the fixing film **13** (#1) where the film thicknesses of the respective layers comply with design values. The design values of the film thickness of the respective layers are 30 μm for the surface layer **13**_d_, 48 μm for the protective layer **13**_c_, 1 μm for the heat generating layer **13**_b_, and 40 μm for the base layer **13**_a_. If the film thicknesses are formed to comply with the design values, the neutral axis y0 will be positioned at 73.8 μm from the outer surface, and will be positioned within the protective layer **13**_c_ at a position deviated by approximately 4.7 μm toward the outer circumference side in the thickness direction from the center of the heat generating layer **13**_b_.

FIGS. **14** and **15** illustrate the fixing film **13** in a case where the position of the neutral axis y0 is varied by the dispersion of film thicknesses according to the present embodiment. FIG. **14** is the fixing film **13** (#2) of a case where the base layer **13**_a_ is thicker than the design value and the protective layer **13**_c_ is thinner than the design value. In this case, the neutral axis y0 is positioned at 72.9 μm from the outer surface, and is positioned within the protective layer **13***c* at a position deviated by approximately 0.6 μm toward the outer circumference side from the heat generating layer **13***b*. FIG. **15** is the fixing film **13** (#3) of a case where the base layer **13***a* is thinner than the design value and the protective layer **13***c* is thicker than the design value. In this case, the neutral axis y0 is positioned at 74.6 μm from the outer surface, and is positioned within the protective layer **13***c* at a position deviated by approximately 8.9 μm toward the outer circumference side from the center of the heat generating layer **13***b*.

As described, according to the present embodiment, even if the position of the neutral axis y0 is varied by dispersion of film thicknesses, a positional relationship in which the neutral axis y0 is positioned within the protective layer **13***c*, i.e., within the outer layer, and the heat generating layer **13***b* is positioned on the inner circumference side of the neutral axis y0 is maintained. In other words, according to the present embodiment, the neutral axis y0 of the fixing film **13** is positioned within the protective layer **13***c*, i.e., within the outer layer.

FIG. **16** illustrates a layer configuration according to a comparative example. FIG. **16** illustrates the fixing film **13** (#4) of a case where the film thicknesses of the respective layers are according to design value of the comparative example. The comparative example is configured such that the neutral axis y0 is positioned approximately at the center of the heat generating layer **13***b*. Specifically, the design values of film thicknesses of the respective layers are 30 μm for the surface layer **13***d*, 37 μm for the protective layer **13***c*, 1 μm for the heat generating layer **13***b*, and 40 μm for the base layer **13***a*. If the film thicknesses are formed according to the design values, the neutral axis y0 will be positioned at 67.3 μm from the outer surface, and is positioned within the heat generating layer **13***b*.

FIGS. **17** and **18** illustrate the fixing film **13** according to a comparative example where the position of the neutral axis y0 is varied by dispersion of film thicknesses. FIG. **17** illustrates the fixing film **13** (#5) of a case where the base layer **13***a* is thicker than the design value and the protective layer **13***c* is thinner than the design value. In this case, the neutral axis y0 is positioned at 66.4 μm from the outer surface, and it is positioned within the base layer **13***a* deviated by approximately 3.9 μm toward the inner circumference side from the center of the heat generating layer **13***b*. FIG. **18** illustrates the fixing film **13** (#6) of a case where the base layer **13***a* is thinner than the design value and the protective layer **13***c* is thicker than the design value. In this case, the neutral axis y0 is positioned at 68.2 μm from the outer surface, and it is positioned within the protective layer **13***c* deviated by approximately 4.3 μm toward the outer circumference side from the center of the heat generating layer **13***b*.

As described, according to the comparative example, in a case where the position of the neutral axis y0 is varied according to dispersion of film thicknesses, a positional relationship may be realized (FIG. **17**) where the neutral axis y0 is positioned within the base layer **13***a*, i.e., within the inner layer, and the heat generating layer **13***b* is positioned on the outer circumference side of the neutral axis y0.

The respective samples #1 to #6 of the fixing film **13** according to the present embodiment and the comparative examples were attached to the fixing unit **12**, the pressing roller **15** and the fixing film **13** were rotated, and the increase rate of electrical resistivity, i.e., degree of increase of resistivity, with respect to the number of revolutions was measured. Table 2 illustrates the degree of increase of resistivity at a point of time where the fixing films **13** according to the respective samples were rotated for 3,000,000 times, wherein the initial resistance value is normalized by 1.

TABLE 2

	FIXING FILM	RESISTIVITY INCREASE RATE WHEN ROTATED 3,000,000 TIMES)
EMBODIMENT	#1	1.014
	#2	1.012
	#3	1.021
COMPARATIVE EXAMPLE	#4	1.012
	#5	1.036
	#6	1.014

As shown in Table 2, when comparing the present embodiment and the comparative examples of cases where the film thicknesses were according to design value (#1 and #4), in both cases, the degree of increase of resistivity was suppressed to a sufficiently low value (1.012 and 1.014) that is sufficient for practical use, wherein the value was somewhat smaller in the comparative example.

However, according to the comparative examples, when comparing the cases having dispersion of film thicknesses (#5 and #6), in one of the cases, the degree of increase of resistivity was significantly increased to 1.036 (#5). In contrast, according to the present embodiment, even if there is a dispersion of film thicknesses (#2 and #3), the degree of increase of resistivity was suppressed to a sufficiently low value (1.012 and 1.021) that is sufficient for practical use.

Therefore, it was confirmed that according to the layer configuration of the present embodiment, the rising of resistance of the heat generating layer **13***b* may be suppressed for a long period of time and more stably, i.e., with robustness, with respect to the dispersion of film thicknesses during manufacture.

As described, according to the present embodiment, by adopting a layer configuration in which the neutral axis y0 is positioned within the protective layer **13***c*, it was possible to suppress the rising of resistance of the heat generating layer **13***b* to a low value. Further, it became possible to allow dispersion during manufacture, such that yield may be improved significantly.

In other words, by setting the position of the neutral axis y0 considering the dispersion of film thicknesses that occurs during manufacture based on the asymmetry of positional deviation of the neutral axis with respect to the tendency of occurrence of rising of resistance of the heat generating layer **13***b*, it becomes possible to manufacture the fixing film **13** that exerts a stable function for a long period of time.

If the position of the neutral axis y0 is set to be within the protective layer **13***c*, the material of the protective layer **13***c* should preferably be an insulator, i.e., insulating resin. Metal, which may cause rising of resistance due to bending fatigue, is not preferable as the material of the protective layer **13***c*. If a metal is adopted as the material of the protective layer **13***c*, current will also flow through the protective layer **13***c* and contribute to heat generation. If the neutral axis y0 is set to be within the protective layer **13***c*, a strong tensile force is applied on the layers constituting the protective layer **13***c* positioned on the outer circumference side of the neutral axis y0 at the contact portion with the protruded portion, i.e., the downstream-side projected portion **14***a***3**, of the sliding member **14**. As a result, microscopic cracks are generated in the protective layer **13***c*, and a significant rising of resistance occurs during a long period of time during which the film is used. That is, the amount of current drops by deterioration of the protective layer **13***c*, and the heating value may be reduced.

Modified Example

In the above-mentioned embodiment, mainly the film thicknesses of the base layer **13***a*, i.e., inner layer, and the protective layer **13***c*, i.e., outer layer, were adjusted as the method for controlling the position of the neutral axis y0, but the position of the neutral axis y0 may also be controlled by the different materials of the base layer **13***a* and the protective layer **13***c*. For example, if the base layer **13***a* is formed of a material having a lower elastic modulus, i.e., Young's modulus, compared to the protective layer **13***c*, the position of the neutral axis y0 may be moved toward the protective layer **13***c* even if the film thicknesses of the base layer **13***a* and the protective layer **13***c* are the same.

Even in a case where the position of the neutral axis y0 is controlled according to the difference in materials, the material of the protective layer **13***c* is still preferably an insulator, i.e., insulating resin. The reason is described above.

As illustrated in FIG. **13**, the position of the neutral axis y0' of the fixing film **13** may be positioned within the protective layer **13***c*, i.e., within the outer layer, in a case where the position is obtained by excluding the surface layer **13***d*. The position of the neutral axis y0' with the surface layer **13***d* excluded is the position of approximately 75.2 μm from the original outer surface (y=0) of the fixing film **13**, and it is within the protective layer **13***c*. While the fixing unit **12** is used for a long period of time, the surface layer **13***d* is worn by contact with the recording material, especially, the edge of the surface layer **13***d* is scraped by having the leading edge of the recording material collide thereto. If the wear of the surface layer **13***d* advances quicker than that of the base layer **13***a* due to edge scraping and the like, the position of the neutral axis is gradually changed from y0 toward y0'.

As long as the neutral axis y0' computed with the surface layer **13***d* excluded is positioned within the protective layer **13***c*, even if the position of the neutral axis is changed from y0 toward y0', the heat generating layer **13***b* will not easily be positioned on the outer circumference side of the neutral axis. That is, even if the position of the neutral axis is varied toward the inner circumference side due to wear of the surface layer **13***d*, microscopic cracks are not easily generated in the heat generating layer **13***b*, such that the rising of resistance of the fixing film **13** may be further suppressed for a long period of time.

Other Examples

In the present embodiment, a configuration has been described where an alternating magnetic field for causing induction heating of the heat generating layer **13***b* of the fixing film **13** is generated by the exciting coil **19** passed through the inner space of the fixing film **13**. However, the present technique is not limited thereto, and the exciting coil for generating an alternating magnetic field for causing induction heating of the heat generating layer **13***b* of the fixing film **13** may be arranged in the outer space of the fixing film **13**. For example, the exciting coil **19** may be arranged above the fixing film **13** in FIG. **2**.

Further, the present technique is not limited to the induction heating method, and current may be supplied to the heat generating layer **13***b* by having a power feed member come into contact with the fixing film **13**. That is, the power feed member and the current supply circuit supplying current to the heat generating layer **13***b* through the power feed member are another example of a heat generation mechanism for causing the heat generating layer **13***b* to generate heat. Even according to this case, for example, if the heat generating layer **13***b* is formed of a helical shape pattern that extends in the longitudinal direction X while circulating the fixing film **13** in the circumferential direction, rising of resistance by microscopic cracks in the heat generating layer **13***b* may occur.

According to the present disclosure, a fixing unit and an image forming apparatus equipped with a film that is capable of exerting a stable performance for a long period of time may be provided.

Other Embodiments

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2022-210817, filed on Dec. 27, 2022, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A fixing unit comprising:

a tubular film;

a nip forming member including a surface configured to be in sliding contact with an inner surface of the film;

a magnetic body inserted to an inner space of the film and that extends in a longitudinal direction of the film;

a coil wound around the magnetic body, formed in a helical shape along the longitudinal direction, and inserted to the inner space of the film with the magnetic body; and

a pressing roller that is configured to be in contact with an outer surface of the film, and that is arranged to sandwich the film together with the nip forming member to form a nip portion between the film and the pressing roller,

wherein the film includes a conductive layer configured to generate heat in a case where an alternating current is supplied to the coil and an electric current is induced in a circumferential direction of the film by principle of induction heating, an inner layer formed on an inner circumference side of the conductive layer, and an outer layer formed on an outer circumference side of the conductive layer,

wherein, in a case where the longitudinal direction is referred to as a first direction, a recording material conveyance direction at the nip portion is referred to as a second direction, and a direction orthogonal to both the first direction and the second direction is referred to as a third direction, the surface of the nip forming member includes a protruded portion that is protruded toward the pressing roller in the third direction, and the surface of the nip forming member is formed such that a curvature of the film when viewed in the first direction is maximum at a contact portion between the film and the protruded portion,

wherein as seen in the first direction, a neutral axis of the film is positioned within the outer layer, and

wherein the outer layer is formed of an insulator.

2. The fixing unit according to claim **1**,

wherein the protruded portion is positioned downstream in the second direction of a center position of the nip portion in the second direction.

3. The fixing unit according to claim **2**,

wherein the surface of the nip forming member includes a recess portion that is dented toward a side receding from the pressing roller in the third direction, and a second protruded portion that is protruded toward the pressing roller in the third direction,

wherein the recess portion is provided downstream of the second protruded portion and upstream of the protruded portion in the second direction, and

wherein a minimum value of a radius of curvature of the protruded portion when viewed in the first direction is smaller than a minimum value of a radius of curvature of the recess portion and a minimum value of the radius of curvature of the second protruded portion when viewed in the first direction.

4. The fixing unit according to claim **1**,

wherein a thickness of the outer layer is greater than a thickness of the inner layer.

5. The fixing unit according to claim **1**,

wherein a Young's modulus of the outer layer is greater than a Young's modulus of the inner layer.

6. The fixing unit according to claim **1**,

wherein the film further includes a surface layer that is formed on an outermost circumference side of the film, and

wherein a neutral axis of the film obtained by excluding the surface layer is positioned within the outer layer.

7. The fixing unit according to claim **1**,

wherein the film further includes a surface layer that is formed on an outermost circumference side of the film and adjacent to an outer circumference side of the outer layer.

8. The fixing unit according to claim **1**,

wherein the film further includes a surface layer that is formed on an outermost circumference side of the film, and an elastic layer that is formed between the outer layer and the surface layer.

9. The fixing unit according to claim **1**,

wherein the inner layer is formed of an insulator.

10. The fixing unit according to claim **1**,

wherein the fixing unit is configured to heat an image on a recording material by the film while nipping and conveying the recording material by the film and the pressing roller at the nip portion.

11. An image forming apparatus comprising:

an image forming portion configured to form an image on a recording material; and

the fixing unit according to claim **1** configured to fix the image on the recording material.

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