

FLEXIBLE PRINTED CIRCUIT AND MANUFACTURING METHOD THEREFOR

BACKGROUND OF THE INVENTION

This invention relates to a flexible printed circuit of
5 a functional part used mainly in electric and electronic fields
and a manufacturing method therefor.

Hitherto, printed circuits rich in flexibility have
been commonly called flexible printed circuits and generally
used in fields of electronics, etc. Generally, to form the
10 flexible printed circuit, a material film is stretched in two
directions of machine and transverse directions and two or more
plastic films are cut out to a predetermined size from the
stretched film and are laminated on each other. The machine
and transverse directions mean longitudinal and lateral
15 directions of the material film. Fig. 16A shows an example of
the flexible printed circuit. A flexible printed circuit 1
comprises predetermined metal electric circuit 3 formed on a
plastic film 4 made of polyimide, polyester, etc., (for a base
layer) by a printing technique, a subtractive method, or the
20 like and a plastic film 2 (for a cover layer) similar to the
plastic film 4 furthermore formed on the metal electric circuit
3. Generally, an adhesive is used to laminate the plastic
films 2 and 4 (lamine bond). An adhesive layer is not shown
in Fig. 16A.

5 Fig. 16B shows a general structure of the flexible
printed circuit. As shown here, the flexible printed circuit



comprises an adhesive layer 8 formed on a plastic film 4 (for a base layer), metal electric circuit 3 formed on the adhesive layer 8, and an adhesive layer 8 formed on a plastic film 2 (for a cover layer) with both plastic films 2 and 4 laminated on each other with their respective adhesive layers 8 facing each other.

The flexible printed circuit, on which electronic parts such as semiconductor devices are mounted, requires precision of its shape. However, warpage called a curl as shown in Fig. 17A occurs in the manufacturing process of the flexible printed circuit. That is, in manufacturing of the flexible printed circuit, plastic films are laminated by pressurization and heat treatment of laminate, etc., and in addition, heat treatment is executed in curing a thermosetting adhesive, in a printing process, etc. When the plastic film lamination (flexible printed circuit) subjected to such heat treatment is restored to room temperature, a curl occurs. The curl occurring on the flexible printed circuit is not a simple curl like warping in one direction and is a so-called twisted curl of warping in opposite directions in two diagonal line directions on a rectangular flexible printed circuit as shown in Fig. 17B.

For example, sticking of a thick curl prevention film is proposed as a method of preventing the flexible printed circuit from curling in Japanese Patent Application No. Hei. 7-95987. However, such a method somewhat suppresses curl owing to the tare weight of the curl prevention film and is not much



effective for fundamental curl suppression; in addition, there is a fear of impairing flexibility, an important property of the flexible printed circuit. If flexibility is impaired, a new problem that the essential property of the flexibility printed circuit cannot be satisfied occurs. Therefore, the method cannot fundamentally solve the curl problem and if curl is suppressed, the essential performance of the flexible printed circuit is not provided.

Thus, curl occurrence raises a problem from the beginning of development of the flexible printed circuit and is still an important problem to be solved at present after a lapse of about twenty years since that time. Providing sufficient flexibility of the flexible printed circuit in addition to suppressing curl occurrence is also left as an important problem to make the most of the essential performance of the flexible printed circuit.

On the other hand, a comparatively thin reinforcing plastic film (stiffener) to such a degree that it does not impair flexibility is stuck on some flexible printed circuits used at places where reasonable rigidity as well as flexibility is required, such as connectors. In this case, as shown in Fig. 26A, plastic films 2 and 4 and a reinforcing plastic film 7 used with the flexible printed circuit differ in thickness and material lot, thus the structure of the flexible printed circuit becomes asymmetrical in the cross-sectional direction. Such a flexible printed circuit of asymmetrical structure on



which the reinforcing plastic film 7 is stuck is furthermore disadvantageous from a stand point of curl occurrence.

Further, to form flexible printed circuits, plastic films are stacked via an adhesive layer and the plastic films in stacked relation are crimped for lamination. However, since the plastic films, metal electric circuit, and the adhesive layers vary in thickness, the entire flexible printed circuit also varies in thickness; partially excessive pressure is applied to the flexible printed circuit crimped under mechanical pressure with a general press, etc., for extending the flexible printed circuit itself in a transverse direction, and the flexible printed circuits thus manufactured may vary in performance, etc., in some cases.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a flexible printed circuit whose curl occurrence is prevented, and a manufacturing method therefor.

According to a first aspect of the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, wherein two plastic films of the laminated plastic films positioned on both outermost layers have the following relationship: Two ellipses of coefficient of linear expansion are created on coordinates in corresponding



parts of film surfaces of the two plastic films by a method (A) described below and are overlapped so that they match in center point and coordinate axes X and Y. At this time, the maximum value of a linear expansion coefficient difference between the two plastic films is equal to or less than 1.4×10^{-5} ($1/^{\circ}\text{C}$):

(A) comprising the steps of defining a predetermined base point P on the film surface of the plastic film, measuring a coefficient of linear expansion at a position separate from an arbitrary axis in angle θ direction on the first and second resin films, the arbitrary axis being selected on the first and second resin films so as to pass through the base point P with the base point P as a center and direct an arbitrary direction, on the other hand, preparing a coordinate system with the arbitrary axis as a Y axis and an axis crossing the Y axis at 90 degrees as an X axis, in this coordinate system, defining an intersection of the X and Y axes as the base point P in the linear expansion coefficient measurement and magnitude of a linear expansion coefficient measurement value as distance r from the base point P, then plotting a tip point of this distance r in the measurement angle θ direction with respect to the Y axis, plotting it multiple times by changing the measurement angle θ , and drawing an analysis line throughout 360-degree directions with the base point P as the center so as to pass through average points of the plotted points for creating an ellipse.

According to the invention, there is provided a



flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, wherein two plastic films of the laminated plastic films positioned on both outermost layers have the following relationship: When two ellipses of coefficient of linear expansion are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (A) described above and are overlapped so that they match in center point and coordinate axes X and Y, the total area of portions where the ellipses do not overlap is equal to or less than $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, wherein two plastic films of the laminated plastic films positioned on both outermost layers have the following relationship: When ultrasonic propagation velocity ellipses are created on coordinates in corresponding parts of film surfaces of the two plastic films by a method (B) described below and are overlapped so that they match in center point and coordinate axes X and Y, a shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30 degrees:

(B) comprising the steps of defining a predetermined



base point P on the film surface of the plastic film, measuring
a ultrasonic propagation velocity at a position separate from
an arbitrary axis in angle θ direction on the first and second
resin films, the arbitrary axis being selected on the first and
5 second resin films so as to pass through the base point P with
the base point P as a center and direct an arbitrary direction,
on the other hand, preparing a coordinate system with the
arbitrary axis as a Y axis and an axis crossing the Y axis at
90 degrees as an X axis, in this coordinate system, defining an
10 intersection of the X and Y axes as the base point P in the
ultrasonic propagation velocity measurement and magnitude of a
ultrasonic propagation velocity measurement value as distance
from the base point P, then plotting a tip point of this
distance r in the measurement angle θ direction with respect to
15 the Y axis, plotting it multiple times by changing the
measurement angle θ , and drawing an analysis line throughout
360-degree directions with the base point P as the center so as
to pass through average points of the plotted points for
creating an ellipse having a crystal orientation main axis in
20 a long-axis direction and a crystal orientation subaxis in a
short-axis direction.

In the flexible printed circuit as described, the two
plastic films of the laminated plastic films positioned on both
the outermost layers may be laminated on each other with the
15 same surfaces of the two plastic films facing each other.

Further, in the flexible printed circuit as described,



metal electric circuit is formed in at least one of two or more laminated plastic films stretched in two directions of a machine direction and a transverse direction and wherein a product of thickness and tensile modulus of the metal electric circuit is 500 kg/mm or less.

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, and having a board face on which a reinforcing plastic film is stuck, wherein a plastic film of the laminated plastic films positioned on an outermost layer on a side where the reinforcing plastic film is not stuck and the reinforcing plastic film have the following relationship: Two ellipses of coefficient of linear expansion are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (A) described above and are overlapped so that they match in center point and coordinate axes X and Y. At this time, the maximum value of a linear expansion coefficient difference between the two plastic films is equal to or less than 1.4×10^{-5} (1/°C).

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, and having a board face on which a



reinforcing plastic film is stuck, wherein a plastic film of the laminated plastic films positioned on an outermost layer on a side where the reinforcing plastic film is not stuck and the reinforcing plastic film have the following relationship: When
5 two ellipses of coefficient of linear expansion are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (A) described above and are overlapped so that they match in center point and coordinate axes X and Y, the total area of portions where the ellipses do
10 not overlap is equal to or less than $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being
15 stretched in two directions of a machine direction and a transverse direction, and having a board face on which a reinforcing plastic film is stuck, wherein a plastic film of the laminated plastic films positioned on an outermost layer on a side where the reinforcing plastic film is not stuck and the
20 reinforcing plastic film have the following relationship: When ultrasonic propagation velocity ellipses are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (B) described above and are overlapped so that they match in center point and coordinate
25 axes X and Y, a shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30



THIS SHEET HAS BEEN
REPLACED

degrees.

In the flexible printed circuit as described, a plurality of plastic films stacked via an adhesive layer may be temporarily crimped by a roll laminate method in stacked
5 relation and then pressurized under gas pressure in an autoclave and crimped.

According to the invention, there is provided a method of manufacturing a flexible printed circuit comprising the steps of stacking a plurality of plastic films via an adhesive
10 layer, temporarily crimping the stacked plastic films by a roll laminate method in stacked relation, and then pressurizing them under gas pressure in an autoclave, thereby crimping them.

In the above methods (A) and (B), an arbitrary axis is selected arbitrarily on the two plastic films, and a coordinate
15 system with the arbitrary axis as a Y axis and an axis crossing the Y axis at 90 degrees as an X axis is prepared. However, it is allowed to settle an axis of the machine direction of plastic film stretch as the Y axis and an axis of the transverse direction of plastic film stretch as an X axis.

In the invention, the coefficient of linear expansion
20 α is derived as follows: When a plastic film is heated, it expands in response to the characteristics of the plastic film. At this time, the coefficient of linear expansion α can be found according to the following expression (1) from the change
5 ratio of the length of the plastic film, p , to temperature t at the measurement time $(\partial p / \partial t)$ and the length of the film, p_0 , at



0°C (Kagaku Binran-Kisohen II, edited by Nippon Kagakukai, published by Maruzen Shuppan).

$$\alpha = 1/p_0 \times \partial p / \partial t \quad \dots(1)$$

However, the coefficient of linear expansion α mentioned in the invention refers to that in region of glass transfer temperature of plastic film (T_g) or less. Since T_g of the plastic films to which the invention is applied is in the temperature range exceeding the room temperature (about 23°C) and a twisted curl becomes a problem in a temperature region near the room temperature, the coefficient of linear expansion at T_g or softening point or less becomes the target. T_g of polyimide films is 300°C or more, which exceeds the operating temperature range, and does not clearing appear, thus the necessity for considering T_g of polyimide films is small.

In the invention, the total area of portions where ellipses do not overlap (C) is defined by the following expression (2) representing the integral value of linear expansion coefficient square value differences ($\Delta\alpha C$). That is, in the invention, the total area of portions where ellipses do not overlap (C) is synonymous with the integral value of linear expansion coefficient square value differences ($\Delta\alpha C$). In the following expression (2), θ is a linear expansion coefficient measurement angle with the axis of the machine direction of stretch as the reference and $\Delta\alpha C(\theta)$ is defined by the following expression (3). The ellipses in the invention contain perfect circles.



$$C = 1/2 \int_0^{2\pi} \Delta\alpha_c(\theta) d\theta \quad \dots(2)$$

$$\Delta\alpha_c(\theta) = |r_1^2(\theta) - r_2^2(\theta)| \quad \dots(3)$$

Further, the ultrasonic propagation velocity in the invention refers to a measurement value of the propagation time (s) or the propagation velocity (m/s) when a ultrasonic pulse (frequency: 25 MHz) is passed through a plastic film and propagates in the plastic film at a predetermined distance.

In the invention, the flexible printed circuit is not limited if it comprises two or more plastic films laminated (laminated and bonded) and is intended for use as a printed circuit. Therefore, in the invention, printed circuits not yet formed with metal electric circuit or those formed with a metal thin film before formation of an electric circuit pattern are also contained in the flexible printed circuits.

In the invention, the expression "both the outermost layers" of "two plastic films positioned on both the outermost layers, of laminated plastic films" does not mean both the outermost layers of the flexible printed circuit and is used to mean both the outermost layers in the plastic film laminate. Therefore, for example, if a flexible printed circuit comprises a shielding layer formed on a plastic film laminate by painting, printing, etc., the shielding layer is not contained in "both the outermost layers" in the invention. Even for a flexible printed circuit on which a reinforcing plastic film is stuck, if the reinforcing plastic film is contained in a plastic film laminate and is stuck on the board face, it forms



one of "both the outermost layers" in the invention.

In the invention, the expression "curl suppression" refers to the case where the curl degree (%) defined below becomes 5% or less. Assume that the length of the long side of the smallest rectangle in which a flexible printed circuit is inscribed is the longest length of the flexible printed circuit, L. Fig. 14 shows an example of smallest rectangle 21 in which a flexible printed circuit 1a like a substantial V-shape is inscribed. As shown here, in the flexible printed circuit 1a, the length of the long side of the rectangle 21 indicated by the dotted line becomes the longest length L. As shown in Fig. 15, one end of the flexible printed circuit 1a is fixed to a reference plane 6 and the height of the maximum warpage of the flexible printed circuit 1a from the reference plane 6, h, is found and is defined as curl amount h. The percentage of the curl amount h to the longest length of the flexible printed circuit, L, namely, $(h/L) \times 100$ is defined as the curl degree (%).

In the invention, the tensile modulus is a value indicating the rigidity of a metal thin film forming metal electric circuit and refers to elastic stress per unit elastic strain (kg/mm^2). It is measured as follows: When a predetermined load is imposed on a metal thin film (metal foil) forming metal electric circuit with a tensile tester and constant elastic strain is given, the elastic stress is measured as the tensile modulus. The tensile modulus is



measured with metal foil. It can be used as a typical value as the tensile modulus of a metal thin film, and can be used even if a film other than metal foil, such as an evaporation film, is formed as the metal thin film of metal electric circuit. In this case, preferably the composition of metal foil used instead is made the same, the same heat history is given, and the resultant crystal state, etc., is set like the metal thin film of the actual flexible printed circuit.

Next, the technical philosophy of the invention will be discussed.

To solve the problem of curl occurrence of flexible printed circuits, the inventor et al. first carried out a detailed analysis of the cause of curl occurrence of flexible printed circuits. As a result, the inventor et al. have found that curl occurrence is caused by the linear expansion coefficient difference between plastic films. If different materials are laminated, it can be easily imagined that warpage (curl) occurs because they differ in coefficient of linear expansion. Normally, flexible printed circuits use plastic films (for example, base and cover layer films) made of the same material and therefore formerly it was considered that the plastic films made of the same material do not differ in coefficient of linear expansion. However, the inventor et al. actually measured coefficients of linear expansion in detail and found that the plastic films of each flexible printed circuit differ in coefficient of linear expansion. Nobodies in



the flexible printed circuit field found this knowledge until the inventor et al. found it.

The inventor et al. continued to examine the linear expansion coefficient difference and found that each
5 bidirectionally stretched plastic film used with a flexible printed circuit shows anisotropy in its coefficient of linear expansion. That is, a predetermined base point P is defined on the film surface of the plastic film and the coefficient of linear expansion in angle θ direction with respect to the axis
10 of the machine direction of plastic film stretch passing through the base point P with the base point P as the center is measured. On the other hand, a coordinate system with the axis of the machine direction of plastic film stretch as a Y axis and the axis of the transverse direction of plastic film stretch as an X axis is prepared. In this coordinate system,
15 the intersection of the X and Y axes is defined as the base point P in the linear expansion coefficient measurement and the magnitude of the linear expansion coefficient measurement value is defined as distance r from the base point P, then the tip point of this distance r is plotted in the measurement angle θ
20 direction with respect to the Y axis. It is plotted multiple times by changing the measurement angle θ and an analysis line is drawn throughout 360-degree directions with the base point P as the center so as to pass through average points of the
25 plotted points. Then, an ellipse as shown in Fig. 1 is provided. In the figure, MD denotes the axis of the machine



direction of stretch (Y axis) and TD denotes the axis of the transverse direction of stretch (X axis). Solid line arrow A indicates the crystal orientation main axis of the plastic film and dotted line arrow B indicates the crystal orientation subaxis of the plastic film. Also, θ is a linear expansion coefficient measurement angle with respect to MD. r represents the linear expansion coefficient magnitude as a distance from the base point P and has a tip plotted with O. Such plotting is called polar coordinate plotting. As seen from the ellipse provided by the polar coordinate plotting (see Fig. 1), normally the crystal orientation main axis of the plastic film (arrow A) becomes a direction inclined from the machine direction of stretch (MD) and the coefficients of linear expansion also vary depending on the direction (anisotropy) because of anisotropy of the crystal orientation. Resultantly, it is considered that the analysis line of the coefficients of linear expansion of the bidirectionally stretched plastic film shows an ellipse.

Next, as shown in Fig. 2, when ellipses on coordinates provided for two stretched plastic films made of the same material are overlapped so that they match in center point and coordinate axes, it is seen that the two plastic films differ in crystal orientation direction and coefficient of linear expansion in parts (directions). Normally, a raw material film is stretched in two directions, from which plastic films used with a flexible printed circuit are cut out to a predetermined



size. Therefore, the reason why the plastic films made of the same material differ in linear expansion coefficient may be that the stress applied when the plastic film is stretched in two directions varies from one part of the plastic film to another.

The inventor et al. examined a method for controlling the linear expansion characteristic difference between the plastic films provided when ellipses created by polar coordinate plotting are overlapped and suppressing curl occurrence of flexible printed circuits. In the process, the inventor et al. hit on an idea of using indexes of the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) and repeated various experiments based on the idea. Resultantly, the inventor et al. have found that if the maximum value of the linear expansion characteristic difference ($\Delta\alpha$) provided when ellipses created for two plastic films positioned on both the outermost layers, of two or more laminated plastic films making up a flexible printed circuit are overlapped is equal to or less than 1.4×10^{-5} ($1/^\circ\text{C}$), curl occurrence of the flexible printed circuit is suppressed. Likewise, the inventor et al. have found that if the total area of the portions where the ellipses do not overlap when they are overlapped (C) is set equal to or less than 6.5×10^{-10} [$(1/^\circ\text{C}) \times (1/^\circ\text{C})$], curl occurrence of the flexible printed circuit is also suppressed.

The point to be noted is that only the two plastic



films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit need to satisfy at least one of the two conditions. Therefore, a plastic film positioned on an intermediate layer need not be considered.

Next, examples of the experiment results from which the predetermined values were derived are shown in graphs of Figs. 4 and 5. In the experiments, the curl amounts were measured by the above-described method and the coefficients of linear expansion were measured by TMA (thermal mechanical analysis). The maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) were derived by a method described later.

The graph of Fig. 4 represents the relationship between the ratio between the curl amount and length [curl degree (%)] and the maximum value of the linear expansion coefficient difference ($\Delta\alpha$). As shown here, it is seen that both indicate a linear relationship and that the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) at which curl occurrence is reliably suppressed (the curl degree is 5% or less) is 1.4×10^{-5} ($1/^\circ\text{C}$).

On the other hand, the graph of Fig. 5 represents the relationship between the ratio between the curl amount and length [curl degree (%)] and the total area of portions where ellipses do not overlap (C). As shown here, it is seen that both indicate a relationship like a quadratic curve and that



the total area of portions where ellipses do not overlap (C) at which curl occurrence is reliably suppressed (the curl degree is 5% or less) is $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

The two indexes of the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) can and should be used at the same time.

Further, the inventor et al. thought that an index for furthermore facilitating control of the linear expansion characteristic difference might exist and repeated examination based on the knowledge that anisotropy of the coefficients of linear expansion as described above is caused by the fact that the stress applied when a plastic film is stretched in two directions varies from one part of the plastic film to another and thus the stretch coefficient varies from one part to another. The inventor et al. supposed that since a bidirectionally stretched plastic film is high in crystal orientation degree in high stretch coefficient direction and the material strength of the plastic film itself raises, its Young's modulus might also increase. Further, since the Young's modulus of each plastic film (E) and the ultrasonic propagation velocity in the plastic film (S) show a correlation as indicated by general expression (4) given below, the inventor et al. hit on an idea that there might be a correlation between the coefficient of linear expansion (α) and the ultrasonic propagation velocity (S), and repeated various



experiments based on the idea. Resultantly, the inventor et al. have found that the ultrasonic propagation velocity (S) and the coefficient of linear expansion (α) of a bidirectionally stretched plastic film show an extremely good correlation and that the ultrasonic propagation velocity (S) can be used as an index indicating the coefficient of linear expansion (α).

$$E \propto \rho S^2 \quad \dots(4)$$

where ρ is the plastic film density.

An example of the experiment results from which the correlation was derived is shown in a graph of Fig. 34. In the experiment, the coefficients of linear expansion were measured by the above-mentioned TMA (thermal mechanical analysis) and the ultrasonic propagation velocities were measured with SST [sonic sheet tester, ultrasonic propagation velocity measuring instrument (on sale from Nomura Shoji Kabusikigaisha)]. As shown in Fig. 34, it is seen that both indicate a linear relationship and shows an extremely good correlation.

The inventor et al. continued to examine the ultrasonic propagation velocities and can recognize that bidirectionally stretched plastic films used with flexible printed circuits show anisotropy in the ultrasonic propagation velocities as with the linear expansion coefficients. That is, when a predetermined base point P was defined on the film surface of a plastic film, a polar coordinate system was set, ultrasonic propagation velocities were measured throughout 360-degree directions with the base point P as the center, and an analysis



line was drawn as in the above-described linear expansion coefficient measurement, an ellipse as shown in Fig. 27 was provided on the coordinates. At this time, arrow A in the long-axis direction of the ellipse indicates the crystal orientation main axis of the plastic film and likewise arrow B in the short-axis direction of the ellipse indicates the crystal orientation subaxis of the plastic film. As seen from the ellipse provided by the polar coordinate plotting (see Fig. 27), the crystal orientation main axis of the plastic film (arrow A) becomes a direction inclined from the machine direction of stretch (MD) and the ultrasonic propagation velocities also show anisotropy because of anisotropy of the crystal orientation.

The inventor et al. examined a method for controlling the ultrasonic propagation velocity (namely, linear expansion characteristic) difference between the plastic films provided when ellipses created by polar coordinate plotting are overlapped and suppressing curl occurrence of flexible printed circuits. Resultantly, the inventor et al. have found that when ellipses created for two plastic films positioned on both the outermost layers, of two or more laminated plastic films making up a flexible printed circuit are overlapped, as shown in Fig. 28, if the shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30 degrees, curl occurrence of the flexible printed circuit is suppressed.



A graph of Fig. 29 represents the relationship between the ratio between the curl amount and length [curl degree (%)] and the shift angle difference between crystal orientation main axes ($\Delta\theta$). As shown here, it is seen that both indicate a linear relationship and that the maximum value of the shift angle difference between crystal orientation main axes ($\Delta\theta$) at which curl occurrence is reliably suppressed (the curl degree is 5% or less) is 30 degrees.

The shift angle difference between crystal orientation main axes ($\Delta\theta$) can be used instead of the two indexes described above of the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C), and two or all of them can also be used together.

If the shift angle difference between crystal orientation main axes ($\Delta\theta$) is used, only the two plastic films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit need to satisfy the condition and a plastic film positioned on an intermediate layer need not be considered as in the case where the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) are used as indexes.

Hereupon, as described above, one of the three conditions, that is, the maximum value of the linear expansion coefficient difference ($\Delta\alpha$), the total area of portions where



THIS SHEET HAS BEEN
REPLACED

ellipses do not overlap (C), and the maximum value of the shift angle difference between crystal orientation main axes ($\Delta\theta$) are satisfied by only the two plastic films positioned on both the outermost layers. Therefore, the directions of the coordinate axes of the ellipses may be selected arbitrarily on the plastic film. In other words, the Y axis of the coordinate is not limited to the machine direction of the plastic film. After the Y axis and the X axis are settled in the arbitrary directions to prepare the coordinate system, the ellipses are created on such coordinates. The two plastic films positioned on both the outermost layers may be selected by using the above ellipse and three conditions.

Next, in the invention, to laminate two or more plastic films, the two plastic films positioned on both the outermost layers may have the same surfaces thereof faced each other. Normally, the surface and rear face of a plastic film cut out from a raw material film stretched in two directions differ plainly in surface (rear face) state of wet property, coarseness, etc. Therefore, if the two plastic films positioned on both the outermost layers are placed in a state in which the same surfaces face each other as described above, the rear faces of the two plastic films exist on the surface and rear face of the flexible printed circuit and the surface and rear face of the flexible printed circuit become the same state. This eliminates the need for considering the difference between the surface and rear face to apply various treatments



to the flexible printed circuit; the effect of enhancing work efficiency, etc., is produced.

In the invention, the surface and rear face of a plastic film are determined appropriately; for example, to cut
5 a raw material film, the upper face can be made the surface and the lower face can be made the rear face. For example, as shown in Fig. 21, the upper face of a raw material film 10 is made a surface 9 and two plastic films 2 and 4 are cut out from the raw material film. Each of the plastic films 2 and 4
10 comprises the same surface 9 as the raw material film 10. As shown in Fig. 22A, the plastic films 4 and 2 are overlapped with their surfaces 9 facing each other. Fig. 22B is a sectional view to show a state of overlapping the plastic films 2 and 4 with their surfaces 9 facing each other.

15 Next, in the invention, to prevent curl occurrence and provide sufficient flexibility, the physical property of metal electric circuit of a flexible printed circuit is specified by a special index (K) originally found by the inventor et al. That is, metal electric circuit, which is the main component of
20 a flexible printed circuit, largely affects flexibility of the flexible printed circuit. Then, the inventor et al. carried out a detailed analysis on the cause for producing flexibility for the metal electric circuit, and found that the tensile modulus and thickness of the metal electric circuit are the
25 main factors affecting flexibility of the flexible printed circuit. When continuing furthermore examination on the

relationship between the two factors, the inventor et al. hit on an idea that the product of the tensile modulus and thickness (K) can become one of indexes on flexibility of the flexible printed circuit. When continuing various experiments based on the idea, the inventor et al. recognized that the index (K) can be used universally for flexibility of the flexible printed circuit regardless of the type of metal electric circuit as expected. Based on the index (K), the inventor et al. have found that if the product of the tensile modulus and thickness (K) is set to 500 kg/mm or less in the relationship with the two conditions of the coefficients of linear expansion of plastic films, curl occurrence prevention means described above, curl occurrence can be prevented and sufficient flexibility can be provided.

Next, in the invention, in a flexible printed circuit on which a reinforcing plastic film is stuck, the linear expansion characteristic difference between a plastic film of laminated plastic films on the side where the reinforcing plastic film is not stuck and the reinforcing plastic film is controlled for suppressing curl occurrence. That is, in the flexible printed circuit on which a reinforcing plastic film is stuck, the reinforcing plastic film and other plastic films differ in thickness, etc., and the structure of the flexible printed circuit becomes asymmetrical with respect to the cross-section direction, thus the flexible printed circuit becomes prone to curl as compared with normal flexible printed circuits



on which no reinforcing plastic film is stuck. If a curl of the flexible printed circuit itself is suppressed, the flexible printed circuit may again curl by stacking a reinforcing plastic film thereon. However, the inventor et al. have found that in the cases, if the maximum value of the linear expansion characteristic difference ($\Delta\alpha$) provided when ellipses created by polar coordinate plotting for the plastic film positioned on the outermost layer on the side where the reinforcing plastic film and the reinforcing plastic film are overlapped is equal to or less than 1.4×10^{-5} ($1/^\circ\text{C}$), curl occurrence of the flexible printed circuit on which the reinforcing plastic film is stuck is suppressed.

Likewise, the inventor et al. have found that if the total area of the portions where the ellipses do not overlap when they are overlapped (C) is set equal to or less than 6.5×10^{-10} [$(1/^\circ\text{C}) \times (1/^\circ\text{C})$], curl occurrence of the flexible printed circuit on which the reinforcing plastic film is stuck is also suppressed. Likewise, the inventor et al. have found that when the ellipses created by polar coordinate plotting are overlapped, if the shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30 degrees, curl occurrence of the flexible printed circuit on which the reinforcing plastic film is stuck is suppressed.

Next, in the invention, the raw material plastic film characteristics are applied for preventing curls from occurring in manufacturing flexible printed circuits and enhancing the



manufacturing efficiency. That is, if either of the two conditions is satisfied, curl occurrence can be prevented, but it is troublesome to measure the linear expansion coefficient differences for each plastic film in manufacturing flexible printed circuits. Then, to solve this problem, the inventor et al. examined the linear expansion coefficient characteristics of raw material plastic films and found that there was given regularity. Then, the linear expansion coefficient ellipses of the parts of a raw material film are previously examined, the linear expansion coefficient characteristics are grasped and standardized, and parts cut out from the raw material plastic film and a combination of cut plastic films are previously determined. In doing so, the maximum value of the linear expansion coefficient difference and the total area of portions where the ellipses do not overlap can be set to the predetermined values or less without creating linear expansion coefficient ellipses for each plastic film. As a result, the production efficiency of flexible printed circuits with curl occurrence suppressed can be improved.

Next, the invention relates to a flexible printed circuit wherein plastic films laminated via an adhesive layer are temporarily crimped by a roll laminate method and then pressurized under gas pressure in an autoclave and crimped, and a manufacturing method therefor. That is, to manufacture a flexible printed circuit, when an adhesive layer is formed on each plastic film and then they are stacked and laminated, the



flexible printed circuit is pressurized in a heating state in stacked relation to remove bubbles occurring in the adhesive layers. After the flexible printed circuit is temporarily crimped by a roll laminate method, it is sealed in an autoclave and pressurized under gas pressure for crimping, whereby the flexible printed circuit is crimped under isotropic pressure produced by the gas pressure. Thus, even if the flexible printed circuit itself varies in thickness, etc., it is pressurized on the full face under uniform gas pressure and no excessive force is applied to the materials of the plastic films, metal electric circuit, etc.,; the flexible printed circuit itself does not extend in the transverse direction or its characteristics are not impaired.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a polar coordinate plotting chart representing a linear expansion coefficient ellipse of a bidirectionally stretched plastic film;

Fig. 2 is a polar coordinate plotting chart of overlapping two linear expansion coefficient ellipses;

Fig. 3 is a schematic diagram to show linear expansion coefficient ellipses in parts in the width direction of a bidirectionally stretched plastic film;

Fig. 4 is a graph to show the relationship between the maximum values of linear expansion coefficient differences and



curl degrees;

Fig. 5 is a graph to show the relationship between the integral values of linear expansion coefficient square value differences ($\Delta\alpha c$) and curl degrees;

5 Fig. 6 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Embodiment 1;

Fig. 7 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Comparison 1;

10 Fig. 8 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Embodiment 2;

Fig. 9 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Comparison 2;

Fig. 10 is a polar coordinate plot chart of overlapping three linear expansion coefficient ellipses in Embodiment 3;

15 Fig. 11 is a polar coordinate plot chart of overlapping three linear expansion coefficient ellipses in Comparison 3;

Fig. 12 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Embodiments 4 and 5 and Comparisons 4 and 5;

20 Fig. 13 is a sectional view to show the structure of a flexible printed circuit with three plastic films laminated;

Fig. 14 is a plan view to show a flexible printed circuit formed like substantial V-shape;

25 Fig. 15 is an illustration of curl amount measurement of a flexible printed circuit;

Fig. 16A is a sectional view to show the structure of



a flexible printed circuit and 16B is a sectional view to show the structure of a flexible printed circuit having an adhesive layer formed on the surface of each of two plastic films;

Fig. 17A is a sectional view of a flexible printed circuit on which a curl occurs and 17B is an illustration to show a state in which a twisted curl occurs on a flexible printed circuit;

Fig. 18A is a sectional view to show a state in which an adhesive layer is formed on a base film and then copper foil is placed on the adhesive layer, 18B is a sectional view to show a state in which the copper foil is formed to electric circuit, 18C is a sectional view to show a state of laminating plastic films for base and cover layers, and 18D is a sectional view to show the structure of a flexible printed circuit thus provided;

Fig. 19 is a sectional view to show a state of manufacturing a flexible printed circuit of a 3-film-layer structure;

Fig. 20 is a sectional view to show the structure of a flexible printed circuit of a 3-film-layer structure;

Fig. 21 is an illustration to show a state of cutting out plastic films from a raw material film;

Fig. 22A is a perspective view to show a state of laminating two plastic films with their surfaces facing each other and 22B is a sectional view to show a state of laminating two plastic films with their surfaces facing each other;



THIS SHEET HAS BEEN
REPLACED

Fig. 23 is a sectional view to show the structure of a flexible printed circuit with metal foil pieces laminated;

Fig. 24 is an illustration to show a measuring instrument of flexibility of flexible printed circuits;

5 Fig. 25 a plan view to show a flexible printed circuit formed like substantial V-shape;

Fig. 26A is a sectional view to show the structure of a flexible printed circuit on which a reinforcing film is stuck and 26B is a sectional view to show the structure of a flexible
10 printed circuit comprising an adhesive layer formed on the surface of each of plastic films on which a reinforcing plastic film is stuck;

Fig. 27 is a polar coordinate plot chart representing a ultrasonic propagation velocity ellipse of a bidirectionally
15 stretched plastic films;

Fig. 28 is a polar coordinate plot chart of overlapping two ultrasonic propagation velocity ellipses;

Fig. 29 is a graph to show the relationship between shift angle difference between crystal orientation main axes
20 ($\Delta\theta$) and curl degree (%);

Fig. 30 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Embodiment 6;

Fig. 31 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Comparison 6;

25 Fig. 32 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Embodiment 7;



Fig. 33 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Comparison 7;

Fig. 34 is a graph to show the relationship between linear expansion coefficients and ultrasonic propagation velocities;

Fig. 35 is an illustration to show a state when a flexible printed circuit on which a reinforcing plastic film is stuck is crimped by a heat press; and

Fig. 36 is a schematic diagram to show linear expansion coefficient ellipses in parts in the width direction of a bidirectionally stretched plastic film.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Next, the invention will be discussed specifically.

A flexible printed circuit of the invention comprises two or more plastic films laminated on each other, the plastic films being manufactured by bidirectional stretch, and normally at least one of the two or more plastic films is formed with metal electric circuit.

For example, a polyimide film, a polyester nitrile film, a polyester sulfone film, a polyethylene terephthalate film, a polyvinyl chloride film and polyethylene naphthalate film can be listed as the plastic film types, among which the polyethylene terephthalate film, polyethylene naphthalate film and polyimide film are preferred totally considering heat resistance, dimension stability, electric characteristics,



mechanical strength characteristics, chemical resistance, costs, etc. The plastic film normally is 0.01 to 0.3 mm thick and preferably 0.025 to 0.125 mm thick.

5 With flexible printed circuits on which a reinforcing plastic film is stuck, films of various materials manufactured by bidirectional stretch like those listed above are used as the reinforcing plastic films and normally are 0.025 to 0.500 mm thick and preferably 0.125 to 0.350 mm thick. However, the reinforcing plastic films as thick as or thicker than other
10 films which constitute the flexible printed circuit itself are used.

It is appropriate to stretch the bidirectionally stretched plastic film generally 1.5 to 15 times and preferably 2 to 9 times in a machine direction and 3 to 8 times in a
15 transverse direction.

Metal such as copper, gold, stainless, aluminum, and nickel and alloys thereof can be listed as the types of metal of the metal electric circuitry, among which copper and a copper alloy are preferred totally considering flexibility,
20 workability, electric characteristics, costs, etc. The metal electric circuit normally is 0.002 to 0.100 mm thick and preferably 0.005 to 0.070 mm thick. Further, when elasticity coefficient is measured in a foil state, it normally is 2000 to 20000 kg/mm² and preferably 4000 to 12000 kg/mm². For example,
25 the elasticity coefficient can be measured conforming to ASTM D-882-83 with TENSILON TESTER (tensile tester). To measure the



elasticity coefficient of metal electric circuit or a metal thin film in a flexible printed circuit completed as a product, a semi-finished product before pattern formation, or the like, additives of plastic films, adhesives, etc., are removed by a method such as plasma etching or excimer laser beam machining for leaving the metal electric circuit or metal thin film only, and the elasticity coefficient thereof in the state can be measured according to the above-mentioned method.

The invention uses an index of the product of the thickness and elasticity coefficient of metal electric circuit (K) so as to enable universal comparison in various metals. As the value, normally, foil metal takes a value of about 4 kg/mm (thickness: 0.002 mm x elasticity coefficient: 2000 kg/mm²) to 2000 kg/mm (thickness: 0.100 mm x elasticity coefficient: 20000 kg/mm²); to suppress a curl of the flexible printed circuit and provide flexibility thereof, desirably it lies in the range of 20 to 500 kg/mm and more preferably 30 to 250 kg/mm. For the elasticity coefficient values, the measurement value in the foil state as described above typifies the elasticity coefficient of metal thin film and if the composition, heat history, and crystal state virtually equal, the same value is taken even if metal thin films are other than metal foil (for example, evaporation film, plating coat, etc.,).

Normally, an adhesive is used to laminate (laminate and bond) two or more plastic films. A thermosetting adhesive (for



example, an epoxy rubber adhesive or a polyester adhesive comprising an isocyanate curing agent added to a polyester resin), a thermoplastic adhesive (for example, a synthetic rubber adhesive), and a tackiness agent (pressure-sensitive adhesive, for example, an acrylic tackiness agent) can be listed as the adhesive, among which the thermosetting adhesive is preferred because it is good in characteristics of an adhesion force, heat resistance, moisture and heat resistance, workability, durability, etc. To laminate a reinforcing plastic film, the various adhesives are also used.

Next, a manufacturing method of the flexible printed circuit of the invention will be discussed.

The manufacturing method of the flexible printed circuit of the structure wherein the two plastic films 2 and 4 shown in Fig. 16B are laminated and one of the plastic films is formed with the metal electric circuit 3 will be described as an example. First, two plastic films 2 and 4 are prepared. Generally, polyethylene terephthalate is used as the plastic films. As described above, the two plastic films 2 and 4 need to satisfy at least one of the conditions that when ellipses of coefficient of linear expansion are overlapped, the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) should be equal to or less than 1.4×10^{-5} ($1/^\circ\text{C}$), that the total area of the portions other than the overlap (C) should be equal to or less than 6.5×10^{-10} [$(1/^\circ\text{C}) \times (1/^\circ\text{C})$], or that when ellipses of ultrasonic propagation velocities are



overlapped, the shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) should be within 30 degrees. The plastic films 2 and 4 of the same thickness are used, whereby curl occurrence can be prevented more efficiently.

First, as shown in Fig. 18A, an adhesive layer 8 is formed on the surface of the plastic film 4 for the base layer, for example, by applying an adhesive onto the plastic film 4, then drying or by stacking an adhesive applied onto a separator on the plastic film 4, then removing the separator. The adhesive layer 8 normally is 0.003 to 0.2 mm thick and preferably 0.005 to 0.05 mm thick. Next, a metal thin film 3a is formed on the adhesive layer 8, for example, by placing metal foil such as copper foil on the adhesive layer 8 and roll laminate. The metal thin film 3a can also be formed by an electroplating method or a sputtering method, in which case it can be formed directly on the plastic film 4 without forming the adhesive layer 8. As shown in Fig. 18B, a known method such as a printing, subtractive, or additive method is used to treat the metal thin film 3a for forming metal electric circuit 3 in a predetermined circuit pattern. On the other hand, plastic film 2 for cover layer is prepared and an adhesive layer 8 is formed on the surface of the plastic film 2 in a similar manner to that described above. If the adhesive layer 8 is formed on the rear face of the plastic film 4 for the base layer, the adhesive layer 8 is formed on the rear face of the



plastic film 2 for the cover layer.

As shown in Fig. 18C, both the plastic film 4 for the base layer and the plastic film 2 for the cover layer are stacked with their surfaces facing each other and laminated (laminated and bonded) in the stacked relation, for example, by a crimping method with a heat press or by a laminate method of applying at least heat or pressure after temporary crimping by rolling and laminating. The laminating method and conditions are determined appropriately by the types of plastic films, adhesives, etc.

The flexible printed circuit as shown in Figs. 18D or 16B can be thus manufactured. The pressure and temperature conditions common to the crimping method and the roll laminate method in the laminating normally are 40°C to 300°C x 1 to 100 kg/cm^2 and preferably 50°C to 200°C x 8 to 70 kg/cm^2 .

In the laminating, if the plastic films in the stacked relation are temporarily crimped by the roll laminate method and then pressurized under gas pressure in an autoclave and crimped, the flexible printed circuit is crimped under uniform pressure over the full face by isotropic pressure of the gas pressure; even if the flexible printed circuit itself varies in thickness, etc., the materials of the plastic films, metal electric circuit, etc., are not strained. With the flexible printed circuit thus manufactured, for the metal electric circuit, the plastic films and adhesive layers of insulation layers vary less in thickness and high-frequency



characteristics of relative permittivity (dielectric constant),
etc., as a complex of the plastic films and adhesive layers
become stable. The above described method so as to pressurize
under gas pressure is more excellent than the heat press or the
5 like in the following points, that is, it is hardness to put
traces caused by minute dust, foreign material, etc., and has
the effect of leading to enhancement of quality, performance,
etc.

The relative permittivity of the flexible printed
10 circuit manufactured by the above-described method (ratio of
permittivity of measured substance to permittivity in vacuum)
can be evaluated by the following method: It can be measured
by a method defined in JIS C6481. When the relative
permittivity of each of the plastic films and adhesive layers
15 is measured separately, the relative permittivity as a complex
of the plastic films and adhesive layers generally is found by
the following expression (5):

$$\epsilon = \frac{(d_1 + d_2)\epsilon_1\epsilon_2}{d_1\epsilon_2 + d_2\epsilon_1} \quad \dots(5)$$

20 where d_1 and ϵ_1 are thickness and relative permittivity of the
plastic film and d_2 and ϵ_2 are those of the adhesive layer.

In the crimping in the autoclave described above,
various gases, such as nitrogen gas, argon gas, helium gas, and
air (atmosphere), are used as gases introduced into the
25 autoclave; particularly nitrogen gas is preferred from
standpoints of safety, costs, and easily providing a high



pressure by vaporizing liquid because it has a relatively high boiling point and is available as liquid. As conditions for crimping, the pressure condition normally is 1 to 30 kg/cm² and preferably about 5 to 20 kg/cm² and the temperature condition normally is 40°C to 300°C and preferably about 50°C to 200°C.

On the other hand, a flexible printed circuit on which a reinforcing plastic film is stuck is manufactured as follows:

First, as described above, an adhesive layer 8 is formed on the surface of a plastic film 4 for a base layer and metal electric circuit 3 like that mentioned above is formed on the adhesive layer 8. Next, a plastic film 2 for a cover layer is prepared and an adhesive layer 8 is formed on the surface of the plastic film 2 (see Fig. 18C). On the other hand, a reinforcing plastic film 7 formed on the surface with an adhesive layer 8 is prepared and the plastic film 4 for the base layer and the plastic film 2 for the cover layer are stacked on the top of the reinforcing plastic film 7. Next, in stacked relation, they are crimped by the heat press method or roll laminate method as described above, providing a flexible printed circuit on which the reinforcing plastic film is stuck, as shown in Fig. 26B. When the flexible printed circuit on which the reinforcing plastic film is stuck is thus manufactured, if the lamination is temporarily crimped by the roll laminate method and then pressurized under gas pressure in an autoclave and crimped, particularly an excessive load imposed on the materials is reduced. That is, to stick a



reinforcing plastic film by the heat press method, stress concentration occurs on the flexible printed circuit itself at an end 30 of the reinforcing plastic film 7, as shown in Fig. 35, and metal electric circuit is easily broken, damaged, etc.

5 However, if the lamination is pressurized under gas pressure in the autoclave, defects as described above are removed and good properties of enhancement of durability, etc., can be provided.

The measurement method of the coefficient of linear expansion of a plastic film or reinforcing plastic film is a
10 direct measurement method by TMA or a ultrasonic propagation velocity measurement method with SST, as described above. Particularly, the method using the ultrasonic propagation velocities takes an extremely short measurement time of about two minutes as compared with the TMA method, is substantially
15 at the same level of measurement accuracy as the TMA method, and has the advantage of no skill required. The measurement temperature in SST measurement is about $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

The above-mentioned linear expansion coefficient difference ($\Delta\alpha$) can be derived as follows: First, a linear
20 expansion coefficient ellipse for a plastic film is created by polar coordinate plotting according to the procedure described above (see Fig. 1). The radius of the ellipse, r , can be represented as a function of linear expansion coefficient measurement angle θ (rad), as in Expression (6) below. In
25 Expression (6), ξ denotes an eccentricity and is defined by Expression (7) below. a is the long-axis radius of the ellipse



and becomes the maximum value of r ($r_{\max}$). On the other hand, b is the short-axis radius of the ellipse and becomes the minimum value of r ($r_{\min}$).

$$r = r(\theta) = \sqrt{\frac{b^2}{1 - \xi^2 \cos^2 \theta}} \quad \dots(6)$$

$$\xi = \frac{\sqrt{a^2 - b^2}}{a} \quad \dots(7)$$

10

where a : long-axis radius of ellipse (maximum value of r ; $r_{\max}$)

b : short-axis radius of ellipse (minimum value of r ; $r_{\min}$)

15

Assuming that the radiuses of ellipses for two plastic films 2 and 4 positioned on both outermost layers are r_1 and r_2 , the linear expansion coefficient difference ($\Delta\alpha$) can be represented by the following expression (8):

$$\Delta\alpha = | \Delta\alpha(\theta) | = | r_1(\theta) - r_2(\theta) | \quad \dots(8)$$

20

According to Expression (8), comparison is made over 0 to 360 degrees (0 to 2π rad) with respect to the measurement angle θ and the maximum value is the maximum value ($\Delta\alpha_{\max}$) of the linear expansion coefficient difference ($\Delta\alpha$) between the two plastic films. The maximum value ($\Delta\alpha_{\max}$) can also be derived by using a computer with Expressions (6), (7), and (8) programmed.

25



On the other hand, the total area (C) of portions where the ellipses do not overlap can be derived, for example, according to cumulative expression (9), which is one of approximate expressions of Expression (2) for defining the area (C). Approximating of Expression (2) by other expressions is not limited.

$$C \approx 1/2 \sum_{n=1}^m \left[\frac{\Delta\alpha c(n \times \Delta\theta) + \Delta\alpha c\{(n-1) \times \Delta\theta\}}{2} \right] \Delta\theta \quad \dots(9)$$

10 where $m = (2\pi/\Delta\theta)$

To use cumulative expression (9), normally m takes 120 to 2880 values and preferably 360 to 1080 values, and $\Delta\theta = 2\pi/m$.

In selection of the plastic films, the most basic method is to measure the coefficient of linear expansion for each plastic film and execute polar coordinate plotting for creating a linear expansion coefficient ellipse to check whether or not the conditions are satisfied; but it lacks practicality. Then, to solve this problem, the present inventor et al. examined linear expansion coefficient characteristics at points of a raw material film of plastic films and found out that there is given regularity in the film width direction (transverse direction of stretch).

Fig. 3 shows linear expansion coefficient characteristics in the width direction of a raw material film 5 bidirectionally stretched. In the figure, the raw material film 5 is divided into nine parts in the width direction



thereof and the parts are represented by relative positions (-4, -3, -2, -1, 0, 1, 2, 3, and 4) with the center as the reference (0). Linear expansion coefficient ellipses are shown in the parts and crystal orientation main axes are indicated by dotted line arrows. MD denotes the machine direction of stretch and TD denotes the transverse direction of stretch. As shown in Fig. 3, the crystal orientation main axis and the machine direction of stretch match at the center of the raw material film 5 and as the part of the raw material film 5 deviates from the center, its corresponding crystal orientation main axis shifts from the machine direction of stretch (the corresponding dotted line arrow is inclined with respect to the MD direction). The point to be noted is that the crystal orientation main axes shift from the machine direction of stretch symmetrically. Specifically, in Fig. 3, the crystal orientation main axes in the parts at relative positions (1) and (-1), (2) and (-2), (3) and (-3), and (4) and (-4) are symmetrical. Using the fact, minus (-) relative positions are used for cover layers (C/L) and plus (+) relative positions are used for base layers (B/S). As shown in the figure, when symmetrical parts (relative positions) are extracted and laminated with their surfaces facing each other, the crystal orientation main axes substantially match and the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area (C) of portions where the ellipses do not overlap fall below the predetermined values.



On the other hand, as a second method, a raw material plastic film is divided into two parts (a cover layer cut portion and a base layer cut portion) in parallel with the length direction of the plastic film, from which cover and base layer plastic films are cut out in parallel with the length direction and the cover and base layer plastic films having a relationship satisfying at least one of the two conditions are placed on both the outermost layers of the plastic film laminate.

Fig. 36 shows coefficient of linear expansion characteristics as similar to Fig. 3. In Fig. 36, the raw material film 5 is divided into eight parts and the parts are represented by relative positions (-4, -3, -2, -1, 1, 2, 3 and 4) with the center as a center line CL. The relative linear expansion coefficient difference is not so large in the adjacent portion (-3, -2, -1, 1, 2 and 3) of the center line CL of the raw material film 5. As shown in Fig. 36, relative positions (-3) to (-1) are used for the cover layer cut portion and relative positions (1) to (3) are used for the base layer cut portion. In the case that two layers which is selected out from the above are positioned on the outer most layers and the flexible printed circuit is made, the occurrence of curling is prevented. In Fig. 36, a plastic film for cover layer cut out from the relative position (-3) and a plastic film for base layer cut out from the relative position (2) are laminated.

Dividing of the raw material plastic film is shown as



an example; in fact, it is determined appropriately by the size, stretch degree, etc., of the raw material plastic film. For example, for a raw material plastic film 2 to 6 m wide, if the division width (band width) is set to 200 to 1000 mm, the number of divisions becomes six to ten. Specifically, for example, if the raw material plastic film is 2 m wide, it can be divided into 10 parts (divisions) with the division width (band width) set to 200 mm. If the raw material plastic film is 6 m wide, it can be divided into six parts (divisions) with the division width (band width) set to 1000 mm. For example, if the raw material plastic film is 5 m wide, preferably it can be divided into 10 parts (divisions) with the division width (band width) set to 500 mm for the reason of good workability.

Therefore, the linear expansion coefficient ellipses of the parts of a raw material film are previously examined, the linear expansion coefficient characteristics are grasped and standardized, predetermined parts of the raw material film are extracted, and the parts with the linear expansion coefficient ellipses substantially symmetric are combined. In doing so, the maximum value of the linear expansion coefficient difference and the total area of portions where the ellipses do not overlap can be set to predetermined values or less without creating linear expansion coefficient ellipses each time a plastic film is selected. As a result, the production efficiency of flexible printed circuits with curl occurrence suppressed can be improved.



Which of the first and second methods is selected for manufacturing flexible printed circuits is determined appropriately by manufacturing conditions, etc. That is, the second method is excellent as compared with the first method from the viewpoint of the manufacturing efficiency; the latter is excellent as compared with the former from the viewpoint of curl occurrence prevention. Therefore, considering the points, either of the two methods can be selected depending on which of the manufacturing efficiency and curl occurrence prevention takes precedence.

The two plastic films positioned on both the outermost layers of plastic film laminates are laminated on each other with their surfaces facing each other, whereby there are provided advantages of enhancing the adhesion strength and eliminating the need for considering the difference between the surface and rear face of the flexible printed circuit. That is, the surface and rear face of a plastic film cut out from a raw material plastic film stretched in two directions differ plainly in surface (rear face) state of wet property, coarseness, etc. Therefore, if two plastic films are placed on both the outermost layers in a state in which the same surfaces face each other, the rear faces of the two plastic films exist on the surface and rear face of the flexible printed circuit and the surface and rear face of the flexible printed circuit become the same state. This eliminates the need for considering the difference between the surface and rear face to



apply various treatments to the flexible printed circuit. Specifically, for example, it becomes less necessary to take notice of the difference between the surface and rear face of the flexible printed circuit in characteristics such as printability on the flexible printed circuit, wear resistance, sliding property, intimate contact with a reinforcing plate, and close adherence of electromagnetic wave shielding paint, and work efficiency when treatments are applied to the flexible printed circuit and efficiency of a mounting process, etc., of electronic parts, etc., can be improved.

In a flexible printed circuit on which a reinforcing plastic film is stuck, normally, separate raw material films are used for the reinforcing plastic film and other plastic films. Thus, the above-described method cannot be applied to flexible printed circuits on which a reinforcing plastic film is stuck. Even in this case, however, if ultrasonic propagation velocities of plastic films are measured with SST and linear expansion coefficient characteristic differences are controlled by a method of using the shift angle difference ($\Delta\theta$) between the crystal orientation main axes of ellipses, the time required for measurement is extremely short and no skill is required, thus predetermined production efficiency can be maintained.

The two plastic films positioned on both the outermost layers of plastic film laminates are laminated on each other with their surfaces facing each other, whereby there are



provided advantages of enhancing the adhesion strength and eliminating the need for considering the difference between the surface and rear face of the flexible printed circuit, as described above. Specifically, for example, it becomes less
5 necessary to take notice of the difference between the surface and rear face of the flexible printed circuit in characteristics such as printability on the flexible printed circuit, wear resistance, sliding property, intimate contact with a reinforcing plate, and close adherence of
10 electromagnetic wave shielding paint, and work efficiency when treatments are applied to the flexible printed circuit and efficiency of a mounting process, etc., of electronic parts, etc., can be improved.

We have discussed the flexible printed circuits of the
15 invention by taking those with two plastic films laminated and those with two plastic films laminated on which a reinforcing plastic film is stuck as examples. However, the invention is not limited to them and can also be applied to those with three or more plastic films laminated in addition to a reinforcing
20 plastic film. As described above, in this case, only two plastic films positioned on both the outermost layers of plastic film laminates making up the flexible printed circuit need satisfy the predetermined conditions of the invention, and the plastic film positioned on an intermediate layer need not
25 be considered. That is, in the flexible printed circuit on which a reinforcing plastic film is stuck, both the outermost



layers which need to satisfy the predetermined conditions of the invention are a plastic film on the side on which the reinforcing plastic film is not stuck and the reinforcing plastic film; a plastic film positioned therebetween need not
5 be considered.

The thickness of the flexible printed circuit according to the invention is determined appropriately by applications, etc., of the flexible printed circuit, but generally set to 50 to 800 μm and preferably 100 to 600 μm . The shape of the
10 flexible printed circuit is not limited either; for example, the flexible printed circuit is formed as shapes responsive to various applications in addition to substantial ?? shape shown in Fig. 14. The size of the flexible printed circuit is not limited either; for example, the flexible printed circuit may
15 have the above-mentioned longest length L in the range of 10 to 1000 mm and preferably in the range of 30 to 600 mm.

Flexibility of the flexible printed circuits according to the invention is measured with a compression tester as shown in Fig. 24, for example. In the figure, numeral 22 is an upper
20 fixed plate above which a load cell (load detector) 25 is disposed, and a lower moving plate 24 that can move up and down in conjunction with a drive section (linear motor) 23 is disposed so as to face the lower side of the upper fixed plate 22. First, a flexible printed circuit 1 is placed between the
25 upper fixed plate 22 and the lower moving plate 24 in a state in which it is bent like a U-shape in horizontal orientation in



a long-side direction. Next, the drive section 23 is actuated for causing the lower moving plate 24 to rise for compressing the bent flexible printed circuit 1 sandwiched between the lower moving plate 24 and the upper fixed plate 22. When the bent flexible printed circuit 1 is compressed a given amount to a predetermined bend radius R , a repulsion force detected by the load cell 25 is measured and flexibility (repulsion force) is calculated from the expression (10) shown below for evaluation. Since the distance between the upper fixed plate 22 and the lower moving plate 24 at the measurement time becomes double the bend radius R of the flexible printed circuit 1, the bend radius R can be calculated from the distance.

Repulsion force (kg/cm) = repulsion force detection value (g)/length of short side (width) of flexible printed circuit (cm) (10)

The flexibility of the flexible printed circuit thus measured normally is in the range of repulsion force = 2 g/cm when bend radius R = 5 mm to repulsion force = 600 g/cm when bend radius R = 15 mm and preferably in the range of repulsion force = 4 g/cm when bend radius R = 5 mm to repulsion force = 400g/cm when bend radius R = 15 mm regardless of whether or not a reinforcing plastic film is stuck on the flexible printed circuit.

The flexibility evaluation method is applied to rectangular flexible printed circuits, but can also be applied



to flexible printed circuits of any other shape than a rectangle. For example, for a flexible printed circuit 1a shaped like substantially V-shaped as shown in Fig. 25, a predetermined rectangle (for example, maximum rectangle 26 indicated by the chain line involved in the flexible printed circuit 1a substantially V-shaped shown in Fig. 25) is previously cut out from the flexible printed circuit and the flexibility of this sample is evaluated by the above-described method, then cutting to the predetermined substantial shape may be performed. In this case, if the shape and size of samples for measurement are standardized, the flexibility can be evaluated objectively.

As we have discussed, for the flexible printed circuit of the invention, when linear expansion coefficient ellipses representing the linear expansion coefficient characteristics of the plastic films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit are created and overlapped, the maximum value of the linear expansion coefficient difference and the total area of portions where the ellipses do not overlap are set to predetermined values or less. Resultantly, curl occurrence of the flexible printed circuit of the invention is suppressed. Therefore, the flexible printed circuit of the invention is high in accuracy of the shape; if it is used to mount electronic parts, the electronic parts can be mounted with high accuracy even in automatic mounting by a machine.



In the flexible printed circuit of the invention, the plastic films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit are placed in a state in which their surfaces face each other, the surface and rear face of the flexible printed circuit becomes the same state and the need for considering the difference therebetween is eliminated. Resultantly, the advantages such as enhancing the work efficiency when various treatments are applied to the flexible printed circuit or electronic parts, etc., are mounted thereon can be provided.

Further, in the flexible printed circuit of the invention, if metal electric circuit is formed in at least one of two or more laminated plastic films and the product of the thickness and tensile modulus of the metal electric circuit (K) is set to 500 kg/mm or less, sufficient flexibility of the flexible printed circuit is provided and curl occurrence thereof is also suppressed, providing a high-performance flexible printed circuit. Therefore, for example, the flexible printed circuit becomes suitable for frequently bent places such as a connection part of a print head and a mother board of a printer.

Moreover, in the invention, in a flexible printed circuit on which a reinforcing plastic film is stuck, if the linear expansion characteristic difference between a plastic film of laminated plastic films on the side where the reinforcing plastic film is not stuck and the reinforcing



plastic film is controlled using a predetermined index, curl occurrence is suppressed even for the flexible printed circuit of an asymmetric structure on which the reinforcing plastic film is stuck.

5 The fact that there is given regularity about coefficients of linear expansion in the transverse direction of an stretched raw material plastic film is used to previously select parts of the raw material plastic film from which plastic films are to be cut out, or combine plastic films so
10 that the cut parts becomes substantially symmetric. In doing so, two plastic films can be placed on both the outermost layers so as to satisfy at least one of the above conditions without measuring the coefficient of linear expansion for each plastic film or the ultrasonic propagation velocity. This
15 results in prevention of curl occurrence and enhancement of the manufacturing efficiency of flexible printed circuits.

 Further, in the flexible printed circuit of the invention, if a plurality of plastic films stacked via an adhesive layer are temporarily crimped by the roll laminate
20 method in stacked relation and then pressurized under gas pressure in an autoclave and crimped, the flexible printed circuit is crimped under uniform pressure on the full face by isotropic pressure produced by the gas pressure, thus no excessive force is applied to parts of the materials of the
25 plastic films, metal electric circuit, etc., and the quality and performance of the finally provided product become good.



Next, embodiments will be discussed together with comparisons.

Embodiment 1:

A bidirectionally stretched polyethylene terephthalate
5 film 0.05 mm thick (manufactured by TORAY) was used a raw
material film, from which plastic films (film-1 and film-2)
each having a size of 100 x 200 mm were cut out. Linear
expansion coefficients were measured by the above-described TMA
method and linear expansion coefficient ellipses were created
10 by polar coordinate plotting and were overlapped. These
overlapped ellipses are shown in a graph of Fig. 6. From this
graph, the maximum value of the linear expansion coefficient
difference between film-1 and film 2 ($\Delta\alpha$) was calculated by
using a control computer attached to TMA programmed based on
15]Expressions (6), (7), and (8) described above. The result was
 0.53×10^{-5} ($1/^\circ\text{C}$), which was equal to or less than a
predetermined value. The linear expansion coefficient
measurement by TMA was executed to exclude the effects of
hygroscopic expansion and heat shrinkage as follows: The
20 plastic films were left standing for 60 minutes at 150°C for
drying, then while the plastic films were cooled from 150°C to
 30°C , the plastic film length and temperature were measured
simultaneously and consecutively, and linear expansion
coefficients were found based on Expression (1) for regions of
15 T_g or less.

Next, a polyester family thermosetting adhesive was



applied to the surface of film-1, then dried to form an adhesive layer 0.03 mm thick. Film-1 and film-2 were laminated by crimping by a heat press (conditions: 150 x 1 h x 30 kg/cm²) with the surfaces of film-1 and film-2 facing each other. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 4.2 mm and the curl degree was 2.1%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured as shown in Fig. 18. That is, first the same film-1 and film-2 as described above were prepared. As shown in Fig. 18A to 18D, an adhesive layer was formed on the surface of film-2 (for a base layer) as described above. Copper foil 3a 0.018 mm thick was placed on the adhesive layer 8 and they were bonded by the roll laminate method (surface temperature was set to 120°C). Next, as shown in Fig. 18B, the copper foil was etched by the subtractive method to form metal electric circuit 3. On the other hand, an adhesive layer was formed on the surface of film-1 (for a cover layer) as described above. As shown in Fig. 18C, film-1 and film-2 were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²) with the surfaces of film-1 and film-2 facing each other, manufacturing a flexible printed circuit as shown in Fig. 18D.

For the flexible printed circuit, the curl amount h was



measured as described above. As a result, the curl amount h was 3.9 mm and the curl degree was 2.0%; curl occurrence was suppressed.

Comparison 1:

5 A new plastic film (film-3) having a size of 100 x 200 mm was cut out from the polyethylene terephthalate film used with Embodiment 1. On the other hand, the same film-1 as in Embodiment 1 was prepared. Linear expansion coefficient ellipses were created and overlapped as in Embodiment 1. These
10 overlapped ellipses are shown in a graph of Fig. 7. From this graph, the maximum value of the linear expansion coefficient difference between film-1 and film-3 ($\Delta\alpha$) was calculated. The result was 1.77×10^{-5} ($1/^\circ\text{C}$), which exceeded a predetermined value.

15 A plastic film laminate of film-1 and film-3 was created as in Embodiment 1. The curl amount h of the plastic film laminate was measured as in Embodiment 1. As a result, the curl amount h was 14.0 mm and the curl degree was 7.0%; a curl occurred.

20 On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-1 (for a cover layer) and film-3 (for a base layer) as described above were prepared. An adhesive layer was formed on the surface of
25 film-3 as in Embodiment 1, then electric circuit was formed by the subtractive method and an adhesive layer was formed on the



surface of film-1. In a similar manner to that described above, film-1 and film-3 were laminated to manufacture a flexible printed circuit. For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 13.5 mm and the curl degree was 6.8%; a curl occurred.

Embodiment 2:

A bidirectionally stretched polyimide film 0.125 mm thick (manufactured by TORAY-Dupont) was used a raw material film, from which plastic films (film-4 and film-5) each having a size of 200 x 360 mm were cut out. Linear expansion coefficients were measured by the above-described TMA method and linear expansion coefficient ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses are shown in a graph of Fig. 8. From this graph, the total area of portions where the ellipses of film-4 and film-5 do not overlap (C) was $3.44 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$, which was equal to or less than a predetermined value. The area was calculated by using a control computer attached to a TMA measuring instrument according to cumulative expression (9) described above by setting $m=720$ and $\Delta\theta=(2\pi/720)\approx 0.00873$ (rad).

Next, an epoxy family thermosetting adhesive was applied to the surface of film-4, then dried to form an adhesive layer 0.03 mm thick. Film-4 and film-5 were temporarily crimped by the roll laminate method with the surfaces of film-4 and film-5 facing each other, then cured in



an autoclave (conditions: 150°C x 1 h x 15 kg/cm^2) and laminated. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 9.5 mm and the curl degree was 2.6%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-4 (for a cover layer) and film-5 (for a base layer) as described above were prepared. An adhesive layer was formed on the surface of film-5 as in Embodiment 1, then copper electric circuit 0.035 mm thick was formed by the subtractive method and an adhesive layer was formed on the surface of film-4. Film-4 and film-5 were laminated as in Embodiment 1, manufacturing a flexible printed circuit. For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 8.3 mm and the curl degree was 2.3%; curl occurrence was suppressed.

Comparison 2:

A new plastic film (film-6) having a size of 200 x 360 mm was cut out from the polyimide film used with Embodiment 2. On the other hand, the same film-4 as in Embodiment 2 was prepared. Linear expansion coefficient ellipses were created and overlapped as in Embodiment 2. These overlapped ellipses are shown in a graph of Fig. 9. Based on this graph, the total area of portions where the ellipses of film-4 and film-6 do not



overlap (C) was calculated as in Embodiment 2. The result was $7.71 \times 10^{-10} [(1/^{\circ}\text{C}) \times (1/^{\circ}\text{C})]$, which exceeded a predetermined value.

Next, a plastic film laminate of film-4 and film-6 was created as in Embodiment 2. The curl amount h of the plastic film laminate was measured as in Embodiment 2. As a result, the curl amount h was 28.0 mm and the curl degree was 7.8%; a curl occurred.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-4 (for a cover layer) and film-6 (for a base layer) as described above were prepared. An adhesive layer was formed on the surface of film-6 as in Embodiment 2, then metal electric circuit was formed by the subtractive method and an adhesive layer was formed on the surface of film-4. In a similar manner to that described above, film-4 and film-6 were laminated to manufacture a flexible printed circuit. For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 25.2 mm and the curl degree was 7.0%; a curl occurred.

Embodiment 3:

A bidirectionally stretched polyethylene terephthalate film 0.125 mm thick (manufactured by TORAY) was used a raw material film, from which plastic films (film-7 and film-8) each having a size of 200 x 360 mm were cut out. A



bidirectionally stretched polyethylene terephthalate film 0.250 mm thick (manufactured by TORAY) was used a raw material film, from which a plastic film (film-10) having a size of 200 x 360 mm was cut out. Three linear expansion coefficient ellipses were created as in Embodiment 1 and were overlapped. These overlapped ellipses are shown in a graph of Fig. 10. From this graph, the maximum values of the linear expansion coefficient differences among film-7, film-8, and film-10 were calculated as in Embodiment 1. As a result, the maximum value of the linear expansion coefficient difference between film-7 and film-8 was 0.54×10^{-5} ($1/^{\circ}\text{C}$); that between film-7 and film-10 was 4.49×10^{-5} ($1/^{\circ}\text{C}$); and that between film-8 and film-10 was 3.94×10^{-5} ($1/^{\circ}\text{C}$).

Next, a polyester family thermosetting adhesive shaped like a sheet 0.05 mm thick was prepared and temporarily crimped on the surface and rear face of film-10 with a roll. Next, film-7 and film-8 were placed on the surface and rear face of film-10 and they were temporarily crimped by the roll laminate method, then cured in an autoclave (conditions: $110^{\circ}\text{C} \times 2 \text{ h} \times 10 \text{ kg/cm}^2$) for manufacturing a plastic film laminate of a 3-layer structure as shown in Fig. 13. In the figure, numeral 8 denotes an adhesive layer. Positioned on the outermost layers of the plastic film laminate are film-7 and film-8. As described above, the maximum value of the linear expansion coefficient difference between film-7 and film-8 is 0.54×10^{-5} ($1/^{\circ}\text{C}$), which is equal to or less than the predetermined value



of the invention. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 5.4 mm and the curl degree was 1.5%; curl occurrence was suppressed.

5 On the other hand, aside from the plastic film laminate, a flexible printed circuit of a 3-film-layer structure formed with metal electric circuit was manufactured. That is, the same film-7, film-8, and film-10 as described above were prepared. As shown in Fig. 19, a polyester family
10 thermosetting adhesive shaped like a sheet was used to form an adhesive layer 8 on the surfaces of film-7 and film-8 in a similar manner to that described above, then copper electric circuit 3 0.035 mm thick was formed on the adhesive layer 8 by the subtractive method as in Embodiment 1. As shown in Fig.
15 19, a polyester family thermosetting adhesive shaped like a sheet was used to form an adhesive layer 8 on the surface and rear face of film-10 in a similar manner to that described above. As shown in the figure, with the surfaces of film-7 and film-8 facing each other with film-10 between, the three films
20 were temporarily crimped by the roll laminate method, then cured in an autoclave (conditions: $110^{\circ}\text{C} \times 2 \text{ h} \times 10 \text{ kg/cm}^2$) for manufacturing a flexible printed circuit of a 3-film-layer structure as shown in Fig. 20. Parts identical with those previously described with reference to Fig. 19 are denoted by
25 the same reference numerals in Fig. 20.

For the flexible printed circuit of the 3-film-layer



structure, the curl amount h was measured as described above. As a result, the curl amount h was 5.0 mm and the curl degree was 1.4%; curl occurrence was suppressed.

Comparison 3:

5 A new plastic film (film-9) having a size of 200 x 360 mm was cut out from the polyethylene terephthalate film 0.125 mm thick used with Embodiment 3. On the other hand, the same film-7 and film-10 as in Embodiment 3 were prepared. Three linear expansion coefficient ellipses were created and
10 overlapped as in Embodiment 3. These overlapped ellipses are shown in a graph of Fig. 11. From this graph, the maximum values of the linear expansion coefficient differences among film-7, film-9, and film-10 were calculated as in Embodiment 1. As a result, the maximum value of the linear expansion
15 coefficient difference between film-7 and film-9 was 1.66×10^{-5} ($1/^\circ\text{C}$) and that between film-9 and film-10 was 4.17×10^{-5} ($1/^\circ\text{C}$). As described above, the maximum value of the linear expansion coefficient difference between film-7 and film-10 is 4.49×10^{-5} ($1/^\circ\text{C}$).

20 Next, a plastic film laminate of a 3-film-layer structure (see Fig. 13) was created in the same manner to that in Embodiment 3 except that film-9 was used in place of film-8. The curl amount h of the plastic film laminate was measured as in Embodiment 3. As a result, the curl amount h was 18.7 mm
5 and the curl degree was 5.2%; a curl occurred.

On the other hand, aside from the plastic film



laminates, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-7, film-9, and film-10 as described above were prepared. An adhesive layer 8 and copper electric circuit were formed on the surfaces of film-7 and film-9 by the subtractive method as in Embodiment 3. An adhesive layer 8 was formed on the surface and rear face of film-10. In a similar manner to that in Embodiment 3, the three films were laminated (see Fig. 19) to manufacture a flexible printed circuit (see Fig. 20). For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 18.9 mm and the curl degree was 5.3%; a curl occurred.

Embodiment 4:

A bidirectionally stretched polyethylene terephthalate film 0.050 mm thick (manufactured by TORAY) was used as a raw material film, from which plastic films (film-11 and film-12) each having a size of 100 x 200 mm were cut out. Linear expansion coefficients were measured by the above-described TMA method and linear expansion coefficient ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses are shown in a graph of Fig. 12. From this graph, the maximum value of the linear expansion coefficient difference between film-11 and film 12 ($\Delta\alpha$) was calculated as in Embodiment 1. The calculation result was 0.11×10^{-5} ($1/^\circ\text{C}$).

Stainless steel foil 0.050 mm thick was used as raw material of metal electric circuit 3, from which stainless



steel foil having a size of 100 x 200 mm was cut out. The tensile modulus of the stainless steel foil was measured by the above-described method. The measurement result was 10000 kg/mm². That is, the product of the thickness and the tensile modulus (K) was 500 kg/mm.

Next, a polyester family thermosetting adhesive applied onto a separator was stuck on the same surfaces 9 of plastic film-11 and plastic film-12, then the separator was removed to form an adhesive layer 0.025 mm thick. The stainless steel foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the stainless steel foil and film-12 were furthermore temporarily crimped by the roll laminate method with the surfaces of the stainless steel foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²). (See Fig. 23.)

The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 0.8 mm and the curl degree was 0.4%; curl occurrence was suppressed.

The flexibility of the plastic film laminate (repulsion force g/cm) was measured by the above-described method. As a result, when bend radius R = 5 mm, repulsion force = 160 g/cm, indicating good flexibility.

Comparison 4:

First, the same films as the polyethylene terephthalate film used with Embodiment 4 (film-11 and film-12) were



prepared. As in Embodiment 4, linear expansion coefficients were measured and linear expansion coefficient ellipses were created by polar coordinate plotting and overlapped (see Fig. 12). As in Embodiment 4, the maximum value of the linear expansion coefficient difference between film-11 and film 12 ($\Delta\alpha$) was calculated. The calculation result was 0.11×10^{-5} ($1/^\circ\text{C}$) as in Embodiment 4.

Stainless steel foil 0.075 mm thick was used as raw material of metal electric circuit 3, from which stainless steel foil having a size of 100 x 200 mm was cut out. The tensile modulus of the stainless steel foil was measured by the above-described method. The measurement result was 8000 kg/mm². That is, the product of the thickness and the tensile modulus (K) was 600 kg/mm, which exceeded the predetermined value.

Next, an adhesive layer 0.025 mm thick was formed on the same surfaces 9 of film-11 and film-12 as in Embodiment 4. The stainless steel foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the stainless steel foil and film-12 were furthermore temporarily crimped by the roll laminate method with the surfaces of the stainless steel foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²). (See Fig. 23.)

The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl



amount h was 0.4 mm and the curl degree was 0.2%; curl occurrence was suppressed in both cases.

The flexibility of the plastic film laminate (repulsion force g/cm) was measured by the above-described method. As a
5 result, when bend radius $R = 5$ mm, repulsion force = 240 g/cm, indicating poor flexibility as compared with Embodiment 4.

Embodiment 5:

First, the same films as the polyethylene terephthalate film used with Embodiment 4 (film-11 and film-12) were
10 prepared. As in Embodiment 4, linear expansion coefficients were measured and linear expansion coefficient ellipses were created by polar coordinate plotting and overlapped (see Fig. 12). As in Embodiment 4, the maximum value of the linear expansion coefficient difference between film-11 and film 12
15 ($\Delta\alpha$) was calculated. The calculation result was 0.11×10^{-5} ($1/^\circ\text{C}$) as in Embodiment 4.

Three pieces of electrodeposited copper foil 0.018 mm, 0.035 mm, and 0.070 mm thick were used as raw material of metal conductor layer 3, from which three pieces of copper foil each
20 having a size of 100 x 200 mm were cut out. The tensile modulus of the three copper foil pieces were measured by the above-described method. The measurement results were 6600 kg/mm², 6050 kg/mm², and 5500 kg/mm². That is, the product of the thickness and the tensile modulus of each copper foil piece
25 (K) was 118.8 kg/mm, 192.5 kg/mm, or 315 kg/mm. These values were equal to or less than the predetermined value.



Next, a polyester family thermosetting adhesive applied onto a separator was stuck on the same surfaces 9 of film-11 and film-12, then the separator was removed to form an adhesive layer 0.025 mm thick. Each piece of the copper foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the copper foil and film-12 were furthermore temporarily crimped by the roll laminate method with the surfaces of the copper foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: $150^{\circ}\text{C} \times 1 \text{ h} \times 30 \text{ kg/cm}^2$). (See Fig. 23.)

Further, the curl amount h of each of the plastic film laminates was measured by the above-described method. As a result, when the copper foil was 0.018 mm thick, the curl amount h was 1.2 mm and the curl degree was 0.6%; when the copper foil was 0.035 mm thick, the curl amount h was 0.7 mm and the curl degree was 0.35%; when the copper foil was 0.070 mm thick, the curl amount h was 0.5 mm and the curl degree was 0.25%. Curl occurrence was suppressed in every case.

The flexibility of each of the plastic film laminates (repulsion force g/cm) was measured by the above-described method. As a result, when the copper foil was 0.018 mm thick, repulsion force = 57 g/cm when bend radius $R = 5 \text{ mm}$; when the copper foil was 0.035 mm thick, repulsion force = 72 g/cm when bend radius $R = 5 \text{ mm}$; when the copper foil was 0.070 mm thick, repulsion force = 125 g/cm when bend radius $R = 5 \text{ mm}$. Good flexibility was indicated in every case.



Comparison 5:

First, the same films as the polyethylene terephthalate film used with Embodiment 4 (film-11 and film-12) were prepared. As in Embodiment 4, coefficients of linear expansion were measured and linear expansion coefficient ellipses were created by polar coordinate plotting and overlapped (see Fig. 12). As in Embodiment 4, the maximum value of the linear expansion coefficient difference between film-11 and film 12 ($\Delta\alpha$) was calculated. The calculation result was 0.11×10^{-5} ($1/^{\circ}\text{C}$) as in Embodiment 4.

Two pieces of electrodeposited copper foil 0.2 mm, and 0.3 mm thick were used as raw material of metal conductor layer 3, from which two pieces of electrodeposited copper foil each having a size of 100 x 200 mm were cut out. The tensile modulus of the two electrodeposited copper foil pieces were measured by the above-described method. The measurement results were 3600 kg/mm² and 3400 kg/mm². That is, the product of the thickness and the tensile modulus of each electrodeposited copper foil piece (K) was 720 kg/mm or 1020 kg/mm. These values exceeded the predetermined value.

Next, an adhesive layer 0.025 mm thick was formed on the same surfaces 9 of film-11 and film-12 as in Embodiment 4. Each piece of the electrodeposited copper foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the electrodeposited copper foil and film-12 were furthermore temporarily crimped by the roll laminate method



with the surfaces of the electrodeposited copper foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: $150^{\circ}\text{C} \times 1 \text{ h} \times 30 \text{ kg/cm}^2$). (See Fig. 23.)

The curl amount h of each of the plastic film laminates was measured by the above-described method. As a result, when the electrodeposited copper foil was 0.2 mm thick, the curl amount h was 0.6 mm and the curl degree was 0.3%; when the electrodeposited copper foil was 0.3 mm thick, the curl amount h was 0.3 mm and the curl degree was 0.15%. Curl occurrence was suppressed in both cases.

The flexibility of each of the plastic film laminates (repulsion force g/cm) was measured by the above-described method. As a result, when the electrodeposited copper foil was 0.2 mm thick, repulsion force = 615 g/cm when bend radius $R = 5 \text{ mm}$; when the electrodeposited copper foil was 0.3 mm thick, repulsion force = 710 g/cm when bend radius $R = 10 \text{ mm}$. Poor flexibility was indicated in both cases as compared with Embodiment 4.

Embodiment 6:

A bidirectionally stretched polyethylene terephthalate film 0.05 mm thick (manufactured by TORAY) was used a raw material film, from which plastic films (film-13 and film-14) each having a size of 100 x 200 mm were cut out. A bidirectionally stretched polyethylene terephthalate film 0.25 mm thick (manufactured by TORAY) was used a raw material film, from which a plastic film (film-15) having a size of 100 x 200



mm were cut out. The ultrasonic propagation velocities of the three plastic films were measured by the above-described method and three ultrasonic propagation velocity ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses of film-13 and film-15 are shown in a graph of Fig. 30. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-13 and film-15 of the outermost layers ($\Delta\theta$) is 0 degrees, showing that both match.

Next, a polyester family thermosetting adhesive was applied to the surfaces of film-13, film-14, and film-15, then dried to form an adhesive layer 0.025 mm thick. Film-13 and film-14 were laminated by crimping by a heat press (conditions: $150^{\circ}\text{C} \times 1 \text{ h} \times 30 \text{ kg/cm}^2$) with the surfaces of film-13 and film-14 facing each other. Reinforcing film-15 was temporarily crimped on the rear face of film-14 by the roll laminate method, then cured in an autoclave (conditions: $110^{\circ}\text{C} \times 2 \text{ h} \times 10 \text{ kg/cm}^2$). The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 5.0 mm and the curl degree was 2.5%; curl occurrence was suppressed. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of all flexible printed circuits fell within 3.40 ± 0.01 .



Comparison 6:

A new plastic film having a size of 100 x 200 mm (film-16) was cut out from the polyethylene terephthalate film used with Embodiment 6. On the other hand, the same film-13 and film-14 as in Embodiment 6 were prepared. The ultrasonic propagation velocity ellipses of the three plastic films were created and were overlapped as in Embodiment 6. These overlapped ellipses of film-13 and film-16 are shown in a graph of Fig. 31. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-13 and film-16 of the outermost layers ($\Delta\theta$) is 90 degrees, showing a large shift.

As in Embodiment 6, a plastic film laminate of film-13 and film-16 was created and reinforcing film-16 was temporarily crimped on the rear face of film-14 by the roll laminate method, then they were crimped by a heat press (conditions: 130 x 1 h x 30 kg/cm²) to form a plastic film laminate. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 19.0 mm and the curl degree was 9.5%; a curl occurred. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of the flexible printed circuits varied in the range of 3.35-3.42.



Embodiment 7:

A bidirectionally stretched polyimide film 0.050 mm thick (manufactured by TORAY-Dupont) was used a raw material film, from which plastic films (film-17 and film-18) each having a size of 100 x 200 mm were cut out. A bidirectionally stretched polyimide film 0.125 mm thick (manufactured by TORAY-Dupont) was used a raw material film, from which a plastic film (film-19) having a size of 100 x 200 mm were cut out. The ultrasonic propagation velocities of the three plastic films were measured by the above-described method and three ultrasonic propagation velocity ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses of film-17 and film-19 are shown in a graph of Fig. 32. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-17 and film-19 of the outermost layers ($\Delta\theta$) is 0 degrees, showing that both match.

Next, a polyester family thermosetting adhesive was applied to the surfaces of film-17, film-18, and film-19, then dried to form an adhesive layer 0.025 mm thick. Film-17 and film-18 were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²) with the surfaces of film-17 and film-18 facing each other. Reinforcing film-19 was temporarily crimped on the rear face of film-18 by the roll laminate method, then cured in an autoclave (conditions: 110°C x 2 h x 10 kg/cm²). The curl amount h of the plastic film laminate was



measured by the above-described method. As a result, the curl amount h was 0.5 mm and the curl degree was 0.25%; curl occurrence was suppressed. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of all flexible printed circuits fell within 3.45 ± 0.01 .

Comparison 7:

A new plastic film having a size of 100 x 200 mm (film-20) was cut out from the polyimide film used with Embodiment 7. On the other hand, the same film-17 and film-18 as in Embodiment 7 were prepared. The ultrasonic propagation velocity ellipses of the three plastic films were created and were overlapped as in Embodiment 7. These overlapped ellipses of film-17 and film-20 are shown in a graph of Fig. 33. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-17 and film-20 of the outermost layers ($\Delta\theta$) is 90 degrees, showing a large shift.

As in Embodiment 7, a plastic film laminate of film-17 and film-18 was created and reinforcing film-20 was temporarily crimped on the rear face of film-18 by the roll laminate method, then they were crimped by a heat press (conditions: 150 x 1 h x 30 kg/cm²) to form a plastic film laminate. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was



THIS SHEET HAS BEEN
REPLACED

14.0 mm and the curl degree was 7.0%; a curl occurred. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of the flexible printed circuits varied in the range of 3.42 to 3.47.

Embodiment 8:

A bidirectionally stretched raw material plastic film made of polyethylene terephthalate 4 m wide was prepared. It was divided into eight parts like bands (each 500 mm wide) parallel with the length direction (machine direction of stretch) of the plastic film, as shown in Fig. 36. In the raw material plastic film, the linear expansion coefficients of the parts (divisions) were measured as in Embodiment 1, and combinations of the relative positions were considered. The condition that the maximum value of the linear expansion coefficient difference is 1.4×10^{-5} ($1/^{\circ}\text{C}$) or less was satisfied in the range of relative positions (-3) to (3). As shown in Fig. 36, a cover layer plastic film (film-21) having a size of 80 x 200 mm was cut out from the relative position (-3) and a base layer plastic film (film-22) having a size of 80 x 200 mm was cut out from the relative position (2). For film-21 and film-22, the linear expansion coefficient differences were measured with the same surfaces of the films facing each other. The maximum value of the linear expansion coefficient



difference was 0.7×10^{-5} ($1/^{\circ}\text{C}$).

As in Embodiment 1, film-21 and film-22 were used to produce a plastic film laminate with the same surfaces facing each other. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 5.6 mm and the curl degree was 2.8%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-21 (for the cover layer) and film-22 (for the base layer) as described above were prepared. An adhesive layer was formed on the surface of film-22 as in Embodiment 1, then electric circuit was formed, and an adhesive layer was formed on the surface of film-21. Film-21 and film-22 were laminated to manufacture a flexible printed circuit by the above-mentioned method. For this flexible printed circuit, the curl amount h was measured by the above-described method. As a result, the curl amount h was 5.3 mm and the curl degree was 2.7%; curl occurrence was suppressed.

Embodiment 9:

A bidirectionally stretched raw material plastic film made of polyethylene terephthalate 4.5 m wide was prepared. It was divided into nine parts like bands (each 500 mm wide) parallel with the length direction (machine direction of stretch) of the plastic film, as shown in Fig. 3. In the raw



material plastic film, a cover layer plastic film (film-23) and a base layer plastic film (film-24) each having a size of 60 x 90 mm were cut out from the parts of the relative positions (-3) and (3) at symmetrical positions with respect to the center line parallel with the length direction (machine direction) of the raw material plastic film. As in Embodiment 1, for film-23 and film-24, the linear expansion coefficient differences were measured with the same surfaces of the films facing each other. The maximum value of the linear expansion coefficient difference was 0.1×10^{-5} ($1/^{\circ}\text{C}$).

As in Embodiment 1, a plastic film laminate of film-23 and film-24 was produced. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 0.4 mm and the curl degree was 0.5%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-23 (for the cover layer) and film-24 (for the base layer) as described above were prepared. An adhesive layer was formed on the surface of film-24 as in Embodiment 1, then electric circuit was formed, and an adhesive layer was formed on the surface of film-23. Film-23 and film-24 were laminated to manufacture a flexible printed circuit by the above-mentioned method. For this flexible printed circuit, the curl amount h was measured by the above-described method. As a result, the curl amount h



was 0.3 mm and the curl degree was 0.3%; curl occurrence was suppressed.

Comparison 8:

5 The same film-23 and film-24 as in Embodiment 9 were prepared. The linear expansion coefficient differences were measured in a state in which the surface of film-23 and the rear face of film-24 face each other. The maximum value of the linear expansion coefficient difference was 1.6×10^{-5} (1/°C). In a state in which the surface of film-23 and the rear face of
10 film-24 face each other, a plastic film laminate was produced as in Embodiment 9, and the curl amount h was measured by the above-described method. As a result, the curl amount h was 5.9 mm and the curl degree was 6.6%; a curl occurred.

15 It is to be understood that the foregoing description and the accompanying drawings are not intended to limit the scope of this invention; rather, various modifications or variations may be made by those of ordinary skill in the art without departing from the scope of this invention which is defined by the appended claims. For example, the present
0 invention also can be applied to an ordinary composite sheet not only to the flexible printed circuit. The composite sheet according to the present may be also applied to IC card, credit card or the like.

This Sheet Has Been Replaced





WHAT IS CLAIMED IS:

1 1. A composite sheet comprising:
2 a first resin film; and
3 a second resin film laminated on the first resin film;
4 wherein two ellipses of coefficient of linear expansion
5 are created on coordinates in corresponding parts of the first
6 and second resin films by the following method (A):

7 (A) comprising the steps of: defining a predetermined
8 base point P on the resin film; measuring a coefficient of
9 linear expansion at a position separate from an arbitrary axis
10 in angle θ direction on the first and second resin films, the
11 arbitrary axis being selected on the first and second resin
12 films so as to pass through the base point P with the base
13 point P as a center and direct an arbitrary direction;
14 preparing a coordinate system with the arbitrary axis as a Y
15 axis and an axis crossing the Y axis at 90 degrees as an X
16 axis, in this coordinate system; defining an intersection of
17 the X and Y axes as the base point P in the linear expansion
18 coefficient measurement and magnitude of a linear expansion
19 coefficient measurement value as distance r from the base point
20 P, then plotting a tip point of the distance r in the
21 measurement angle θ direction with respect to the Y axis,
22 plotting it multiple times by changing the measurement angle θ ,
23 and drawing an analysis line throughout 360-degree directions
24 with the base point P as the center so as to pass through
25 average points of the plotted points for creating the ellipse:





26 and the two ellipse are overlapped so as to match in
27 the center point and coordinate axes X and Y, and the following
28 relationship (B) is satisfied: (B) the maximum value of a
29 linear expansion coefficient difference between the two resin
30 films is equal to or less than a predetermined value.

1 2. The composite sheet according to claim 1, wherein
2 the predetermined value is 1.4×10^{-5} ($1/^{\circ}\text{C}$).

1 3. The composite sheet according to claim 1, wherein
2 the first and second resin film are laminated on each other
3 with the same surfaces thereof facing each other.

1 4. The composite sheet according to claim 1, wherein
2 the composite sheet is a flexible printed circuit.

1 5. The composite sheet according to claim 4, wherein a
2 metal electric circuit is formed between the first and second
3 resin films and a product of thickness and tensile modulus of
4 the metal electric circuit is 500 kg/mm or less.

1 6. The composite sheet according to claim 1, wherein a
2 reinforcing plastic film is stuck on one side of the composite
3 sheet, and one of the first and second resin films positioned
4 on a side where the reinforcing plastic film is not stuck and
5 the reinforcing plastic film satisfy the relationships (A) and



This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

6 (B).

1 7. The composite sheet according to claim 1, wherein
2 one or more other resin films are sandwiched between the first
3 and second resin film.

1 8. The composite sheet according to claim 1, wherein
2 the first and second resin film are laminated via an adhesive
3 layer.

1 9. The composite sheet according to claim 8, wherein
2 the first and second films stacked via the adhesive layer are
3 temporarily crimped by a roll laminate method in stacked
4 relation and then pressurized under gas pressure in an
5 autoclave and crimped.

1 10. A composite sheet comprising:
2 a first resin film; and
3 a second resin film laminated on the first resin film;
4 wherein two ellipses of coefficient of linear expansion
5 are created on coordinates in corresponding parts of the first
6 and second resin films by the following method (C):

7 (C) comprising the steps of: defining a predetermined
8 base point P on the resin film; measuring a coefficient of
9 linear expansion at a position separate from an arbitrary axis
0 in angle θ direction on the first and second resin films, the





11 arbitrary axis being selected on the first and second resin
12 films so as to pass through the base point P with the base
13 point P as a center and direct an arbitrary direction;
14 preparing a coordinate system with the arbitrary axis as a Y
15 axis and an axis crossing the Y axis at 90 degrees as an X
16 axis, in this coordinate system; defining an intersection of
17 the X and Y axes as the base point P in the linear expansion
18 coefficient measurement and magnitude of a linear expansion
19 coefficient measurement value as distance r from the base point
20 P, then plotting a tip point of the distance r in the
21 measurement angle θ direction with respect to the Y axis,
22 plotting it multiple times by changing the measurement angle θ ,
23 and drawing an analysis line throughout 360-degree directions
24 with the base point P as the center so as to pass through
25 average points of the plotted points for creating the ellipse:
26 and the two ellipse are overlapped so as to match in
27 the center point and coordinate axes X and Y, and the following
28 relationship (D) is satisfied: (D) the total area of portions
29 where the ellipses do not overlap is equal to or less than a
30 predetermined value.

1 11. The composite sheet according to claim 10, wherein
2 the predetermined value is $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

1 12. The composite sheet according to claim 10, wherein
2 the first and second resin film are laminated on each other





3 with the same surfaces thereof facing each other.

1 13. The composite sheet according to claim 10, wherein
2 the composite sheet is a flexible printed circuit.

1 14. The composite sheet according to claim 13, wherein
2 a metal electric circuit is formed between the first and second
3 resin films and a product of thickness and tensile modulus of
4 the metal electric circuit is 500 kg/mm or less.

1 15. The composite sheet according to claim 10, wherein
2 a reinforcing plastic film is stuck on one side of the
3 composite sheet, and one of the first and second resin films
4 positioned on a side where the reinforcing plastic film is not
5 stuck and the reinforcing plastic film satisfy the
6 relationships (C) and (D).

1 16. The composite sheet according to claim 10, wherein
2 one or more other resin films are sandwiched between the first
3 and second resin film.

1 17. The composite sheet according to claim 10, wherein
2 the first and second resin film are laminated via an adhesive
3 layer.

1 18. The composite sheet according to claim 17, wherein





2 the first and second films stacked via the adhesive layer are
3 temporarily crimped by a roll laminate method in stacked
4 relation and then pressurized under gas pressure in an
5 autoclave and crimped.

1 19. A composite sheet comprising:
2 a first resin film; and
3 a second resin film laminated on the first resin film;
4 wherein two ellipses of ultrasonic propagation velocity
5 are created on coordinates in corresponding parts of the first
6 and second resin films by the following method (E):

7 (E) comprising the steps of: defining a predetermined
8 base point P on the film surface of the resin film, measuring
9 a ultrasonic propagation velocity at a position separate from
10 an arbitrary axis in angle θ direction on the first and second
11 resin films, the arbitrary axis being selected on the first and
12 second resin films so as to pass through the base point P with
13 the base point P as a center and direct an arbitrary direction,
14 preparing a coordinate system with the arbitrary axis as a Y
15 axis and an axis crossing the Y axis at 90 degrees as an X
16 axis, in this coordinate system, defining an intersection of
17 the X and Y axes as the base point P in the ultrasonic
18 propagation velocity measurement and magnitude of a ultrasonic
19 propagation velocity measurement value as distance r from the
20 base point P, then plotting a tip point of this distance r in
21 the measurement angle θ direction with respect to the Y axis,





plotting it multiple times by changing the measurement angle θ , and drawing an analysis line throughout 360-degree directions with the base point P as the center so as to pass through average points of the plotted points for creating an ellipse having a crystal orientation main axis in a long-axis direction and a crystal orientation subaxis in a short-axis direction:

and the two ellipse are overlapped so as to match in center point and coordinate axes X and Y, and the following relationship (F) is satisfied: (F) a shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30 degrees.

20. The composite sheet according to claim 19, wherein the first and second resin film are laminated on each other with the same surfaces thereof facing each other.

21. The composite sheet according to claim 19, wherein the composite sheet is a flexible printed circuit.

22. The composite sheet according to claim 21, wherein a metal electric circuit is formed between the first and second resin films and a product of thickness and tensile modulus of the metal electric circuit is 500 kg/mm or less.

23. The composite sheet according to claim 19, wherein a reinforcing plastic film is stuck on one side of the





3 composite sheet, and one of the first and second resin films
4 positioned on a side where the reinforcing plastic film is not
5 stuck and the reinforcing plastic film satisfy the
6 relationships (E) and (F).

1 24. The composite sheet according to claim 19, wherein
2 one or more other resin films are sandwiched between the first
3 and second resin film.

1 25. The composite sheet according to claim 19, wherein
2 the first and second resin film are laminated via an adhesive
3 layer.

1 26. The composite sheet according to claim 25, wherein
2 the first and second films stacked via the adhesive layer are
3 temporarily crimped by a roll laminate method in stacked
4 relation and then pressurized under gas pressure in an
5 autoclave and crimped.

1 27. A method for manufacturing a composite sheet
2 comprising the steps of:

3 preparing a first resin film and a second resin film;
4 creating two ellipses of coefficient of linear
5 expansion on coordinates in corresponding parts of the first
6 and second resin films by the following (1) to (7) steps:

7 (1) defining a predetermined base point P on the resin





8 film;

9 (2) measuring a coefficient of linear expansion at a
10 position separate from an arbitrary axis in angle θ direction
11 on the first and second resin films, the arbitrary axis being
12 selected on the first and second resin films so as to pass
13 through the base point P with the base point P as a center and
14 direct an arbitrary direction;

15 (3) preparing a coordinate system with the arbitrary
16 axis as a Y axis and an axis crossing the Y axis at 90 degrees
17 as an X axis, in this coordinate system;

18 (4) defining an intersection of the X and Y axes as the
19 base point P in the linear expansion coefficient measurement
20 and magnitude of a linear expansion coefficient measurement
21 value as distance r from the base point P,

22 (5) plotting a tip point of the distance r in the
23 measurement angle θ direction with respect to the Y axis,

24 (6) repeating plotting the tip point multiple times by
25 changing the measurement angle θ ; and

26 (7) drawing an analysis line throughout 360-degree
27 directions with the base point P as the center so as to pass
28 through average points of the plotted points for creating the
29 ellipse;

30 laminating the first and second resin film in such a
31 manner that the following relationship (G) is satisfied: (G)
32 the maximum value of a linear expansion coefficient difference
33 between the two resin films is equal to or less than a





34 predetermined value when the two ellipses are overlapped so as
35 to match in the center point and coordinate axes X and Y.

1 28. The method for manufacturing a composite sheet
2 according to claim 27, wherein the predetermined value is 1.4
3 $\times 10^{-5}$ ($1/^{\circ}\text{C}$).

1 29. The method of manufacturing a composite sheet
2 according to claim 27, further comprising the steps of:
3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;

5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;

8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction; and

11 cutting out the first and second layer cut parts in
12 parallel with the length direction from the first and second
13 resin films respectively.

1 30. The method for manufactuirng a composite sheet
2 according to claim 29, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an





6 autoclave and crimping.

1 31. The method of manufacturing a composite sheet
2 according to claim 27, further comprising the steps:

3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;

5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;

8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction;

11 cutting out the first and second layer cut parts at
12 substantially symmetrical positions with respect to a center
13 line parallel with the length direction from the first and 1
14 econd resin films respectively; and

15 laminating the first and second layer cut parts in a
16 state in which the same surfaces of the first and second layer
17 cut parts face each other.

1 32. The method for manufactuirng a composite sheet
2 according to claim 31, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an
6 autoclave and crimping.





1 33. A method for manufacturing a composite sheet
2 comprising the steps of:

3 preparing a first resin film and a second resin film;

4 creating two ellipses of coefficient of linear
5 expansion on coordinates in corresponding parts of the first
6 and second resin films by the following (1) to (7) steps:

7 (1) defining a predetermined base point P on the resin
8 film;

9 (2) measuring a coefficient of linear expansion at a
10 position separate from an arbitrary axis in angle θ direction
11 on the first and second resin films, the arbitrary axis being
12 selected on the first and second resin films so as to pass
13 through the base point P with the base point P as a center and
14 direct an arbitrary direction;

15 (3) preparing a coordinate system with the arbitrary
16 axis as a Y axis and an axis crossing the Y axis at 90 degrees
17 as an X axis, in this coordinate system;

18 (4) defining an intersection of the X and Y axes as the
19 base point P in the linear expansion coefficient measurement
20 and magnitude of a linear expansion coefficient measurement
21 value as distance r from the base point P,

22 (5) plotting a tip point of the distance r in the
23 measurement angle θ direction with respect to the Y axis,

24 (6) repeating plotting the tip point multiple times by
25 changing the measurement angle θ ; and

26 (7) drawing an analysis line throughout 360-degree





27 directions with the base point P as the center so as to pass
28 through average points of the plotted points for creating the
29 ellipse;

30 laminating the first and second resin film in such a
31 manner that the following relationship (H) is satisfied: (H)
32 the total area of portions where the ellipses do not overlap is
33 equal to or less than a predetermined value when the two
34 ellipses are overlapped so as to match in the center point and
35 coordinate axes X and Y.

1 34. The method for manufacturing a composite sheet
2 according to claim 33, wherein the predetermined value is 6.5
3 $\times 10^{-10} [(1/^{\circ}\text{C}) \times (1/^{\circ}\text{C})]$.

1 35. The method of manufacturing a composite sheet
2 according to claim 33, further comprising the steps of:
3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;

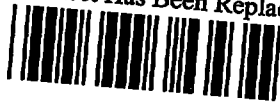
5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;

8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction; and

11 cutting out the first and second layer cut parts in
12 parallel with the length direction from the first and second



This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

13 resin films respectively.

1 36. The method for manufactuirng a composite sheet
2 according to claim 35, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an
6 autoclave and crimping.

1 37. The method of manufacturing a composite sheet
2 according to claim 33, further comprising the steps:

3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;

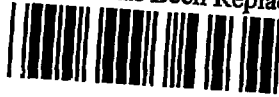
5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;

8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction;

11 cutting out the first and second layer cut parts at
12 substantially symmetrical positions with respect to a center
13 line parallel with the length direction from the first and
14 second resin films respectively; and

15 laminating the first and second layer cut parts in a
16 state in which the same surfaces of the first and second resin
17 films face each other.





1 38. The method for manufactuirng a composite sheet
2 according to claim 37, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an
6 autoclave and crimping.

1 39. The composite sheet according to claim 1, wherein
2 the arbitrary axis is settled on a machine direction of film
3 stretch, so that the Y axis is settled on the machine direction
4 and the X axis is settled on a transverse direction of film
5 stretch.

1 40. The composite sheet according to claim 1, wherein
2 the composite sheet is a flexible printed circuit, and the
3 arbitrary axis is settled on a machine direction of film
4 stretch, so that the Y axis is settled on the machine direction
5 and the X axis is settled on a transverse direction of film
6 stretch.

1 41. The composite sheet according to claim 10, wherein
2 the arbitrary axis is settled on a machine direction of film
3 stretch, so that the Y axis is settled on the machine direction
4 and the X axis is settled on a transverse direction of film
5 stretch.



THIS SHEET HAS BEEN
REPLACED

1 42. The composite sheet according to claim 10, wherein
2 the composite sheet is a flexible printed circuit, and the
3 arbitrary axis is settled on a machine direction of film
4 stretch, so that the Y axis is settled on the machine direction
5 and the X axis is settled on a transverse direction of film
6 stretch.

1 43. The composite sheet according to claim 19, wherein
2 the arbitrary axis is settled on a machine direction of film
3 stretch, so that the Y axis is settled on the machine direction
4 and the X axis is settled on a transverse direction of film
5 stretch.

1 44. The composite sheet according to claim 19, wherein
2 the composite sheet is a flexible printed circuit, and the
3 arbitrary axis is settled on a machine direction of film
4 stretch, so that the Y axis is settled on the machine direction
5 and the X axis is settled on a transverse direction of film
6 stretch.

This Sheet Has Been Replaced



ABSTRACT OF THE DISCLOSURE

A composite sheet comprises a first resin film; and a second resin film laminated on the first resin film; wherein two ellipses of coefficient of linear expansion are created on polar coordinates in corresponding parts of the first and second resin films by a predetermined method and the two ellipse are overlapped so as to match in the center point and coordinate axes X and Y, and the maximum value of a linear expansion coefficient difference between the two resin films is equal to or less than a predetermined value.

This Sheet Has Been Replaced

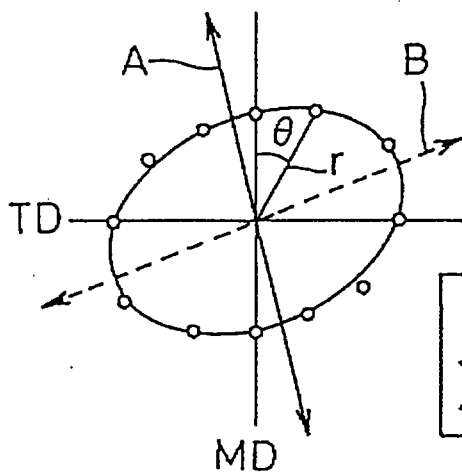


【書類名】 図面

【図1】

THIS SHEET HAS BEEN
REPLACED

Fig-1

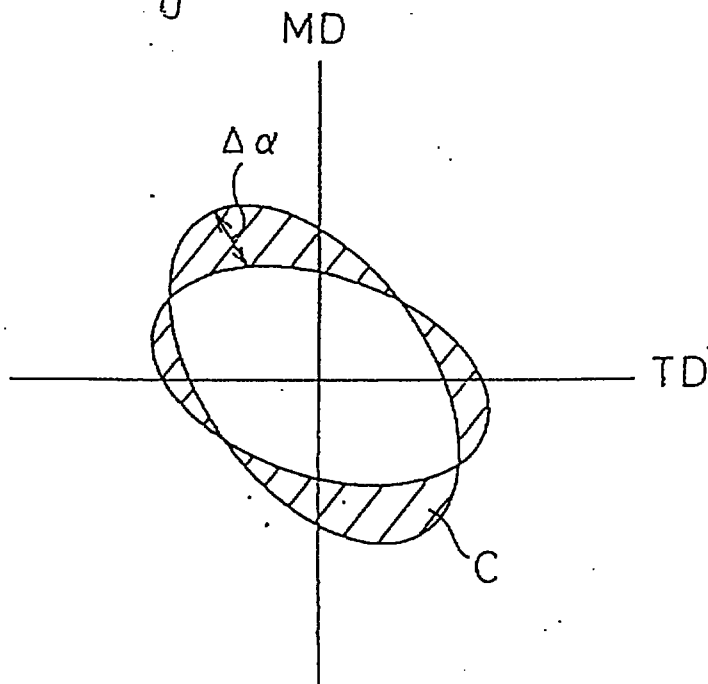


ABSOLUTE VALUE OF
LINEAR EXPANSION COEFFICIENT
 $|r|$: 線膨張率の絶対値
 θ : 測定角度
MEASUREMENT ANGLE

○ 測定データ MEASUREMENT DATA
←--→ 結晶配向副軸 CRYSTAL ORIENTATION SUBAXIS
←--→ 結晶配向主軸 CRYSTAL ORIENTATION MAIN AXIS

【図2】

Fig-2



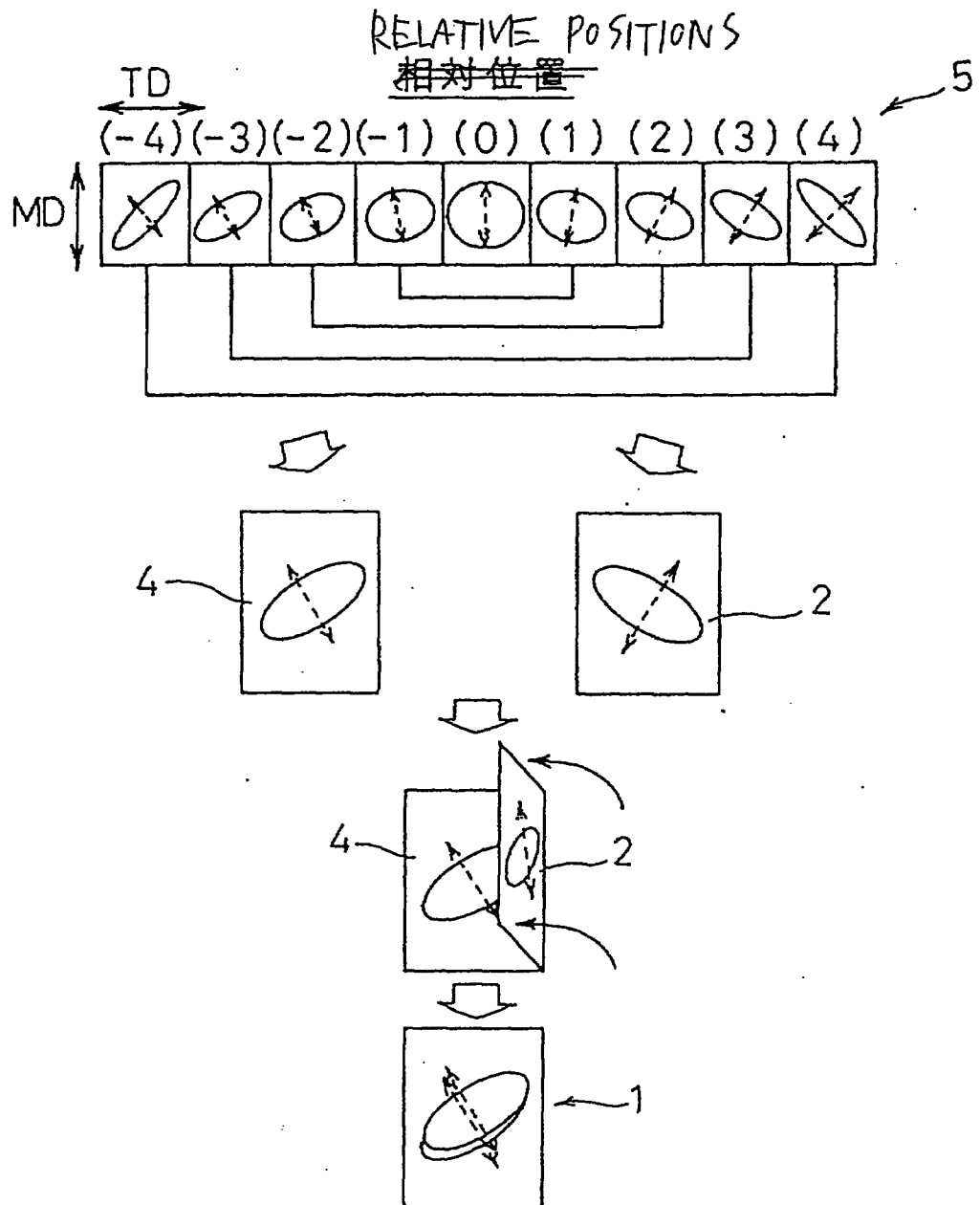
This Sheet Has Been Replaced



【図3】

Fig-3

THIS SHEET HAS BEEN REPLACED

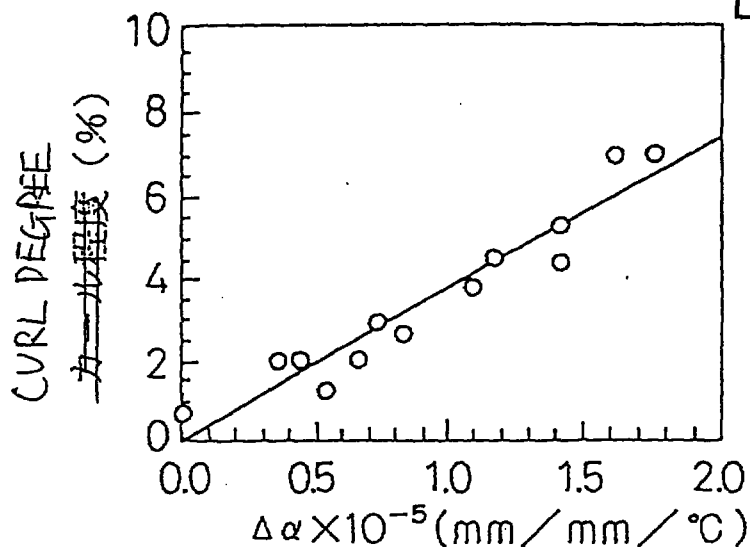


This Sheet Has Been Replaced



【図4】

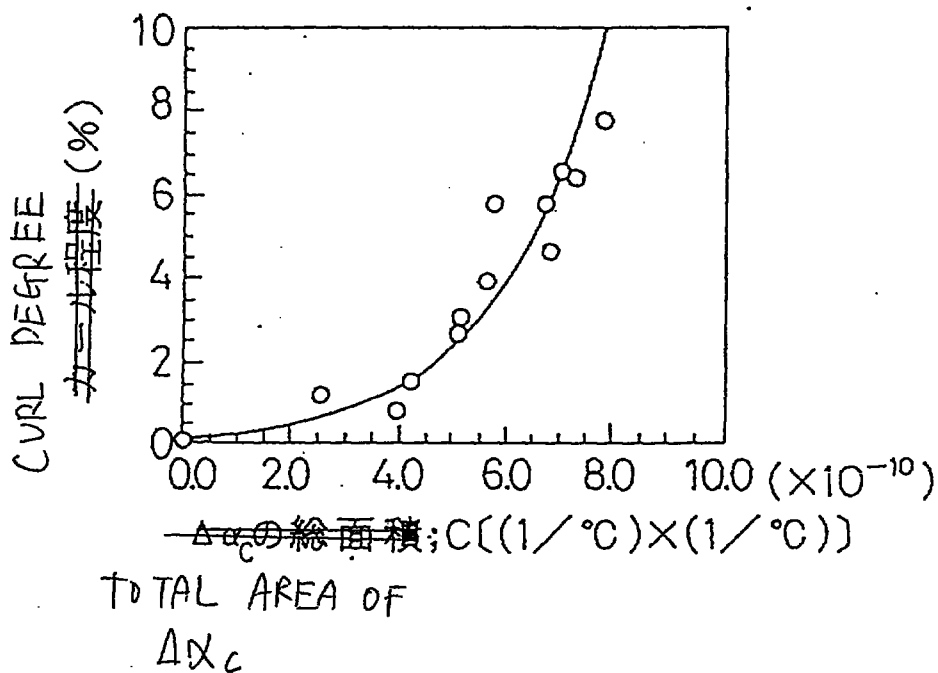
Fig. 4



THIS SHEET HAS BEEN REPLACED

【図5】

Fig. 5



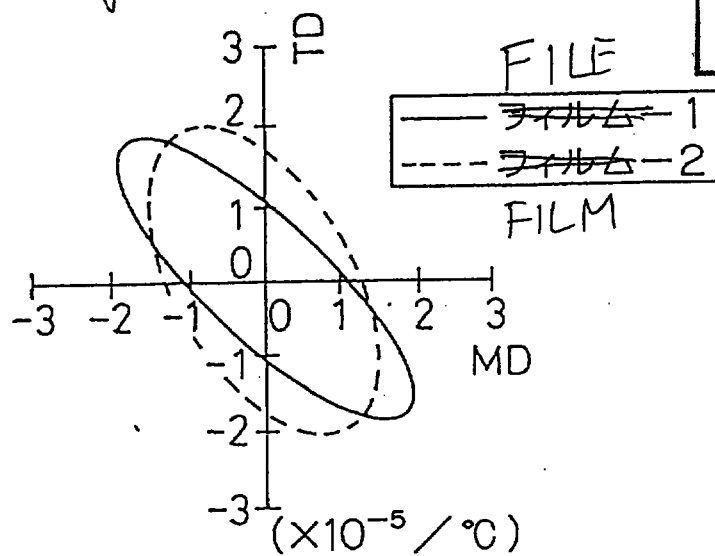
This Sheet Has Been Replaced



57

【図6】

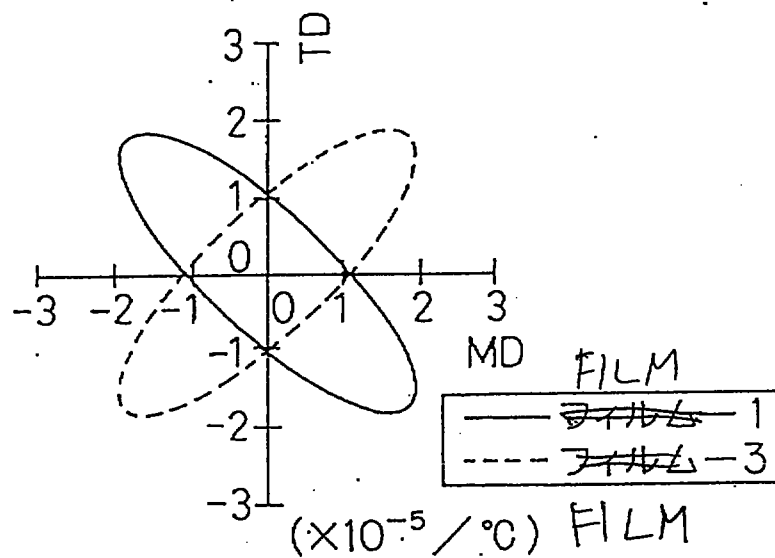
Fig. 6



THIS SHEET HAS BEEN REPLACED

【図7】

Fig. 7



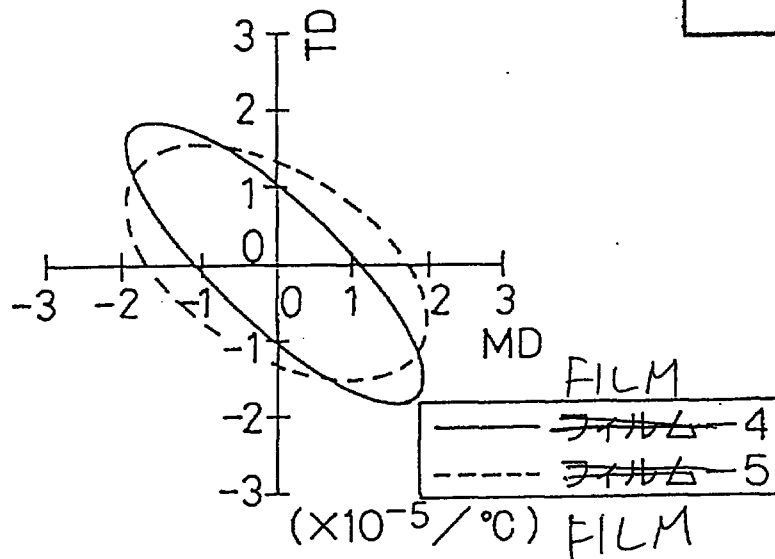
This Sheet Has Been Replaced



【図8】

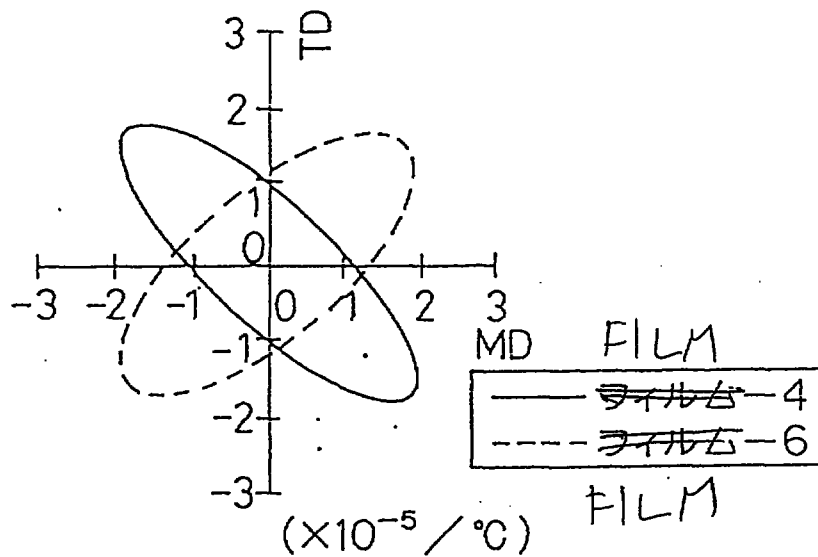
Fig. 8

THIS SHEET HAS BEEN REPLACED



【図9】

Fig. 9

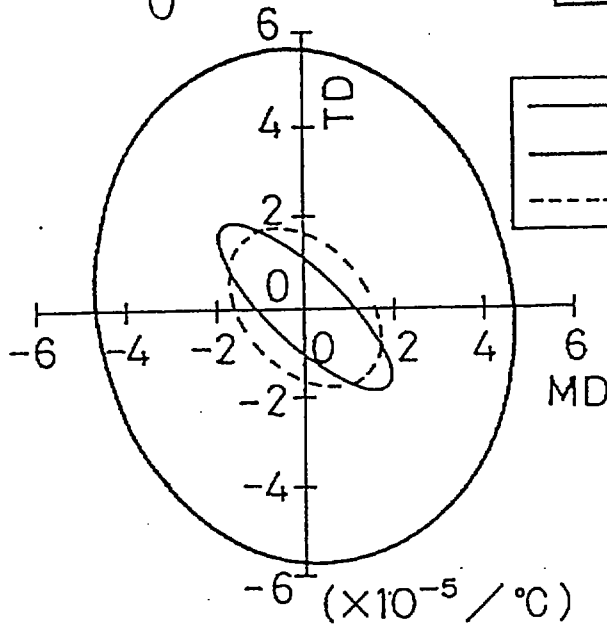


This Sheet Has Been Replaced



【図10】

Fig. 10



THIS SHEET HAS BEEN REPLACED

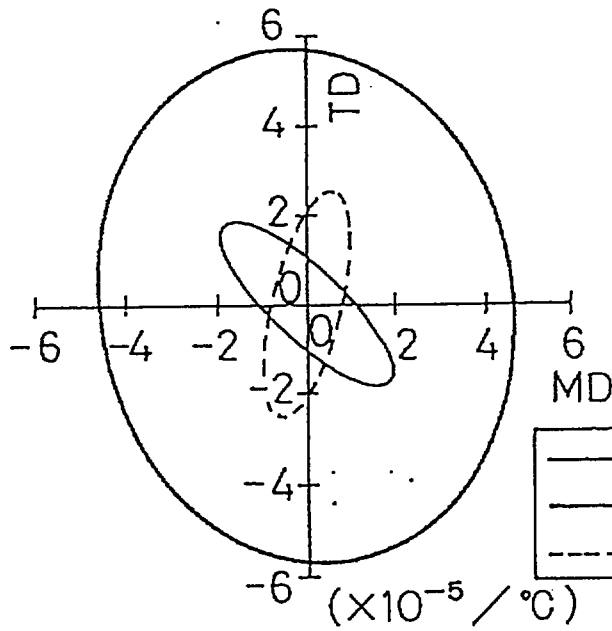
FILM

—	フィルム	7
—	FILM	10
- - -	フィルム	8

FILM

【図11】

Fig. 11



FILM

—	フィルム	7
—	FILM	10
- - -	フィルム	9

FILM

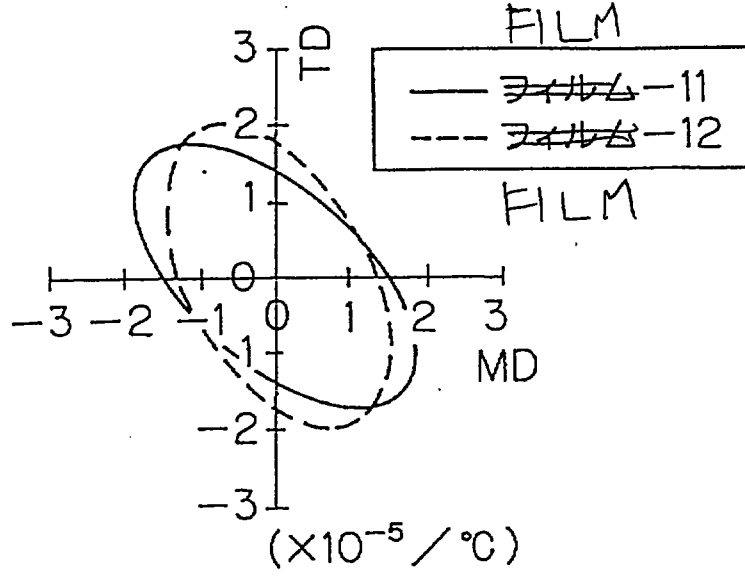
This Sheet Has Been Replaced



~~図12~~

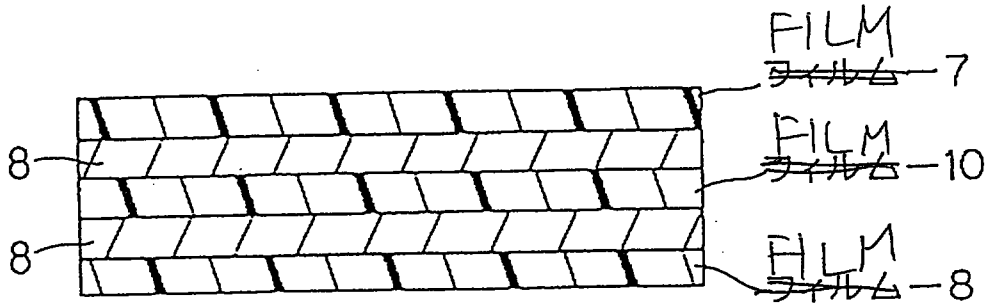
Fig. 12

THIS SHEET HAS BEEN REPLACED



~~図13~~

Fig. 13

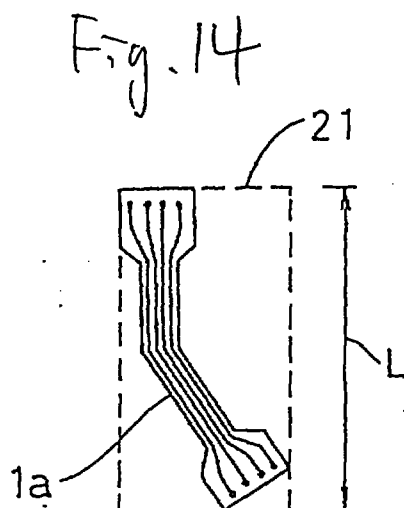


This Sheet Has Been Replaced



61

【図 1 4】



THIS SHEET HAS BEEN REPLACED

【図 1 5】



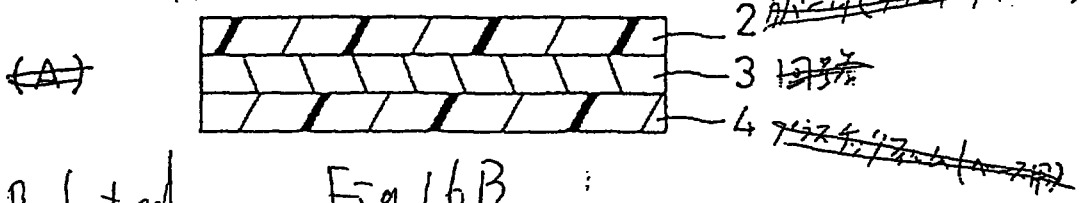
This Sheet Has Been Replaced



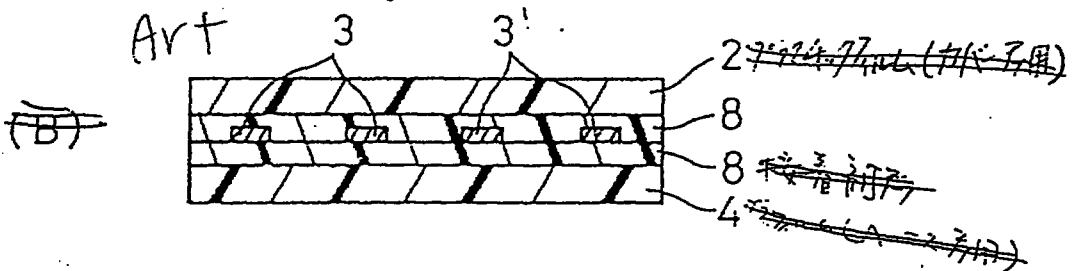
【~~図16~~】

THIS SHEET HAS BEEN REPLACED

Related Fig. 16A
Art



Related Fig. 16B
Art



【~~図17~~】

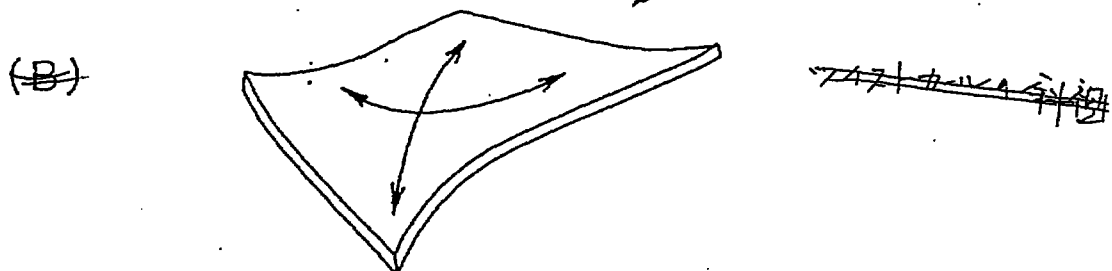
Fig. 17A

Prior Art



Fig. 17B

Prior Art



This Sheet Has Been Replaced



~~【図18】~~

Fig. 18A

THIS SHEET HAS BEEN REPLACED

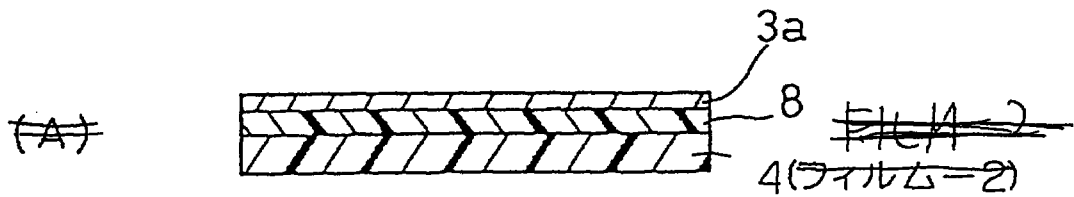


Fig. 18B

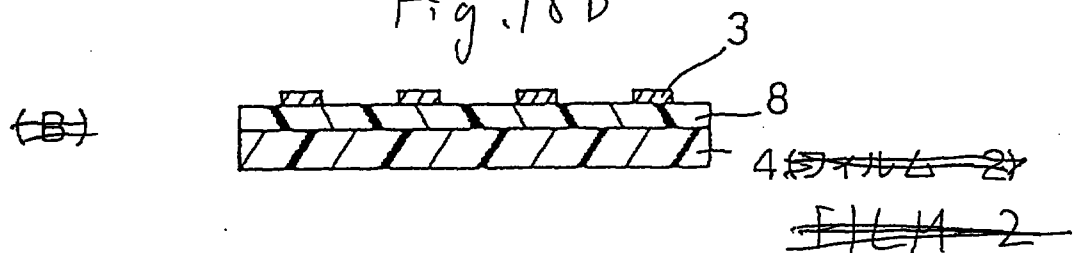


Fig. 18C

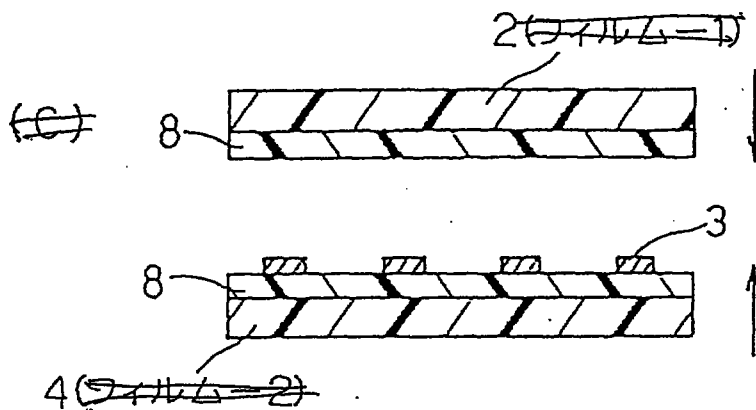
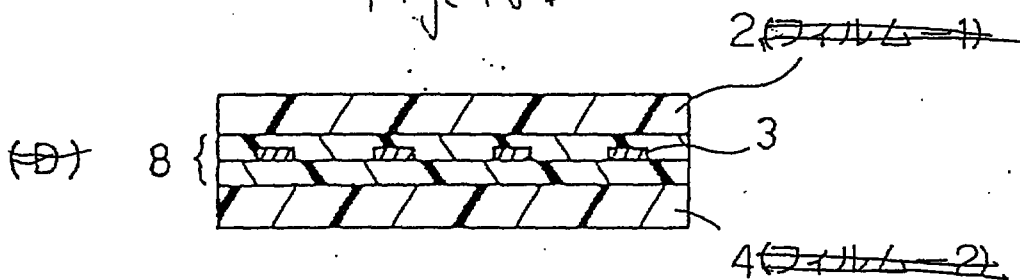


Fig. 18D



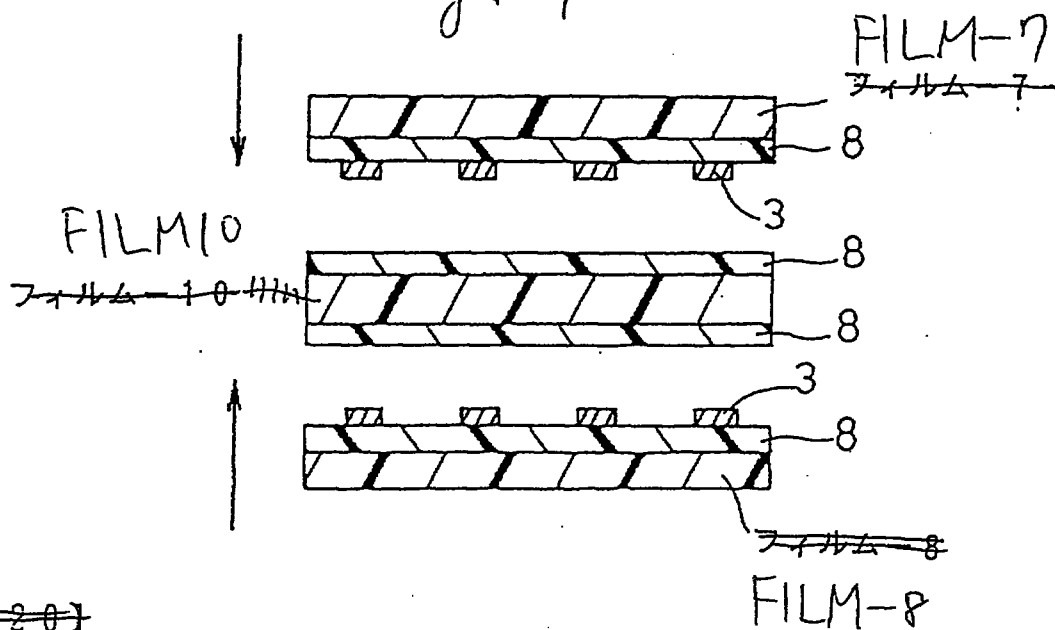
This Sheet Has Been Replaced



~~【図19】~~

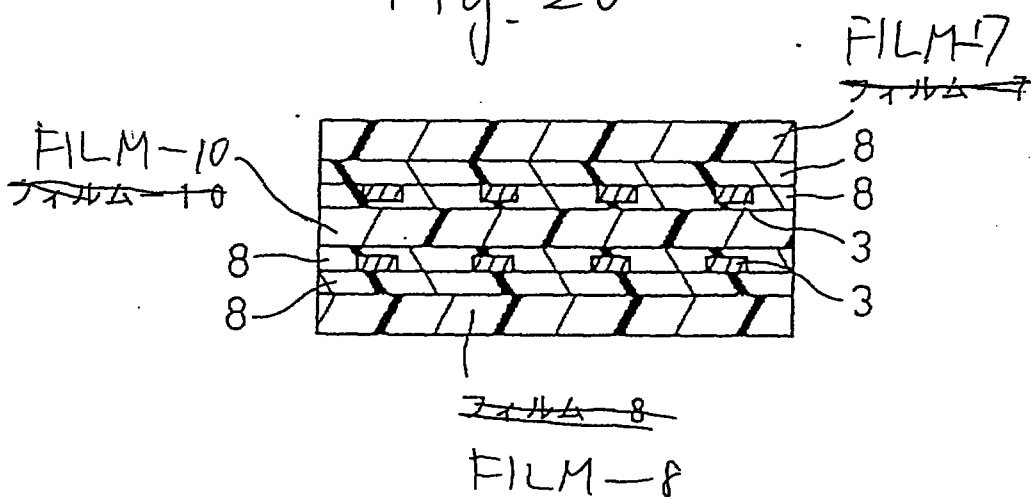
Fig. 19

THIS SHEET HAS BEEN REPLACED



~~【図20】~~

Fig. 20



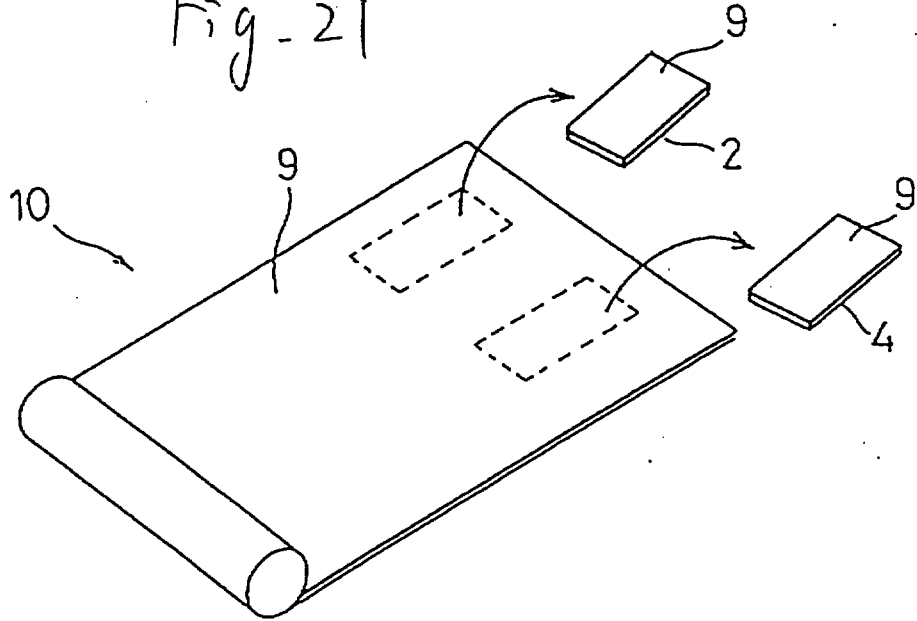
This Sheet Has Been Replaced



【図21】

THIS SHEET HAS BEEN
REPLACED

Fig-21



This Sheet Has Been Replaced



64

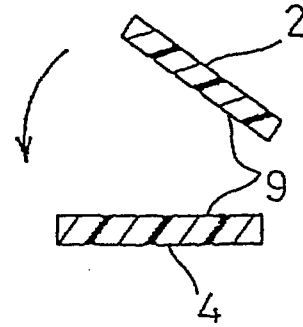
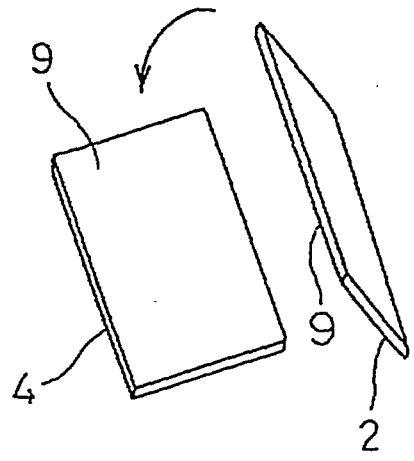
(66)

~~【図22】~~

THIS SHEET HAS BEEN REPLACED

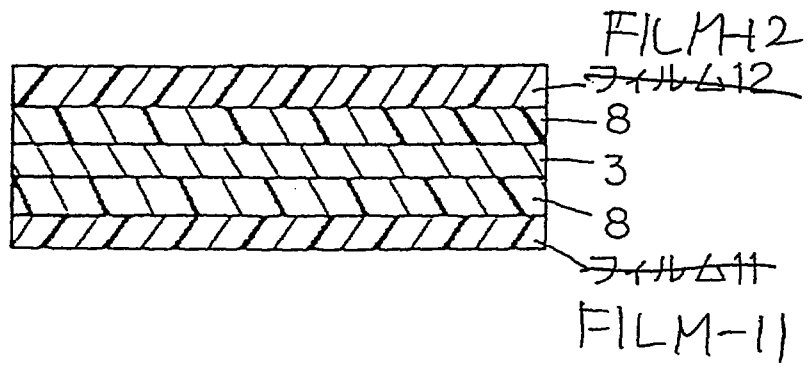
Fig-22A
~~(A)~~

Fig-22B
~~(B)~~



~~【図23】~~

Fig-23

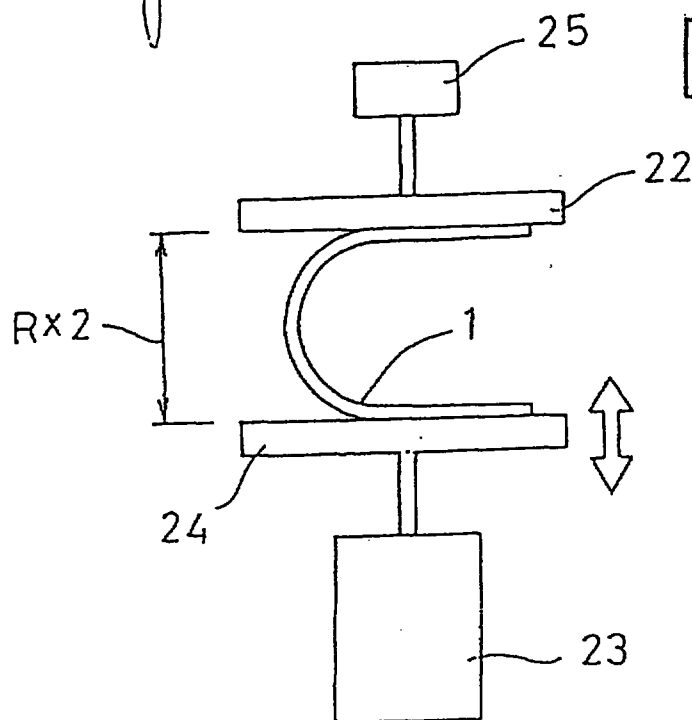


This Sheet Has Been Replaced



~~【図24】~~

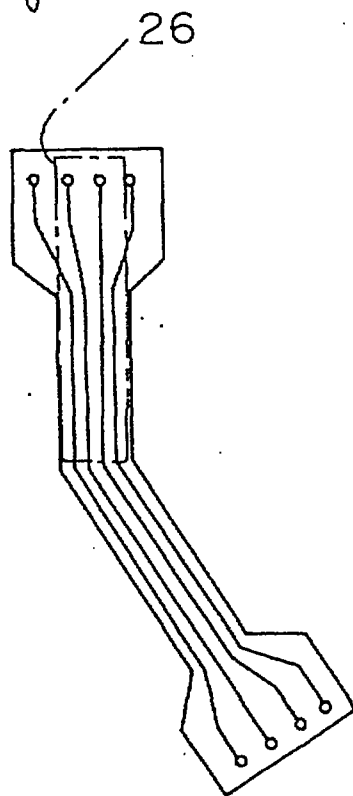
Fig. 24



THIS SHEET HAS BEEN REPLACED

~~【図25】~~

Fig. 25



This Sheet Has Been Replaced



【図26】

Fig. 26 A
Related Art

THIS SHEET HAS BEEN REPLACED

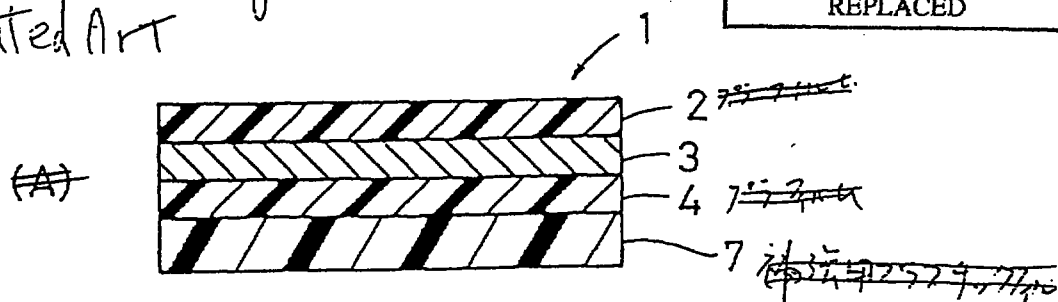
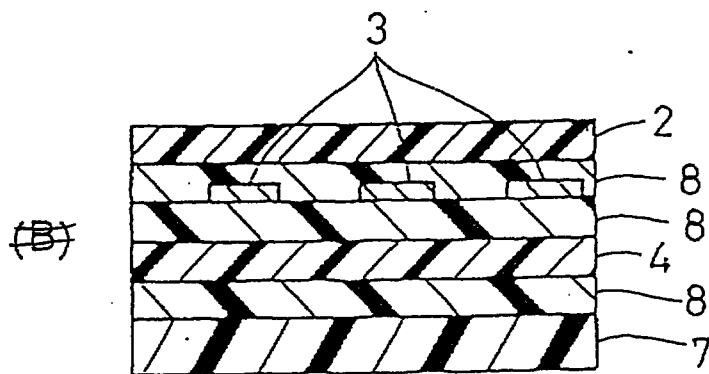


Fig. 26 B



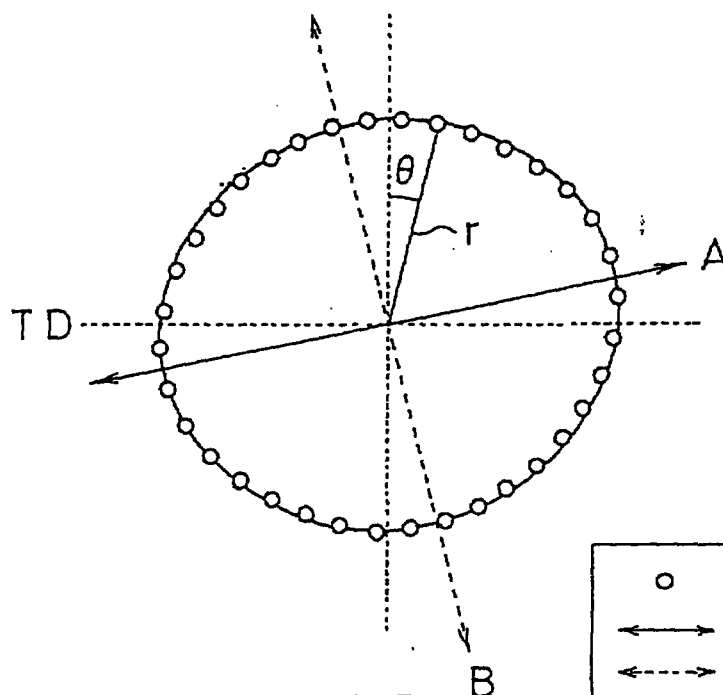
This Sheet Has Been Replaced



【図27】

Fig. 27

ULTRASONIC PROPAGATION
VELOCITY IN MD
~~MDの超音波伝播速度~~ ($\times 10^3 \text{ m/s}$)



THIS SHEET HAS BEEN
REPLACED

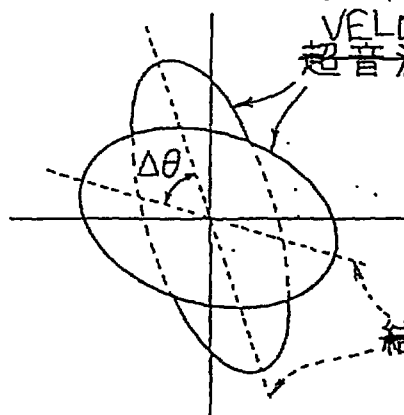
ULTRASONIC MD
VELOCITY IN TD
~~TDの超音波伝播速度~~ ($\times 10^3 \text{ m/s}$)

○	測定データ	MEASUREMENT DATA
→	主軸	MAIN AXIS
→	副軸	SUBAXIS

【図28】

Fig. 28

ULTRASONIC PROPAGATION
VELOCITY ELLIPSE
~~超音波伝播速度楕円体~~



CRYSTAL ORIENTATION
MAIN AXIS DIRECTION
~~結晶配向主軸方向~~

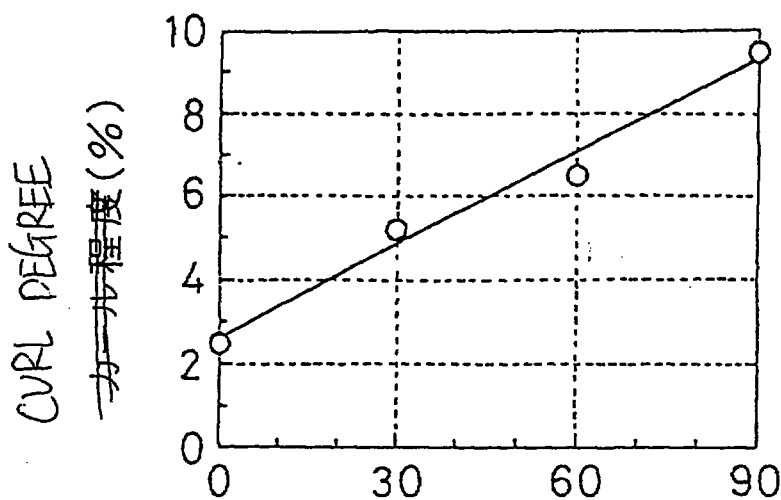
This Sheet Has Been Replaced



【図29】

Fig. 29

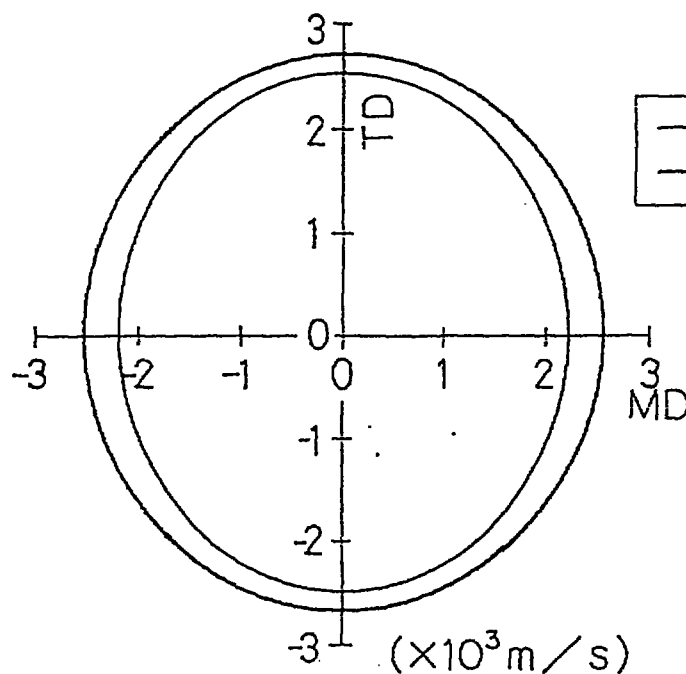
THIS SHEET HAS BEEN REPLACED



結晶配向軸のずれ角度差(Δθ;°)
SHIFT ANGLE DIFFERENCE
BETWEEN CRYSTAL ORIENTATION MAIN AXES

【図30】

Fig. 30



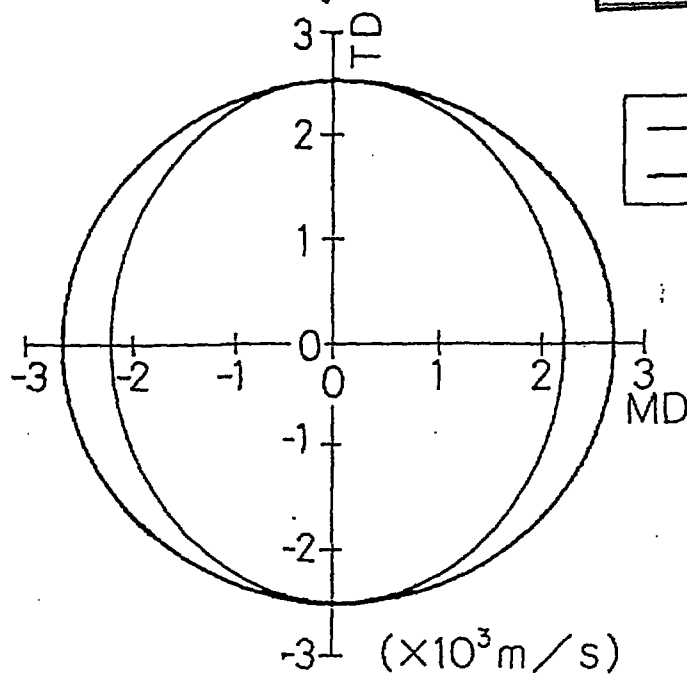
FILM
——— ヲィルム-13
——— ヲィルム-15
FILM

This Sheet Has Been Replaced



【図31】

Fig. 31



THIS SHEET HAS BEEN REPLACED

FILM

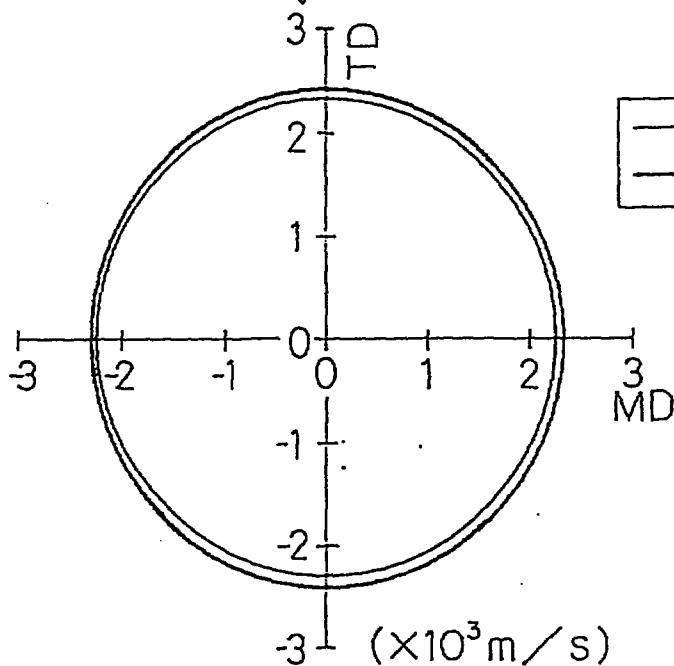
—— ~~フィルム~~-13

—— ~~フィルム~~-16

FILM

【図32】

Fig. 32



FILM

—— ~~フィルム~~-17

—— ~~フィルム~~-19

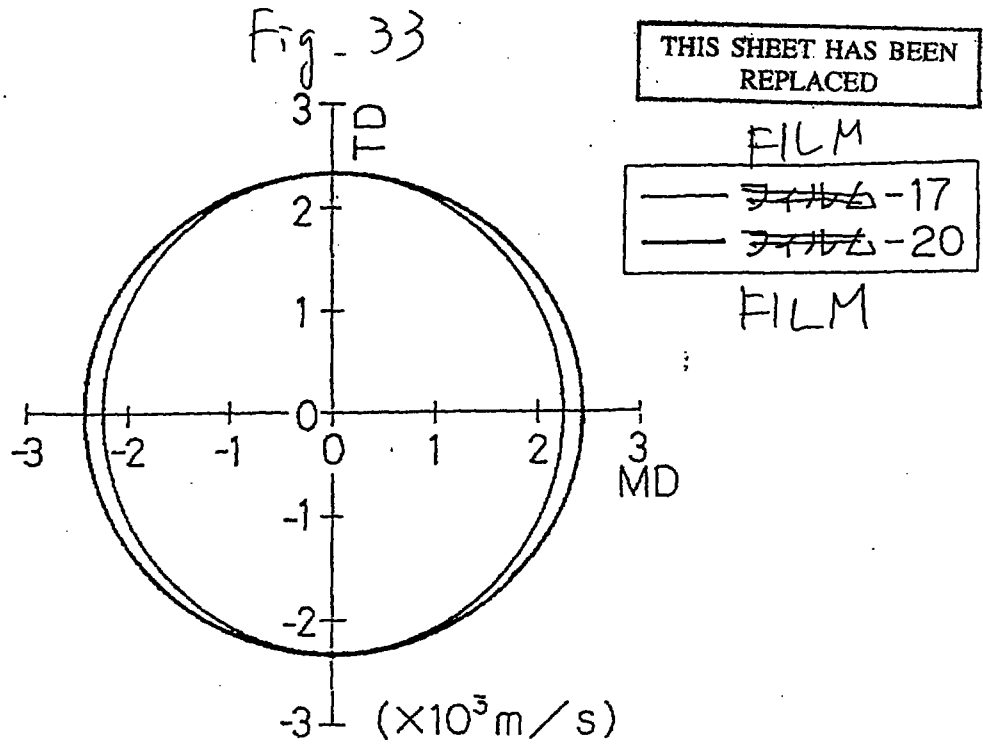
FILM

This Sheet Has Been Replaced



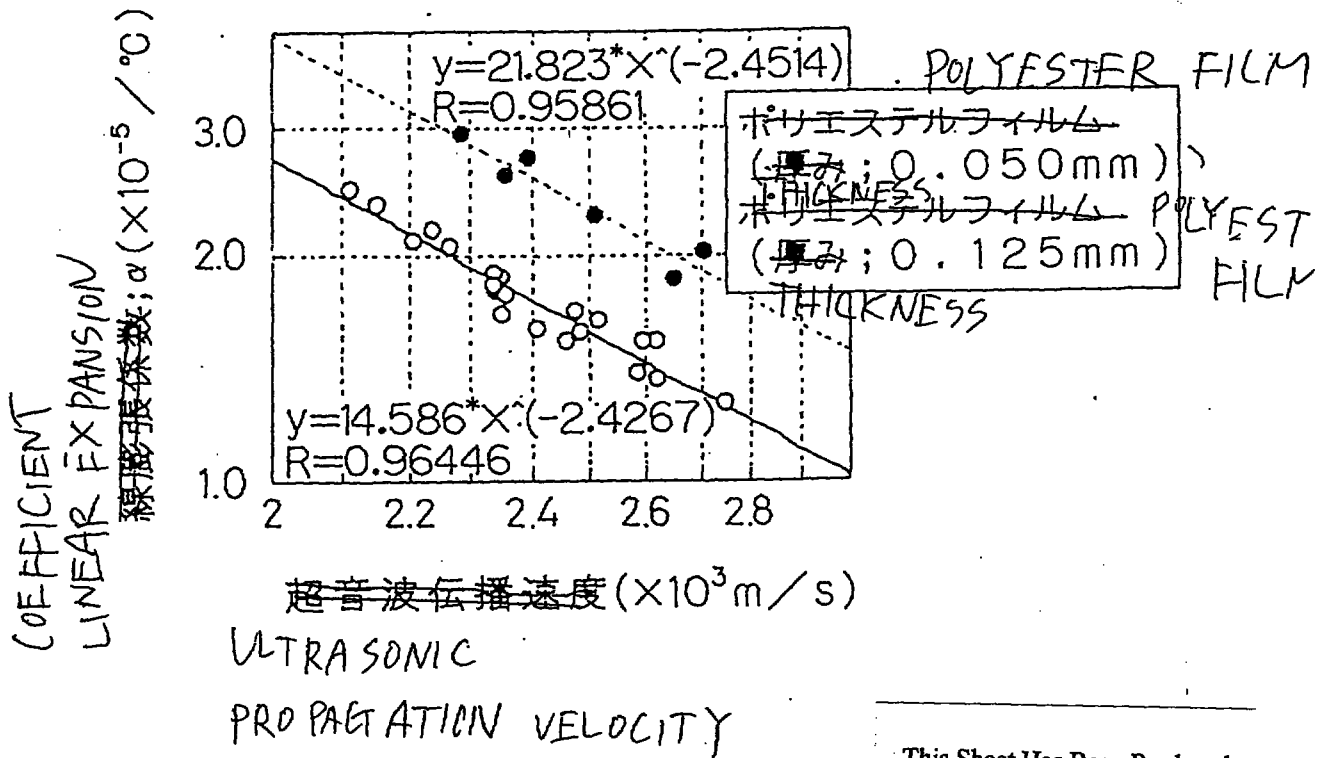
【図33】

24



【図34】

Fig. 34



This Sheet Has Been Replaced

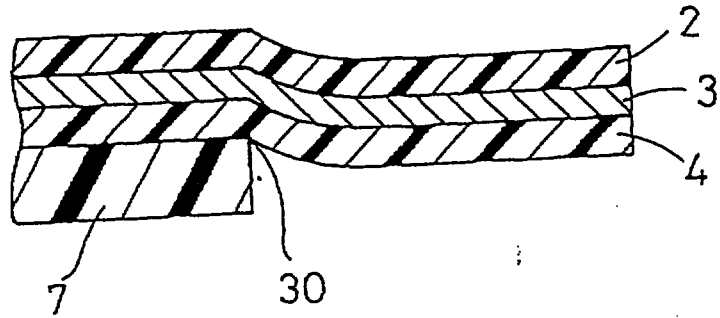


【図35】

Fig. 35

THIS SHEET HAS BEEN
REPLACED

(73)



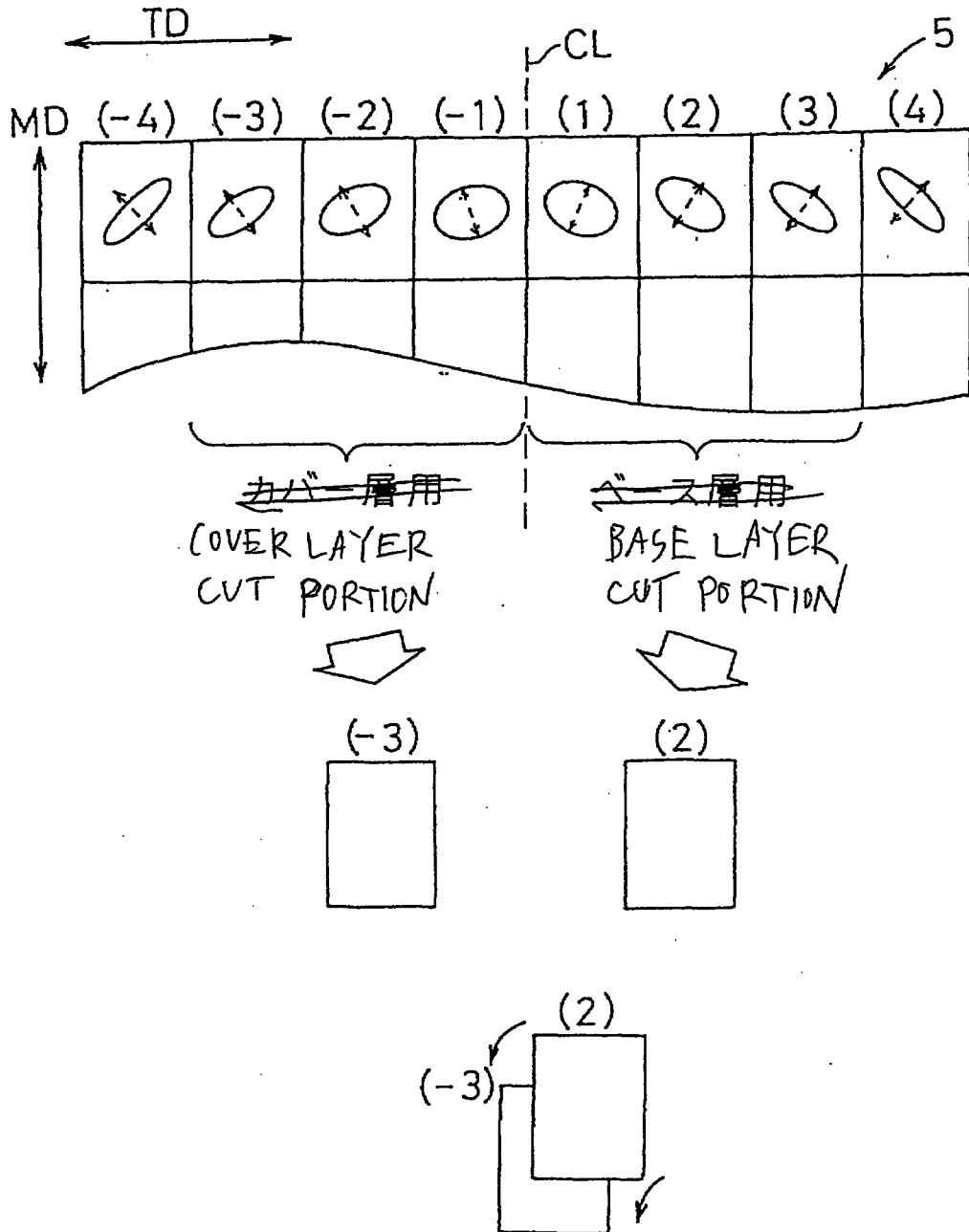
This Sheet Has Been Replaced



図 3

Fig. 36

THIS SHEET HAS BEEN REPLACED



This Sheet Has Been Replaced



14 JAN 1997

FLEXIBLE PRINTED CIRCUIT AND MANUFACTURING METHOD THEREFOR

BACKGROUND OF THE INVENTION

This invention relates to a flexible printed circuit of
5 a functional part used mainly in electric and electronic fields
and a manufacturing method therefor.

Hitherto, printed circuits rich in flexibility have
been commonly called flexible printed circuits and generally
used in fields of electronics, etc. Generally, to form the
10 flexible printed circuit, a material film is stretched in two
directions of machine and transverse directions and two or more
plastic films are cut out to a predetermined size from the
stretched film and are laminated on each other. The machine
and transverse directions mean longitudinal and lateral
15 directions of the material film. Fig. 16A shows an example of
the flexible printed circuit. A flexible printed circuit 1
comprises predetermined metal electric circuit 3 formed on a
plastic film 4 made of polyimide, polyester, etc., (for a base
layer) by a printing technique, a subtractive method, or the
20 like and a plastic film 2 (for a cover layer) similar to the
plastic film 4 furthermore formed on the metal electric circuit
3. Generally, an adhesive is used to laminate the plastic
films 2 and 4 (lamine bond). An adhesive layer is not shown
in Fig. 16A.

25 Fig. 16B shows a general structure of the flexible
printed circuit. As shown here, the flexible printed circuit

14 JAN 1997

comprises an adhesive layer 8 formed on a plastic film 4 (for a base layer), metal electric circuit 3 formed on the adhesive layer 8, and an adhesive layer 8 formed on a plastic film 2 (for a cover layer) with both plastic films 2 and 4 laminated on each other with their respective adhesive layers 8 facing each other.

The flexible printed circuit, on which electronic parts such as semiconductor devices are mounted, requires precision of its shape. However, warpage called a curl as shown in Fig. 17A occurs in the manufacturing process of the flexible printed circuit. That is, in manufacturing of the flexible printed circuit, plastic films are laminated by pressurization and heat treatment of laminate, etc., and in addition, heat treatment is executed in curing a thermosetting adhesive, in a printing process, etc. When the plastic film lamination (flexible printed circuit) subjected to such heat treatment is restored to room temperature, a curl occurs. The curl occurring on the flexible printed circuit is not a simple curl like warping in one direction and is a so-called twisted curl of warping in opposite directions in two diagonal line directions on a rectangular flexible printed circuit as shown in Fig. 17B.

For example, sticking of a thick curl prevention film is proposed as a method of preventing the flexible printed circuit from curling in Japanese Patent Application No. Hei. 7-95987. However, such a method somewhat suppresses curl owing to the tare weight of the curl prevention film and is not much

14 JAN 1997

effective for fundamental curl suppression; in addition, there is a fear of impairing flexibility, an important property of the flexible printed circuit. If flexibility is impaired, a new problem that the essential property of the flexibility printed circuit cannot be satisfied occurs. Therefore, the method cannot fundamentally solve the curl problem and if curl is suppressed, the essential performance of the flexible printed circuit is not provided.

Thus, curl occurrence raises a problem from the beginning of development of the flexible printed circuit and is still an important problem to be solved at present after a lapse of about twenty years since that time. Providing sufficient flexibility of the flexible printed circuit in addition to suppressing curl occurrence is also left as an important problem to make the most of the essential performance of the flexible printed circuit.

On the other hand, a comparatively thin reinforcing plastic film (stiffener) to such a degree that it does not impair flexibility is stuck on some flexible printed circuits used at places where reasonable rigidity as well as flexibility is required, such as connectors. In this case, as shown in Fig. 26A, plastic films 2 and 4 and a reinforcing plastic film 7 used with the flexible printed circuit differ in thickness and material lot, thus the structure of the flexible printed circuit becomes asymmetrical in the cross-sectional direction. Such a flexible printed circuit of asymmetrical structure on

14 JAN 1997

which the reinforcing plastic film 7 is stuck is furthermore disadvantageous from a stand point of curl occurrence.

Further, to form flexible printed circuits, plastic films are stacked via an adhesive layer and the plastic films in stacked relation are crimped for lamination. However, since the plastic films, metal electric circuit, and the adhesive layers vary in thickness, the entire flexible printed circuit also varies in thickness; partially excessive pressure is applied to the flexible printed circuit crimped under mechanical pressure with a general press, etc., for extending the flexible printed circuit itself in a transverse direction, and the flexible printed circuits thus manufactured may vary in performance, etc., in some cases.

15

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a flexible printed circuit whose curl occurrence is prevented, and a manufacturing method therefor.

According to a first aspect of the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, wherein two plastic films of the laminated plastic films positioned on both outermost layers have the following relationship: Two ellipses of coefficient of linear expansion are created on coordinates in corresponding

14 JAN 1997

parts of film surfaces of the two plastic films by a method (A) described below and are overlapped so that they match in center point and coordinate axes X and Y. At this time, the maximum value of a linear expansion coefficient difference between the two plastic films is equal to or less than 1.4×10^{-5} ($1/^{\circ}\text{C}$):

(A) comprising the steps of defining a predetermined base point P on the film surface of the plastic film, measuring a coefficient of linear expansion at a position separate from an arbitrary axis in angle θ direction on the first and second resin films, the arbitrary axis being selected on the first and second resin films so as to pass through the base point P with the base point P as a center and direct an arbitrary direction, on the other hand, preparing a coordinate system with the arbitrary axis as a Y axis and an axis crossing the Y axis at 90 degrees as an X axis, in this coordinate system, defining an intersection of the X and Y axes as the base point P in the linear expansion coefficient measurement and magnitude of a linear expansion coefficient measurement value as distance r from the base point P, then plotting a tip point of this distance r in the measurement angle θ direction with respect to the Y axis, plotting it multiple times by changing the measurement angle θ , and drawing an analysis line throughout 360-degree directions with the base point P as the center so as to pass through average points of the plotted points for creating an ellipse.

According to the invention, there is provided a

14 JAN 1997

flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, wherein two plastic films of the laminated plastic films positioned on both outermost layers have the following relationship: When two ellipses of coefficient of linear expansion are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (A) described above and are overlapped so that they match in center point and coordinate axes X and Y, the total area of portions where the ellipses do not overlap is equal to or less than $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, wherein two plastic films of the laminated plastic films positioned on both outermost layers have the following relationship: When ultrasonic propagation velocity ellipses are created on coordinates in corresponding parts of film surfaces of the two plastic films by a method (B) described below and are overlapped so that they match in center point and coordinate axes X and Y, a shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30 degrees:

(B) comprising the steps of defining a predetermined

14 JAN 1997

base point P on the film surface of the plastic film, measuring
a ultrasonic propagation velocity at a position separate from
an arbitrary axis in angle θ direction on the first and second
resin films, the arbitrary axis being selected on the first and
5 second resin films so as to pass through the base point P with
the base point P as a center and direct an arbitrary direction,
on the other hand, preparing a coordinate system with the
arbitrary axis as a Y axis and an axis crossing the Y axis at
90 degrees as an X axis, in this coordinate system, defining an
10 intersection of the X and Y axes as the base point P in the
ultrasonic propagation velocity measurement and magnitude of a
ultrasonic propagation velocity measurement value as distance
from the base point P, then plotting a tip point of this
distance r in the measurement angle θ direction with respect to
15 the Y axis, plotting it multiple times by changing the
measurement angle θ , and drawing an analysis line throughout
360-degree directions with the base point P as the center so as
to pass through average points of the plotted points for
creating an ellipse having a crystal orientation main axis in
20 a long-axis direction and a crystal orientation subaxis in a
short-axis direction.

In the flexible printed circuit as described, the two
plastic films of the laminated plastic films positioned on both
the outermost layers may be laminated on each other with the
25 same surfaces of the two plastic films facing each other.

Further, in the flexible printed circuit as described,

14 JAN 1997

metal electric circuit is formed in at least one of two or more laminated plastic films stretched in two directions of a machine direction and a transverse direction and wherein a product of thickness and tensile modulus of the metal electric circuit is 500 kg/mm or less.

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, and having a board face on which a reinforcing plastic film is stuck, wherein a plastic film of the laminated plastic films positioned on an outermost layer on a side where the reinforcing plastic film is not stuck and the reinforcing plastic film have the following relationship: Two ellipses of coefficient of linear expansion are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (A) described above and are overlapped so that they match in center point and coordinate axes X and Y. At this time, the maximum value of a linear expansion coefficient difference between the two plastic films is equal to or less than 1.4×10^{-5} ($1/^{\circ}\text{C}$).

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being stretched in two directions of a machine direction and a transverse direction, and having a board face on which a

14 JAN 1997

reinforcing plastic film is stuck, wherein a plastic film of the laminated plastic films positioned on an outermost layer on a side where the reinforcing plastic film is not stuck and the reinforcing plastic film have the following relationship: When
5 two ellipses of coefficient of linear expansion are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (A) described above and are overlapped so that they match in center point and coordinate axes X and Y, the total area of portions where the ellipses do
10 not overlap is equal to or less than $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

According to the invention, there is provided a flexible printed circuit comprising two or more plastic films laminated on each other, the two or more plastic films being
15 stretched in two directions of a machine direction and a transverse direction, and having a board face on which a reinforcing plastic film is stuck, wherein a plastic film of the laminated plastic films positioned on an outermost layer on a side where the reinforcing plastic film is not stuck and the
20 reinforcing plastic film have the following relationship: When ultrasonic propagation velocity ellipses are created on coordinates in corresponding parts of film surfaces of the two plastic films by the method (B) described above and are overlapped so that they match in center point and coordinate
25 axes X and Y, a shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30

14 JAN 1997

degrees.

In the flexible printed circuit as described, a plurality of plastic films stacked via an adhesive layer may be temporarily crimped by a roll laminate method in stacked
5 relation and then pressurized under gas pressure in an autoclave and crimped.

According to the invention, there is provided a method of manufacturing a flexible printed circuit comprising the steps of stacking a plurality of plastic films via an adhesive
10 layer, temporarily crimping the stacked plastic films by a roll laminate method in stacked relation, and then pressurizing them under gas pressure in an autoclave, thereby crimping them.

In the above methods (A) and (B), an arbitrary axis is selected arbitrarily on the two plastic films, and a coordinate
15 system with the arbitrary axis as a Y axis and an axis crossing the Y axis at 90 degrees as an X axis is prepared. However, it is allowed to settle an axis of the machine direction of plastic film stretch as the Y axis and an axis of the transverse direction of plastic film stretch as an X axis.

20 In the invention, the coefficient of linear expansion α is derived as follows: When a plastic film is heated, it expands in response to the characteristics of the plastic film. At this time, the coefficient of linear expansion α can be found according to the following expression (1) from the change
25 ratio of the length of the plastic film, p , to temperature t at the measurement time ($\partial p / \partial t$) and the length of the film, p_0 , at

14 JAN 1997

0°C (Kagaku Binran-Kisohen II, edited by Nippon Kagakukai, published by Maruzen Shuppan).

$$\alpha = 1/p_0 \times \partial p / \partial t \quad \dots(1)$$

However, the coefficient of linear expansion α mentioned in the invention refers to that in region of glass transfer temperature of plastic film (T_g) or less. Since T_g of the plastic films to which the invention is applied is in the temperature range exceeding the room temperature (about 23°C) and a twisted curl becomes a problem in a temperature region near the room temperature, the coefficient of linear expansion at T_g or softening point or less becomes the target. T_g of polyimide films is 300°C or more, which exceeds the operating temperature range, and does not clearing appear, thus the necessity for considering T_g of polyimide films is small.

In the invention, the total area of portions where ellipses do not overlap (C) is defined by the following expression (2) representing the integral value of linear expansion coefficient square value differences ($\Delta\alpha C$). That is, in the invention, the total area of portions where ellipses do not overlap (C) is synonymous with the integral value of linear expansion coefficient square value differences ($\Delta\alpha C$). In the following expression (2), θ is a linear expansion coefficient measurement angle with the axis of the machine direction of stretch as the reference and $\Delta\alpha C (\theta)$ is defined by the following expression (3). The ellipses in the invention contain perfect circles.

14 JAN 1997

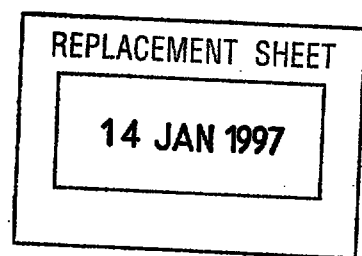
$$C = 1/2 \int_0^{2\pi} \Delta\alpha_c(\theta) d\theta \quad \dots(2)$$

$$\Delta\alpha_c(\theta) = |r_1^2(\theta) - r_2^2(\theta)| \quad \dots(3)$$

Further, the ultrasonic propagation velocity in the invention refers to a measurement value of the propagation time (s) or the propagation velocity (m/s) when a ultrasonic pulse (frequency: 25 MHz) is passed through a plastic film and propagates in the plastic film at a predetermined distance.

In the invention, the flexible printed circuit is not limited if it comprises two or more plastic films laminated (laminated and bonded) and is intended for use as a printed circuit. Therefore, in the invention, printed circuits not yet formed with metal electric circuit or those formed with a metal thin film before formation of an electric circuit pattern are also contained in the flexible printed circuits.

In the invention, the expression "both the outermost layers" of "two plastic films positioned on both the outermost layers, of laminated plastic films" does not mean both the outermost layers of the flexible printed circuit and is used to mean both the outermost layers in the plastic film laminate. Therefore, for example, if a flexible printed circuit comprises a shielding layer formed on a plastic film laminate by painting, printing, etc., the shielding layer is not contained in "both the outermost layers" in the invention. Even for a flexible printed circuit on which a reinforcing plastic film is stuck, if the reinforcing plastic film is contained in a plastic film laminate and is stuck on the board face, it forms



one of "both the outermost layers" in the invention.

In the invention, the expression "curl suppression" refers to the case where the curl degree (%) defined below becomes 5% or less. Assume that the length of the long side of the smallest rectangle in which a flexible printed circuit is inscribed is the longest length of the flexible printed circuit, L. Fig. 14 shows an example of smallest rectangle 21 in which a flexible printed circuit 1a like a substantial V-shape is inscribed. As shown here, in the flexible printed circuit 1a, the length of the long side of the rectangle 21 indicated by the dotted line becomes the longest length L. As shown in Fig. 15, one end of the flexible printed circuit 1a is fixed to a reference plane 6 and the height of the maximum warpage of the flexible printed circuit 1a from the reference plane 6, h, is found and is defined as curl amount h. The percentage of the curl amount h to the longest length of the flexible printed circuit, L, namely, $(h/L) \times 100$ is defined as the curl degree (%).

In the invention, the tensile modulus is a value indicating the rigidity of a metal thin film forming metal electric circuit and refers to elastic stress per unit elastic strain (kg/mm^2). It is measured as follows: When a predetermined load is imposed on a metal thin film (metal foil) forming metal electric circuit with a tensile tester and constant elastic strain is given, the elastic stress is measured as the tensile modulus. The tensile modulus is

14 JAN 1997

measured with metal foil. It can be used as a typical value as the tensile modulus of a metal thin film, and can be used even if a film other than metal foil, such as an evaporation film, is formed as the metal thin film of metal electric circuit. In this case, preferably the composition of metal foil used instead is made the same, the same heat history is given, and the resultant crystal state, etc., is set like the metal thin film of the actual flexible printed circuit.

Next, the technical philosophy of the invention will be discussed.

To solve the problem of curl occurrence of flexible printed circuits, the inventor et al. first carried out a detailed analysis of the cause of curl occurrence of flexible printed circuits. As a result, the inventor et al. have found that curl occurrence is caused by the linear expansion coefficient difference between plastic films. If different materials are laminated, it can be easily imagined that warpage (curl) occurs because they differ in coefficient of linear expansion. Normally, flexible printed circuits use plastic films (for example, base and cover layer films) made of the same material and therefore formerly it was considered that the plastic films made of the same material do not differ in coefficient of linear expansion. However, the inventor et al. actually measured coefficients of linear expansion in detail and found that the plastic films of each flexible printed circuit differ in coefficient of linear expansion. Nobodies in

14 JAN 1997

the flexible printed circuit field found this knowledge until the inventor et al. found it.

The inventor et al. continued to examine the linear expansion coefficient difference and found that each
5 bidirectionally stretched plastic film used with a flexible printed circuit shows anisotropy in its coefficient of linear expansion. That is, a predetermined base point P is defined on the film surface of the plastic film and the coefficient of linear expansion in angle θ direction with respect to the axis
10 of the machine direction of plastic film stretch passing through the base point P with the base point P as the center is measured. On the other hand, a coordinate system with the axis of the machine direction of plastic film stretch as a Y axis and the axis of the transverse direction of plastic film
15 stretch as an X axis is prepared. In this coordinate system, the intersection of the X and Y axes is defined as the base point P in the linear expansion coefficient measurement and the magnitude of the linear expansion coefficient measurement value is defined as distance r from the base point P, then the tip
20 point of this distance r is plotted in the measurement angle θ direction with respect to the Y axis. It is plotted multiple times by changing the measurement angle θ and an analysis line is drawn throughout 360-degree directions with the base point P as the center so as to pass through average points of the
25 plotted points. Then, an ellipse as shown in Fig. 1 is provided. In the figure, MD denotes the axis of the machine

14 JAN 1997

direction of stretch (Y axis) and TD denotes the axis of the transverse direction of stretch (X axis). Solid line arrow A indicates the crystal orientation main axis of the plastic film and dotted line arrow B indicates the crystal orientation subaxis of the plastic film. Also, θ is a linear expansion coefficient measurement angle with respect to MD. r represents the linear expansion coefficient magnitude as a distance from the base point P and has a tip plotted with O. Such plotting is called polar coordinate plotting. As seen from the ellipse provided by the polar coordinate plotting (see Fig. 1), normally the crystal orientation main axis of the plastic film (arrow A) becomes a direction inclined from the machine direction of stretch (MD) and the coefficients of linear expansion also vary depending on the direction (anisotropy) because of anisotropy of the crystal orientation. Resultantly, it is considered that the analysis line of the coefficients of linear expansion of the bidirectionally stretched plastic film shows an ellipse.

Next, as shown in Fig. 2, when ellipses on coordinates provided for two stretched plastic films made of the same material are overlapped so that they match in center point and coordinate axes, it is seen that the two plastic films differ in crystal orientation direction and coefficient of linear expansion in parts (directions). Normally, a raw material film is stretched in two directions, from which plastic films used with a flexible printed circuit are cut out to a predetermined

14 JAN 1997

size. Therefore, the reason why the plastic films made of the same material differ in linear expansion coefficient may be that the stress applied when the plastic film is stretched in two directions varies from one part of the plastic film to another.

The inventor et al. examined a method for controlling the linear expansion characteristic difference between the plastic films provided when ellipses created by polar coordinate plotting are overlapped and suppressing curl occurrence of flexible printed circuits. In the process, the inventor et al. hit on an idea of using indexes of the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) and repeated various experiments based on the idea. Resultantly, the inventor et al. have found that if the maximum value of the linear expansion characteristic difference ($\Delta\alpha$) provided when ellipses created for two plastic films positioned on both the outermost layers, of two or more laminated plastic films making up a flexible printed circuit are overlapped is equal to or less than 1.4×10^{-5} ($1/^\circ\text{C}$), curl occurrence of the flexible printed circuit is suppressed. Likewise, the inventor et al. have found that if the total area of the portions where the ellipses do not overlap when they are overlapped (C) is set equal to or less than 6.5×10^{-10} [$(1/^\circ\text{C}) \times (1/^\circ\text{C})$], curl occurrence of the flexible printed circuit is also suppressed.

The point to be noted is that only the two plastic

14 JAN 1997

films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit need to satisfy at least one of the two conditions. Therefore, a plastic film positioned on an intermediate layer need not be considered.

Next, examples of the experiment results from which the predetermined values were derived are shown in graphs of Figs. 4 and 5. In the experiments, the curl amounts were measured by the above-described method and the coefficients of linear expansion were measured by TMA (thermal mechanical analysis). The maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) were derived by a method described later.

The graph of Fig. 4 represents the relationship between the ratio between the curl amount and length [curl degree (%)] and the maximum value of the linear expansion coefficient difference ($\Delta\alpha$). As shown here, it is seen that both indicate a linear relationship and that the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) at which curl occurrence is reliably suppressed (the curl degree is 5% or less) is 1.4×10^{-5} ($1/^\circ\text{C}$).

On the other hand, the graph of Fig. 5 represents the relationship between the ratio between the curl amount and length [curl degree (%)] and the total area of portions where ellipses do not overlap (C). As shown here, it is seen that both indicate a relationship like a quadratic curve and that

14 JAN 1997

the total area of portions where ellipses do not overlap (C) at which curl occurrence is reliably suppressed (the curl degree is 5% or less) is $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

5 The two indexes of the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) can and should be used at the same time.

10 Further, the inventor et al. thought that an index for furthermore facilitating control of the linear expansion characteristic difference might exist and repeated examination based on the knowledge that anisotropy of the coefficients of linear expansion as described above is caused by the fact that the stress applied when a plastic film is stretched in two directions varies from one part of the plastic film to another and thus the stretch coefficient varies from one part to another. The inventor et al. supposed that since a bidirectionally stretched plastic film is high in crystal orientation degree in high stretch coefficient direction and the material strength of the plastic film itself raises, its 15 Young's modulus might also increase. Further, since the Young's modulus of each plastic film (E) and the ultrasonic propagation velocity in the plastic film (S) show a correlation as indicated by general expression (4) given below, the inventor et al. hit on an idea that there might be a 20 correlation between the coefficient of linear expansion (α) and the ultrasonic propagation velocity (S), and repeated various

25

14 JAN 1997

experiments based on the idea. Resultantly, the inventor et al. have found that the ultrasonic propagation velocity (S) and the coefficient of linear expansion (α) of a bidirectionally stretched plastic film show an extremely good correlation and that the ultrasonic propagation velocity (S) can be used as an index indicating the coefficient of linear expansion (α).

$$E \propto \rho S^2 \quad \dots(4)$$

where ρ is the plastic film density.

An example of the experiment results from which the correlation was derived is shown in a graph of Fig. 34. In the experiment, the coefficients of linear expansion were measured by the above-mentioned TMA (thermal mechanical analysis) and the ultrasonic propagation velocities were measured with SST [sonic sheet tester, ultrasonic propagation velocity measuring instrument (on sale from Nomura Shoji Kabusikigaisha)]. As shown in Fig. 34, it is seen that both indicate a linear relationship and shows an extremely good correlation.

The inventor et al. continued to examine the ultrasonic propagation velocities and can recognize that bidirectionally stretched plastic films used with flexible printed circuits show anisotropy in the ultrasonic propagation velocities as with the linear expansion coefficients. That is, when a predetermined base point P was defined on the film surface of a plastic film, a polar coordinate system was set, ultrasonic propagation velocities were measured throughout 360-degree directions with the base point P as the center, and an analysis

14 JAN 1997

line was drawn as in the above-described linear expansion coefficient measurement, an ellipse as shown in Fig. 27 was provided on the coordinates. At this time, arrow A in the long-axis direction of the ellipse indicates the crystal orientation main axis of the plastic film and likewise arrow B in the short-axis direction of the ellipse indicates the crystal orientation subaxis of the plastic film. As seen from the ellipse provided by the polar coordinate plotting (see Fig. 27), the crystal orientation main axis of the plastic film (arrow A) becomes a direction inclined from the machine direction of stretch (MD) and the ultrasonic propagation velocities also show anisotropy because of anisotropy of the crystal orientation.

The inventor et al. examined a method for controlling the ultrasonic propagation velocity (namely, linear expansion characteristic) difference between the plastic films provided when ellipses created by polar coordinate plotting are overlapped and suppressing curl occurrence of flexible printed circuits. Resultantly, the inventor et al. have found that when ellipses created for two plastic films positioned on both the outermost layers, of two or more laminated plastic films making up a flexible printed circuit are overlapped, as shown in Fig. 28, if the shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30 degrees, curl occurrence of the flexible printed circuit is suppressed.

14 JAN 1997

A graph of Fig. 29 represents the relationship between the ratio between the curl amount and length [curl degree (%)] and the shift angle difference between crystal orientation main axes ($\Delta\theta$). As shown here, it is seen that both indicate a linear relationship and that the maximum value of the shift angle difference between crystal orientation main axes ($\Delta\theta$) at which curl occurrence is reliably suppressed (the curl degree is 5% or less) is 30 degrees.

The shift angle difference between crystal orientation main axes ($\Delta\theta$) can be used instead of the two indexes described above of the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C), and two or all of them can also be used together.

If the shift angle difference between crystal orientation main axes ($\Delta\theta$) is used, only the two plastic films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit need to satisfy the condition and a plastic film positioned on an intermediate layer need not be considered as in the case where the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area of portions where ellipses do not overlap (C) are used as indexes.

Hereupon, as described above, one of the three conditions, that is, the maximum value of the linear expansion coefficient difference ($\Delta\alpha$), the total area of portions where

14 JAN 1997

ellipses do not overlap (C), and the maximum value of the shift angle difference between crystal orientation main axes ($\Delta\theta$) are satisfied by only the two plastic films positioned on both the outermost layers. Therefore, the directions of the coordinate axes of the ellipses may be selected arbitrarily on the plastic film. In other words, the Y axis of the coordinate is not limited to the machine direction of the plastic film. After the Y axis and the X axis are settled in the arbitrary directions to prepare the coordinate system, the ellipses are created on such coordinates. The two plastic films positioned on both the outermost layers may be selected by using the above ellipse and three conditions.

Next, in the invention, to laminate two or more plastic films, the two plastic films positioned on both the outermost layers may have the same surfaces thereof faced each other. Normally, the surface and rear face of a plastic film cut out from a raw material film stretched in two directions differ plainly in surface (rear face) state of wet property, coarseness, etc. Therefore, if the two plastic films positioned on both the outermost layers are placed in a state in which the same surfaces face each other as described above, the rear faces of the two plastic films exist on the surface and rear face of the flexible printed circuit and the surface and rear face of the flexible printed circuit become the same state. This eliminates the need for considering the difference between the surface and rear face to apply various treatments

14 JAN 1997

to the flexible printed circuit; the effect of enhancing work efficiency, etc., is produced.

In the invention, the surface and rear face of a plastic film are determined appropriately; for example, to cut a raw material film, the upper face can be made the surface and the lower face can be made the rear face. For example, as shown in Fig. 21, the upper face of a raw material film 10 is made a surface 9 and two plastic films 2 and 4 are cut out from the raw material film. Each of the plastic films 2 and 4 comprises the same surface 9 as the raw material film 10. As shown in Fig. 22A, the plastic films 4 and 2 are overlapped with their surfaces 9 facing each other. Fig. 22B is a sectional view to show a state of overlapping the plastic films 2 and 4 with their surfaces 9 facing each other.

Next, in the invention, to prevent curl occurrence and provide sufficient flexibility, the physical property of metal electric circuit of a flexible printed circuit is specified by a special index (K) originally found by the inventor et al. That is, metal electric circuit, which is the main component of a flexible printed circuit, largely affects flexibility of the flexible printed circuit. Then, the inventor et al. carried out a detailed analysis on the cause for producing flexibility for the metal electric circuit, and found that the tensile modulus and thickness of the metal electric circuit are the main factors affecting flexibility of the flexible printed circuit. When continuing furthermore examination on the

14 JAN 1997

relationship between the two factors, the inventor et al. hit on an idea that the product of the tensile modulus and thickness (K) can become one of indexes on flexibility of the flexible printed circuit. When continuing various experiments based on the idea, the inventor et al. recognized that the index (K) can be used universally for flexibility of the flexible printed circuit regardless of the type of metal electric circuit as expected. Based on the index (K), the inventor et al. have found that if the product of the tensile modulus and thickness (K) is set to 500 kg/mm or less in the relationship with the two conditions of the coefficients of linear expansion of plastic films, curl occurrence prevention means described above, curl occurrence can be prevented and sufficient flexibility can be provided.

Next, in the invention, in a flexible printed circuit on which a reinforcing plastic film is stuck, the linear expansion characteristic difference between a plastic film of laminated plastic films on the side where the reinforcing plastic film is not stuck and the reinforcing plastic film is controlled for suppressing curl occurrence. That is, in the flexible printed circuit on which a reinforcing plastic film is stuck, the reinforcing plastic film and other plastic films differ in thickness, etc., and the structure of the flexible printed circuit becomes asymmetrical with respect to the cross-section direction, thus the flexible printed circuit becomes prone to curl as compared with normal flexible printed circuits

14 JAN 1997

on which no reinforcing plastic film is stuck. If a curl of the flexible printed circuit itself is suppressed, the flexible printed circuit may again curl by stacking a reinforcing plastic film thereon. However, the inventor et al. have found that in the cases, if the maximum value of the linear expansion characteristic difference ($\Delta\alpha$) provided when ellipses created by polar coordinate plotting for the plastic film positioned on the outermost layer on the side where the reinforcing plastic film and the reinforcing plastic film are overlapped is equal to or less than 1.4×10^{-5} ($1/^\circ\text{C}$), curl occurrence of the flexible printed circuit on which the reinforcing plastic film is stuck is suppressed.

Likewise, the inventor et al. have found that if the total area of the portions where the ellipses do not overlap when they are overlapped (C) is set equal to or less than 6.5×10^{-10} [$(1/^\circ\text{C}) \times (1/^\circ\text{C})$], curl occurrence of the flexible printed circuit on which the reinforcing plastic film is stuck is also suppressed. Likewise, the inventor et al. have found that when the ellipses created by polar coordinate plotting are overlapped, if the shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) is within 30 degrees, curl occurrence of the flexible printed circuit on which the reinforcing plastic film is stuck is suppressed.

Next, in the invention, the raw material plastic film characteristics are applied for preventing curls from occurring in manufacturing flexible printed circuits and enhancing the

14 JAN 1997

manufacturing efficiency. That is, if either of the two conditions is satisfied, curl occurrence can be prevented, but it is troublesome to measure the linear expansion coefficient differences for each plastic film in manufacturing flexible printed circuits. Then, to solve this problem, the inventor et al. examined the linear expansion coefficient characteristics of raw material plastic films and found that there was given regularity. Then, the linear expansion coefficient ellipses of the parts of a raw material film are previously examined, the linear expansion coefficient characteristics are grasped and standardized, and parts cut out from the raw material plastic film and a combination of cut plastic films are previously determined. In doing so, the maximum value of the linear expansion coefficient difference and the total area of portions where the ellipses do not overlap can be set to the predetermined values or less without creating linear expansion coefficient ellipses for each plastic film. As a result, the production efficiency of flexible printed circuits with curl occurrence suppressed can be improved.

Next, the invention relates to a flexible printed circuit wherein plastic films laminated via an adhesive layer are temporarily crimped by a roll laminate method and then pressurized under gas pressure in an autoclave and crimped, and a manufacturing method therefor. That is, to manufacture a flexible printed circuit, when an adhesive layer is formed on each plastic film and then they are stacked and laminated, the

14 JAN 1997

flexible printed circuit is pressurized in a heating state in stacked relation to remove bubbles occurring in the adhesive layers. After the flexible printed circuit is temporarily crimped by a roll laminate method, it is sealed in an autoclave and pressurized under gas pressure for crimping, whereby the flexible printed circuit is crimped under isotropic pressure produced by the gas pressure. Thus, even if the flexible printed circuit itself varies in thickness, etc., it is pressurized on the full face under uniform gas pressure and no excessive force is applied to the materials of the plastic films, metal electric circuit, etc.,; the flexible printed circuit itself does not extend in the transverse direction or its characteristics are not impaired.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a polar coordinate plotting chart representing a linear expansion coefficient ellipse of a bidirectionally stretched plastic film;

Fig. 2 is a polar coordinate plotting chart of overlapping two linear expansion coefficient ellipses;

Fig. 3 is a schematic diagram to show linear expansion coefficient ellipses in parts in the width direction of a bidirectionally stretched plastic film;

Fig. 4 is a graph to show the relationship between the maximum values of linear expansion coefficient differences and

14 JAN 1997

curl degrees;

Fig. 5 is a graph to show the relationship between the integral values of linear expansion coefficient square value differences ($\Delta\alpha c$) and curl degrees;

5 Fig. 6 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Embodiment 1;

Fig. 7 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Comparison 1;

10 Fig. 8 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Embodiment 2;

Fig. 9 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Comparison 2;

Fig. 10 is a polar coordinate plot chart of overlapping three linear expansion coefficient ellipses in Embodiment 3;

15 Fig. 11 is a polar coordinate plot chart of overlapping three linear expansion coefficient ellipses in Comparison 3;

Fig. 12 is a polar coordinate plot chart of overlapping two linear expansion coefficient ellipses in Embodiments 4 and 5 and Comparisons 4 and 5;

20 Fig. 13 is a sectional view to show the structure of a flexible printed circuit with three plastic films laminated;

Fig. 14 is a plan view to show a flexible printed circuit formed like substantial V-shape;

25 Fig. 15 is an illustration of curl amount measurement of a flexible printed circuit;

Fig. 16A is a sectional view to show the structure of

14 JAN 1997

a flexible printed circuit and 16B is a sectional view to show the structure of a flexible printed circuit having an adhesive layer formed on the surface of each of two plastic films;

5 Fig. 17A is a sectional view of a flexible printed circuit on which a curl occurs and 17B is an illustration to show a state in which a twisted curl occurs on a flexible printed circuit;

10 Fig. 18A is a sectional view to show a state in which an adhesive layer is formed on a base film and then copper foil is placed on the adhesive layer, 18B is a sectional view to show a state in which the copper foil is formed to electric circuit, 18C is a sectional view to show a state of laminating plastic films for base and cover layers, and 18D is a sectional view to show the structure of a flexible printed circuit thus
15 provided;

Fig. 19 is a sectional view to show a state of manufacturing a flexible printed circuit of a 3-film-layer structure;

20 Fig. 20 is a sectional view to show the structure of a flexible printed circuit of a 3-film-layer structure;

Fig. 21 is an illustration to show a state of cutting out plastic films from a raw material film;

25 Fig. 22A is a perspective view to show a state of laminating two plastic films with their surfaces facing each other and 22B is a sectional view to show a state of laminating two plastic films with their surfaces facing each other;

14 JAN 1997

Fig. 23 is a sectional view to show the structure of a flexible printed circuit with metal foil pieces laminated;

Fig. 24 is an illustration to show a measuring instrument of flexibility of flexible printed circuits;

5 Fig. 25 a plan view to show a flexible printed circuit formed like substantial V-shape;

Fig. 26A is a sectional view to show the structure of a flexible printed circuit on which a reinforcing film is stuck and 26B is a sectional view to show the structure of a flexible
10 printed circuit comprising an adhesive layer formed on the surface of each of plastic films on which a reinforcing plastic film is stuck;

Fig. 27 is a polar coordinate plot chart representing a ultrasonic propagation velocity ellipse of a bidirectionally
15 stretched plastic films;

Fig. 28 is a polar coordinate plot chart of overlapping two ultrasonic propagation velocity ellipses;

Fig. 29 is a graph to show the relationship between shift angle difference between crystal orientation main axes
20 ($\Delta\theta$) and curl degree (%);

Fig. 30 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Embodiment 6;

Fig. 31 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Comparison 6;

25 Fig. 32 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Embodiment 7;

14 JAN 1997

Fig. 33 is a polar coordinate plot chart of overlapping three ultrasonic propagation velocity ellipses in Comparison 7;

Fig. 34 is a graph to show the relationship between linear expansion coefficients and ultrasonic propagation velocities;

Fig. 35 is an illustration to show a state when a flexible printed circuit on which a reinforcing plastic film is stuck is crimped by a heat press; and

Fig. 36 is a schematic diagram to show linear expansion coefficient ellipses in parts in the width direction of a bidirectionally stretched plastic film.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Next, the invention will be discussed specifically.

A flexible printed circuit of the invention comprises two or more plastic films laminated on each other, the plastic films being manufactured by bidirectional stretch, and normally at least one of the two or more plastic films is formed with metal electric circuit.

For example, a polyimide film, a polyester nitrile film, a polyester sulfone film, a polyethylene terephthalate film, a polyvinyl chloride film and polyethylene naphthalate film can be listed as the plastic film types, among which the polyethylene terephthalate film, polyethylene naphthalate film and polyimide film are preferred totally considering heat resistance, dimension stability, electric characteristics,

14 JAN 1997

mechanical strength characteristics, chemical resistance, costs, etc. The plastic film normally is 0.01 to 0.3 mm thick and preferably 0.025 to 0.125 mm thick.

5 With flexible printed circuits on which a reinforcing plastic film is stuck, films of various materials manufactured by bidirectional stretch like those listed above are used as the reinforcing plastic films and normally are 0.025 to 0.500 mm thick and preferably 0.125 to 0.350 mm thick. However, the reinforcing plastic films as thick as or thicker than other
10 films which constitute the flexible printed circuit itself are used.

It is appropriate to stretch the bidirectionally stretched plastic film generally 1.5 to 15 times and preferably 2 to 9 times in a machine direction and 3 to 8 times in a
15 transverse direction.

Metal such as copper, gold, stainless, aluminum, and nickel and alloys thereof can be listed as the types of metal of the metal electric circuitry, among which copper and a copper alloy are preferred totally considering flexibility,
20 workability, electric characteristics, costs, etc. The metal electric circuit normally is 0.002 to 0.100 mm thick and preferably 0.005 to 0.070 mm thick. Further, when elasticity coefficient is measured in a foil state, it normally is 2000 to 20000 kg/mm² and preferably 4000 to 12000 kg/mm². For example,
25 the elasticity coefficient can be measured conforming to ASTM D-882-83 with TENSILON TESTER (tensile tester). To measure the

14 JAN 1997

elasticity coefficient of metal electric circuit or a metal thin film in a flexible printed circuit completed as a product, a semi-finished product before pattern formation, or the like, additives of plastic films, adhesives, etc., are removed by a method such as plasma etching or excimer laser beam machining for leaving the metal electric circuit or metal thin film only, and the elasticity coefficient thereof in the state can be measured according to the above-mentioned method.

The invention uses an index of the product of the thickness and elasticity coefficient of metal electric circuit (K) so as to enable universal comparison in various metals. As the value, normally, foil metal takes a value of about 4 kg/mm (thickness: 0.002 mm x elasticity coefficient: 2000 kg/mm²) to 2000 kg/mm (thickness: 0.100 mm x elasticity coefficient: 20000 kg/mm²); to suppress a curl of the flexible printed circuit and provide flexibility thereof, desirably it lies in the range of 20 to 500 kg/mm and more preferably 30 to 250 kg/mm. For the elasticity coefficient values, the measurement value in the foil state as described above typifies the elasticity coefficient of metal thin film and if the composition, heat history, and crystal state virtually equal, the same value is taken even if metal thin films are other than metal foil (for example, evaporation film, plating coat, etc.,).

Normally, an adhesive is used to laminate (laminate and bond) two or more plastic films. A thermosetting adhesive (for

14 JAN 1997

example, an epoxy rubber adhesive or a polyester adhesive comprising an isocyanate curing agent added to a polyester resin), a thermoplastic adhesive (for example, a synthetic rubber adhesive), and a tackiness agent (pressure-sensitive adhesive, for example, an acrylic tackiness agent) can be listed as the adhesive, among which the thermosetting adhesive is preferred because it is good in characteristics of an adhesion force, heat resistance, moisture and heat resistance, workability, durability, etc. To laminate a reinforcing plastic film, the various adhesives are also used.

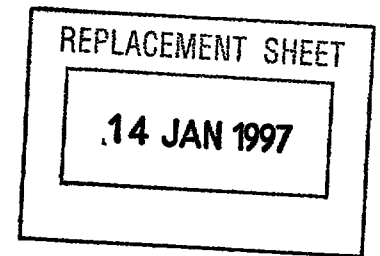
Next, a manufacturing method of the flexible printed circuit of the invention will be discussed.

The manufacturing method of the flexible printed circuit of the structure wherein the two plastic films 2 and 4 shown in Fig. 16B are laminated and one of the plastic films is formed with the metal electric circuit 3 will be described as an example. First, two plastic films 2 and 4 are prepared. Generally, polyethylene terephthalate is used as the plastic films. As described above, the two plastic films 2 and 4 need to satisfy at least one of the conditions that when ellipses of coefficient of linear expansion are overlapped, the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) should be equal to or less than 1.4×10^{-5} ($1/^\circ\text{C}$), that the total area of the portions other than the overlap (C) should be equal to or less than 6.5×10^{-10} [$(1/^\circ\text{C}) \times (1/^\circ\text{C})$], or that when ellipses of ultrasonic propagation velocities are

14 JAN 1997

overlapped, the shift angle difference between crystal orientation main axes of the ellipses ($\Delta\theta$) should be within 30 degrees. The plastic films 2 and 4 of the same thickness are used, whereby curl occurrence can be prevented more efficiently.

First, as shown in Fig. 18A, an adhesive layer 8 is formed on the surface of the plastic film 4 for the base layer, for example, by applying an adhesive onto the plastic film 4, then drying or by stacking an adhesive applied onto a separator on the plastic film 4, then removing the separator. The adhesive layer 8 normally is 0.003 to 0.2 mm thick and preferably 0.005 to 0.05 mm thick. Next, a metal thin film 3a is formed on the adhesive layer 8, for example, by placing metal foil such as copper foil on the adhesive layer 8 and roll laminate. The metal thin film 3a can also be formed by an electroplating method or a sputtering method, in which case it can be formed directly on the plastic film 4 without forming the adhesive layer 8. As shown in Fig. 18B, a known method such as a printing, subtractive, or additive method is used to treat the metal thin film 3a for forming metal electric circuit 3 in a predetermined circuit pattern. On the other hand, plastic film 2 for cover layer is prepared and an adhesive layer 8 is formed on the surface of the plastic film 2 in a similar manner to that described above. If the adhesive layer 8 is formed on the rear face of the plastic film 4 for the base layer, the adhesive layer 8 is formed on the rear face of the



plastic film 2 for the cover layer.

As shown in Fig. 18C, both the plastic film 4 for the base layer and the plastic film 2 for the cover layer are stacked with their surfaces facing each other and laminated (laminated and bonded) in the stacked relation, for example, by a crimping method with a heat press or by a laminate method of applying at least heat or pressure after temporary crimping by rolling and laminating. The laminating method and conditions are determined appropriately by the types of plastic films, adhesives, etc.

The flexible printed circuit as shown in Figs. 18D or 16B can be thus manufactured. The pressure and temperature conditions common to the crimping method and the roll laminate method in the laminating normally are 40°C to 300°C x 1 to 100 kg/cm² and preferably 50°C to 200°C x 8 to 70 kg/cm².

In the laminating, if the plastic films in the stacked relation are temporarily crimped by the roll laminate method and then pressurized under gas pressure in an autoclave and crimped, the flexible printed circuit is crimped under uniform pressure over the full face by isotropic pressure of the gas pressure; even if the flexible printed circuit itself varies in thickness, etc., the materials of the plastic films, metal electric circuit, etc., are not strained. With the flexible printed circuit thus manufactured, for the metal electric circuit, the plastic films and adhesive layers of insulation layers vary less in thickness and high-frequency

14 JAN 1997

characteristics of relative permittivity (dielectric constant), etc., as a complex of the plastic films and adhesive layers become stable. The above described method so as to pressurize under gas pressure is more excellent than the heat press or the like in the following points, that is, it is hardness to put traces caused by minute dust, foreign material, etc., and has the effect of leading to enhancement of quality, performance, etc.

The relative permittivity of the flexible printed circuit manufactured by the above-described method (ratio of permittivity of measured substance to permittivity in vacuum) can be evaluated by the following method: It can be measured by a method defined in JIS C6481. When the relative permittivity of each of the plastic films and adhesive layers is measured separately, the relative permittivity as a complex of the plastic films and adhesive layers generally is found by the following expression (5):

$$\epsilon = \frac{(d_1 + d_2)\epsilon_1\epsilon_2}{d_1\epsilon_2 + d_2\epsilon_1} \quad \dots(5)$$

where d_1 and ϵ_1 are thickness and relative permittivity of the plastic film and d_2 and ϵ_2 are those of the adhesive layer.

In the crimping in the autoclave described above, various gases, such as nitrogen gas, argon gas, helium gas, and air (atmosphere), are used as gases introduced into the autoclave; particularly nitrogen gas is preferred from standpoints of safety, costs, and easily providing a high

14 JAN 1997

pressure by vaporizing liquid because it has a relatively high boiling point and is available as liquid. As conditions for crimping, the pressure condition normally is 1 to 30 kg/cm² and preferably about 5 to 20 kg/cm² and the temperature condition normally is 40°C to 300°C and preferably about 50°C to 200°C.

On the other hand, a flexible printed circuit on which a reinforcing plastic film is stuck is manufactured as follows:

First, as described above, an adhesive layer 8 is formed on the surface of a plastic film 4 for a base layer and metal electric circuit 3 like that mentioned above is formed on the adhesive layer 8. Next, a plastic film 2 for a cover layer is prepared and an adhesive layer 8 is formed on the surface of the plastic film 2 (see Fig. 18C). On the other hand, a reinforcing plastic film 7 formed on the surface with an adhesive layer 8 is prepared and the plastic film 4 for the base layer and the plastic film 2 for the cover layer are stacked on the top of the reinforcing plastic film 7. Next, in stacked relation, they are crimped by the heat press method or roll laminate method as described above, providing a flexible printed circuit on which the reinforcing plastic film is stuck, as shown in Fig. 26B. When the flexible printed circuit on which the reinforcing plastic film is stuck is thus manufactured, if the lamination is temporarily crimped by the roll laminate method and then pressurized under gas pressure in an autoclave and crimped, particularly an excessive load imposed on the materials is reduced. That is, to stick a

14 JAN 1997

reinforcing plastic film by the heat press method, stress concentration occurs on the flexible printed circuit itself at an end 30 of the reinforcing plastic film 7, as shown in Fig. 35, and metal electric circuit is easily broken, damaged, etc. However, if the lamination is pressurized under gas pressure in the autoclave, defects as described above are removed and good properties of enhancement of durability, etc., can be provided.

The measurement method of the coefficient of linear expansion of a plastic film or reinforcing plastic film is a direct measurement method by TMA or a ultrasonic propagation velocity measurement method with SST, as described above. Particularly, the method using the ultrasonic propagation velocities takes an extremely short measurement time of about two minutes as compared with the TMA method, is substantially at the same level of measurement accuracy as the TMA method, and has the advantage of no skill required. The measurement temperature in SST measurement is about $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

The above-mentioned linear expansion coefficient difference ($\Delta\alpha$) can be derived as follows: First, a linear expansion coefficient ellipse for a plastic film is created by polar coordinate plotting according to the procedure described above (see Fig. 1). The radius of the ellipse, r , can be represented as a function of linear expansion coefficient measurement angle θ (rad), as in Expression (6) below. In Expression (6), ξ denotes an eccentricity and is defined by Expression (7) below. a is the long-axis radius of the ellipse

14 JAN 1997

and becomes the maximum value of r ($r_{\max}$). On the other hand, b is the short-axis radius of the ellipse and becomes the minimum value of r ($r_{\min}$).

5

$$r = r(\theta) = \sqrt{\frac{b^2}{1 - \xi^2 \cos^2 \theta}} \quad \dots (6)$$

$$\xi = \frac{\sqrt{a^2 - b^2}}{a} \quad \dots (7)$$

10

where a : long-axis radius of ellipse (maximum value of r ; $r_{\max}$)

b : short-axis radius of ellipse (minimum value of r ; $r_{\min}$)

15

Assuming that the radiuses of ellipses for two plastic films 2 and 4 positioned on both outermost layers are r_1 and r_2 , the linear expansion coefficient difference ($\Delta\alpha$) can be represented by the following expression (8):

$$\Delta\alpha = | \Delta\alpha(\theta) | = | r_1(\theta) - r_2(\theta) | \quad \dots (8)$$

20

According to Expression (8), comparison is made over 0 to 360 degrees (0 to 2π rad) with respect to the measurement angle θ and the maximum value is the maximum value ($\Delta\alpha_{\max}$) of the linear expansion coefficient difference ($\Delta\alpha$) between the two plastic films. The maximum value ($\Delta\alpha_{\max}$) can also be derived by using a computer with Expressions (6), (7), and (8) programmed.

25

14 JAN 1997

On the other hand, the total area (C) of portions where the ellipses do not overlap can be derived, for example, according to cumulative expression (9), which is one of approximate expressions of Expression (2) for defining the area (C). Approximating of Expression (2) by other expressions is not limited.

$$C \approx 1/2 \sum_{n=1}^m \left[\frac{\Delta\alpha_c(n \times \Delta\theta) + \Delta\alpha_c\{(n-1) \times \Delta\theta\}}{2} \right] \Delta\theta \quad \dots(9)$$

where $m = (2\pi/\Delta\theta)$

To use cumulative expression (9), normally m takes 120 to 2880 values and preferably 360 to 1080 values, and $\Delta\theta=2\pi/m$.

In selection of the plastic films, the most basic method is to measure the coefficient of linear expansion for each plastic film and execute polar coordinate plotting for creating a linear expansion coefficient ellipse to check whether or not the conditions are satisfied; but it lacks practicality. Then, to solve this problem, the present inventor et al. examined linear expansion coefficient characteristics at points of a raw material film of plastic films and found out that there is given regularity in the film width direction (transverse direction of stretch).

Fig. 3 shows linear expansion coefficient characteristics in the width direction of a raw material film 5 bidirectionally stretched. In the figure, the raw material film 5 is divided into nine parts in the width direction

14 JAN 1997

thereof and the parts are represented by relative positions (-4, -3, -2, -1, 0, 1, 2, 3, and 4) with the center as the reference (0). Linear expansion coefficient ellipses are shown in the parts and crystal orientation main axes are indicated by dotted line arrows. MD denotes the machine direction of stretch and TD denotes the transverse direction of stretch. As shown in Fig. 3, the crystal orientation main axis and the machine direction of stretch match at the center of the raw material film 5 and as the part of the raw material film 5 deviates from the center, its corresponding crystal orientation main axis shifts from the machine direction of stretch (the corresponding dotted line arrow is inclined with respect to the MD direction). The point to be noted is that the crystal orientation main axes shift from the machine direction of stretch symmetrically. Specifically, in Fig. 3, the crystal orientation main axes in the parts at relative positions (1) and (-1), (2) and (-2), (3) and (-3), and (4) and (-4) are symmetrical. Using the fact, minus (-) relative positions are used for cover layers (C/L) and plus (+) relative positions are used for base layers (B/S). As shown in the figure, when symmetrical parts (relative positions) are extracted and laminated with their surfaces facing each other, the crystal orientation main axes substantially match and the maximum value of the linear expansion coefficient difference ($\Delta\alpha$) and the total area (C) of portions where the ellipses do not overlap fall below the predetermined values.

14 JAN 1997

On the other hand, as a second method, a raw material plastic film is divided into two parts (a cover layer cut portion and a base layer cut portion) in parallel with the length direction of the plastic film, from which cover and base layer plastic films are cut out in parallel with the length direction and the cover and base layer plastic films having a relationship satisfying at least one of the two conditions are placed on both the outermost layers of the plastic film laminate.

Fig. 36 shows coefficient of linear expansion characteristics as similar to Fig. 3. In Fig. 36, the raw material film 5 is divided into eight parts and the parts are represented by relative positions (-4, -3, -2, -1, 1, 2, 3 and 4) with the center as a center line CL. The relative linear expansion coefficient difference is not so large in the adjacent portion (-3, -2, -1, 1, 2 and 3) of the center line CL of the raw material film 5. As shown in Fig. 36, relative positions (-3) to (-1) are used for the cover layer cut portion and relative positions (1) to (3) are used for the base layer cut portion. In the case that two layers which is selected out from the above are positioned on the outer most layers and the flexible printed circuit is made, the occurrence of curling is prevented. In Fig. 36, a plastic film for cover layer cut out from the relative position (-3) and a plastic film for base layer cut out from the relative position (2) are laminated.

Dividing of the raw material plastic film is shown as

14 JAN 1997

an example; in fact, it is determined appropriately by the size, stretch degree, etc., of the raw material plastic film. For example, for a raw material plastic film 2 to 6 m wide, if the division width (band width) is set to 200 to 1000 mm, the number of divisions becomes six to ten. Specifically, for example, if the raw material plastic film is 2 m wide, it can be divided into 10 parts (divisions) with the division width (band width) set to 200 mm. If the raw material plastic film is 6 m wide, it can be divided into six parts (divisions) with the division width (band width) set to 1000 mm. For example, if the raw material plastic film is 5 m wide, preferably it can be divided into 10 parts (divisions) with the division width (band width) set to 500 mm for the reason of good workability.

Therefore, the linear expansion coefficient ellipses of the parts of a raw material film are previously examined, the linear expansion coefficient characteristics are grasped and standardized, predetermined parts of the raw material film are extracted, and the parts with the linear expansion coefficient ellipses substantially symmetric are combined. In doing so, the maximum value of the linear expansion coefficient difference and the total area of portions where the ellipses do not overlap can be set to predetermined values or less without creating linear expansion coefficient ellipses each time a plastic film is selected. As a result, the production efficiency of flexible printed circuits with curl occurrence suppressed can be improved.

14 JAN 1997

Which of the first and second methods is selected for manufacturing flexible printed circuits is determined appropriately by manufacturing conditions, etc. That is, the second method is excellent as compared with the first method from the viewpoint of the manufacturing efficiency; the latter is excellent as compared with the former from the viewpoint of curl occurrence prevention. Therefore, considering the points, either of the two methods can be selected depending on which of the manufacturing efficiency and curl occurrence prevention takes precedence.

The two plastic films positioned on both the outermost layers of plastic film laminates are laminated on each other with their surfaces facing each other, whereby there are provided advantages of enhancing the adhesion strength and eliminating the need for considering the difference between the surface and rear face of the flexible printed circuit. That is, the surface and rear face of a plastic film cut out from a raw material plastic film stretched in two directions differ plainly in surface (rear face) state of wet property, coarseness, etc. Therefore, if two plastic films are placed on both the outermost layers in a state in which the same surfaces face each other, the rear faces of the two plastic films exist on the surface and rear face of the flexible printed circuit and the surface and rear face of the flexible printed circuit become the same state. This eliminates the need for considering the difference between the surface and rear face to

14 JAN 1997

apply various treatments to the flexible printed circuit. Specifically, for example, it becomes less necessary to take notice of the difference between the surface and rear face of the flexible printed circuit in characteristics such as printability on the flexible printed circuit, wear resistance, sliding property, intimate contact with a reinforcing plate, and close adherence of electromagnetic wave shielding paint, and work efficiency when treatments are applied to the flexible printed circuit and efficiency of a mounting process, etc., of electronic parts, etc., can be improved.

In a flexible printed circuit on which a reinforcing plastic film is stuck, normally, separate raw material films are used for the reinforcing plastic film and other plastic films. Thus, the above-described method cannot be applied to flexible printed circuits on which a reinforcing plastic film is stuck. Even in this case, however, if ultrasonic propagation velocities of plastic films are measured with SST and linear expansion coefficient characteristic differences are controlled by a method of using the shift angle difference ($\Delta\theta$) between the crystal orientation main axes of ellipses, the time required for measurement is extremely short and no skill is required, thus predetermined production efficiency can be maintained.

The two plastic films positioned on both the outermost layers of plastic film laminates are laminated on each other with their surfaces facing each other, whereby there are

14 JAN 1997

provided advantages of enhancing the adhesion strength and eliminating the need for considering the difference between the surface and rear face of the flexible printed circuit, as described above. Specifically, for example, it becomes less
5 necessary to take notice of the difference between the surface and rear face of the flexible printed circuit in characteristics such as printability on the flexible printed circuit, wear resistance, sliding property, intimate contact with a reinforcing plate, and close adherence of
10 electromagnetic wave shielding paint, and work efficiency when treatments are applied to the flexible printed circuit and efficiency of a mounting process, etc., of electronic parts, etc., can be improved.

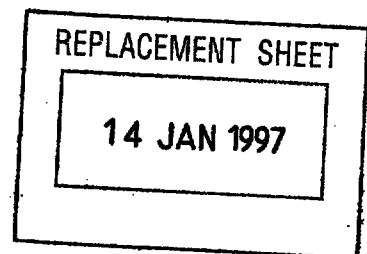
We have discussed the flexible printed circuits of the
15 invention by taking those with two plastic films laminated and those with two plastic films laminated on which a reinforcing plastic film is stuck as examples. However, the invention is not limited to them and can also be applied to those with three or more plastic films laminated in addition to a reinforcing
20 plastic film. As described above, in this case, only two plastic films positioned on both the outermost layers of plastic film laminates making up the flexible printed circuit need satisfy the predetermined conditions of the invention, and the plastic film positioned on an intermediate layer need not
25 be considered. That is, in the flexible printed circuit on which a reinforcing plastic film is stuck, both the outermost

14 JAN 1997

layers which need to satisfy the predetermined conditions of the invention are a plastic film on the side on which the reinforcing plastic film is not stuck and the reinforcing plastic film; a plastic film positioned therebetween need not be considered.

The thickness of the flexible printed circuit according to the invention is determined appropriately by applications, etc., of the flexible printed circuit, but generally set to 50 to 800 μm and preferably 100 to 600 μm . The shape of the flexible printed circuit is not limited either; for example, the flexible printed circuit is formed as shapes responsive to various applications in addition to substantial ?? shape shown in Fig. 14. The size of the flexible printed circuit is not limited either; for example, the flexible printed circuit may have the above-mentioned longest length L in the range of 10 to 1000 mm and preferably in the range of 30 to 600 mm.

Flexibility of the flexible printed circuits according to the invention is measured with a compression tester as shown in Fig. 24, for example. In the figure, numeral 22 is an upper fixed plate above which a load cell (load detector) 25 is disposed, and a lower moving plate 24 that can move up and down in conjunction with a drive section (linear motor) 23 is disposed so as to face the lower side of the upper fixed plate 22. First, a flexible printed circuit 1 is placed between the upper fixed plate 22 and the lower moving plate 24 in a state in which it is bent like a U-shape in horizontal orientation in



a long-side direction. Next, the drive section 23 is actuated for causing the lower moving plate 24 to rise for compressing the bent flexible printed circuit 1 sandwiched between the lower moving plate 24 and the upper fixed plate 22. When the bent flexible printed circuit 1 is compressed a given amount to a predetermined bend radius R , a repulsion force detected by the load cell 25 is measured and flexibility (repulsion force) is calculated from the expression (10) shown below for evaluation. Since the distance between the upper fixed plate 22 and the lower moving plate 24 at the measurement time becomes double the bend radius R of the flexible printed circuit 1, the bend radius R can be calculated from the distance.

Repulsion force (kg/cm) = repulsion force detection value (g)/length of short side (width) of flexible printed circuit (cm) (10)

The flexibility of the flexible printed circuit thus measured normally is in the range of repulsion force = 2 g/cm when bend radius R = 5 mm to repulsion force = 600 g/cm when bend radius R = 15 mm and preferably in the range of repulsion force = 4 g/cm when bend radius R = 5 mm to repulsion force = 400g/cm when bend radius R = 15 mm regardless of whether or not a reinforcing plastic film is stuck on the flexible printed circuit.

The flexibility evaluation method is applied to rectangular flexible printed circuits, but can also be applied

14 JAN 1997

to flexible printed circuits of any other shape than a rectangle. For example, for a flexible printed circuit 1a shaped like substantially V-shaped as shown in Fig. 25, a predetermined rectangle (for example, maximum rectangle 26 indicated by the chain line involved in the flexible printed circuit 1a substantially V-shaped shown in Fig. 25) is previously cut out from the flexible printed circuit and the flexibility of this sample is evaluated by the above-described method, then cutting to the predetermined substantial shape may be performed. In this case, if the shape and size of samples for measurement are standardized, the flexibility can be evaluated objectively.

As we have discussed, for the flexible printed circuit of the invention, when linear expansion coefficient ellipses representing the linear expansion coefficient characteristics of the plastic films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit are created and overlapped, the maximum value of the linear expansion coefficient difference and the total area of portions where the ellipses do not overlap are set to predetermined values or less. Resultantly, curl occurrence of the flexible printed circuit of the invention is suppressed. Therefore, the flexible printed circuit of the invention is high in accuracy of the shape; if it is used to mount electronic parts, the electronic parts can be mounted with high accuracy even in automatic mounting by a machine.

14 JAN 1997

In the flexible printed circuit of the invention, the plastic films positioned on both the outermost layers, of laminated plastic films making up the flexible printed circuit are placed in a state in which their surfaces face each other, the surface and rear face of the flexible printed circuit becomes the same state and the need for considering the difference therebetween is eliminated. Resultantly, the advantages such as enhancing the work efficiency when various treatments are applied to the flexible printed circuit or electronic parts, etc., are mounted thereon can be provided.

Further, in the flexible printed circuit of the invention, if metal electric circuit is formed in at least one of two or more laminated plastic films and the product of the thickness and tensile modulus of the metal electric circuit (K) is set to 500 kg/mm or less, sufficient flexibility of the flexible printed circuit is provided and curl occurrence thereof is also suppressed, providing a high-performance flexible printed circuit. Therefore, for example, the flexible printed circuit becomes suitable for frequently bent places such as a connection part of a print head and a mother board of a printer.

Moreover, in the invention, in a flexible printed circuit on which a reinforcing plastic film is stuck, if the linear expansion characteristic difference between a plastic film of laminated plastic films on the side where the reinforcing plastic film is not stuck and the reinforcing

14 JAN 1997

plastic film is controlled using a predetermined index, curl occurrence is suppressed even for the flexible printed circuit of an asymmetric structure on which the reinforcing plastic film is stuck.

5 The fact that there is given regularity about coefficients of linear expansion in the transverse direction of an stretched raw material plastic film is used to previously select parts of the raw material plastic film from which plastic films are to be cut out, or combine plastic films so
10 that the cut parts becomes substantially symmetric. In doing so, two plastic films can be placed on both the outermost layers so as to satisfy at least one of the above conditions without measuring the coefficient of linear expansion for each plastic film or the ultrasonic propagation velocity. This
15 results in prevention of curl occurrence and enhancement of the manufacturing efficiency of flexible printed circuits.

 Further, in the flexible printed circuit of the invention, if a plurality of plastic films stacked via an adhesive layer are temporarily crimped by the roll laminate
20 method in stacked relation and then pressurized under gas pressure in an autoclave and crimped, the flexible printed circuit is crimped under uniform pressure on the full face by isotropic pressure produced by the gas pressure, thus no excessive force is applied to parts of the materials of the
25 plastic films, metal electric circuit, etc., and the quality and performance of the finally provided product become good.

14 JAN 1997

Next, embodiments will be discussed together with comparisons.

Embodiment 1:

A bidirectionally stretched polyethylene terephthalate
5 film 0.05 mm thick (manufactured by TORAY) was used a raw
material film, from which plastic films (film-1 and film-2)
each having a size of 100 x 200 mm were cut out. Linear
expansion coefficients were measured by the above-described TMA
method and linear expansion coefficient ellipses were created
10 by polar coordinate plotting and were overlapped. These
overlapped ellipses are shown in a graph of Fig. 6. From this
graph, the maximum value of the linear expansion coefficient
difference between film-1 and film 2 ($\Delta\alpha$) was calculated by
using a control computer attached to TMA programmed based on
15]Expressions (6), (7), and (8) described above. The result was
 0.53×10^{-5} (1/°C), which was equal to or less than a
predetermined value. The linear expansion coefficient
measurement by TMA was executed to exclude the effects of
hygroscopic expansion and heat shrinkage as follows: The
20 plastic films were left standing for 60 minutes at 150°C for
drying, then while the plastic films were cooled from 150°C to
30°C, the plastic film length and temperature were measured
simultaneously and consecutively, and linear expansion
coefficients were found based on Expression (1) for regions of
25 Tg or less.

Next, a polyester family thermosetting adhesive was

14 JAN 1997

applied to the surface of film-1, then dried to form an adhesive layer 0.03 mm thick. Film-1 and film-2 were laminated by crimping by a heat press (conditions: 150 x 1 h x 30 kg/cm²) with the surfaces of film-1 and film-2 facing each other. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 4.2 mm and the curl degree was 2.1%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured as shown in Fig. 18. That is, first the same film-1 and film-2 as described above were prepared. As shown in Fig. 18A to 18D, an adhesive layer was formed on the surface of film-2 (for a base layer) as described above. Copper foil 3a 0.018 mm thick was placed on the adhesive layer 8 and they were bonded by the roll laminate method (surface temperature was set to 120°C). Next, as shown in Fig. 18B, the copper foil was etched by the subtractive method to form metal electric circuit 3. On the other hand, an adhesive layer was formed on the surface of film-1 (for a cover layer) as described above. As shown in Fig. 18C, film-1 and film-2 were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²) with the surfaces of film-1 and film-2 facing each other, manufacturing a flexible printed circuit as shown in Fig. 18D.

For the flexible printed circuit, the curl amount h was

14 JAN 1997

measured as described above. As a result, the curl amount h was 3.9 mm and the curl degree was 2.0%; curl occurrence was suppressed.

Comparison 1:

5 A new plastic film (film-3) having a size of 100 x 200 mm was cut out from the polyethylene terephthalate film used with Embodiment 1. On the other hand, the same film-1 as in Embodiment 1 was prepared. Linear expansion coefficient ellipses were created and overlapped as in Embodiment 1. These
10 overlapped ellipses are shown in a graph of Fig. 7. From this graph, the maximum value of the linear expansion coefficient difference between film-1 and film-3 ($\Delta\alpha$) was calculated. The result was 1.77×10^{-5} ($1/^\circ\text{C}$), which exceeded a predetermined value.

15 A plastic film laminate of film-1 and film-3 was created as in Embodiment 1. The curl amount h of the plastic film laminate was measured as in Embodiment 1. As a result, the curl amount h was 14.0 mm and the curl degree was 7.0%; a curl occurred.

20 On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-1 (for a cover layer) and film-3 (for a base layer) as described above were prepared. An adhesive layer was formed on the surface of
25 film-3 as in Embodiment 1, then electric circuit was formed by the subtractive method and an adhesive layer was formed on the

14 JAN 1997

surface of film-1. In a similar manner to that described above, film-1 and film-3 were laminated to manufacture a flexible printed circuit. For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 13.5 mm and the curl degree was 6.8%; a curl occurred.

Embodiment 2:

A bidirectionally stretched polyimide film 0.125 mm thick (manufactured by TORAY-Dupont) was used a raw material film, from which plastic films (film-4 and film-5) each having a size of 200 x 360 mm were cut out. Linear expansion coefficients were measured by the above-described TMA method and linear expansion coefficient ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses are shown in a graph of Fig. 8. From this graph, the total area of portions where the ellipses of film-4 and film-5 do not overlap (C) was $3.44 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$, which was equal to or less than a predetermined value. The area was calculated by using a control computer attached to a TMA measuring instrument according to cumulative expression (9) described above by setting $m=720$ and $\Delta\theta=(2\pi/720)\approx 0.00873$ (rad).

Next, an epoxy family thermosetting adhesive was applied to the surface of film-4, then dried to form an adhesive layer 0.03 mm thick. Film-4 and film-5 were temporarily crimped by the roll laminate method with the surfaces of film-4 and film-5 facing each other, then cured in

14 JAN 1997

an autoclave (conditions: 150°C x 1 h x 15 kg/cm²) and laminated. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 9.5 mm and the curl degree was 2.6%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-4 (for a cover layer) and film-5 (for a base layer) as described above were prepared. An adhesive layer was formed on the surface of film-5 as in Embodiment 1, then copper electric circuit 0.035 mm thick was formed by the subtractive method and an adhesive layer was formed on the surface of film-4. Film-4 and film-5 were laminated as in Embodiment 1, manufacturing a flexible printed circuit. For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 8.3 mm and the curl degree was 2.3%; curl occurrence was suppressed.

Comparison 2:

A new plastic film (film-6) having a size of 200 x 360 mm was cut out from the polyimide film used with Embodiment 2. On the other hand, the same film-4 as in Embodiment 2 was prepared. Linear expansion coefficient ellipses were created and overlapped as in Embodiment 2. These overlapped ellipses are shown in a graph of Fig. 9. Based on this graph, the total area of portions where the ellipses of film-4 and film-6 do not

14 JAN 1997

overlap (C) was calculated as in Embodiment 2. The result was $7.71 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$, which exceeded a predetermined value.

Next, a plastic film laminate of film-4 and film-6 was created as in Embodiment 2. The curl amount h of the plastic film laminate was measured as in Embodiment 2. As a result, the curl amount h was 28.0 mm and the curl degree was 7.8%; a curl occurred.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-4 (for a cover layer) and film-6 (for a base layer) as described above were prepared. An adhesive layer was formed on the surface of film-6 as in Embodiment 2, then metal electric circuit was formed by the subtractive method and an adhesive layer was formed on the surface of film-4. In a similar manner to that described above, film-4 and film-6 were laminated to manufacture a flexible printed circuit. For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 25.2 mm and the curl degree was 7.0%; a curl occurred.

Embodiment 3:

A bidirectionally stretched polyethylene terephthalate film 0.125 mm thick (manufactured by TORAY) was used a raw material film, from which plastic films (film-7 and film-8) each having a size of 200 x 360 mm were cut out. A

14 JAN 1997

bidirectionally stretched polyethylene terephthalate film 0.250 mm thick (manufactured by TORAY) was used a raw material film, from which a plastic film (film-10) having a size of 200 x 360 mm was cut out. Three linear expansion coefficient ellipses were created as in Embodiment 1 and were overlapped. These overlapped ellipses are shown in a graph of Fig. 10. From this graph, the maximum values of the linear expansion coefficient differences among film-7, film-8, and film-10 were calculated as in Embodiment 1. As a result, the maximum value of the linear expansion coefficient difference between film-7 and film-8 was 0.54×10^{-5} ($1/^{\circ}\text{C}$); that between film-7 and film-10 was 4.49×10^{-5} ($1/^{\circ}\text{C}$); and that between film-8 and film-10 was 3.94×10^{-5} ($1/^{\circ}\text{C}$).

Next, a polyester family thermosetting adhesive shaped like a sheet 0.05 mm thick was prepared and temporarily crimped on the surface and rear face of film-10 with a roll. Next, film-7 and film-8 were placed on the surface and rear face of film-10 and they were temporarily crimped by the roll laminate method, then cured in an autoclave (conditions: $110^{\circ}\text{C} \times 2 \text{ h} \times 10 \text{ kg/cm}^2$) for manufacturing a plastic film laminate of a 3-layer structure as shown in Fig. 13. In the figure, numeral 8 denotes an adhesive layer. Positioned on the outermost layers of the plastic film laminate are film-7 and film-8. As described above, the maximum value of the linear expansion coefficient difference between film-7 and film-8 is 0.54×10^{-5} ($1/^{\circ}\text{C}$), which is equal to or less than the predetermined value

14 JAN 1997

of the invention. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 5.4 mm and the curl degree was 1.5%; curl occurrence was suppressed.

5 On the other hand, aside from the plastic film laminate, a flexible printed circuit of a 3-film-layer structure formed with metal electric circuit was manufactured. That is, the same film-7, film-8, and film-10 as described above were prepared. As shown in Fig. 19, a polyester family
10 thermosetting adhesive shaped like a sheet was used to form an adhesive layer 8 on the surfaces of film-7 and film-8 in a similar manner to that described above, then copper electric circuit 3 0.035 mm thick was formed on the adhesive layer 8 by the subtractive method as in Embodiment 1. As shown in Fig.
15 19, a polyester family thermosetting adhesive shaped like a sheet was used to form an adhesive layer 8 on the surface and rear face of film-10 in a similar manner to that described above. As shown in the figure, with the surfaces of film-7 and film-8 facing each other with film-10 between, the three films
20 were temporarily crimped by the roll laminate method, then cured in an autoclave (conditions: 110°C x 2 h x 10 kg/cm²) for manufacturing a flexible printed circuit of a 3-film-layer structure as shown in Fig. 20. Parts identical with those previously described with reference to Fig. 19 are denoted by
25 the same reference numerals in Fig. 20.

For the flexible printed circuit of the 3-film-layer

14 JAN 1997

structure, the curl amount h was measured as described above. As a result, the curl amount h was 5.0 mm and the curl degree was 1.4%; curl occurrence was suppressed.

Comparison 3:

5 A new plastic film (film-9) having a size of 200 x 360 mm was cut out from the polyethylene terephthalate film 0.125 mm thick used with Embodiment 3. On the other hand, the same film-7 and film-10 as in Embodiment 3 were prepared. Three linear expansion coefficient ellipses were created and
10 overlapped as in Embodiment 3. These overlapped ellipses are shown in a graph of Fig. 11. From this graph, the maximum values of the linear expansion coefficient differences among film-7, film-9, and film-10 were calculated as in Embodiment 1. As a result, the maximum value of the linear expansion
15 coefficient difference between film-7 and film-9 was 1.66×10^{-5} ($1/^\circ\text{C}$) and that between film-9 and film-10 was 4.17×10^{-5} ($1/^\circ\text{C}$). As described above, the maximum value of the linear expansion coefficient difference between film-7 and film-10 is 4.49×10^{-5} ($1/^\circ\text{C}$).

20 Next, a plastic film laminate of a 3-film-layer structure (see Fig. 13) was created in the same manner to that in Embodiment 3 except that film-9 was used in place of film-8. The curl amount h of the plastic film laminate was measured as in Embodiment 3. As a result, the curl amount h was 18.7 mm
25 and the curl degree was 5.2%; a curl occurred.

On the other hand, aside from the plastic film

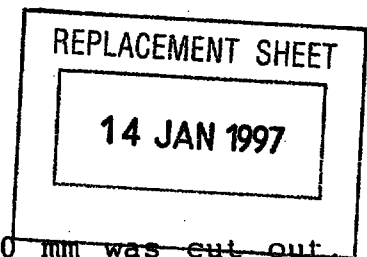
14 JAN 1997

laminated, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-7, film-9, and film-10 as described above were prepared. An adhesive layer 8 and copper electric circuit were formed on the surfaces of film-7 and film-9 by the subtractive method as in Embodiment 3. An adhesive layer 8 was formed on the surface and rear face of film-10. In a similar manner to that in Embodiment 3, the three films were laminated (see Fig. 19) to manufacture a flexible printed circuit (see Fig. 20). For this flexible printed circuit, the curl amount h was measured as described above. As a result, the curl amount h was 18.9 mm and the curl degree was 5.3%; a curl occurred.

Embodiment 4:

A bidirectionally stretched polyethylene terephthalate film 0.050 mm thick (manufactured by TORAY) was used as a raw material film, from which plastic films (film-11 and film-12) each having a size of 100 x 200 mm were cut out. Linear expansion coefficients were measured by the above-described TMA method and linear expansion coefficient ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses are shown in a graph of Fig. 12. From this graph, the maximum value of the linear expansion coefficient difference between film-11 and film 12 ($\Delta\alpha$) was calculated as in Embodiment 1. The calculation result was 0.11×10^{-5} ($1/^\circ\text{C}$).

Stainless steel foil 0.050 mm thick was used as raw material of metal electric circuit 3, from which stainless



steel foil having a size of 100 x 200 mm was cut out. The tensile modulus of the stainless steel foil was measured by the above-described method. The measurement result was 10000 kg/mm². That is, the product of the thickness and the tensile modulus (K) was 500 kg/mm.

Next, a polyester family thermosetting adhesive applied onto a separator was stuck on the same surfaces 9 of plastic film-11 and plastic film-12, then the separator was removed to form an adhesive layer 0.025 mm thick. The stainless steel foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the stainless steel foil and film-12 were furthermore temporarily crimped by the roll laminate method with the surfaces of the stainless steel foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²). (See Fig. 23.)

The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 0.8 mm and the curl degree was 0.4%; curl occurrence was suppressed.

The flexibility of the plastic film laminate (repulsion force g/cm) was measured by the above-described method. As a result, when bend radius $R = 5$ mm, repulsion force = 160 g/cm, indicating good flexibility.

Comparison 4:

First, the same films as the polyethylene terephthalate film used with Embodiment 4 (film-11 and film-12) were

14 JAN 1997

prepared. As in Embodiment 4, linear expansion coefficients were measured and linear expansion coefficient ellipses were created by polar coordinate plotting and overlapped (see Fig. 12). As in Embodiment 4, the maximum value of the linear expansion coefficient difference between film-11 and film 12 ($\Delta\alpha$) was calculated. The calculation result was 0.11×10^{-5} ($1/^\circ\text{C}$) as in Embodiment 4.

Stainless steel foil 0.075 mm thick was used as raw material of metal electric circuit 3, from which stainless steel foil having a size of 100 x 200 mm was cut out. The tensile modulus of the stainless steel foil was measured by the above-described method. The measurement result was 8000 kg/mm². That is, the product of the thickness and the tensile modulus (K) was 600 kg/mm, which exceeded the predetermined value.

Next, an adhesive layer 0.025 mm thick was formed on the same surfaces 9 of film-11 and film-12 as in Embodiment 4. The stainless steel foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the stainless steel foil and film-12 were furthermore temporarily crimped by the roll laminate method with the surfaces of the stainless steel foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²). (See Fig. 23.)

The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl

14 JAN 1997

amount h was 0.4 mm and the curl degree was 0.2%; curl occurrence was suppressed in both cases.

The flexibility of the plastic film laminate (repulsion force g/cm) was measured by the above-described method. As a
5 result, when bend radius $R = 5$ mm, repulsion force = 240 g/cm, indicating poor flexibility as compared with Embodiment 4.

Embodiment 5:

First, the same films as the polyethylene terephthalate film used with Embodiment 4 (film-11 and film-12) were
10 prepared. As in Embodiment 4, linear expansion coefficients were measured and linear expansion coefficient ellipses were created by polar coordinate plotting and overlapped (see Fig. 12). As in Embodiment 4, the maximum value of the linear expansion coefficient difference between film-11 and film 12
15 ($\Delta\alpha$) was calculated. The calculation result was 0.11×10^{-5} ($1/^\circ\text{C}$) as in Embodiment 4.

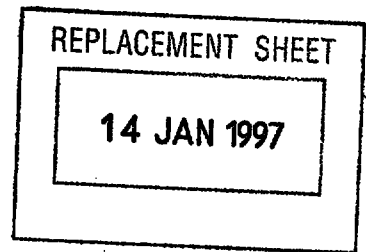
Three pieces of electrodeposited copper foil 0.018 mm, 0.035 mm, and 0.070 mm thick were used as raw material of metal conductor layer 3, from which three pieces of copper foil each
20 having a size of 100 x 200 mm were cut out. The tensile modulus of the three copper foil pieces were measured by the above-described method. The measurement results were 6600 kg/mm², 6050 kg/mm², and 5500 kg/mm². That is, the product of the thickness and the tensile modulus of each copper foil piece
25 (K) was 118.8 kg/mm, 192.5 kg/mm, or 315 kg/mm. These values were equal to or less than the predetermined value.

14 JAN 1997

Next, a polyester family thermosetting adhesive applied onto a separator was stuck on the same surfaces 9 of film-11 and film-12, then the separator was removed to form an adhesive layer 0.025 mm thick. Each piece of the copper foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the copper foil and film-12 were furthermore temporarily crimped by the roll laminate method with the surfaces of the copper foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²). (See Fig. 23.)

Further, the curl amount h of each of the plastic film laminates was measured by the above-described method. As a result, when the copper foil was 0.018 mm thick, the curl amount h was 1.2 mm and the curl degree was 0.6%; when the copper foil was 0.035 mm thick, the curl amount h was 0.7 mm and the curl degree was 0.35%; when the copper foil was 0.070 mm thick, the curl amount h was 0.5 mm and the curl degree was 0.25%. Curl occurrence was suppressed in every case.

The flexibility of each of the plastic film laminates (repulsion force g/cm) was measured by the above-described method. As a result, when the copper foil was 0.018 mm thick, repulsion force = 57 g/cm when bend radius R = 5 mm; when the copper foil was 0.035 mm thick, repulsion force = 72 g/cm when bend radius R = 5 mm; when the copper foil was 0.070 mm thick, repulsion force = 125 g/cm when bend radius R = 5 mm. Good flexibility was indicated in every case.



Comparison 5:

First, the same films as the polyethylene terephthalate film used with Embodiment 4 (film-11 and film-12) were prepared. As in Embodiment 4, coefficients of linear expansion were measured and linear expansion coefficient ellipses were created by polar coordinate plotting and overlapped (see Fig. 12). As in Embodiment 4, the maximum value of the linear expansion coefficient difference between film-11 and film 12 ($\Delta\alpha$) was calculated. The calculation result was 0.11×10^{-5} (1/°C) as in Embodiment 4.

Two pieces of electrodeposited copper foil 0.2 mm, and 0.3 mm thick were used as raw material of metal conductor layer 3, from which two pieces of electrodeposited copper foil each having a size of 100 x 200 mm were cut out. The tensile modulus of the two electrodeposited copper foil pieces were measured by the above-described method. The measurement results were 3600 kg/mm² and 3400 kg/mm². That is, the product of the thickness and the tensile modulus of each electrodeposited copper foil piece (K) was 720 kg/mm or 1020 kg/mm. These values exceeded the predetermined value.

Next, an adhesive layer 0.025 mm thick was formed on the same surfaces 9 of film-11 and film-12 as in Embodiment 4. Each piece of the electrodeposited copper foil was temporarily crimped on the surface of film-11 by the roll laminate method, then the electrodeposited copper foil and film-12 were furthermore temporarily crimped by the roll laminate method

14 JAN 1997

with the surfaces of the electrodeposited copper foil and film-12 facing each other and were laminated by crimping by a heat press (conditions: $150^{\circ}\text{C} \times 1 \text{ h} \times 30 \text{ kg/cm}^2$). (See Fig. 23.)

The curl amount h of each of the plastic film laminates was measured by the above-described method. As a result, when the electrodeposited copper foil was 0.2 mm thick, the curl amount h was 0.6 mm and the curl degree was 0.3%; when the electrodeposited copper foil was 0.3 mm thick, the curl amount h was 0.3 mm and the curl degree was 0.15%. Curl occurrence was suppressed in both cases.

The flexibility of each of the plastic film laminates (repulsion force g/cm) was measured by the above-described method. As a result, when the electrodeposited copper foil was 0.2 mm thick, repulsion force = 615 g/cm when bend radius $R = 5 \text{ mm}$; when the electrodeposited copper foil was 0.3 mm thick, repulsion force = 710 g/cm when bend radius $R = 10 \text{ mm}$. Poor flexibility was indicated in both cases as compared with Embodiment 4.

Embodiment 6:

A bidirectionally stretched polyethylene terephthalate film 0.05 mm thick (manufactured by TORAY) was used a raw material film, from which plastic films (film-13 and film-14) each having a size of $100 \times 200 \text{ mm}$ were cut out. A bidirectionally stretched polyethylene terephthalate film 0.25 mm thick (manufactured by TORAY) was used a raw material film, from which a plastic film (film-15) having a size of 100×200

14 JAN 1997

mm were cut out. The ultrasonic propagation velocities of the three plastic films were measured by the above-described method and three ultrasonic propagation velocity ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses of film-13 and film-15 are shown in a graph of Fig. 30. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-13 and film-15 of the outermost layers ($\Delta\theta$) is 0 degrees, showing that both match.

Next, a polyester family thermosetting adhesive was applied to the surfaces of film-13, film-14, and film-15, then dried to form an adhesive layer 0.025 mm thick. Film-13 and film-14 were laminated by crimping by a heat press (conditions: $150^{\circ}\text{C} \times 1 \text{ h} \times 30 \text{ kg/cm}^2$) with the surfaces of film-13 and film-14 facing each other. Reinforcing film-15 was temporarily crimped on the rear face of film-14 by the roll laminate method, then cured in an autoclave (conditions: $110^{\circ}\text{C} \times 2 \text{ h} \times 10 \text{ kg/cm}^2$). The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 5.0 mm and the curl degree was 2.5%; curl occurrence was suppressed. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of all flexible printed circuits fell within 3.40 ± 0.01 .

14 JAN 1997

Comparison 6:

A new plastic film having a size of 100 x 200 mm (film-16) was cut out from the polyethylene terephthalate film used with Embodiment 6. On the other hand, the same film-13 and film-14 as in Embodiment 6 were prepared. The ultrasonic propagation velocity ellipses of the three plastic films were created and were overlapped as in Embodiment 6. These overlapped ellipses of film-13 and film-16 are shown in a graph of Fig. 31. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-13 and film-16 of the outermost layers ($\Delta\theta$) is 90 degrees, showing a large shift.

As in Embodiment 6, a plastic film laminate of film-13 and film-16 was created and reinforcing film-16 was temporarily crimped on the rear face of film-14 by the roll laminate method, then they were crimped by a heat press (conditions: 130 x 1 h x 30 kg/cm²) to form a plastic film laminate. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 19.0 mm and the curl degree was 9.5%; a curl occurred. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of the flexible printed circuits varied in the range of 3.35-3.42.

14 JAN 1997

Embodiment 7:

A bidirectionally stretched polyimide film 0.050 mm thick (manufactured by TORAY-Dupont) was used a raw material film, from which plastic films (film-17 and film-18) each having a size of 100 x 200 mm were cut out. A bidirectionally stretched polyimide film 0.125 mm thick (manufactured by TORAY-Dupont) was used a raw material film, from which a plastic film (film-19) having a size of 100 x 200 mm were cut out. The ultrasonic propagation velocities of the three plastic films were measured by the above-described method and three ultrasonic propagation velocity ellipses were created by polar coordinate plotting and were overlapped. These overlapped ellipses of film-17 and film-19 are shown in a graph of Fig. 32. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-17 and film-19 of the outermost layers ($\Delta\theta$) is 0 degrees, showing that both match.

Next, a polyester family thermosetting adhesive was applied to the surfaces of film-17, film-18, and film-19, then dried to form an adhesive layer 0.025 mm thick. Film-17 and film-18 were laminated by crimping by a heat press (conditions: 150°C x 1 h x 30 kg/cm²) with the surfaces of film-17 and film-18 facing each other. Reinforcing film-19 was temporarily crimped on the rear face of film-18 by the roll laminate method, then cured in an autoclave (conditions: 110°C x 2 h x 10 kg/cm²). The curl amount h of the plastic film laminate was

14 JAN 1997

measured by the above-described method. As a result, the curl amount h was 0.5 mm and the curl degree was 0.25%; curl occurrence was suppressed. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of all flexible printed circuits fell within 3.45 ± 0.01 .

Comparison 7:

10 A new plastic film having a size of 100 x 200 mm (film-20) was cut out from the polyimide film used with Embodiment 7. On the other hand, the same film-17 and film-18 as in Embodiment 7 were prepared. The ultrasonic propagation velocity ellipses of the three plastic films were created and were overlapped as in Embodiment 7. These overlapped ellipses of film-17 and film-20 are shown in a graph of Fig. 33. This graph indicates that the shift angle difference between crystal orientation main axis directions of film-17 and film-20 of the outermost layers ($\Delta\theta$) is 90 degrees, showing a large shift.

20 As in Embodiment 7, a plastic film laminate of film-17 and film-18 was created and reinforcing film-20 was temporarily crimped on the rear face of film-18 by the roll laminate method, then they were crimped by a heat press (conditions: 150 x 1 h x 30 kg/cm²) to form a plastic film laminate. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was

14 JAN 1997

14.0 mm and the curl degree was 7.0%; a curl occurred. Ten flexible printed circuits thus manufactured were prepared and the relative permittivity of each flexible printed circuit as a complex of plastic films and adhesive layers was measured at measurement frequency 1 MHz. Resultantly, the relative permittivities of the flexible printed circuits varied in the range of 3.42 to 3.47.

Embodiment 8:

A bidirectionally stretched raw material plastic film made of polyethylene terephthalate 4 m wide was prepared. It was divided into eight parts like bands (each 500 mm wide) parallel with the length direction (machine direction of stretch) of the plastic film, as shown in Fig. 36. In the raw material plastic film, the linear expansion coefficients of the parts (divisions) were measured as in Embodiment 1, and combinations of the relative positions were considered. The condition that the maximum value of the linear expansion coefficient difference is 1.4×10^{-5} ($1/^{\circ}\text{C}$) or less was satisfied in the range of relative positions (-3) to (3). As shown in Fig. 36, a cover layer plastic film (film-21) having a size of 80 x 200 mm was cut out from the relative position (-3) and a base layer plastic film (film-22) having a size of 80 x 200 mm was cut out from the relative position (2). For film-21 and film-22, the linear expansion coefficient differences were measured with the same surfaces of the films facing each other. The maximum value of the linear expansion coefficient

14 JAN 1997

difference was 0.7×10^{-5} ($1/^{\circ}\text{C}$).

As in Embodiment 1, film-21 and film-22 were used to produce a plastic film laminate with the same surfaces facing each other. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 5.6 mm and the curl degree was 2.8%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-21 (for the cover layer) and film-22 (for the base layer) as described above were prepared. An adhesive layer was formed on the surface of film-22 as in Embodiment 1, then electric circuit was formed, and an adhesive layer was formed on the surface of film-21. Film-21 and film-22 were laminated to manufacture a flexible printed circuit by the above-mentioned method. For this flexible printed circuit, the curl amount h was measured by the above-described method. As a result, the curl amount h was 5.3 mm and the curl degree was 2.7%; curl occurrence was suppressed.

Embodiment 9:

A bidirectionally stretched raw material plastic film made of polyethylene terephthalate 4.5 m wide was prepared. It was divided into nine parts like bands (each 500 mm wide) parallel with the length direction (machine direction of stretch) of the plastic film, as shown in Fig. 3. In the raw

14 JAN 1997

material plastic film, a cover layer plastic film (film-23) and a base layer plastic film (film-24) each having a size of 60 x 90 mm were cut out from the parts of the relative positions (-3) and (3) at symmetrical positions with respect to the center line parallel with the length direction (machine direction) of the raw material plastic film. As in Embodiment 1, for film-23 and film-24, the linear expansion coefficient differences were measured with the same surfaces of the films facing each other. The maximum value of the linear expansion coefficient difference was 0.1×10^{-5} ($1/^{\circ}\text{C}$).

As in Embodiment 1, a plastic film laminate of film-23 and film-24 was produced. The curl amount h of the plastic film laminate was measured by the above-described method. As a result, the curl amount h was 0.4 mm and the curl degree was 0.5%; curl occurrence was suppressed.

On the other hand, aside from the plastic film laminate, a flexible printed circuit formed with metal electric circuit was manufactured. That is, the same film-23 (for the cover layer) and film-24 (for the base layer) as described above were prepared. An adhesive layer was formed on the surface of film-24 as in Embodiment 1, then electric circuit was formed, and an adhesive layer was formed on the surface of film-23. Film-23 and film-24 were laminated to manufacture a flexible printed circuit by the above-mentioned method. For this flexible printed circuit, the curl amount h was measured by the above-described method. As a result, the curl amount h

was 0.3 mm and the curl degree was 0.3%; curl occurrence was suppressed.

Comparison 8:

5 The same film-23 and film-24 as in Embodiment 9 were prepared. The linear expansion coefficient differences were measured in a state in which the surface of film-23 and the rear face of film-24 face each other. The maximum value of the linear expansion coefficient difference was 1.6×10^{-5} (1/°C). In a state in which the surface of film-23 and the rear face of
10 film-24 face each other, a plastic film laminate was produced as in Embodiment 9, and the curl amount h was measured by the above-described method. As a result, the curl amount h was 5.9 mm and the curl degree was 6.6%; a curl occurred.

15 It is to be understood that the foregoing description and the accompanying drawings are not intended to limit the scope of this invention; rather, various modifications or variations may be made by those of ordinary skill in the art without departing from the scope of this invention which is defined by the appended claims. For example, the present
20 invention also can be applied to an ordinary composite sheet not only to the flexible printed circuit. The composite sheet according to the present may be also applied to IC card, credit card or the like.



14 JAN 1997

WHAT IS CLAIMED IS:

- 1 1. A composite sheet comprising:
- 2 a first resin film; and
- 3 a second resin film laminated on the first resin film;
- 4 wherein two ellipses of coefficient of linear expansion
- 5 are created on coordinates in corresponding parts of the first
- 6 and second resin films by the following method (A):
- 7 (A) comprising the steps of: defining a predetermined
- 8 base point P on the resin film; measuring a coefficient of
- 9 linear expansion at a position separate from an arbitrary axis
- 10 in angle θ direction on the first and second resin films, the
- 11 arbitrary axis being selected on the first and second resin
- 12 films so as to pass through the base point P with the base
- 13 point P as a center and direct an arbitrary direction;
- 14 preparing a coordinate system with the arbitrary axis as a Y
- 15 axis and an axis crossing the Y axis at 90 degrees as an X
- 16 axis, in this coordinate system; defining an intersection of
- 17 the X and Y axes as the base point P in the linear expansion
- 18 coefficient measurement and magnitude of a linear expansion
- 19 coefficient measurement value as distance r from the base point
- 20 P, then plotting a tip point of the distance r in the
- 21 measurement angle θ direction with respect to the Y axis,
- 22 plotting it multiple times by changing the measurement angle θ ,
- 23 and drawing an analysis line throughout 360-degree directions
- 24 with the base point P as the center so as to pass through
- 25 average points of the plotted points for creating the ellipse:



14 JAN 1997

26 and the two ellipse are overlapped so as to match in
27 the center point and coordinate axes X and Y, and the following
28 relationship (B) is satisfied: (B) the maximum value of a
29 linear expansion coefficient difference between the two resin
30 films is equal to or less than a predetermined value.

1 2. The composite sheet according to claim 1, wherein
2 the predetermined value is 1.4×10^{-5} (1/°C).

1 3. The composite sheet according to claim 1, wherein
2 the first and second resin film are laminated on each other
3 with the same surfaces thereof facing each other.

1 4. The composite sheet according to claim 1, wherein
2 the composite sheet is a flexible printed circuit.

1 5. The composite sheet according to claim 4, wherein a
2 metal electric circuit is formed between the first and second
3 resin films and a product of thickness and tensile modulus of
4 the metal electric circuit is 500 kg/mm or less.

1 6. The composite sheet according to claim 1, wherein a
2 reinforcing plastic film is stuck on one side of the composite
3 sheet, and one of the first and second resin films positioned
4 on a side where the reinforcing plastic film is not stuck and
5 the reinforcing plastic film satisfy the relationships (A) and



14 JAN 1997

6 (B).

1 7. The composite sheet according to claim 1, wherein
2 one or more other resin films are sandwiched between the first
3 and second resin film.

1 8. The composite sheet according to claim 1, wherein
2 the first and second resin film are laminated via an adhesive
3 layer.

1 9. The composite sheet according to claim 8, wherein
2 the first and second films stacked via the adhesive layer are
3 temporarily crimped by a roll laminate method in stacked
4 relation and then pressurized under gas pressure in an
5 autoclave and crimped.

1 10. A composite sheet comprising:
2 a first resin film; and
3 a second resin film laminated on the first resin film;
4 wherein two ellipses of coefficient of linear expansion
5 are created on coordinates in corresponding parts of the first
6 and second resin films by the following method (C):

7 (C) comprising the steps of: defining a predetermined
8 base point P on the resin film; measuring a coefficient of
9 linear expansion at a position separate from an arbitrary axis
10 in angle θ direction on the first and second resin films, the



14 JAN 1997

11 arbitrary axis being selected on the first and second resin
12 films so as to pass through the base point P with the base
13 point P as a center and direct an arbitrary direction;
14 preparing a coordinate system with the arbitrary axis as a Y
15 axis and an axis crossing the Y axis at 90 degrees as an X
16 axis, in this coordinate system; defining an intersection of
17 the X and Y axes as the base point P in the linear expansion
18 coefficient measurement and magnitude of a linear expansion
19 coefficient measurement value as distance r from the base point
20 P, then plotting a tip point of the distance r in the
21 measurement angle θ direction with respect to the Y axis,
22 plotting it multiple times by changing the measurement angle θ ,
23 and drawing an analysis line throughout 360-degree directions
24 with the base point P as the center so as to pass through
25 average points of the plotted points for creating the ellipse:
26 and the two ellipse are overlapped so as to match in
27 the center point and coordinate axes X and Y, and the following
28 relationship (D) is satisfied: (D) the total area of portions
29 where the ellipses do not overlap is equal to or less than a
30 predetermined value.

1 11. The composite sheet according to claim 10, wherein
2 the predetermined value is $6.5 \times 10^{-10} [(1/^\circ\text{C}) \times (1/^\circ\text{C})]$.

1 12. The composite sheet according to claim 10, wherein
2 the first and second resin film are laminated on each other



14 JAN 1997

3 with the same surfaces thereof facing each other.

1 13. The composite sheet according to claim 10, wherein
2 the composite sheet is a flexible printed circuit.

1 14. The composite sheet according to claim 13, wherein
2 a metal electric circuit is formed between the first and second
3 resin films and a product of thickness and tensile modulus of
4 the metal electric circuit is 500 kg/mm or less.

1 15. The composite sheet according to claim 10, wherein
2 a reinforcing plastic film is stuck on one side of the
3 composite sheet, and one of the first and second resin films
4 positioned on a side where the reinforcing plastic film is not
5 stuck and the reinforcing plastic film satisfy the
6 relationships (C) and (D).

1 16. The composite sheet according to claim 10, wherein
2 one or more other resin films are sandwiched between the first
3 and second resin film.

1 17. The composite sheet according to claim 10, wherein
2 the first and second resin film are laminated via an adhesive
3 layer.

1 18. The composite sheet according to claim 17, wherein

14 JAN 1997



2 the first and second films stacked via the adhesive layer are
3 temporarily crimped by a roll laminate method in stacked
4 relation and then pressurized under gas pressure in an
5 autoclave and crimped.

1 19. A composite sheet comprising:

2 a first resin film; and

3 a second resin film laminated on the first resin film;

4 wherein two ellipses of ultrasonic propagation velocity
5 are created on coordinates in corresponding parts of the first
6 and second resin films by the following method (E):

7 (E) comprising the steps of: defining a predetermined
8 base point P on the film surface of the resin film, measuring
9 a ultrasonic propagation velocity at a position separate from
10 an arbitrary axis in angle θ direction on the first and second
11 resin films, the arbitrary axis being selected on the first and
12 second resin films so as to pass through the base point P with
13 the base point P as a center and direct an arbitrary direction,
14 preparing a coordinate system with the arbitrary axis as a Y
15 axis and an axis crossing the Y axis at 90 degrees as an X
16 axis, in this coordinate system, defining an intersection of
17 the X and Y axes as the base point P in the ultrasonic
18 propagation velocity measurement and magnitude of a ultrasonic
19 propagation velocity measurement value as distance r from the
20 base point P, then plotting a tip point of this distance r in
21 the measurement angle θ direction with respect to the Y axis,



14 JAN 1997

22 plotting it multiple times by changing the measurement angle θ ,
23 and drawing an analysis line throughout 360-degree directions
24 with the base point P as the center so as to pass through
25 average points of the plotted points for creating an ellipse
25 having a crystal orientation main axis in a long-axis direction
26 and a crystal orientation subaxis in a short-axis direction:

27 and the two ellipse are overlapped so as to match in
28 center point and coordinate axes X and Y, and the following
29 relationship (F) is satisfied: (F) a shift angle difference
30 between crystal orientation main axes of the ellipses ($\Delta\theta$) is
31 within 30 degrees.

1 20. The composite sheet according to claim 19, wherein
2 the first and second resin film are laminated on each other
3 with the same surfaces thereof facing each other.

1 21. The composite sheet according to claim 19, wherein
2 the composite sheet is a flexible printed circuit.

1 22. The composite sheet according to claim 21, wherein
2 a metal electric circuit is formed between the first and second
3 resin films and a product of thickness and tensile modulus of
4 the metal electric circuit is 500 kg/mm or less.

1 23. The composite sheet according to claim 19, wherein
2 a reinforcing plastic film is stuck on one side of the



14 JAN 1997

3 composite sheet, and one of the first and second resin films
4 positioned on a side where the reinforcing plastic film is not
5 stuck and the reinforcing plastic film satisfy the
6 relationships (E) and (F).

1 24. The composite sheet according to claim 19, wherein
2 one or more other resin films are sandwiched between the first
3 and second resin film.

1 25. The composite sheet according to claim 19, wherein
2 the first and second resin film are laminated via an adhesive
3 layer.

1 26. The composite sheet according to claim 25, wherein
2 the first and second films stacked via the adhesive layer are
3 temporarily crimped by a roll laminate method in stacked
4 relation and then pressurized under gas pressure in an
5 autoclave and crimped.

1 27. A method for manufacturing a composite sheet
2 comprising the steps of:

3 preparing a first resin film and a second resin film;
4 creating two ellipses of coefficient of linear
5 expansion on coordinates in corresponding parts of the first
6 and second resin films by the following (1) to (7) steps:

7 (1) defining a predetermined base point P on the resin



14 JAN 1997

8 film;

9 (2) measuring a coefficient of linear expansion at a
10 position separate from an arbitrary axis in angle θ direction
11 on the first and second resin films, the arbitrary axis being
12 selected on the first and second resin films so as to pass
13 through the base point P with the base point P as a center and
14 direct an arbitrary direction;

15 (3) preparing a coordinate system with the arbitrary
16 axis as a Y axis and an axis crossing the Y axis at 90 degrees
17 as an X axis, in this coordinate system;

18 (4) defining an intersection of the X and Y axes as the
19 base point P in the linear expansion coefficient measurement
20 and magnitude of a linear expansion coefficient measurement
21 value as distance r from the base point P,

22 (5) plotting a tip point of the distance r in the
23 measurement angle θ direction with respect to the Y axis,

24 (6) repeating plotting the tip point multiple times by
25 changing the measurement angle θ ; and

26 (7) drawing an analysis line throughout 360-degree
27 directions with the base point P as the center so as to pass
28 through average points of the plotted points for creating the
29 ellipse;

30 laminating the first and second resin film in such a
31 manner that the following relationship (G) is satisfied: (G)
32 the maximum value of a linear expansion coefficient difference
33 between the two resin films is equal to or less than a



14 JAN 1997

34 predetermined value when the two ellipses are overlapped so as
35 to match in the center point and coordinate axes X and Y.

1 28. The method for manufacturing a composite sheet
2 according to claim 27, wherein the predetermined value is 1.4
3 $\times 10^{-5}$ ($1/^{\circ}\text{C}$).

1 29. The method of manufacturing a composite sheet
2 according to claim 27, further comprising the steps of:
3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;
5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;
8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction; and
11 cutting out the first and second layer cut parts in
12 parallel with the length direction from the first and second
13 resin films respectively.

1 30. The method for manufactuirng a composite sheet
2 according to claim 29, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an



14 JAN 1997

6 autoclave and crimping.

1 31. The method of manufacturing a composite sheet
2 according to claim 27, further comprising the steps:

3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;

5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;

8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction;

11 cutting out the first and second layer cut parts at
12 substantially symmetrical positions with respect to a center
13 line parallel with the length direction from the first and 1
14 econd resin films respectively; and

15 laminating the first and second layer cut parts in a
16 state in which the same surfaces of the first and second layer
17 cut parts face each other.

1 32. The method for manufactuirng a composite sheet
2 according to claim 31, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an
6 autoclave and crimping.



14 JAN 1997

1 33. A method for manufacturing a composite sheet
2 comprising the steps of:

3 preparing a first resin film and a second resin film;
4 creating two ellipses of coefficient of linear
5 expansion on coordinates in corresponding parts of the first
6 and second resin films by the following (1) to (7) steps:

7 (1) defining a predetermined base point P on the resin
8 film;

9 (2) measuring a coefficient of linear expansion at a
10 position separate from an arbitrary axis in angle θ direction
11 on the first and second resin films, the arbitrary axis being
12 selected on the first and second resin films so as to pass
13 through the base point P with the base point P as a center and
14 direct an arbitrary direction;

15 (3) preparing a coordinate system with the arbitrary
16 axis as a Y axis and an axis crossing the Y axis at 90 degrees
17 as an X axis, in this coordinate system;

18 (4) defining an intersection of the X and Y axes as the
19 base point P in the linear expansion coefficient measurement
20 and magnitude of a linear expansion coefficient measurement
21 value as distance r from the base point P,

22 (5) plotting a tip point of the distance r in the
23 measurement angle θ direction with respect to the Y axis,

24 (6) repeating plotting the tip point multiple times by
25 changing the measurement angle θ ; and

26 (7) drawing an analysis line throughout 360-degree



14 JAN 1997

27 directions with the base point P as the center so as to pass
28 through average points of the plotted points for creating the
29 ellipse;

30 laminating the first and second resin film in such a
31 manner that the following relationship (H) is satisfied: (H)
32 the total area of portions where the ellipses do not overlap is
33 equal to or less than a predetermined value when the two
34 ellipses are overlapped so as to match in the center point and
35 coordinate axes X and Y.

1 34. The method for manufacturing a composite sheet
2 according to claim 33, wherein the predetermined value is 6.5
3 $\times 10^{-10} [(1/^{\circ}\text{C}) \times (1/^{\circ}\text{C})]$.

1 35. The method of manufacturing a composite sheet
2 according to claim 33, further comprising the steps of:
3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;

5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;

8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction; and

11 cutting out the first and second layer cut parts in
12 parallel with the length direction from the first and second



14 JAN 1997

13 resin films respectively.

1 36. The method for manufactuirng a composite sheet
2 according to claim 35, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an
6 autoclave and crimping.

1 37. The method of manufacturing a composite sheet
2 according to claim 33, further comprising the steps:

3 stretching a raw material resin film in two directions
4 of a machine direction and a transverse direction;

5 cutting out a resin film to a predetermined size with
6 either the machine direction or the transverse direction as a
7 length direction from the raw material resin film;

8 dividing the resin film into two substantially equal
9 parts of a first layer cut part and a second layer cut part in
10 parallel with the length direction;

11 cutting out the first and second layer cut parts at
12 substantially symmetrical positions with respect to a center
13 line parallel with the length direction from the first and
14 second resin films respectively; and

15 laminating the first and second layer cut parts in a
16 state in which the same surfaces of the first and second resin
17 films face each other.

14 JAN 1997



1 38. The method for manufactuirng a composite sheet
2 according to claim 37, further comprising the step of
3 temporarily crimping the first and second layer cut parts
4 stacked via an adhesive layer by a roll laminate method in
5 stacked relation and then pressurizing under gas pressure in an
6 autoclave and crimping.

1 39. The composite sheet according to claim 1, wherein
2 the arbitrary axis is settled on a machine direction of film
3 stretch, so that the Y axis is settled on the machine direction
4 and the X axis is settled on a transverse direction of film
5 stretch.

1 40. The composite sheet according to claim 1, wherein
2 the composite sheet is a flexible printed circuit, and the
3 arbitrary axis is settled on a machine direction of film
4 stretch, so that the Y axis is settled on the machine direction
5 and the X axis is settled on a transverse direction of film
6 stretch.

1 41. The composite sheet according to claim 10, wherein
2 the arbitrary axis is settled on a machine direction of film
3 stretch, so that the Y axis is settled on the machine direction
4 and the X axis is settled on a transverse direction of film
5 stretch.

14 JAN 1997

1 42. The composite sheet according to claim 10, wherein
2 the composite sheet is a flexible printed circuit, and the
3 arbitrary axis is settled on a machine direction of film
4 stretch, so that the Y axis is settled on the machine direction
5 and the X axis is settled on a transverse direction of film
6 stretch.

1 43. The composite sheet according to claim 19, wherein
2 the arbitrary axis is settled on a machine direction of film
3 stretch, so that the Y axis is settled on the machine direction
4 and the X axis is settled on a transverse direction of film
5 stretch.

1 44. The composite sheet according to claim 19, wherein
2 the composite sheet is a flexible printed circuit, and the
3 arbitrary axis is settled on a machine direction of film
4 stretch, so that the Y axis is settled on the machine direction
5 and the X axis is settled on a transverse direction of film
6 stretch.



14 JAN 1997

FLEXIBLE PRINTED CIRCUIT AND MANUFACTURING METHOD THEREFOR

ABSTRACT OF THE DISCLOSURE

A composite sheet comprises a first resin film; and a second resin film laminated on the first resin film; wherein two ellipses of coefficient of linear expansion are created on polar coordinates in corresponding parts of the first and second resin films by a predetermined method and the two ellipse are overlapped so as to match in the center point and coordinate axes X and Y, and the maximum value of a linear expansion coefficient difference between the two resin films is equal to or less than a predetermined value.

No figure suggested

14 JAN 1997

1/21

FIG. 1

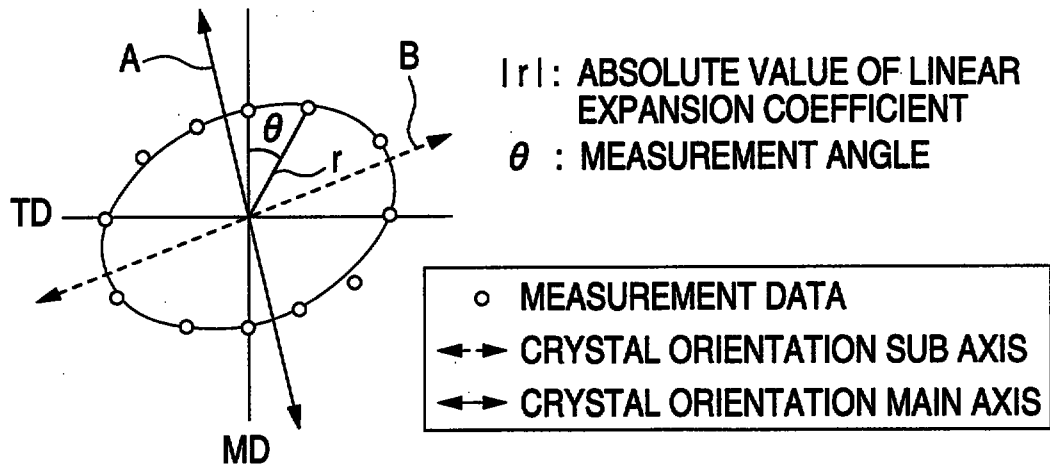
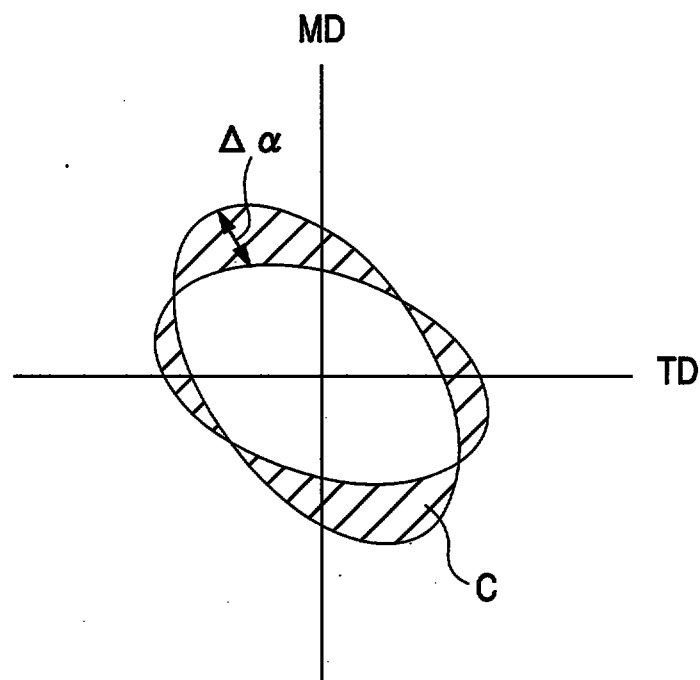


FIG. 2

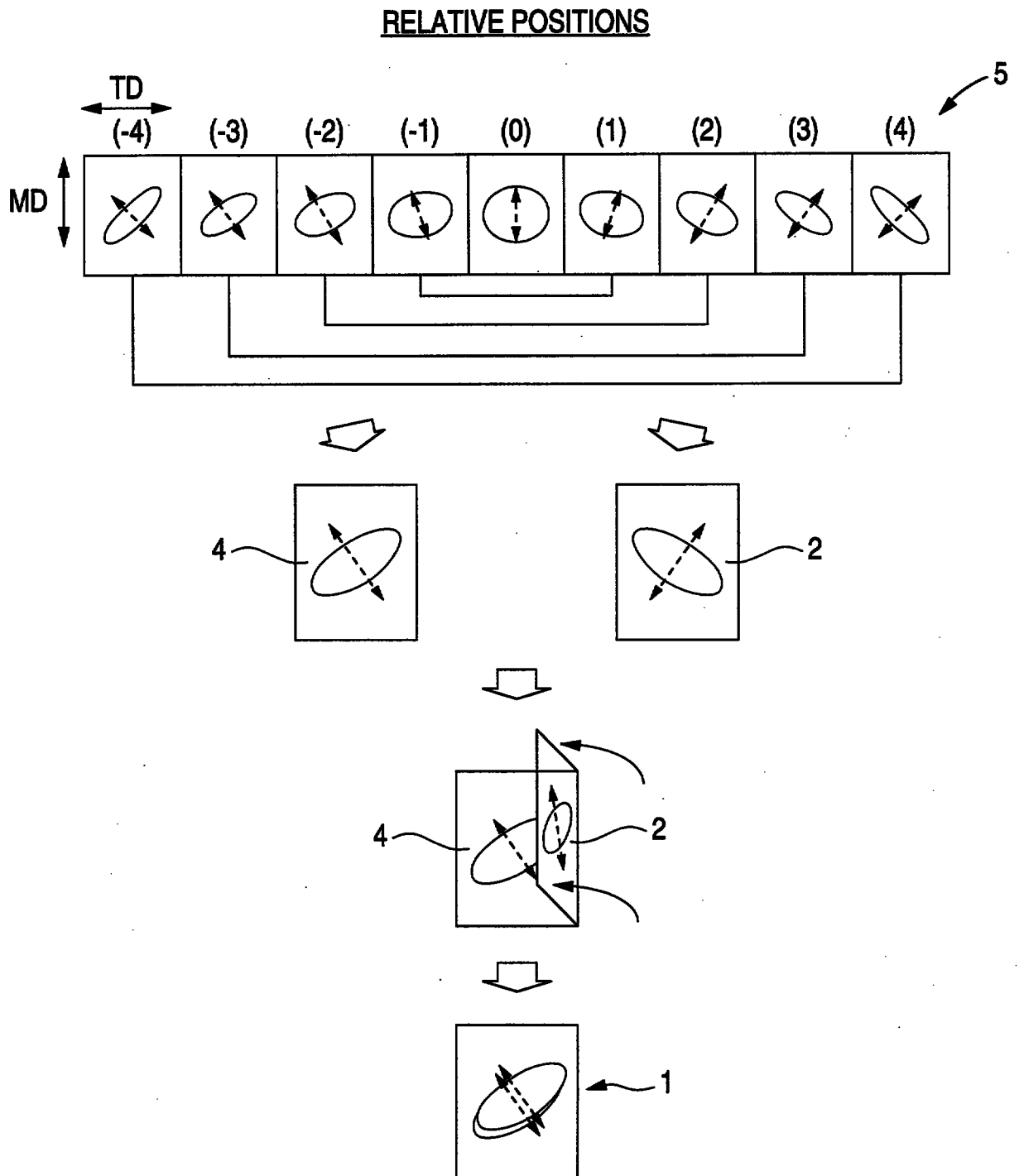


0-1070160

14 JAN 1997

2/21

FIG. 3



14 JAN 1997

3/21

FIG. 4

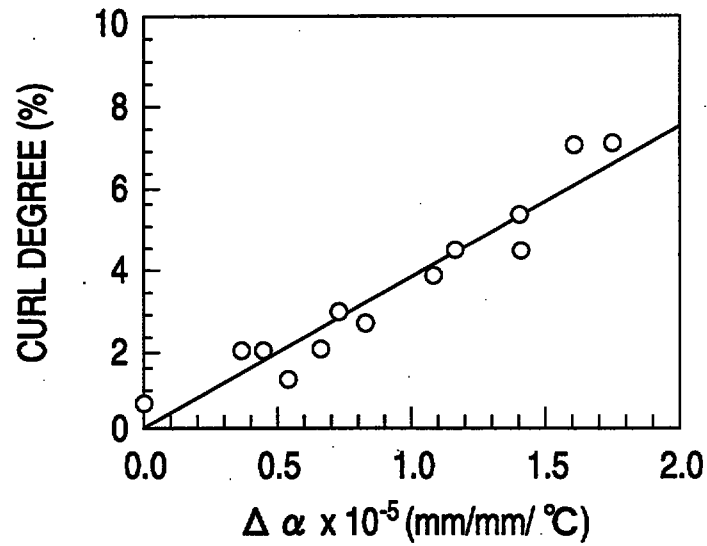
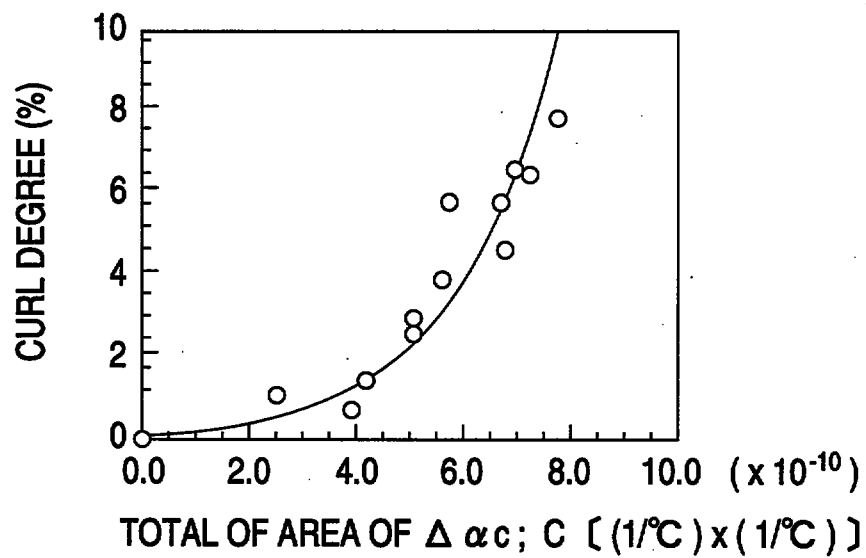


FIG. 5



4/21

REPLACEMENT SHEET

14 JAN 1997

FIG. 6

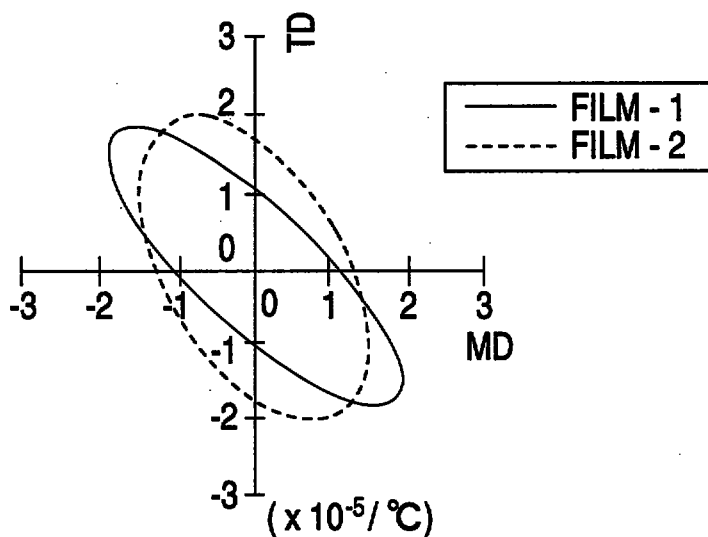
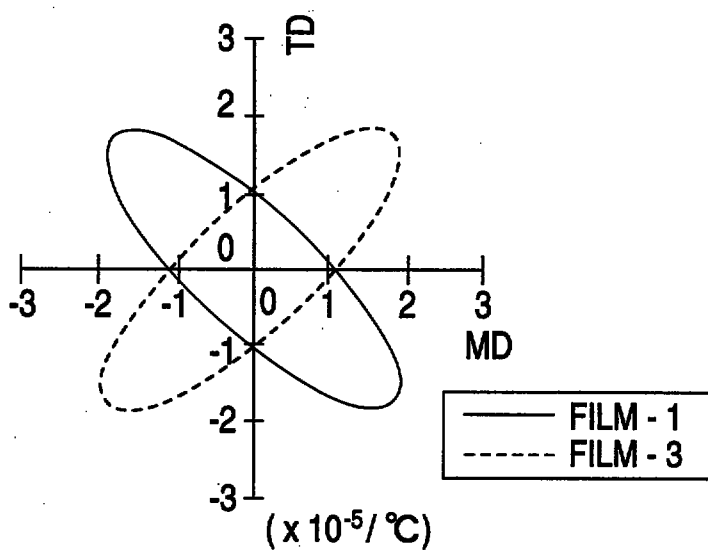


FIG. 7



14 JAN 1997

5/21

FIG. 8

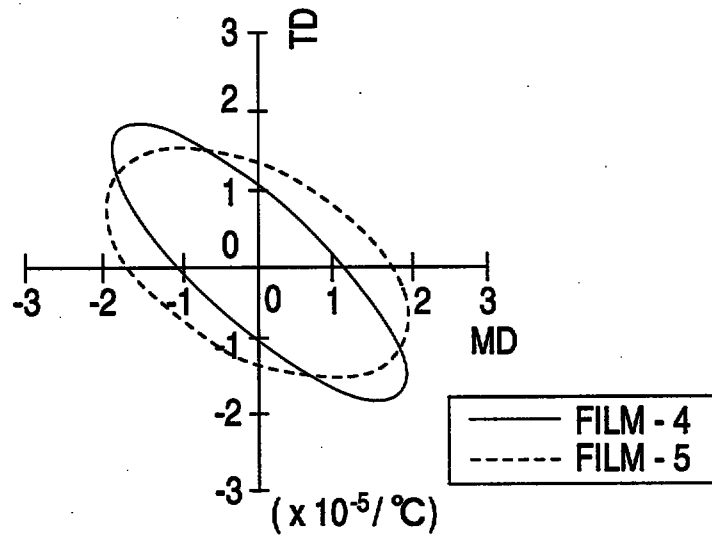
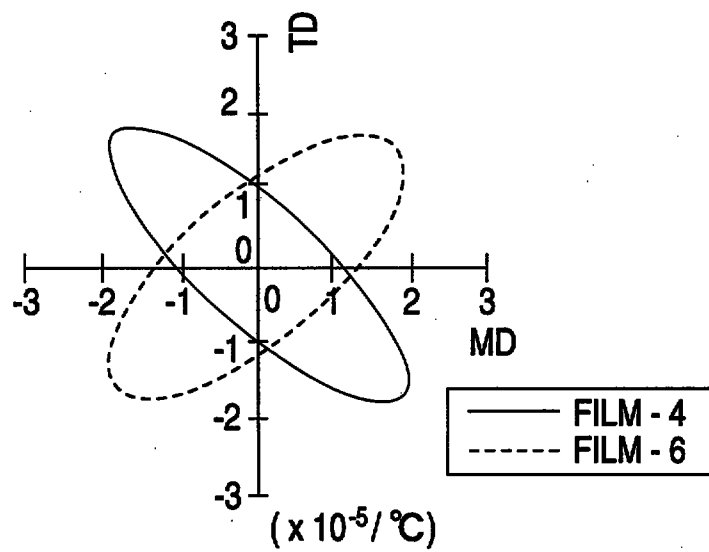


FIG. 9



6/21

REPLACEMENT SHEET

14 JAN 1997

FIG. 10

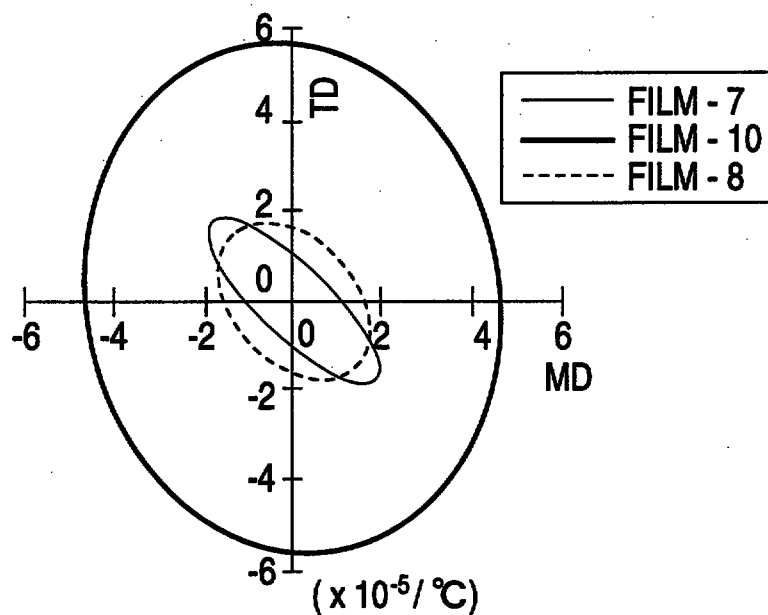
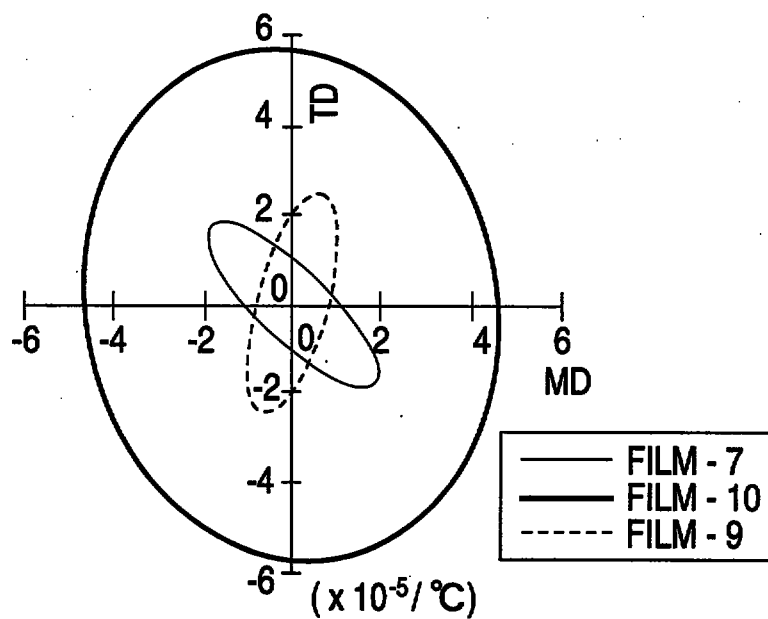


FIG. 11



7/21

REPLACEMENT SHEET

14 JAN 1997

FIG. 12

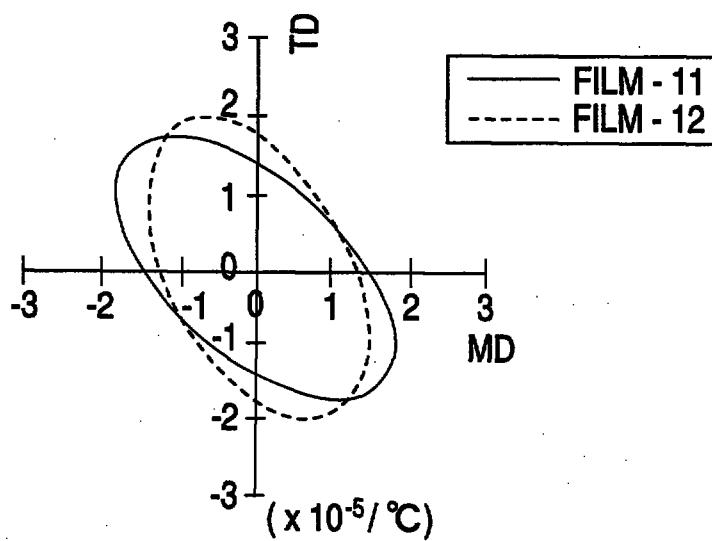
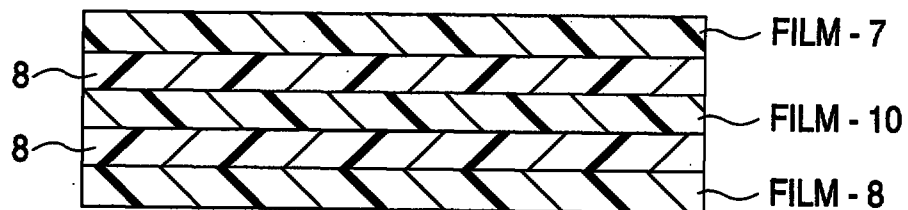


FIG. 13



8/21

REPLACEMENT SHEET

14 JAN 1997

FIG. 14

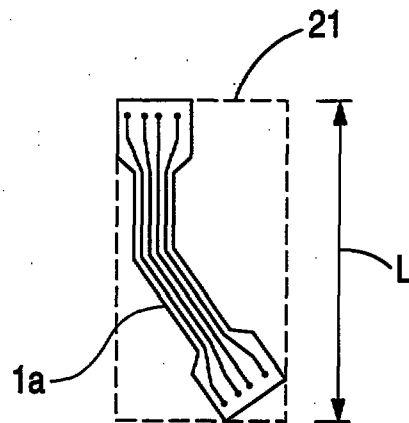
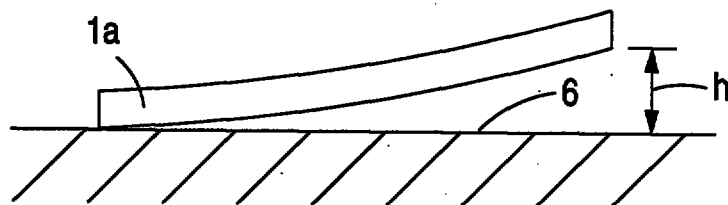


FIG. 15



14 JAN 1997

9/21

FIG. 16A
RELATED ART

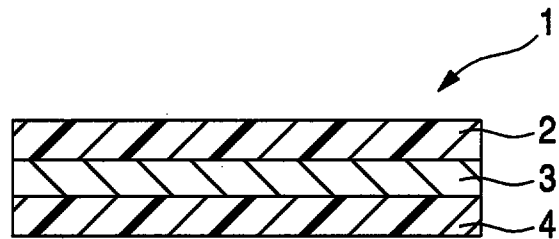


FIG. 16B
RELATED ART

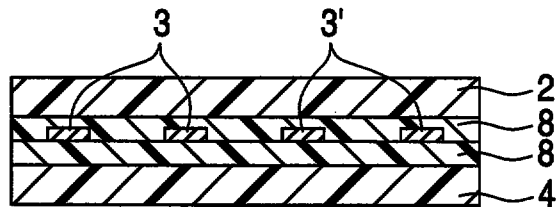


FIG. 17A
PRIOR ART

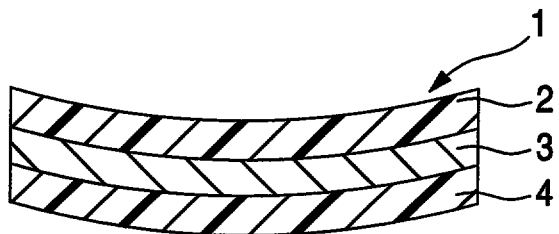
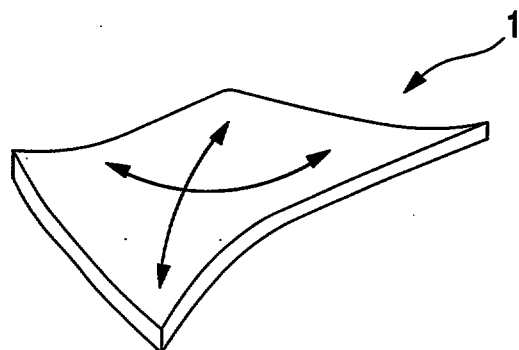


FIG. 17B
PRIOR ART



10/21

REPLACEMENT SHEET

14 JAN 1997

FIG. 18A

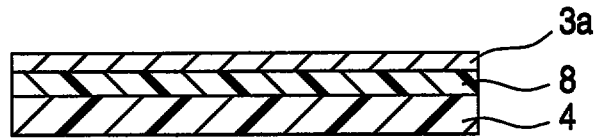


FIG. 18B

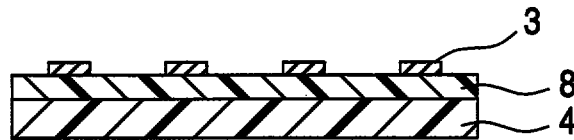


FIG. 18C

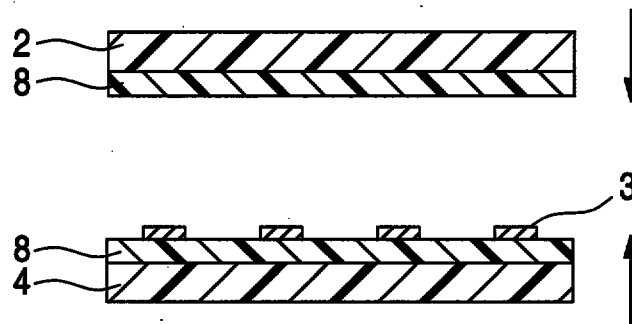
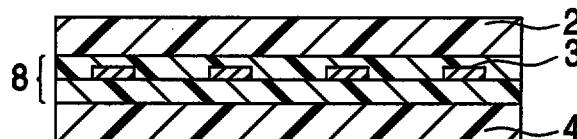


FIG. 18D



14 JAN 1997

FIG. 19

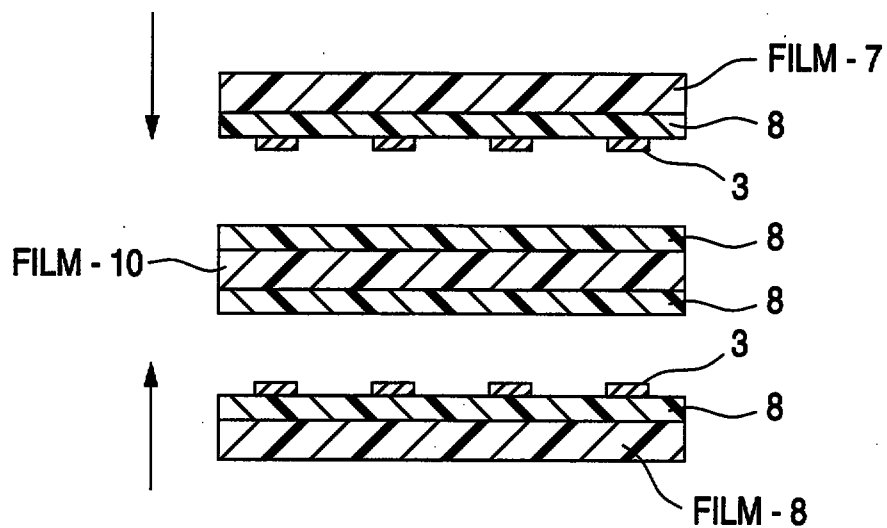
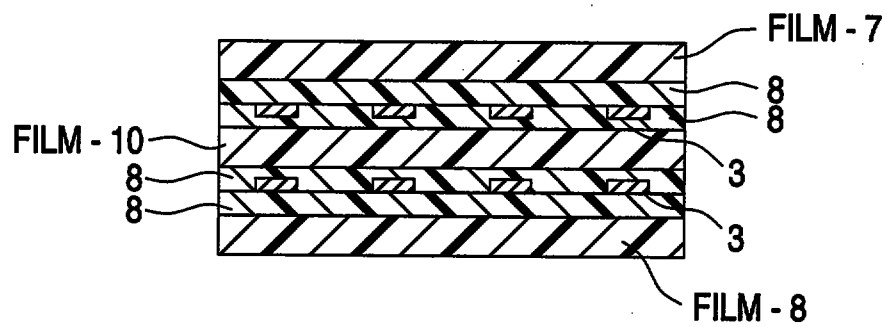


FIG. 20



12/21

14 JAN 1997

FIG. 21

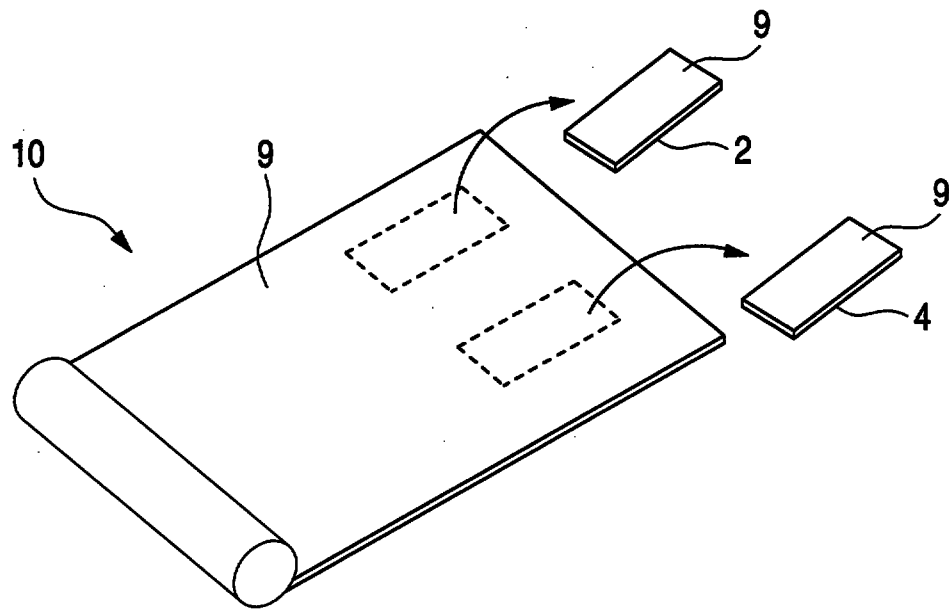


FIG. 22A

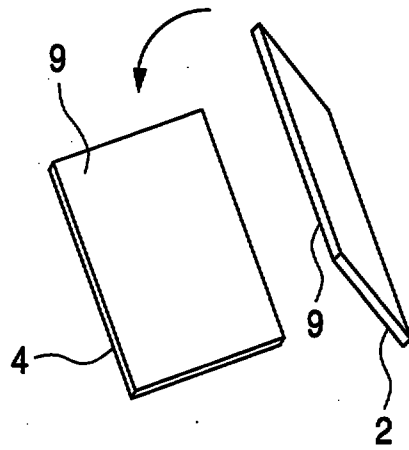


FIG. 22B

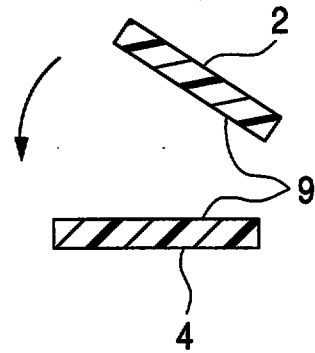
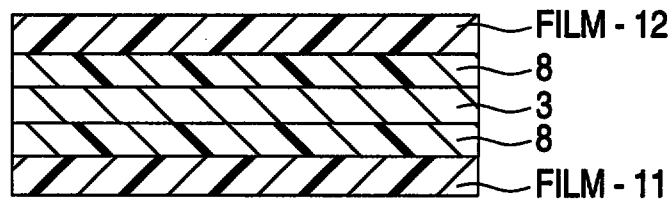


FIG. 23



14/21

14 JAN 1997

FIG. 24

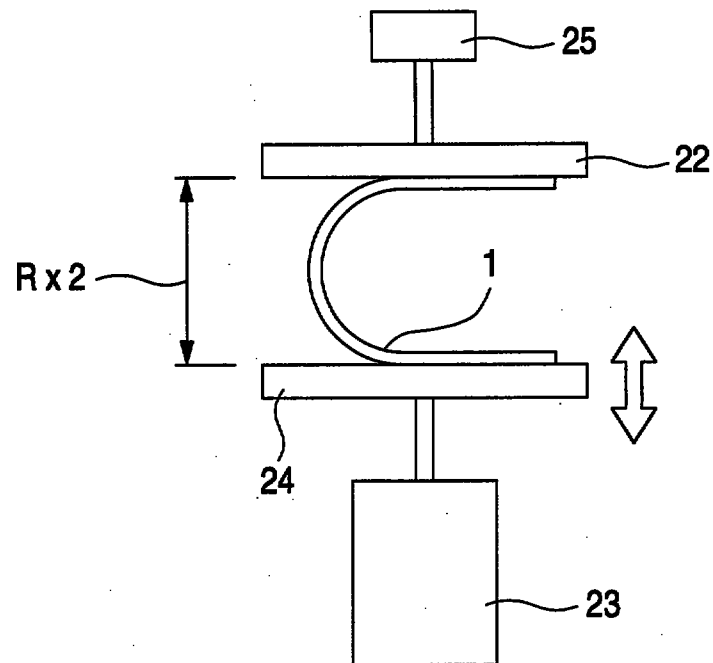


FIG. 25

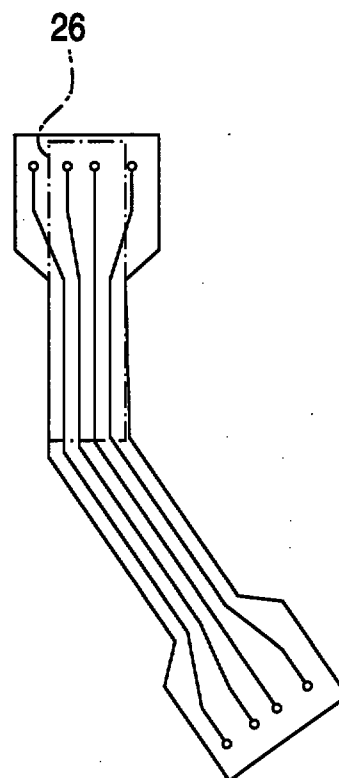


FIG. 26A
RELATED ART

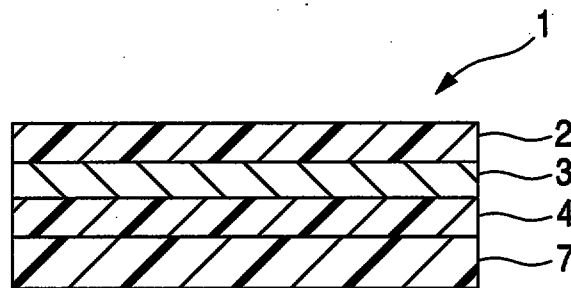
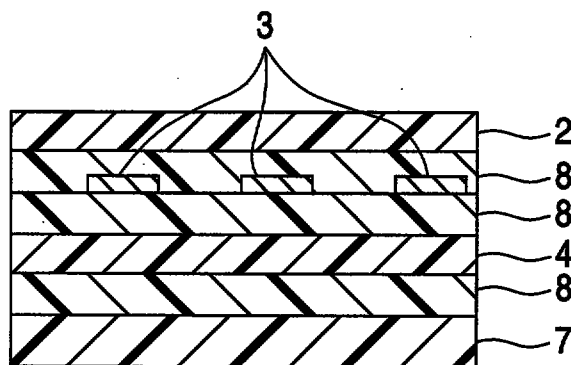


FIG. 26B



14 JAN 1997

16/21

FIG. 27

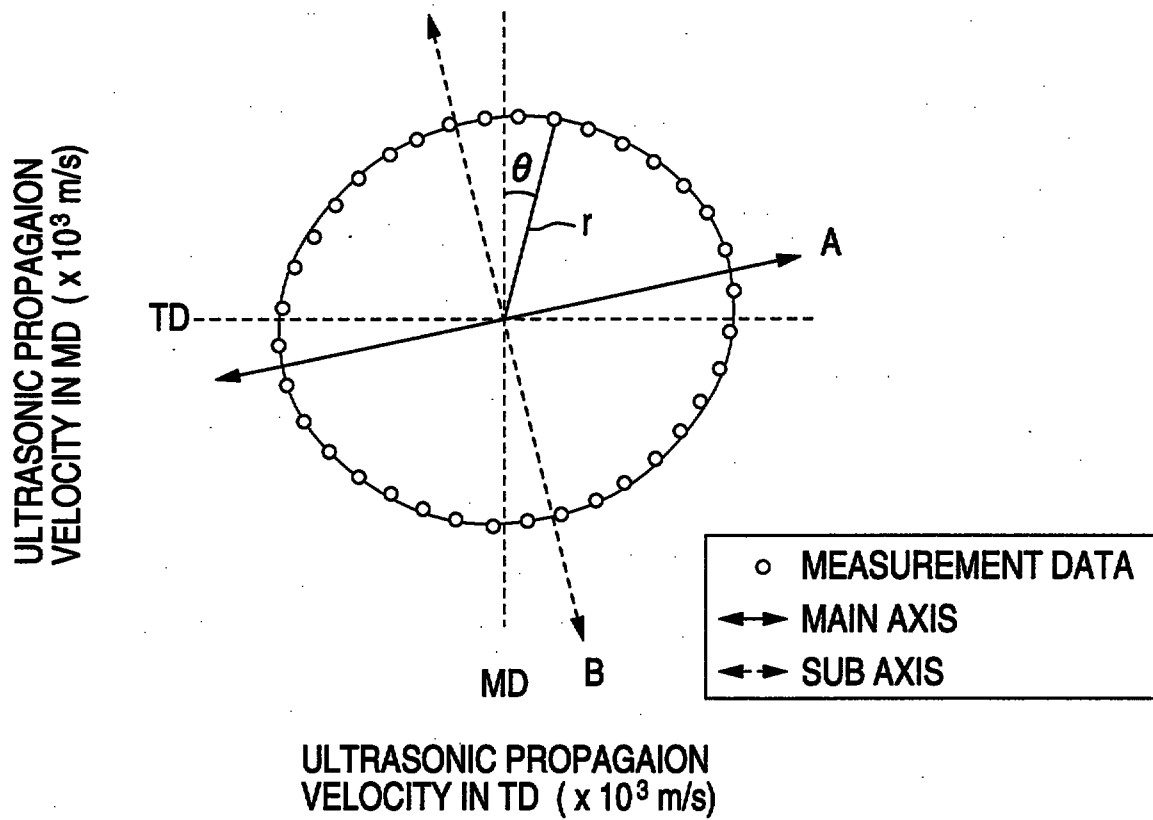
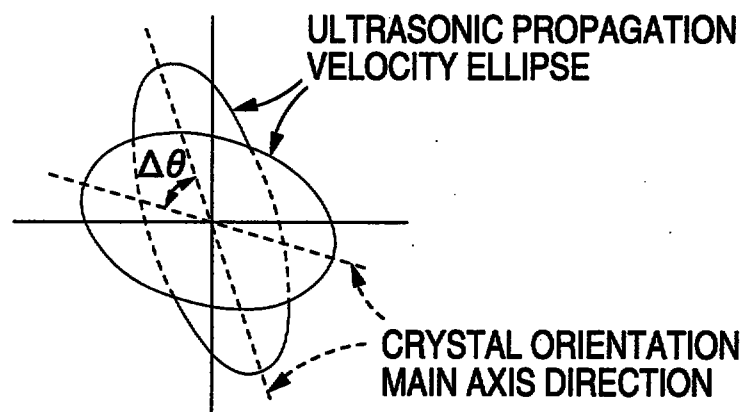


FIG. 28



14 JAN 1997

FIG. 29

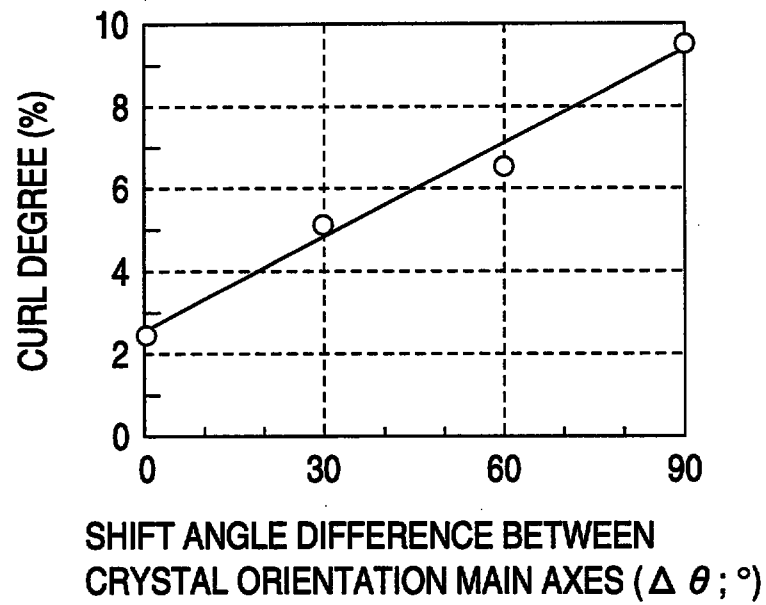
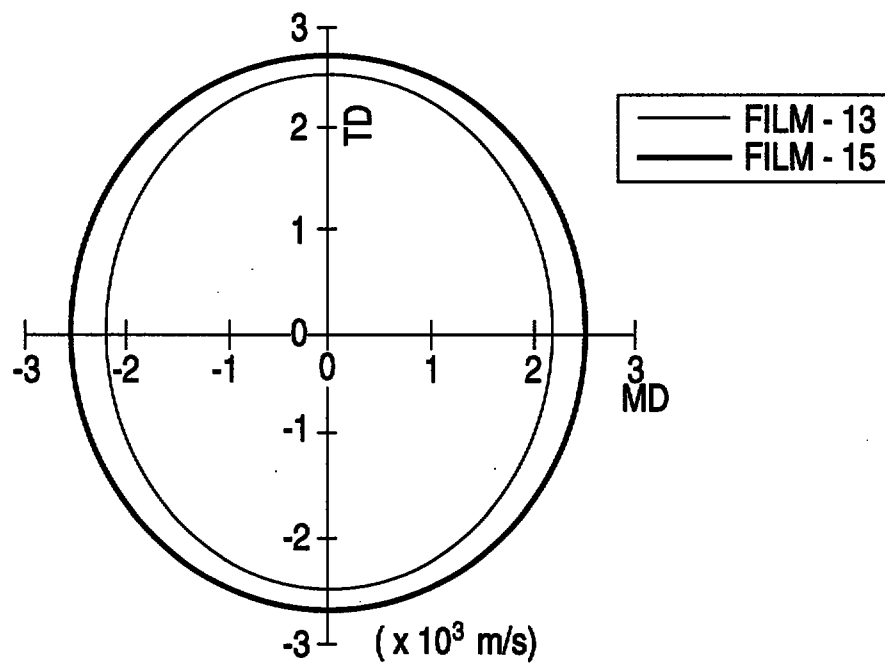


FIG. 30



14 JAN 1997

FIG. 31

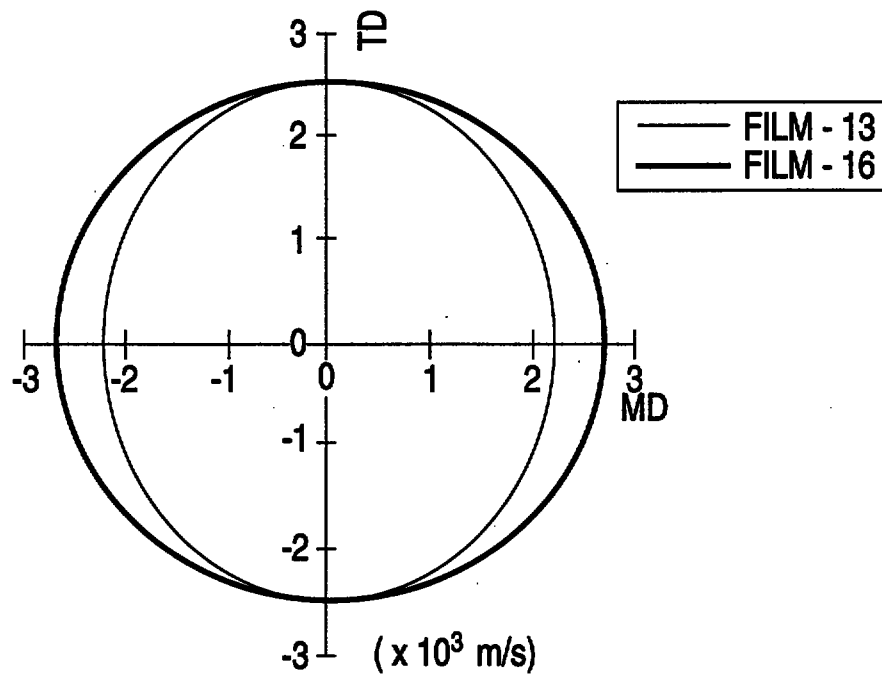
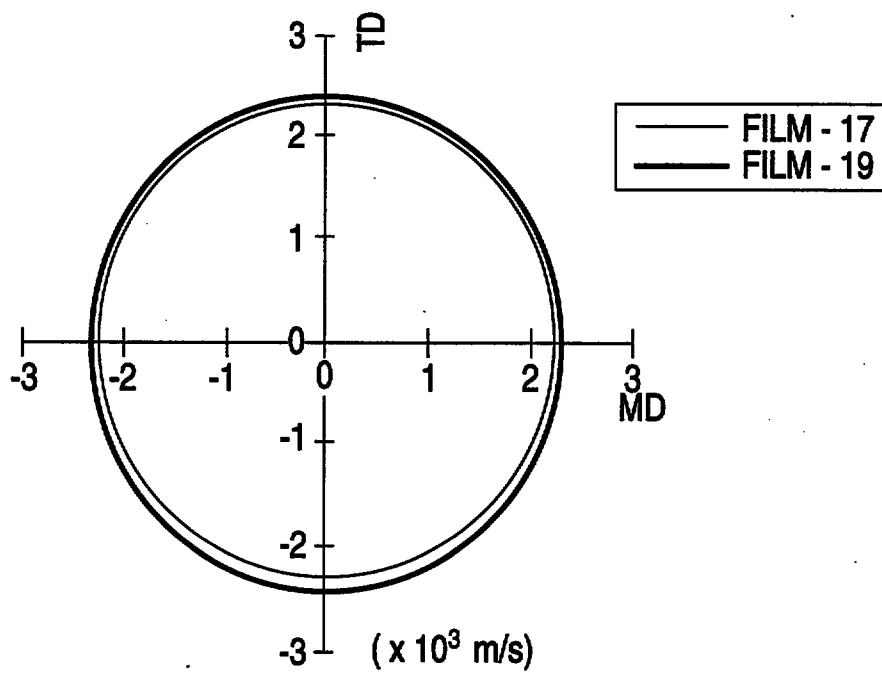


FIG. 32



19/21

REPLACEMENT SHEET

14 JAN 1997

FIG. 33

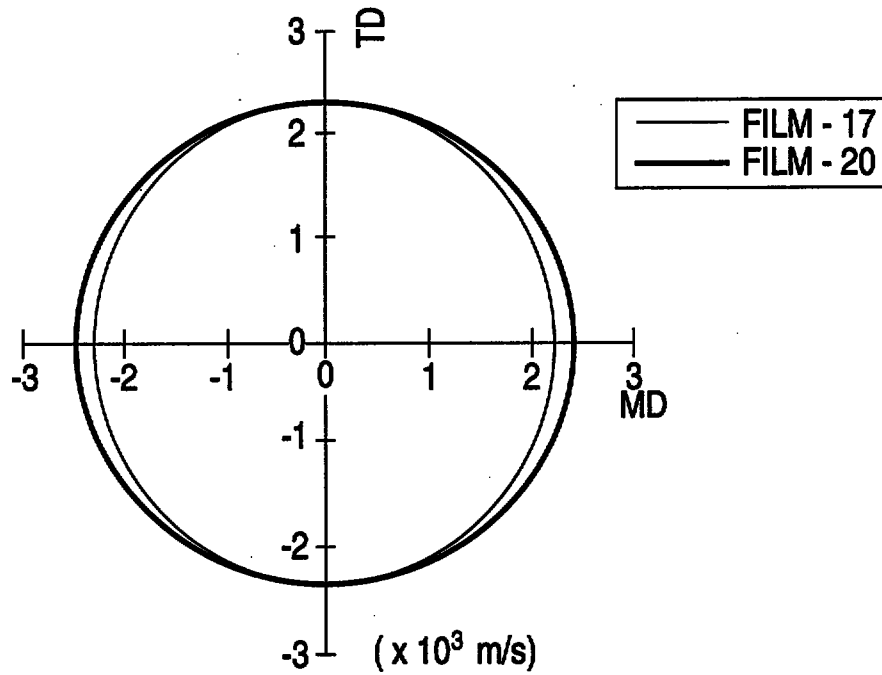
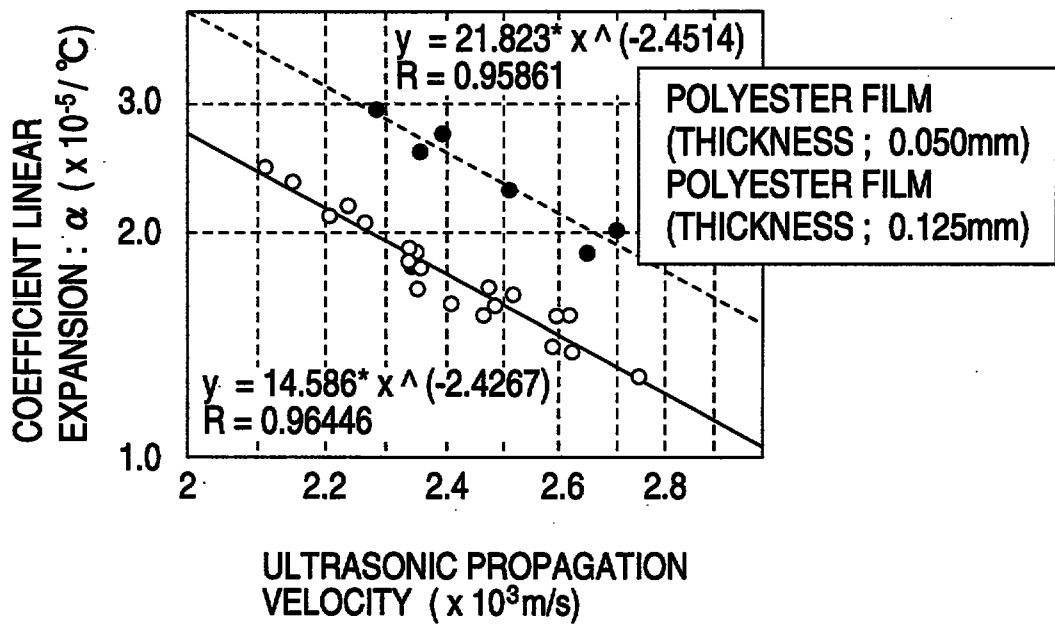
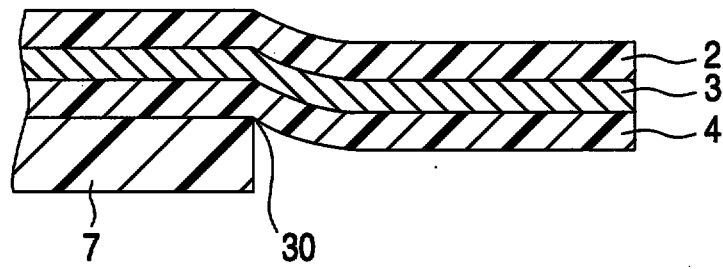


FIG. 34



14 JAN 1997

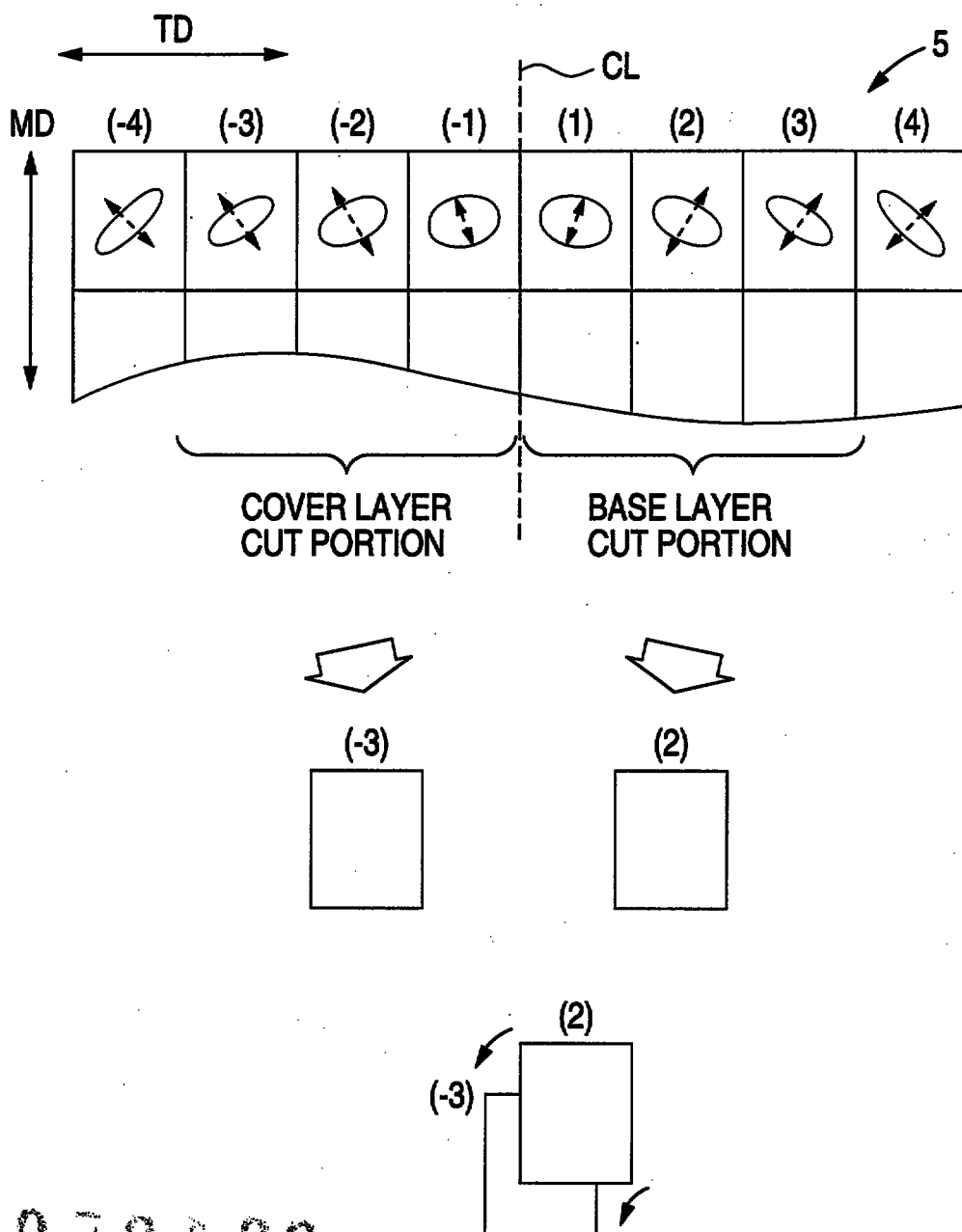
FIG. 35



14 JAN 1997

21/21

FIG. 36



0-0000000000