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INDUCTOR, COIL SUBSTRATE, AND METHOD OF MANUFACTURING INDUCTOR

Abstract

A coil substrate includes: a substrate; a first wiring on a first main surface of the substrate; a second wiring on a second main surface of the substrate; a first insulator covering the first wiring; and a second insulator covering the second wiring. The first wiring includes a first coil portion wound outward from one end, and a first connection portion drawn out from the other end of the first coil portion and connected to a first electrode. The second wiring includes a second coil portion wound outward from one end, and a second connection portion drawn out from the other end of the second coil portion and connected to a second electrode. Respective innermost peripheries of the first coil portion and the second coil portion coincide over the whole circumference, and respective outermost peripheries of the first coil portion and the second coil portion coincide over the whole circumference.

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Background/Summary

CROSS-REFERENCE OF RELATED APPLICATIONS [0001] This application is the U.S. National Phase under 35 U.S.C. § 371 of International Patent Application No. PCT/JP2023/010405, filed on Mar. 16, 2023, which in turn claims the benefit of Japanese Patent Application No. 2022-069636, filed on Apr. 20, 2022, the entire disclosure of which Applications are incorporated by reference herein.

TECHNICAL FIELD
[0002] The present disclosure relates to an inductor, a substrate, and a method of manufacturing an inductor.
BACKGROUND ART
[0003] A conventionally known inductor includes a substrate, a pair of coil portions provided on the front and back surfaces of the substrate, and a via electrode that passes through the substrate to cause the pair of coil portions to be electrically continuous with each other (see, for example, Patent Literature (PTL) 1).
CITATION LIST
Patent Literature
[PTL 1]
[0004] Japanese Unexamined Patent Application Publication No. 2018-117111
SUMMARY OF INVENTION
Technical Problem
[0005] The present disclosure has an object of providing an inductor, etc. that can suppress deformation of a substrate.
Solution to Problem
[0006] An inductor according to an aspect of the present disclosure is an inductor including: a coil substrate; a magnetic core that contains at least part of the coil substrate; and a first electrode and a second electrode that are connected to the coil substrate, wherein the coil substrate includes: a substrate; a first wiring provided on a first main surface of the substrate; a second wiring provided on a second main surface of the substrate opposite to the first main surface; a first insulator provided on the first main surface and covering the first wiring; and a second insulator provided on the second main surface and covering the second wiring, the first wiring includes a first coil portion wound outward from one end, and a first connection portion drawn out from the other end of the first coil portion and connected to the first electrode, the second wiring includes a second coil portion wound outward from one end, and a second connection portion drawn out from the other end of the second coil portion and connected to the second electrode, the one end of the second coil portion being electrically connected to the one end of the first coil portion, and an innermost periphery of the first coil portion and an innermost periphery of the second coil portion coincide with each other over whole circumference, and an outermost periphery of the first coil portion and an outermost periphery of the second coil portion coincide with each other over whole circumference.
[0007] A method of manufacturing an inductor according to an aspect of the present disclosure is a method of manufacturing the above-described inductor, including: forming the first wiring and the second wiring on the first main surface and the second main surface of the substrate respectively; forming the first insulator and the second insulator to cover the first wiring and the second wiring

respectively; and forming a through hole in the substrate.

[0008] A coil substrate according to an aspect of the present disclosure is a coil substrate that is at least partly contained in a magnetic core in a state of being connected to a first electrode and a second electrode, the coil substrate including: a substrate; a first wiring provided on a first main surface of the substrate; a second wiring provided on a second main surface of the substrate opposite to the first main surface; a first insulator provided on the first main surface and covering the first wiring; and a second insulator provided on the second main surface and covering the second wiring, wherein the first wiring includes a first coil portion wound outward from one end, and a first connection portion drawn out from the other end of the first coil portion and connected to the first electrode, the second wiring includes a second coil portion wound outward from one end, and a second connection portion drawn out from the other end of the second coil portion and connected to the second electrode, the one end of the second coil portion being electrically connected to the one end of the first coil portion, and an innermost periphery of the first coil portion and an innermost periphery of the second coil portion coincide with each other over whole circumference, and an outermost periphery of the first coil portion and an outermost periphery of the second coil portion coincide with each other over whole circumference.

[0009] A substrate according to an aspect of the present disclosure is a coil substrate that is connected to a first electrode and a second electrode, the coil substrate including: a substrate; a first wiring provided on a first main surface of the substrate; a second wiring provided on a second main surface of the substrate opposite to the first main surface; a first insulator provided on the first main surface and covering the first wiring; and a second insulator provided on the second main surface and covering the second wiring, wherein the first wiring includes a first coil portion wound outward from one end, and a first connection portion drawn out from the other end of the first coil portion and connected to the first electrode, the second wiring includes a second coil portion wound outward from one end, and a second connection portion drawn out from the other end of the second coil portion and connected to the second electrode, the one end of the second coil portion being electrically connected to the one end of the first coil portion, and an innermost periphery of the first coil portion and an innermost periphery of the second coil portion coincide with each other over whole circumference, and an outermost periphery of the first coil portion and an outermost periphery of the second coil portion coincide with each other over whole circumference.

Advantageous Effects of Invention

[0010] According to the present disclosure, it is possible to provide an inductor, etc. that can suppress deformation of a substrate.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. **1** is a perspective view of inductor **10** according to an embodiment.

[0012] FIG. **2** is a perspective view of a coil substrate according to the embodiment.

[0013] FIG. **3** is a perspective view of the coil substrate according to the embodiment excluding a first insulator and a second insulator.

[0014] FIG. **4** is an explanatory diagram illustrating the planar shapes of first wiring and second wiring according to the embodiment.

[0015] FIG. **5** is an explanatory diagram illustrating a method of manufacturing an inductor by a first technique according to the embodiment.

[0016] FIG. **6** is an explanatory diagram illustrating the method of manufacturing an inductor by the first technique according to the embodiment.

[0017] FIG. **7** is an explanatory diagram illustrating the method of manufacturing an inductor by the first technique according to the embodiment.

[0018] FIG. **8** is an explanatory diagram illustrating a method of manufacturing an inductor by a second technique according to the embodiment.
[0019] FIG. **9** is an explanatory diagram illustrating the method of manufacturing an inductor by the second technique according to the embodiment.
[0020] FIG. **10** is an explanatory diagram illustrating the method of manufacturing an inductor by the second technique according to the embodiment.
[0021] FIG. **11** is an explanatory diagram illustrating the planar shapes of first wiring and second wiring according to Variation 1.
[0022] FIG. **12** is an explanatory diagram illustrating the planar shapes of first wiring and second wiring according to Variation 2.
[0023] FIG. **13** is an explanatory diagram illustrating the planar shapes of first wiring and second wiring according to Variation 3.
[0024] FIG. **14** is an exploded perspective view of an inductor according to Variation 4.
[0025] FIG. **15** is a perspective view of the inductor according to Variation 4.
[0026] FIG. **16** is a cross-sectional view of an inductor according to Variation 5.
[0027] FIG. **17** is a cross-sectional view of an inductor according to Variation 6.

DESCRIPTION OF EMBODIMENTS

Inventor's Knowledge

[0028] The inventor has found that, in the foregoing conventional inductor, the pair of coil portions do not overlap each other near the via electrode in a plan view of the substrate, which causes the substrate to deform. Specifically, since the pair of coil portions do not overlap each other near the via electrode, the overall linear expansion coefficient of the coil portions varies. Accordingly, when the coil portions are heated due to a temperature rise during the manufacture or use of the inductor, the substrate warps because of variation in overall linear expansion coefficient. The present disclosure is intended to make the overall linear expansion coefficient of the coil portions on the front and back surfaces of the substrate uniform to thereby suppress deformation of the substrate during heating.

EMBODIMENT

[0029] An embodiment will be described in detail below with reference to the drawings. The embodiment described below shows a specific example according to the present disclosure. The numerical values, shapes, materials, structural elements, the arrangement and connection of the structural elements, steps, the order of steps, etc. shown in the embodiment described below are mere examples, and do not limit the scope of the present disclosure. Of the structural elements in the embodiment described below, the structural elements not recited in any one of the independent claims representing the broadest concepts are described as optional structural elements. In the following description, the long-side direction of the inductor is the Y-axis direction, the short-side direction of the inductor is the X-axis direction, and the thickness direction of the inductor is the Z-axis direction.

[Inductor]

[0030] The structure of an inductor according to an embodiment will be described with reference to FIG. **1**. FIG. **1** is a perspective view of inductor **10** according to the embodiment.
[0031] As illustrated in FIG. **1**, inductor **10** includes coil substrate **40**, magnetic core **20**, first electrode **31**, and second electrode **32**. Magnetic core **20** is obtained by mixing a magnetic powder and a resin powder and pressure-forming the mixture into a rectangular parallelepiped elongated in the Y-axis direction. Magnetic core **20** contains coil substrate **40**.
[0032] First electrode **31** and second electrode **32** are formed of conductive members. First electrode **31** is provided at the end of magnetic core **20** on the positive side (i.e. the side indicated by the arrow) in the Y-axis direction, and second electrode **32** is provided at the end of magnetic core **20** on the negative side (i.e. the opposite side to the side indicated by the arrow) in the Y-axis direction.

[0033] Next, coil substrate **40** will be described in detail. FIG. **2** is a perspective view of coil substrate **40** according to the embodiment. FIG. **2** illustrates inductor **10** in FIG. **1** excluding magnetic core **20**, first electrode **31**, and second electrode **32**. FIG. **3** is a perspective view of coil substrate **40** according to the embodiment excluding first insulator **81** and second insulator **82**.
[0034] As illustrated in FIGS. **2** and **3**, coil substrate **40** includes substrate **50**, first wiring **60**, second wiring **70**, first insulator **81**, and second insulator **82**, and has, at its center, through hole **41** in the Z-axis direction.
[0035] Substrate **50** is, for example, a flexible substrate formed of an insulating film. An example of the material of the insulating film is insulating resin such as polyimide. Substrate **50** may be a glass epoxy substrate. Substrate **50** is a sheet body elongated in the Y-axis direction. The main surface of substrate **50** facing the positive side in the Z-axis direction is first main surface **51**, and the main surface of substrate **50** facing the negative side in the Z-axis direction is second main surface **52**. Opening **53** is formed through substrate **50** at its center in the Z-axis direction. Opening **53** forms part of through hole **41**.
[0036] First wiring **60** is provided on first main surface **51** of substrate **50** and electrically connected to first electrode **31**. Second wiring **70** is provided on second main surface **52** of substrate **50** and electrically connected to second electrode **32**. First wiring **60** and second wiring **70** are formed, for example, of a conductive material such as copper. The specific structures of first wiring **60** and second wiring **70** will be described later.
[0037] First insulator **81** is provided on first main surface **51** so as to cover first wiring **60**. Second insulator **82** is provided on second main surface **52** so as to cover second wiring **70**. First insulator **81** and second insulator **82** are formed, for example, of a solder resist or a coverlay film. The coverlay film is a film obtained by laminating an adhesive layer on one side of an insulating film made of polyimide, for example. First insulator **81** and second insulator **82** have through hole **41**.
[First Wiring and Second Wiring]
[0038] Next, the specific structures of first wiring **60** and second wiring **70** will be described. FIG. **4** is an explanatory diagram illustrating the planar shapes of first wiring **60** and second wiring **70** according to the embodiment. Specifically, (a) in FIG. **4** is a plan view illustrating the planar shape of first wiring **60**, and (b) in FIG. **4** is a plan view illustrating the planar shape of second wiring **70**. (a) and (b) in FIG. **4** are plan views of first wiring **60** and second wiring **70** as seen from the same direction (the positive side in the Z-axis direction). In FIG. **4**, first main surface **51** and second main surface **52** are dot-hatched.
[0039] As illustrated in (a) in FIG. **4**, first wiring **60** includes wound first coil portion **61** and first connection portion **62** drawn out from first coil portion **61** and electrically connected to first electrode **31**. First coil portion **61** has one end **63** at a position on first main surface **51** that is at the center in the Y-axis direction and is closer to the positive side in the X-axis direction than the center in the X-axis direction. First coil portion **61** is wound clockwise outward from one end **63**. The number of turns of first coil portion **61** is approximately 1 and ¾ turns. The other end **64** of first coil portion **61** is located at the end of first main surface **51** on the positive side in the Y-axis direction and the negative side in the X-axis direction, and first connection portion **62** is drawn out from the other end **64**. The other end **64** has a shape that smoothly widens toward the tip. Boundary L**1** between the other end **64** and first connection portion **62** is designated by the dot-dot-dash line. First connection portion **62** has a rectangular shape elongated in the X-axis direction.
[0040] In first coil portion **61**, the ¾ turn part from one end **63** is narrow portion **65** having a predetermined line width, the ¼ turn part from narrow portion **65** is wide portion **66** larger in line width than narrow portion **65**, and the ¾ turn part beyond wide portion **66** from the part overlapping one end **63** to the other end **64** is narrow portion **67** equal in line width to narrow portion **65**.
[0041] Hence, innermost periphery **68** in first coil portion **61** is composed of the inner peripheral edge of narrow portion **65** and the inner peripheral edge of wide portion **66**. Innermost periphery **68**

has an oval shape elongated in the Y-axis direction. Opening **53** is located inside innermost periphery **68**.

[0042] Outermost periphery **69** in first coil portion **61** is composed of the outer peripheral edge of wide portion **66** and the outer peripheral edge of narrow portion **67**. Outermost periphery **69** has an oval shape elongated in the Y-axis direction. The contour of first coil portion **61** includes innermost periphery **68**, outermost periphery **69**, and boundary L**1**. This contour is referred to as first coil region R**1**.

[0043] As illustrated in (b) in FIG. **4**, second wiring **70** includes wound second coil portion **71** and second connection portion **72** drawn out from second coil portion **71** and electrically connected to second electrode **32**. Second coil portion **71** has one end **73** at a position on second main surface **52** that is at the center in the Y-axis direction and is closer to the positive side in the X-axis direction than the center in the X-axis direction. Second coil portion **71** is wound counterclockwise outward from one end **73**. The number of turns of second coil portion **71** is approximately 1 and ¾ turns. The other end **74** of second coil portion **71** is located at the end of second main surface **52** on the negative side in the Y-axis direction and the negative side in the X-axis direction, and second connection portion **72** is drawn out from the other end **74**. The other end **74** has a shape that smoothly widens toward the tip. Boundary L**2** between the other end **74** and second connection portion **72** is designated by the dot-dot-dash line. Second connection portion **72** has a rectangular shape elongated in the X-axis direction.

[0044] Via electrode **80** that passes through substrate **50** and is electrically continuous with one end **63** of first coil portion **61** is formed at one end **73** of second coil portion **71**. Thus, first coil portion **61** and second coil portion **71** as a whole have a coil shape that is wound counterclockwise from the other end **64** of first coil portion **61**.

[0045] In second coil portion **71**, the ¾ turn part from one end **73** is narrow portion **75** having a predetermined line width, the ¼ turn part from narrow portion **75** is wide portion **76** larger in line width than narrow portion **75**, and the ¾ turn part beyond wide portion **76** from the part overlapping one end **73** to the other end **74** is narrow portion **77** equal in line width to narrow portion **75**.

[0046] Hence, innermost periphery **78** in second coil portion **71** is composed of the inner peripheral edge of narrow portion **75** and the inner peripheral edge of wide portion **76**. Innermost periphery **78** has an oval shape elongated in the Y-axis direction. Opening **53** is located inside innermost periphery **78**.

[0047] Outermost periphery **79** in second coil portion **71** is composed of the outer peripheral edge of wide portion **76** and the outer peripheral edge of narrow portion **77**. Outermost periphery **79** has an oval shape elongated in the Y-axis direction. The contour of second coil portion **71** includes innermost periphery **78**, outermost periphery **79**, and boundary L**2**. This contour is referred to as second coil region R**2**. In (b) in FIG. **4**, first coil region R**1** of first wiring **60** is designated by the dash lines.

[0048] As illustrated in (b) in FIG. **4**, innermost periphery **68** of first wiring **60** and innermost periphery **78** of second wiring **70** coincide with each other over the whole circumference in a plan view (i.e. as seen in the Z-axis direction). Moreover, outermost periphery **69** of first wiring **60** and outermost periphery **79** of second wiring **70** coincide with each other over the whole circumference in a plan view. Since innermost peripheries **68** and **78** coincide with each other over the whole circumference and outermost peripheries **69** and **79** coincide with each other over the whole circumference, the overall linear expansion coefficient of first coil portion **61** and second coil portion **71** is made uniform with little variation. Herein, the expression “coincide with each other over the whole circumference” means that the peripheries coincide with each other preferably by 85% or more of the circumference, more preferably by 90% or more of the circumference, and further preferably by 95% or more of the circumference.

[0049] In other words, first coil region R**1** and second coil region R**2** roughly overlap each other (i.e. coincide with each other) in a plan view. With such relationship, the overall linear expansion coefficient of first coil portion **61** and second coil portion **71** is made uniform with little variation. Specifically, the overlapping rate of first coil region R**1** and second coil region R**2** is preferably 75% or more, more preferably 80% or more, and further preferably 85% or more.

[Method of Manufacturing Inductor]

[0050] Next, a method of manufacturing inductor **10** will be described. Inductor **10** can be formed by a first technique or a second technique. First, the first technique will be described. FIGS. **5** to **7** are explanatory diagrams illustrating a method of manufacturing inductor **10** by the first technique according to the embodiment. FIGS. **5** to **7** are end views of members during manufacture, corresponding to a cut end surface including line C-C in FIG. **4**. In other words, FIGS. **5** to **7** are cross-sectional views of parts corresponding to first coil portion **61** and second coil portion **71**.

[0051] First, substrate **100** laminated with seed layer **110** on both sides is prepared (see (a) in FIG. **5**). Substrate **100** is a member that is to form substrate **50** in inductor **10**. Next, through hole **101** is formed through substrate **100** at a position corresponding to via electrode **80** (see (b) in FIG. **5**). Through hole **101** is formed, for example, by laser machining or drilling.

[0052] Next, resist layer **120** is laminated on each seed layer **110** (see (c) in FIG. **5**). Resist layer **120** is formed, for example, using a film or by screen printing. Each resist layer **120** is then exposed and developed to perform patterning with part of resist layer **120** remaining and the other part of resist layer **120** removed (see (d) in FIG. **5**).

[0053] Next, substrate **100** that has been patterned is electroplated, as a result of which conductive layer **130** made of, for example, copper is formed on both sides of substrate **100** (see (e) in FIG. **5**). Conductive layers **130** are integrated with respective seed layers **110**.

[0054] Next, each resist layer **120** is peeled off and removed (see (a) in FIG. **6**). After this, each seed layer **110** exposed from conductive layer **130** is removed by flash etching or the like (see (b) in FIG. **6**). Respective conductive layers **130** remaining on both sides of substrate **100** form first wiring **60** and second wiring **70** in inductor **10**. Thus, first wiring **60** is formed on first main surface **51** of substrate **50** and second wiring **70** is formed on second main surface **52** of substrate **50**.

[0055] Next, a pair of coverlay films **140** are arranged on both sides of substrate **100** (see (c) in FIG. **6**). The pair of coverlay films **140** each have adhesive layer **141** on the substrate **100** side and insulating film **142** on the opposite side to substrate **100**. The pair of coverlay films **140** then sandwich substrate **100** to cover first wiring **60** and second wiring **70** (see (a) in FIG. **7**). The pair of coverlay films **140** form first insulator **81** and second insulator **82** in inductor **10**. Thus, first insulator **81** is formed on first main surface **51** of substrate **50** so as to cover first wiring **60**, and second insulator **82** is formed on second main surface **52** of substrate **50** so as to cover second wiring **70**. For example, the thickness of first insulator **81** directly above first wiring **60** (thickness in the Z-axis direction) is greater than the thickness of first insulator **81** between the lines of first wiring **60** (inter-line width). This ensures stable insulation. The same applies to second insulator **82**.

[0056] Next, the pair of coverlay films **140** and substrate **100** are holed together to form through hole **41** through substrate **100** at its center. Through hole **41** is formed by laser machining or punching (see (b) in FIG. **7**). Through hole **41** is formed through the center (region inside innermost periphery **68**) of first coil portion **61** of first wiring **60** and the center (region inside innermost periphery **78**) of second coil portion **71** of second wiring **70**.

[0057] Next, a magnetic powder and a resin powder are mixed and pressure-formed into magnetic core **20** that covers first insulator **81** and second insulator **82** (see (c) in FIG. **7**). Inductor **10** illustrated in FIG. **1** is thus formed.

[0058] Next, the second technique will be described. FIGS. **8** to **10** are explanatory diagrams illustrating a method of manufacturing inductor **10** by the second technique according to the embodiment.

[0059] First, substrate **100** laminated with seed layer **110** on both sides is prepared (see (a) in FIG.

8). Substrate **100** is a member that is to form substrate **50** in inductor **10**. Next, through hole **101** is formed through substrate **100** at a position corresponding to via electrode **80** (see (b) in FIG. **8**). Through hole **101** is formed, for example, by laser machining or drilling.
[0060] Next, resist layer **150** is laminated on each seed layer **110** (see (c) in FIG. **8**). Resist layer **150** is formed, for example, using a film or by screen printing. Resist layer **150** is thinner than resist layer **120** formed in the first technique.
[0061] Each resist layer **150** is then exposed and developed to perform patterning with part of resist layer **150** remaining and the other part of resist layer **150** removed (see (d) in FIG. **8**). Substrate **100** that has been patterned is then etched to remove seed layer **110** exposed from resist layer **150** (see (e) in FIG. **8**).
[0062] Next, each resist layer **150** is peeled off and removed (see (f) in FIG. **8**). This exposes seed layer **110** covered with resist layer **150**.
[0063] Next, resist layer **160** is laminated on both sides of substrate **100** (see (a) in FIG. **9**). Resist layer **160** is formed, for example, using a film or by screen printing. Resist layer **160** is thicker than resist layer **150**.
[0064] Each resist layer **160** is then exposed and developed to perform patterning with part of resist layer **160** remaining and the other part of resist layer **160** removed (see (b) in FIG. **9**). This exposes seed layer **110**.
[0065] Next, substrate **100** that has been patterned is electroplated, as a result of which conductive layer **170** made of, for example, copper is formed (see (c) in FIG. **9**). Here, conductive layers **170** are integrated with respective seed layers **110** to form first wiring **60** and second wiring **70** in inductor **10**. Thus, first wiring **60** is formed on first main surface **51** of substrate **50** and second wiring **70** is formed on second main surface **52** of substrate **50**.
[0066] Next, resist layer **180** is formed on each conductive layer **170**. As a result, each conductive layer **170** is covered with resist layers **160** and **180** (see (a) in FIG. **10**). Resist layers **160** and **180** form first insulator **81** and second insulator **82** in inductor **10**. Thus, first insulator **81** is formed on first main surface **51** of substrate **50** so as to cover first wiring **60**, and second insulator **82** is formed on second main surface **52** of substrate **50** so as to cover second wiring **70**.
[0067] Next, through hole **41** is formed through substrate **100** at its center (see (b) in FIG. **10**). Through hole **41** is formed by laser machining or punching. Through hole **41** is formed through the center (region inside innermost periphery **68**) of first coil portion **61** of first wiring **60** and the center (region inside innermost periphery **78**) of second coil portion **71** of second wiring **70**.
[0068] Next, a magnetic powder and a resin powder are mixed and pressure-formed into magnetic core **20** that covers first insulator **81** and second insulator **82** (see (c) in FIG. **10**). Inductor **10** illustrated in FIG. **1** is thus formed.
[0069] In both the first technique and the second technique, first wiring **60** and second wiring **70** are formed on both sides of substrate **100** before through hole **41** is formed. Here, if the innermost periphery of the first wiring and the innermost periphery of the second wiring do not coincide with each other over the whole circumference, the strength of the substrate varies. This causes distortion of the substrate during the formation of the through hole, hindering accurate through hole formation. This is noticeable when the through hole is formed by punching.
[0070] In this embodiment, innermost periphery **68** of first wiring **60** and innermost periphery **78** of second wiring **70** coincide with each other over the whole circumference. This makes the strength of substrate **100** uniform, and prevents substrate **100** from being distorted during the formation of the through hole. Hence, through hole **41** can be formed accurately.
[0071] Particularly in the first technique, the pair of coverlay films **140** and substrate **100** are holed together to form through hole **41**. Since distortion of substrate **100** is further suppressed, through hole **41** can be formed more accurately.
Effects, Etc
[0072] As described above, inductor **10** according to the embodiment is an inductor including: coil

substrate **40**; magnetic core **20** that contains at least part of coil substrate **40**; and first electrode **31** and second electrode **32** that are connected to coil substrate **40**. Coil substrate **40** includes: substrate **50**; first wiring **60** provided on first main surface **51** of substrate **50**; second wiring **70** provided on second main surface **52** of substrate **50** opposite to first main surface **51**; first insulator **81** provided on first main surface **51** and covering first wiring **60**; and second insulator **82** provided on second main surface **52** and covering second wiring **70**. First wiring **60** includes first coil portion **61** wound outward from one end **63**, and first connection portion **62** drawn out from the other end **64** of first coil portion **61** and connected to first electrode **31**. Second wiring **70** includes second coil portion **71** wound outward from one end **73**, and second connection portion **72** drawn out from the other end **74** of second coil portion **71** and connected to second electrode **32**, one end **73** of second coil portion **71** being electrically connected to one end **63** of first coil portion **61**. Innermost periphery **68** of first coil portion **61** and innermost periphery **78** of second coil portion **71** coincide with each other over whole circumference, and outermost periphery **69** of first coil portion **61** and outermost periphery **79** of second coil portion **71** coincide with each other over whole circumference.

[0073] A coil substrate according to the embodiment is coil substrate **40** that is at least partly contained in magnetic core **20** in a state of being connected to first electrode **31** and second electrode **32**. Coil substrate **40** includes: substrate **50**; first wiring **60** provided on first main surface **51** of substrate **50**; second wiring **70** provided on second main surface **52** of substrate **50** opposite to first main surface **51**; first insulator **81** provided on first main surface **51** and covering first wiring **60**; and second insulator **82** provided on second main surface **52** and covering second wiring **70**. First wiring **60** includes first coil portion **61** wound outward from one end **63**, and first connection portion **62** drawn out from the other end **64** of first coil portion **61** and connected to first electrode **31**. Second wiring **70** includes second coil portion **71** wound outward from one end **73**, and second connection portion **72** drawn out from the other end **74** of second coil portion **71** and connected to second electrode **32**, one end **73** of second coil portion **71** being electrically connected to one end **63** of first coil portion **61**. Innermost periphery **68** of first coil portion **61** and innermost periphery **78** of second coil portion **71** coincide with each other over whole circumference, and outermost periphery **69** of first coil portion **61** and outermost periphery **79** of second coil portion **71** coincide with each other over whole circumference.

[0074] A coil substrate according to the embodiment is coil substrate **40** that is connected to first electrode **31** and second electrode **32**. Coil substrate **40** includes: substrate **50**; first wiring **60** provided on first main surface **51** of substrate **50**; second wiring **70** provided on second main surface **52** of substrate **50** opposite to first main surface **51**; first insulator **81** provided on first main surface **51** and covering first wiring **60**; and second insulator **82** provided on second main surface **52** and covering second wiring **70**. First wiring **60** includes first coil portion **61** wound outward from one end **63**, and first connection portion **62** drawn out from the other end **64** of first coil portion **61** and connected to first electrode **31**. Second wiring **70** includes second coil portion **71** wound outward from one end **73**, and second connection portion **72** drawn out from the other end **74** of second coil portion **71** and connected to second electrode **32**, one end **73** of second coil portion **71** being electrically connected to one end **63** of first coil portion **61**. Innermost periphery **68** of first coil portion **61** and innermost periphery **78** of second coil portion **71** coincide with each other over whole circumference, and outermost periphery **69** of first coil portion **61** and outermost periphery **79** of second coil portion **71** coincide with each other over whole circumference.

[0075] Since innermost peripheries **68** and **78** coincide with each other over the whole circumference and outermost peripheries **69** and **79** coincide with each other over the whole circumference, the overall linear expansion coefficient of first coil portion **61** and second coil portion **71** is made uniform. Therefore, even if first coil portion **61** and second coil portion **71** are heated due to a temperature rise during the manufacture or use of the inductor, deformation of substrate **50** can be suppressed because the overall linear expansion coefficient of these coil

portions is uniform.
[0076] In addition, since innermost peripheries **68** and **78** coincide with each other over the whole circumference and outermost peripheries **69** and **79** coincide with each other over the whole circumference and wide portion **66** and wide portion **76** have wide line width, the resistance value can be reduced.
[0077] Moreover, substrate **50** is formed of an insulating film.
[0078] Since substrate **50** is formed of an insulating film, it is possible to reduce residual stress when forming through hole **41** by punching. Furthermore, given that an insulating film can be made thinner than rigid materials such as glass epoxy, it is possible to improve magnetic properties, reduce the size of inductor **10**, and improve workability. In particular, the use of a film made of polyimide as an insulating film can enhance heat resistance.
[0079] Moreover, first insulator **81** and second insulator **82** are each formed of a coverlay film.
[0080] Since first insulator **81** and second insulator **82** are each formed of a coverlay film, the insulating film of the coverlay film can suppress damage during the formation of through hole **41**. Stable insulation properties can thus be achieved.
[0081] In addition, since first insulator **81** and second insulator **82** are each formed of a coverlay film, the insulator can be prevented from being damaged by the magnetic material during the formation of magnetic core **20**.
[0082] A method of manufacturing inductor **10** according to the embodiment includes: forming first wiring **60** and second wiring **70** on both surfaces of substrate **100** (first main surface **51** and second main surface **52** of substrate **50** respectively); forming first insulator **81** and second insulator **82** to cover first wiring **60** and second wiring **70** respectively; and forming through hole **41** in substrate **100**.
[0083] In this way, first wiring **60** and second wiring **70** are formed on both sides of substrate **100** before the formation of through hole **41**, and innermost periphery **68** of first wiring **60** and innermost periphery **78** of second wiring **70** coincide with each other over the whole circumference. This makes the strength of substrate **100** uniform, and prevents substrate **100** from being distorted during the formation of the through hole. Hence, through hole **41** can be formed accurately.
DESCRIPTION OF VARIATIONS
[0084] Variations of the foregoing embodiment will be described below. In the following description, the same parts as those in the foregoing embodiment or other variations are given the same reference signs and their description may be omitted.
Variation 1
[0085] Variation 1 of the foregoing embodiment will be described. Variation 1 differs from the foregoing embodiment in the shapes of the first coil portion and second coil portion. FIG. **11** is an explanatory diagram illustrating the planar shapes of first wiring **60***a* and second wiring **70***a* according to Variation 1. FIG. **11** corresponds to FIG. **4**.
[0086] As illustrated in (a) in FIG. **11**, first coil portion **61***a* in first wiring **60***a* has one end **63***a* at a position on first main surface **51** that is at the center in the X-axis direction and is closer to the negative side in the Y-axis direction than the center in the Y-axis direction. First coil portion **61***a* is wound clockwise outward from one end **63***a*. The number of turns of first coil portion **61***a* is approximately 1 and ½ turns. The other end **64***a* of first coil portion **61***a* is located at the end of first main surface **51** on the positive side in the Y-axis direction and the negative side in the X-axis direction, and first connection portion **62***a* is drawn out from the other end **64***a*. The other end **64***a* has a shape that smoothly widens toward the tip. Boundary L**1***a* between the other end **64***a* and first connection portion **62***a* is designated by the dot-dot-dash line.
[0087] In first coil portion **61***a*, the ⅓ turn part from one end **63***a* is narrow portion **65***a* having a predetermined line width, the ⅔ turn part from narrow portion **65***a* is wide portion **66***a* larger in line width than narrow portion **65***a*, and the ½ turn part beyond wide portion **66***a* from the part

overlapping one end **63***a* to the other end **64***a* is narrow portion **67***a* equal in line width to narrow portion **65***a*.

[0088] Hence, innermost periphery **68***a* in first coil portion **61***a* is composed of the inner peripheral edge of narrow portion **65***a* and the inner peripheral edge of wide portion **66***a*. Outermost periphery **69***a* in first coil portion **61***a* is composed of the outer peripheral edge of wide portion **66***a* and the outer peripheral edge of narrow portion **67***a*. The contour of first coil portion **61***a* includes innermost periphery **68***a*, outermost periphery **69***a*, and boundary L**1***a*. This contour is referred to as first coil region R**1***a*.

[0089] As illustrated in (b) in FIG. **11**, second coil portion **71***a* in second wiring **70***a* has one end **73***a* at a position on second main surface **52** that is at the center in the X-axis direction and is closer to the negative side in the Y-axis direction than the center in the Y-axis direction. Second coil portion **71***a* is wound counterclockwise outward from one end **73***a*. The number of turns of second coil portion **71***a* is approximately 1 and ½ turns. The other end **74***a* of second coil portion **71***a* is located at the end of second main surface **52** on the negative side in the Y-axis direction and the negative side in the X-axis direction, and second connection portion **72***a* is drawn out from the other end **74***a*. The other end **74***a* has a shape that smoothly widens toward the tip. Boundary L**2***a* between the other end **74***a* and second connection portion **72***a* is designated by the dot-dot-dash line.

[0090] Via electrode **80***a* that passes through substrate **50** and is electrically continuous with one end **63***a* of first coil portion **61***a* is formed at one end **73***a* of second coil portion **71***a*. Thus, first coil portion **61***a* and second coil portion **71***a* as a whole have a coil shape that is wound counterclockwise from the other end **64***a* of first coil portion **61***a*.

[0091] Second coil portion **71***a* has roughly a uniform line width overall. The contour of second coil portion **71***a* includes innermost periphery **78***a*, outermost periphery **79***a*, and boundary L**2***a*. This contour is referred to as second coil region R**2***a*. In (b) in FIG. **11**, first coil region R**1***a* of first wiring **60***a* is designated by the dash lines.

[0092] As illustrated in (b) in FIG. **11**, innermost periphery **68***a* of first wiring **60***a* and innermost periphery **78***a* of second wiring **70***a* coincide with each other over the whole circumference in a plan view (i.e. as seen in the Z-axis direction). Moreover, outermost periphery **69***a* of first wiring **60***a* and outermost periphery **79***a* of second wiring **70***a* coincide with each other over the whole circumference in a plan view. Since innermost peripheries **68***a* and **78***a* coincide with each other over the whole circumference and outermost peripheries **69***a* and **79***a* coincide with each other over the whole circumference, the linear expansion coefficient of first coil portion **61***a* and second coil portion **71***a* is made uniform.

Variation 2

[0093] Variation 2 of the foregoing embodiment will be described. Variation 2 differs from the foregoing embodiment and Variation 1 in the shapes of the first coil portion and second coil portion. FIG. **12** is an explanatory diagram illustrating the planar shapes of first wiring **60***b* and second wiring **70***b* according to Variation 2. FIG. **12** corresponds to FIG. **4**.

[0094] As illustrated in (a) in FIG. **12**, first coil portion **61***b* in first wiring **60***b* has one end **63***b* at a position on first main surface **51** that is at the center in the X-axis direction and is closer to the positive side in the Y-axis direction than the center in the Y-axis direction. First coil portion **61***b* is wound clockwise outward from one end **63***b*. The number of turns of first coil portion **61***b* is approximately 4 and ¾ turns. The other end **64***b* of first coil portion **61***b* is located at the end of first main surface **51** on the positive side in the Y-axis direction and the negative side in the X-axis direction, and first connection portion **62***b* is drawn out from the other end **64***b*. Boundary L**1***b* between the other end **64***b* and first connection portion **62***b* is designated by the dot-dot-dash line.

[0095] First coil portion **61***b* has roughly a uniform line width overall. The contour of first coil portion **61***b* includes innermost periphery **68***b*, outermost periphery **69***b*, and boundary L**1***b*. This contour is referred to as first coil region R**1***b*.

[0096] As illustrated in (b) in FIG. **12**, second coil portion **71***b* in second wiring **70***b* has one end **73***b* at a position on second main surface **52** that is at the center in the X-axis direction and is closer to the positive side in the Y-axis direction than the center in the Y-axis direction. Second coil portion **71***b* is wound counterclockwise outward from one end **73***b*. The number of turns of second coil portion **71***b* is approximately 3 and ⅓ turns. The other end **74***b* of second coil portion **71***b* is located at the end of second main surface **52** on the negative side in the Y-axis direction and the negative side in the X-axis direction, and second connection portion **72***b* is drawn out from the other end **74***b*. Boundary L**2***b* between the other end **74***b* and second connection portion **72***b* is designated by the dot-dot-dash line.
[0097] Via electrode **80***b* that passes through substrate **50** and is electrically continuous with one end **63***b* of first coil portion **61***b* is formed at one end **73***b* of second coil portion **71***b*. Thus, first coil portion **61***b* and second coil portion **71***b* as a whole have a coil shape that is wound counterclockwise from the other end **64***b* of first coil portion **61***b*.
[0098] In second coil portion **71***b*, the part enclosed by the dot-dash lines in (b) in FIG. **12** is wide portion **76***b*, and the other part is narrow portion **75***b*. Hence, innermost periphery **78***b* in second coil portion **71***b* is composed of the inner peripheral edge of innermost narrow portion **75***b* and the inner peripheral edge of innermost wide portion **76***b*. Outermost periphery **79***b* in second coil portion **71***b* is composed of the outer peripheral edge of outermost narrow portion **75***b* and the outer peripheral edge of outermost wide portion **76***b*. The contour of second coil portion **71***b* includes innermost periphery **78***b*, outermost periphery **79***b*, and boundary L**2***b*. This contour is referred to as second coil region R**2***b*. In (b) in FIG. **12**, first coil region R**1***b* of first wiring **60***b* is designated by the dash lines.
[0099] As illustrated in (b) in FIG. **12**, innermost periphery **68***b* of first wiring **60***b* and innermost periphery **78***b* of second wiring **70***b* coincide with each other over the whole circumference in a plan view (i.e. as seen in the Z-axis direction). Moreover, outermost periphery **69***b* of first wiring **60***b* and outermost periphery **79***b* of second wiring **70***b* coincide with each other over the whole circumference in a plan view. Since innermost peripheries **68***b* and **78***b* coincide with each other over the whole circumference and outermost peripheries **69***b* and **79***b* coincide with each other over the whole circumference, the linear expansion coefficient of first coil portion **61***b* and second coil portion **71***b* is made uniform.
Variation 3
[0100] Variation 3 of the foregoing embodiment will be described. Variation 3 differs from the foregoing embodiment and Variations 1 and 2 in the shapes of the first coil portion and second coil portion. FIG. **13** is an explanatory diagram illustrating the planar shapes of first wiring **60***c* and second wiring **70***c* according to Variation 3. FIG. **13** corresponds to FIG. **4**.
[0101] As illustrated in (a) in FIG. **13**, first coil portion **61***c* in first wiring **60***c* has one end **63***c* at a position on first main surface **51** that is at the center in the Y-axis direction and is closer to the positive side in the X-axis direction than the center in the X-axis direction. First coil portion **61***c* is wound clockwise outward from one end **63***c*. The number of turns of first coil portion **61***c* is approximately 5 and ¾ turns. The other end **64***c* of first coil portion **61***c* is located at the end of first main surface **51** on the positive side in the Y-axis direction and the negative side in the X-axis direction, and first connection portion **62***c* is drawn out from the other end **64***c*. Boundary L**1***c* between the other end **64***c* and first connection portion **62***c* is designated by the dot-dot-dash line.
[0102] In first coil portion **61***c*, the part enclosed by the dot-dash lines in (a) in FIG. **13** is wide portion **66***c*, and the other part is narrow portion **65***c*. Hence, innermost periphery **68***c* in first coil portion **61***c* is composed of the inner peripheral edge of innermost narrow portion **65***c* and the inner peripheral edge of innermost wide portion **66***c*. Outermost periphery **69***c* in first coil portion **61***c* is composed of the outer peripheral edge of outermost narrow portion **65***c* and the outer peripheral edge of outermost wide portion **66***c*. The contour of first coil portion **61***c* includes innermost periphery **68***c*, outermost periphery **69***c*, and boundary L**1***c*. This contour is referred to as first coil

region R**1***c*.

[0103] As illustrated in (b) in FIG. **13**, second coil portion **71***c* in second wiring **70***c* has one end **73***c* at a position on second main surface **52** that is at the center in the Y-axis direction and is closer to the positive side in the X-axis direction than the center in the X-axis direction. Second coil portion **71***c* is wound counterclockwise outward from one end **73***c*. The number of turns of second coil portion **71***c* is approximately 5 and ¾ turns. The other end **74***c* of second coil portion **71***c* is located at the end of second main surface **52** on the negative side in the Y-axis direction and the negative side in the X-axis direction, and second connection portion **72***c* is drawn out from the other end **74***c*. Boundary L**2***c* between the other end **74***c* and second connection portion **72***c* is designated by the dot-dot-dash line.

[0104] Via electrode **80***c* that passes through substrate **50** and is electrically continuous with one end **63***c* of first coil portion **61***c* is formed at one end **73***c* of second coil portion **71***c*. Thus, first coil portion **61***c* and second coil portion **71***c* as a whole have a coil shape that is wound counterclockwise from the other end **64***c* of first coil portion **61***c*.

[0105] In second coil portion **71***c*, the part enclosed by the dot-dash lines in (b) in FIG. **13** is wide portion **76***c*, and the other part is narrow portion **75***c*. Hence, innermost periphery **78***c* in second coil portion **71***c* is composed of the inner peripheral edge of innermost narrow portion **75***c* and the inner peripheral edge of innermost wide portion **76***c*. Outermost periphery **79***c* in second coil portion **71***c* is composed of the outer peripheral edge of outermost narrow portion **75***c* and the outer peripheral edge of outermost wide portion **76***c*. The contour of second coil portion **71***c* includes innermost periphery **78***c*, outermost periphery **79***c*, and boundary L**2***c*. This contour is referred to as second coil region R**2***c*. In (b) in FIG. **13**, first coil region R**1***c* of first wiring **60***c* is designated by the dash lines.

[0106] As illustrated in (b) in FIG. **13**, innermost periphery **68***c* of first wiring **60***c* and innermost periphery **78***c* of second wiring **70***c* coincide with each other over the whole circumference in a plan view (i.e. as seen in the Z-axis direction). Moreover, outermost periphery **69***c* of first wiring **60***c* and outermost periphery **79***c* of second wiring **70***c* coincide with each other over the whole circumference in a plan view. Since innermost peripheries **68***c* and **78***c* coincide with each other over the whole circumference and outermost peripheries **69***c* and **79***c* coincide with each other over the whole circumference, the linear expansion coefficient of first coil portion **61***c* and second coil portion **71***c* is made uniform.

[0107] In the foregoing embodiment and Variations 1, 2, and 3, the relationship 1.15< (the line width of the wide portion)/(the line width of the narrow portion)<2.1 is satisfied. As a result of this relationship being satisfied, the line widths of the narrow portion and the wide portion can be well-balanced. The wide portion is preferably provided for at least ½ turns.

Variation 4

[0108] Variation 4 of the foregoing embodiment will be described. The foregoing embodiment describes magnetic core **20** obtained by mixing a magnetic powder and a resin powder and pressure-forming the mixture, as an example. Variation 4 describes an inductor including a block-shaped magnetic core. FIG. **14** is an exploded perspective view of inductor **10***d* according to Variation 4. FIG. **15** is a perspective view of inductor **10***d* according to Variation 4.

[0109] As illustrated in FIGS. **14** and **15**, inductor **10***d* according to Variation 4 includes magnetic core **20***d* composed of a pair of magnetic blocks **21***d* and **22***d*. Magnetic blocks **21***d* and **22***d* are each a block body, and respectively have protrusions **211***d* and **222***d* that are inserted into through hole **41** of coil substrate **40**. When magnetic blocks **21***d* and **22***d* are attached to coil substrate **40** and magnetic core **20***d* is assembled, the center of coil substrate **40** in the Y-axis direction is covered with magnetic core **20***d* and both ends of coil substrate **40** in the Y-axis direction are exposed from magnetic core **20***d*. In this way, at least part of coil substrate **40** is contained in magnetic core **20***d*.

Variations 5 and 6

[0110] The foregoing embodiment describes an example in which first coil portion **61** and second coil portion **71** are symmetrical in the Z-axis direction as illustrated in (c) in FIG. **7**. However, the first coil portion and the second coil portion may be rotationally symmetrical or asymmetrical in a cross-sectional view as long as their occupancy rates are equal.
[0111] FIG. **16** is a cross-sectional view of inductor **10***e* according to Variation 5. A via electrode is omitted in FIG. **16**. In inductor **10***e*, first coil portion **61***e* and second coil portion **71***e* are equal in occupancy rate and are rotationally symmetrical in a cross-sectional view, as illustrated in FIG. **16**.
[0112] FIG. **17** is a cross-sectional view of inductor **10***f* according to Variation 6. A via electrode is omitted in FIG. **17**. In inductor **10***f*, first coil portion **61***f* and second coil portion **71***f* are equal in occupancy rate and are asymmetrical in a cross-sectional view, as illustrated in FIG. **17**.
Other Embodiments, Etc
[0113] While the magnetic materials and the like according to an embodiment of the present disclosure have been described above, the present disclosure is not limited to such an embodiment.
[0114] Examples of the inductor described above include inductance components such as high-frequency reactors, inductors, and transformers.
[0115] The foregoing embodiment describes substrate **50** formed of an insulating film as an example, but the substrate may be formed of an insulating rigid plate of glass epoxy or the like. This is preferable because the substrate resists deformation when a through hole is formed all at once by pressing during manufacture.
[0116] The present disclosure is not limited to these embodiments. Other modifications obtained by applying various changes conceivable by a person skilled in the art to the foregoing embodiment and any combinations of the structural elements in different embodiments without departing from the scope of the present disclosure are also included in the scope of one or more aspects.
INDUSTRIAL APPLICABILITY
[0117] The present disclosure can be applied to, for example, an inductor included in a power supply device.
REFERENCE SIGNS LIST
[0118] **10**, **10***d*, **10***e*, **10***f* inductor [0119] **20**, **20***d* magnetic core [0120] **21***d*, **22***d* magnetic block [0121] **31** first electrode [0122] **32** second electrode [0123] **40** coil substrate [0124] **41** through hole [0125] **50** substrate [0126] **51** first main surface [0127] **52** second main surface [0128] **53** opening [0129] **60**, **60***a*, **60***b*, **60***c* first wiring [0130] **61**, **61***a*, **61***b*, **61***c*, **61***e*, **61***f* first coil portion [0131] **62**, **62***a*, **62***b*, **62***c* first connection portion [0132] **63**, **63***a*, **63***b*, **63***c* one end [0133] **64**, **64***a*, **64***b*, **64***c* other end [0134] **65**, **65***a*, **65***c*, **67**, **67***a* narrow portion [0135] **66**, **66***a*, **66***c* wide portion [0136] **68**, **68***a*, **68***b*, **68***c* innermost periphery [0137] **69**, **69***a*, **69***b*, **69***c* outermost periphery [0138] **70**, **70***a*, **70***b*, **70***c* second wiring [0139] **71**, **71***a*, **71***b*, **71***c*, **71***e*, **71***f* second coil portion [0140] **72**, **72***a*, **72***b*, **72***c* second connection portion [0141] **73**, **73***a*, **73***b*, **73***c* one end [0142] **74**, **74***a*, **74***b*, **74***c* other end [0143] **75**, **75***b*, **75***c*, **77** narrow portion [0144] **76**, **76***b*, **76***c* wide portion [0145] **78**, **78***a*, **78***b*, **78***c* innermost periphery [0146] **79**, **79***a*, **79***b*, **79***c* outermost periphery [0147] **80**, **80***a*, **80***b*, **80***c* via electrode [0148] **81** first insulator [0149] **82** second insulator [0150] **100** substrate [0151] **101** through hole [0152] **110** seed layer [0153] **120**, **150**, **160**, **180** resist layer [0154] **130**, **170** conductive layer [0155] **140** coverlay film [0156] **141** adhesive layer [0157] **142** insulating film [0158] **211***d* protrusion [0159] **222***d* protrusion [0160] L**1**, L**1***a*, L**1***b*, L**1***c*, L**2**, L**2***a*, L**2***b*, L**2***c* boundary [0161] R**1**, R**1***a*, R**1***b*, R**1***c* first coil region [0162] R**2**, R**2***a*, R**2***b*, R**2***c* second coil region

Claims

1. An inductor comprising: a coil substrate; a magnetic core that contains at least part of the coil substrate; and a first electrode and a second electrode that are connected to the coil substrate, wherein the coil substrate includes: a substrate; a first wiring provided on a first main surface of the substrate; a second wiring provided on a second main surface of the substrate opposite to the first main surface; a first insulator provided on the first main surface and covering the first wiring; and a second insulator provided on the second main surface and covering the second wiring, the first wiring includes a first coil portion wound outward from one end, and a first connection portion drawn out from the other end of the first coil portion and connected to the first electrode, the second wiring includes a second coil portion wound outward from one end, and a second connection portion drawn out from the other end of the second coil portion and connected to the second electrode, the one end of the second coil portion being electrically connected to the one end of the first coil portion, and an innermost periphery of the first coil portion and an innermost periphery of the second coil portion coincide with each other over whole circumference, and an outermost periphery of the first coil portion and an outermost periphery of the second coil portion coincide with each other over whole circumference.

2. The inductor according to claim 1, wherein the first coil portion and the second coil portion each include a narrow portion having a predetermined line width and a wide portion having a line width greater than the line width of the narrow portion, and the following relationship is satisfied: 1.15<(the line width of the wide portion)/(the line width of the narrow portion)<2.1.

3. The inductor according to claim 1, wherein the substrate is formed of an insulating film.

4. The inductor according to claim 1, wherein the first insulator and the second insulator are each formed of a coverlay film.

5. A method of manufacturing the inductor according to claim 1, the method comprising: forming the first wiring and the second wiring on the first main surface and the second main surface of the substrate respectively; forming the first insulator and the second insulator to cover the first wiring and the second wiring respectively; and forming a through hole in the substrate.

6. A coil substrate that is at least partly contained in a magnetic core in a state of being connected to a first electrode and a second electrode, the coil substrate comprising: a substrate; a first wiring provided on a first main surface of the substrate; a second wiring provided on a second main surface of the substrate opposite to the first main surface; a first insulator provided on the first main surface and covering the first wiring; and a second insulator provided on the second main surface and covering the second wiring, wherein the first wiring includes a first coil portion wound outward from one end, and a first connection portion drawn out from the other end of the first coil portion and connected to the first electrode, the second wiring includes a second coil portion wound outward from one end, and a second connection portion drawn out from the other end of the second coil portion and connected to the second electrode, the one end of the second coil portion being electrically connected to the one end of the first coil portion, and an innermost periphery of the first coil portion and an innermost periphery of the second coil portion coincide with each other over whole circumference, and an outermost periphery of the first coil portion and an outermost periphery of the second coil portion coincide with each other over whole circumference.

7. A coil substrate that is connected to a first electrode and a second electrode, the coil substrate comprising: a substrate; a first wiring provided on a first main surface of the substrate; a second wiring provided on a second main surface of the substrate opposite to the first main surface; a first insulator provided on the first main surface and covering the first wiring; and a second insulator provided on the second main surface and covering the second wiring, wherein the first wiring includes a first coil portion wound outward from one end, and a first connection portion drawn out from the other end of the first coil portion and connected to the first electrode, the second wiring includes a second coil portion wound outward from one end, and a second connection portion drawn out from the other end of the second coil portion and connected to the second electrode, the one end of the second coil portion being electrically connected to the one end of the first coil portion, and an innermost periphery of the first coil portion and an innermost periphery of the second coil portion coincide with each other over whole circumference, and an outermost periphery of the first coil portion and an outermost periphery of the second coil portion coincide with each other over whole circumference.