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High-frequency circuit

Abstract

A high-frequency circuit includes a first electric conductor layer, a first dielectric layer, a circuit layer, a second dielectric layer, a second electric conductor layer arranged in this order, and the circuit layer includes a ground pattern and a transmission line of a high-frequency signal. An electromagnetic wave shield is disposed around the transmission line. The electromagnetic wave shield includes a ground electric conductor on inner surfaces of a plurality of holes extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer. The plurality of holes are a plurality of elongated holes provided at an interval in a direction in which the transmission line is surrounded. In each of the plurality of elongated holes, a longitudinal dimension in the direction in which the transmission line is surrounded is larger than a width dimension.

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Background/Summary

TECHNICAL FIELD

(1) The present disclosure relates to a high-frequency circuit.

(2) The present application claims priority based on Japanese Patent Application No. 2020-084545 filed on May 13, 2020, and the entire contents of the Japanese patent application are incorporated herein by reference.

BACKGROUND ART

(3) PTL 1 discloses a structure including multiple shield vias that are electrically connected to a front surface ground and a back surface ground of a dielectric substrate.

CITATION LIST

Patent Literature

(4) PTL 1: Japanese Unexamined Patent Application Publication No. 8-274513

SUMMARY OF INVENTION

(5) An aspect of the present disclosure provides a high-frequency circuit. The high-frequency circuit according to the present disclosure includes a first dielectric layer, a circuit layer disposed on the first dielectric layer and including a transmission line of a high-frequency signal and a ground pattern disposed around the transmission line, a second dielectric layer disposed such that the circuit layer is located between the first dielectric layer and the second dielectric layer, a first electric conductor layer disposed such that the first dielectric layer is located between the circuit layer and the first electric conductor layer, a second electric conductor layer disposed such that the second dielectric layer is located between the circuit layer and the second electric conductor layer, and an electromagnetic wave shield disposed around the transmission line. The electromagnetic wave shield includes a ground electric conductor on inner surfaces of a plurality of holes extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer. The plurality of holes are a plurality of elongated holes provided at an interval in a direction in which the transmission line is surrounded. In each of the plurality of elongated holes, a longitudinal dimension in the direction in which the transmission line is surrounded is larger than a width dimension.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is a plan view of a high-frequency circuit according to an embodiment.
(2) FIG. **2** is a B-B sectional view of FIG. **1**.
(3) FIG. **3** is an exploded perspective view of a first electric conductor layer, a circuit layer, and a second electric conductor layer.
(4) FIG. **4** includes views illustrating the first half of a process of producing the high-frequency circuit according to the embodiment.
(5) FIG. **5** includes views illustrating the second half of the process of producing the high-frequency circuit according to the embodiment.
(6) FIG. **6** is a plan view illustrating a modification of the high-frequency circuit.
(7) FIG. **7** is a plan view of a high-frequency circuit according to a comparative example.

DESCRIPTION OF EMBODIMENTS

Problems to be Solved by Present Disclosure

(8) Shield vias are formed by forming multiple through-holes each having a circular shape in plan view and extending through a dielectric substrate in the thickness direction of the dielectric substrate, and providing an electric conductor such as copper in the through-holes. The shield vias are used as an electromagnetic wave shield that prevents electromagnetic waves from leaking in the dielectric substrate.
(9) FIG. **7** illustrates an example of the structure of a high-frequency circuit **100** having a signal transmission line **101**, in which multiple shield vias **102** are formed so as to surround the signal transmission line **101**. Unnecessary electromagnetic waves are radiated from the signal transmission line **101** of high-frequency waves. The electromagnetic waves are noise for peripheral circuits and deteriorate characteristics of the peripheral circuits.
(10) When the multiple shield vias **102** are provided around the signal transmission line **101**, the multiple shield vias **102** function as an electromagnetic wave shield. This electromagnetic wave shield can shield electromagnetic waves leaking from the signal transmission line **101**.
(11) However, the leakage of electromagnetic waves may occur from a gap between the shield vias **102**. To more reliably prevent the leakage of electromagnetic waves, it is conceivable that a plurality of lines of shield vias **102** are arranged in parallel around the signal transmission line **101**, as illustrated in FIG. **7**. In this case, there occurs the problem that the number of the shield vias **102** is very large. If the number of the shield vias **102** is increased, a large number of holes for the shield vias **102** need to be formed, resulting in a decrease in the production efficiency of the circuit.
(12) On the other hand, if the number of the shield vias **102** is reduced in view of the production efficiency of the circuit, electromagnetic waves tend to leak from a gap between the shield vias **102**, and the shielding performance against electromagnetic waves is impaired.
(13) Accordingly, it is desirable to efficiently prevent the leakage of electromagnetic waves.

Advantageous Effects of Present Disclosure

(14) According to the present disclosure, the leakage of electromagnetic waves can be effectively prevented.

1. Description of Embodiment of Present Disclosure

(15) (1) A high-frequency circuit according to an embodiment includes a first dielectric layer, a circuit layer disposed on the first dielectric layer and including a transmission line of a high-frequency signal and a ground pattern disposed around the transmission line, a second dielectric layer disposed such that the circuit layer is located between the first dielectric layer and the second dielectric layer, a first electric conductor layer disposed such that the first dielectric layer is located between the circuit layer and the first electric conductor layer, a second electric conductor layer disposed such that the second dielectric layer is located between the circuit layer and the second electric conductor layer, and an electromagnetic wave shield disposed around the transmission line. Since the circuit layer is sandwiched between the first electric conductor layer and the second

electric conductor layer, electromagnetic waves are prevented from leaking from the transmission line in a thickness direction of the high-frequency circuit. The electromagnetic wave shield includes a ground electric conductor on inner surfaces of a plurality of holes extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer. The plurality of holes are a plurality of elongated holes provided at an interval in a direction in which the transmission line is surrounded, and in each of the plurality of elongated holes, a longitudinal dimension in the direction in which the transmission line is surrounded is larger than a width dimension. Since the holes in which the electromagnetic wave shield is formed are formed to be elongated in the direction in which the transmission line is surrounded, even when the number of holes is reduced, the leakage of electromagnetic waves can be efficiently prevented compared with the case where circular shield vias are provided.
(16) (2) The longitudinal dimension is preferably more than five times larger than the width dimension. When the longitudinal dimension of each of the holes is more than five times larger than the width dimension of the hole, the hole is sufficiently elongated, and the leakage of electromagnetic waves can be efficiently prevented.
(17) (3) The longitudinal dimension is preferably larger than the interval. When the longitudinal dimension of each of the holes is larger than the interval of the holes, the leakage of electromagnetic waves can be efficiently prevented.
(18) (4) The longitudinal dimension is preferably more than five times larger than the interval. When the longitudinal dimension of each of the holes is more than five times larger than the interval of the holes, the leakage of electromagnetic waves can be efficiently prevented.
(19) (5) Preferably, each of the plurality of holes continuously extends through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer. The continuously extending through-holes can more reliably prevent the leakage of electromagnetic waves.
(20) (6) Preferably, the electromagnetic wave shield includes at least a first shield disposed around the transmission line and a second shield disposed on an outer peripheral side of the first shield, the first shield includes the ground electric conductor on inner surfaces of a plurality of first holes extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer, the plurality of first holes are a plurality of first elongated holes provided at an interval in a direction in which the transmission line is surrounded, in each of the plurality of first elongated holes, a longitudinal dimension in the direction in which the transmission line is surrounded is larger than a width dimension, the second shield includes, on an outer peripheral side of the plurality of first holes, the ground electric conductor on inner surfaces of a plurality of second holes extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer, the plurality of second holes are a plurality of second elongated holes provided at an interval in a direction in which the transmission line is surrounded, in each of the plurality of second elongated holes, a longitudinal dimension in the direction in which the transmission line is surrounded is larger than a width dimension, and the second shield is arranged so as to shield electromagnetic waves leaking from a gap between the plurality of first elongated holes. In this case, the leakage of electromagnetic waves can be more efficiently prevented.
(21) (7) The high-frequency circuit preferably includes a cover film applied to a surface of at least one of the first electric conductor layer and the second electric conductor layer. In this case, the strength of the high-frequency circuit in which the elongated holes are formed can be ensured by the cover film.
2. Details of Embodiment of Present Disclosure
(22) Hereinafter, in the drawings, the same reference signs denote the same components.
(23) FIGS. **1** to **6** illustrate a high-frequency circuit **10** according to an embodiment. The high-

frequency circuit **10** according to the embodiment is configured as a flexible printed circuit (FPC) used for transmitting high-frequency signals. The FPC has a structure in which a conductor such as copper foil is applied to a thin, flexible, insulator base film. The high-frequency circuit **10** is not limited to the FPC and may be a circuit formed on a rigid substrate.
(24) As illustrated in FIG. **2**, the high-frequency circuit **10** according to the embodiment includes a first dielectric layer **11**, a circuit layer **21**, a second dielectric layer **12**, a first electric conductor layer **31**, a second electric conductor layer **32**, and electromagnetic wave shields **150**. The high-frequency circuit **10** according to the embodiment has a multilayer structure having three electric conductor layers. The number of electric conductor layers is not particularly limited and may be 2, 4, 5, or more. In FIG. **2**, among the three electric conductor layers, the electric conductor layer disposed at a middle position is the circuit layer **21** having a transmission line **21**A of high-frequency waves. The first electric conductor layer **31**, which is one of the three electric conductor layers, is disposed on the lower side of FIG. **2**, which is one side of the circuit layer **21** in the thickness direction. The second electric conductor layer **32**, which is the remaining one of the three electric conductor layers, is disposed on the upper side of FIG. **2**, which is the other side of the circuit layer **21** in the thickness direction.
(25) As illustrated in FIG. **3**, the circuit layer **21** has a transmission line **21**A and a ground pattern **21**B located around the transmission line **21**A. The region between the transmission line **21**A and the ground pattern **21**B is removed by etching, so that the transmission line **21**A and the ground pattern **21**B are insulated from each other. In FIG. **3**, the transmission line **21**A is formed linearly, but may be formed in a curved manner. Holes **21**C that form part of holes **151** for the electromagnetic wave shields **150** described later are formed around the transmission line **21**A.
(26) As illustrated in FIG. **2**, the first dielectric layer **11** is disposed between the circuit layer **21** and the first electric conductor layer **31**. That is, the circuit layer **21** is disposed on the first dielectric layer **11**. In other words, the circuit layer **21** is disposed over the first electric conductor layer **31** with the first dielectric layer **11** therebetween. The circuit layer **21** and the first dielectric layer **11** are bonded to each other with an adhesive **60** therebetween. As illustrated in FIG. **3**, substantially the entire surface of the first electric conductor layer **31** is constituted by a ground pattern **31**B except for holes **31**C that form part of the holes **151** for the electromagnetic wave shields **150** described later. That is, the first electric conductor layer **31** is a ground layer.
(27) The adhesive **60** is preferably an adhesive having good flexibility and heat resistance. The adhesive **60** is, for example, a resin-based adhesive such as a modified polyphenylene ether-based, styrene resin-based, epoxy resin-based, butyral resin-based, or acrylic resin-based adhesive.
(28) A main component of the adhesive **60** is preferably a thermosetting resin. The lower limit of the curing temperature of the thermosetting resin serving as the main component of the adhesive **60** is preferably 120° C., and more preferably 150° C. The upper limit of the curing temperature of the thermosetting resin serving as the main component of the adhesive **60** is preferably 250° C., more preferably 230° C., and still more preferably 200° C. If the curing temperature of the thermosetting resin serving as the main component of the adhesive **60** is higher than the lower limit, the adhesive **60** is easily handled. If the curing temperature of the thermosetting resin serving as the main component of the adhesive **60** is lower than the upper limit, thermal deformation of the layers bonded with the adhesive **60** can be reduced during curing of the adhesive **60**. The reduction of thermal deformation can suppress a decrease in the dimensional accuracy of the high-frequency circuit **10**.
(29) The lower limit of the relative dielectric constant of the adhesive **60** is preferably as small as possible; however, in reality, the limit is considered to be 1.5 in order to satisfy other conditions such as insulating properties and mechanical strength. The upper limit of the relative dielectric constant of the adhesive **60** is, for example, 3, preferably 2.8, and more preferably 2.6. If the relative dielectric constant of the adhesive **60** is smaller than the upper limit, dielectric loss can be reduced in the case of transmitting high-frequency signals through the high-frequency circuit **10**.

(30) As illustrated in FIG. **2**, the second dielectric layer **12** is disposed between the circuit layer **21** and the second electric conductor layer **32**. That is, the second dielectric layer **12** is disposed such that the circuit layer **21** is located between the first dielectric layer **11** and the second dielectric layer **12**. As illustrated in FIG. **3**, substantially the entire surface of the second electric conductor layer **32** is constituted by a ground pattern **32**B except for a transmission line **32**A of high-frequency signals and holes **32**C that form part of the holes **151** for the electromagnetic wave shields **150**. That is, the second electric conductor layer **32** is a ground layer.
(31) As illustrated in FIG. **2**, the first electric conductor layer **31** and the second electric conductor layer **32** that serve as ground layers are disposed on both the upper and lower sides of the circuit layer **21**, that is, on both sides in the Z direction of FIG. **2**. Accordingly, of electromagnetic waves radiated from the transmission line **21**A, electromagnetic waves radiated to both sides of the high-frequency circuit **10** in the thickness direction, that is, to both sides in the Z direction of FIG. **2** are shielded by the first electric conductor layer **31** and the second electric conductor layer **32**.
(32) Some of the electromagnetic waves radiated from the transmission line **21**A are radiated in the direction parallel to the X-Y plane of FIG. **2**. The electromagnetic waves radiated in the direction parallel to the X-Y plane cannot be shielded by the first electric conductor layer **31** and the second electric conductor layer **32** and may leak to the outside of the high-frequency circuit **10** through the first dielectric layer **11** and the second dielectric layer **12**. In view of this, the high-frequency circuit **10** according to the embodiment includes the electromagnetic wave shields **150** for shielding electromagnetic waves radiated in the direction parallel to the X-Y plane. Note that the X-Y plane is a plane perpendicular to the thickness direction of the high-frequency circuit **10**. The Z direction is the thickness direction of the high-frequency circuit **10** and corresponds to a stacking direction of the aforementioned multilayer structure of the electric conductor layers.
(33) In the high-frequency circuit **10** according to the embodiment, electromagnetic waves radiated in the Z direction are shielded by the first electric conductor layer **31** and the second electric conductor layer **32**. Electromagnetic waves radiated in the direction parallel to the X-Y plane are shielded by the electromagnetic wave shields **150**. Thus, electromagnetic waves radiated from the transmission line **21**A can be effectively prevented from leaking to the outside of the high-frequency circuit **10**. As a result, the influence of leaking electromagnetic waves on other peripheral circuits can be reduced.
(34) The electromagnetic wave shields **150** are configured to function as a shield wall that shields electromagnetic waves passing through the first dielectric layer **11** and the second dielectric layer **12** around the transmission line **21**A. As illustrated in FIG. **1**, the electromagnetic wave shields **150** are formed so as to surround the transmission line **21**A in plan view. In the embodiment, a plurality of electromagnetic wave shields **150** are disposed at an interval D in a direction in which the transmission line **21**A is surrounded.
(35) As illustrated in FIG. **2**, the electromagnetic wave shields **150** include ground electric conductors **152** on inner surfaces of the holes **151** extending through the first dielectric layer **11**, the ground pattern **21**B of the circuit layer **21**, the second dielectric layer **12**, the first electric conductor layer **31**, and the second electric conductor layer **32**. In the first electric conductor layer **31** and the second electric conductor layer **32**, the ground electric conductors **152** are provided on the inner surfaces of the holes **151** formed in the ground patterns **31**B and **32**B. Since the ground electric conductors **152** are provided so as to surround the transmission line **21**A, they can shield electromagnetic waves passing through the first dielectric layer **11** and the second dielectric layer **12**. Incidentally, on the lower side of FIG. **1**, the transmission line **21**A is not surrounded by the electromagnetic wave shields **150**. This is just because, for the convenience of drawing, the illustration of the transmission line **21**A is omitted on the lower side of FIG. **1**, and the illustration of the electromagnetic wave shields **150** is also omitted accordingly. Therefore, in reality, the electromagnetic wave shields **150** can also surround the lower side of the transmission line **21**A.
(36) As illustrated in FIG. **7**, it has been a common knowledge that the shield vias **102** in the related

art each have a circular shape in plan view. Therefore, to shield leaking electromagnetic waves, it is necessary to densely arrange multiple shield vias **102** so as to surround the signal transmission line **101**. In contrast to this, as illustrated in FIG. **1**, the electromagnetic wave shields **150** in the embodiment each have a shape elongated in a direction in which the transmission line **21**A is surrounded. Specifically, in each of the electromagnetic wave shields **150**, a longitudinal dimension L in a direction in which the transmission line **21**A is surrounded is larger than a width dimension W. Therefore, leaking electromagnetic waves can be effectively shielded with a smaller number of electromagnetic wave shields **150** than the shield vias **102** having a circular shape.
(37) FIGS. **4** and **5** illustrate a method for producing the high-frequency circuit **10** according to the embodiment. In step S**11** illustrated in FIG. **4**, a double-sided copper-clad fluororesin substrate is prepared as one example of a substrate. The double-sided copper-clad fluororesin substrate includes a fluororesin substrate constituting a second dielectric layer **12**, copper constituting a circuit layer **21**, and copper constituting a second electric conductor layer **32**. The material of the substrate is not limited to a fluororesin.
(38) In step S**12**, a through-hole **41** that extends through the circuit layer **21**, the second dielectric layer **12**, and the second electric conductor layer **32** is formed at a position of a transmission line **21**A and a transmission line **32**A.
(39) In step S**13**, the inside of the through-hole **41** is filled with an electric conductor by plating. Thus, a via **40** that electrically connects the transmission line **21**A to the transmission line **32**A is formed. The transmission line **32**A functions as, for example, an external connection terminal for the transmission line **21**A. Incidentally, the surface of the inside of the through-hole **41** may be covered by plating, and the remaining space may be filled with a synthetic resin.
(40) In step S**14**, the circuit layer **21** and the second electric conductor layer **32** of the double-sided copper-clad fluororesin substrate are subjected to an etching process to form the transmission line **21**A of the circuit layer **21** and the transmission line **32**A of the second electric conductor layer **32**.
(41) In step S**15**, a single-sided fluororesin substrate is bonded on the circuit layer **21** side. The single-sided fluororesin substrate includes a fluororesin substrate constituting a first dielectric layer **11** and copper constituting a first electric conductor layer **31**. In step S**15**, bonding is performed with an adhesive **60** such that the first dielectric layer **11** and the circuit layer **21** face with each other. The adhesive **60** is, for example, a bonding sheet. The bonding sheet is used for bonding between layers of the substrates. The bonding sheet has insulating properties and adhesiveness.
(42) In step S**31** subsequent to step S**15**, to form electromagnetic wave shields **150**, a plurality of holes **151** that continuously extend from the first electric conductor layer **31** to the second electric conductor layer **32** are formed by press punching. The method for forming the holes **151** is not limited to press punching, but the use of press punching is advantageous in that the plurality of holes **151** can be formed at the same time. The holes **151** may be formed by laser processing.
(43) The plurality of holes **151** are provided at an interval D in a direction in which the transmission line **21**A are surrounded. Each of the plurality of holes **151** has a longitudinal dimension L in the direction in which the transmission line **21**A is surrounded and a width dimension W orthogonal to the direction of the longitudinal dimension L. Each of the plurality of holes **151** is an elongated hole. That is, each of the plurality of holes **151** has a longitudinal dimension L larger than the width dimension W. The longitudinal dimension L is preferably more than 5 times larger than the width dimension W, more preferably more than 10 times larger than the width dimension W, still more preferably more than 15 times larger than the width dimension W, and still more preferably more than 20 times larger than the width dimension W. By making the longitudinal dimension L sufficiently larger than the width dimension W, the number of the holes **151** can be reduced. Furthermore, by making the width dimension W sufficiently smaller than the longitudinal dimension L, the area of a region necessary for forming the electromagnetic wave shields **150** around the transmission line **21**A can be reduced.
(44) The longitudinal dimension L is larger than the interval D. The longitudinal dimension L is

preferably more than 5 times larger than the interval D, preferably more than 10 times larger than the interval D, preferably more than 15 times larger than the interval D, and still more preferably more than 20 times larger than the interval D. To reduce the leakage of electromagnetic waves in the interval D, the interval D is preferably smaller than ¼ of a wavelength λ of high-frequency waves transmitted by the transmission line **21**A, more preferably smaller than ⅛ of the wavelength λ, and still more preferably smaller than 1/16 of the wavelength λ. As the interval D is decreased, the leakage of electromagnetic waves can be further reduced. By making the interval D smaller than 1/16 of the wavelength λ, the leakage of electromagnetic waves can be sufficiently reduced.
(45) Since the interval D is provided between the pluralities of holes **151**, the decrease in the strength of the high-frequency circuit **10** can be suppressed compared with the case where a single hole **151** having a long length is continuously formed.
(46) As the width dimension W is increased, the thickness of each of the electromagnetic wave shields **150** increases, and thus the interval D that is allowable increases. That is, when the width dimension W is increased, the leakage of electromagnetic waves can be reduced even in the case where the interval D between the pluralities of holes **151** is the same.
(47) In step S**32**, electric conductors **152** are formed on the inner surfaces of the holes **151** by plating. FIG. **2** illustrates a case where the electric conductors **152** are disposed in contact with the entire inner surfaces of the holes **151**, and the electric conductors **152** are each formed into a tubular shape having an outer peripheral shape corresponding to the inner peripheral shape of a hole **151**. The electric conductors **152** may be formed only on the inner surfaces of the holes **151** or may be formed so as to completely fill the inside of the holes **151**. The insides of the electric conductors **152** may be filled with a dielectric substance such as a synthetic resin or may be filled with an electric conductor such as a conductive paste.
(48) The electric conductors **152** electrically connect the ground pattern **21**B, the ground pattern **31**B, and the ground pattern **32**B together. Accordingly, the electric conductors **152** are ground electric conductors **152**. The ground electric conductors **152** are provided inside the respective plurality of holes **151** surrounding the periphery of the transmission line **21**A. Therefore, the plurality of ground electric conductors **152** formed in the plurality of holes **151** function as the electromagnetic wave shields **150** surrounding the periphery of the transmission line **21**A. The ground electric conductors **152** can shield electromagnetic waves radiated through the first dielectric layer **11** and the second dielectric layer **12**.
(49) That is, the electric conductors **152** electrically connect the ground pattern **21**B of the circuit layer **21** to the ground pattern **31**B of the first electric conductor layer **31**. Accordingly, the electric conductors **152** have an electric potential equal to that of the ground patterns **21**B and **31**B and thus serve as ground electric conductors **152**. Since the ground electric conductors **152** are disposed in the holes **151** surrounding the periphery of the transmission line **21**A, they function as the electromagnetic wave shields **150** surrounding the periphery of the transmission line **21**A. The ground electric conductors **152** located in the first dielectric layer **11** can shield electromagnetic waves radiated through the first dielectric layer **11**.
(50) The electric conductors **152** electrically connect the ground pattern **21**B of the circuit layer **21** to the ground pattern **32**B of the second electric conductor layer **32**. Accordingly, the electric conductors **152** have an electric potential equal to that of the ground patterns **21**B and **32**B and thus serve as ground electric conductors **152**. Since the ground electric conductors **152** are disposed in the holes **151** surrounding the periphery of the transmission line **21**A, they function as the electromagnetic wave shields **150** surrounding the periphery of the transmission line **21**A. The ground electric conductors **152** located in the second dielectric layer **12** can shield electromagnetic waves radiated through the second dielectric layer **12**.
(51) In step S**33**, cover films **71** and **72** are applied to the surfaces of the first electric conductor layer **31** and the second electric conductor layer **32** with adhesives **81** and **82**, respectively, therebetween. The cover films **71** and **72** are composed of, for example, a polyimide, and protect

the first electric conductor layer **31** and the second electric conductor layer **32**, respectively. The application of the cover films **71** and **72** can ensure the strength of the high-frequency circuit **10** in which the holes **151** are formed.

(52) The plurality of electromagnetic wave shields **150** and holes **151** illustrated in FIG. **1** are formed around the transmission line **21**A so as to surround in one line, but may be formed so as to surround in a plurality of lines, as illustrated in FIG. **6**. FIG. **6** illustrates a case where a plurality of electromagnetic wave shields **150** and holes **151** are arranged in two lines on the inner and outer sides.

(53) Specifically, electromagnetic wave shields **150** illustrated in FIG. **6** include first shields **150**A disposed around a transmission line **21**A and second shields **150**B disposed on the outer peripheral side of the first shields **150**A. Other shields may be further provided on the outer peripheral side of the second shields **150**B.

(54) The first shields **150**A include ground electric conductors **152** on inner surfaces of a plurality of first holes **151**A that continuously extend from the first electric conductor layer **31** to the second electric conductor layer **32**, as in the holes **151**. Similarly to the holes **151**, the plurality of first holes **151**A are each an elongated hole and may be herein referred to as first elongated holes. A line formed of the plurality of first holes **151**A constitutes a first line arranged at intervals in a direction in which the periphery of the transmission line **21**A is surrounded. In each of the plurality of first elongated holes **151**A, a longitudinal dimension L in the direction in which the transmission line **21**A is surrounded is larger than a width dimension W, as in the holes **151**.

(55) The second shields **150**B include ground electric conductors **152** on inner surfaces of a plurality of second holes **151**B that continuously extend from the first electric conductor layer **31** to the second electric conductor layer **32**, as in the holes **151**. Similarly to the holes **151**, the plurality of second holes **151**B are each an elongated hole and may be herein referred to as second elongated holes. A line formed of the plurality of second holes **151**B constitutes, on the outer peripheral side of the plurality of the first elongated holes **151**A, a second line arranged at intervals in the direction in which the periphery of the transmission line **21**A is surrounded. In each of the plurality of second elongated holes **151**B, a longitudinal dimension L in the direction in which the transmission line **21**A is surrounded is larger than a width dimension W, as in the holes **151**.

(56) The second elongated holes **151**B are arranged so as to be located at positions corresponding to gaps between the first elongated holes **151**A. That is, the second elongated holes **151**B are arranged so as to cover the gaps between the first elongated holes **151**A from the outer peripheral side of the first elongated holes **151**A. Accordingly, the second shields **150**B constituted by the ground electric conductors **152** in the second elongated holes **151**B can shield electromagnetic waves leaking from the gaps between the first shields **150**A. In this manner, in FIG. **6**, the line of the second shields **150**B serving as outer electromagnetic wave shields are arranged so as to shield electromagnetic waves leaking from the line of the first shields **150**A serving as inner electromagnetic wave shields. The arrangement of the electromagnetic wave shields **150** in a plurality of lines enables leaking electromagnetic waves to be efficiently shielded. In addition, since the first holes **151**A and the second holes **151**B are elongated holes, they can efficiently shield leaking electromagnetic waves even in a small number of lines.

(57) It is to be understood that the embodiment disclosed herein is only illustrative and non-restrictive in all respects. The scope of the present invention is defined not by the meaning described above but by the claims, and is intended to include meaning equivalents to the scope of the claims and all modifications within the scope of the claims.

REFERENCE SIGNS LIST

(58) **10**: high-frequency circuit **11**: first dielectric layer **12**: second dielectric layer **21**: circuit layer **21**A: transmission line **21**B: ground pattern **21**C: hole **31**: first electric conductor layer **31**C: hole **31**B: ground pattern **32**: second electric conductor layer **32**A: transmission line **32**B: ground pattern **32**C: hole **40**: via **41**: through-hole **60**: adhesive **71**: cover film **72**: cover film **81**: adhesive **82**:

adhesive **100**: high-frequency circuit **101**: signal transmission line **102**: shield via **150**: electromagnetic wave shield **150**A: first shield **150**B: second shield **151**: hole **151**A: first hole, first elongated hole **151**B: second hole, second elongated hole **152**: electric conductor, ground electric conductor L: longitudinal dimension W: width dimension D: interval

Claims

1. A high-frequency circuit comprising: a first dielectric layer; a circuit layer disposed on the first dielectric layer and including a first transmission line of a high-frequency signal and a ground pattern disposed around the first transmission line; a second dielectric layer disposed such that the circuit layer is located between the first dielectric layer and the second dielectric layer; a first electric conductor layer disposed such that the first dielectric layer is located between the circuit layer and the first electric conductor layer; an adhesive that bonds the circuit layer and the first dielectric layer to each other; a second electric conductor layer disposed such that the second dielectric layer is located between the circuit layer and the second electric conductor layer; and an electromagnetic wave shield disposed around the first transmission line, wherein the second electric conductor layer includes a second transmission line, the second transmission line is electrically connected to the first transmission line and is an external connection terminal for the first transmission line, the electromagnetic wave shield includes a ground electric conductor on inner surfaces of a plurality of holes continuously extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer, the plurality of holes are a plurality of elongated holes spaced apart by an interval between edges of the holes in a direction in which the first transmission line is surrounded, and in each of the plurality of elongated holes, a longitudinal dimension in the direction in which the first transmission line is surrounded is larger than a width dimension.
2. The high-frequency circuit according to claim 1, wherein the longitudinal dimension is more than five times larger than the width dimension.
3. The high-frequency circuit according to claim 1, wherein the longitudinal dimension is larger than the interval.
4. The high-frequency circuit according to claim 3, wherein the longitudinal dimension is more than five times larger than the interval.
5. The high-frequency circuit according to claim 1, wherein the electromagnetic wave shield includes at least a first shield disposed around the first transmission line and a second shield disposed on an outer peripheral side of the first shield, the first shield includes the ground electric conductor on inner surfaces of a plurality of first holes extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer, the plurality of first holes are a plurality of first elongated holes provided at an interval in a direction in which the first transmission line is surrounded, in each of the plurality of first elongated holes, a longitudinal dimension in the direction in which the first transmission line is surrounded is larger than a width dimension, the second shield includes, on an outer peripheral side of the plurality of first holes, the ground electric conductor on inner surfaces of a plurality of second holes extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer, the plurality of second holes are a plurality of second elongated holes provided at an interval in a direction in which the first transmission line is surrounded, in each of the plurality of second elongated holes, a longitudinal dimension in the direction in which the first transmission line is surrounded is larger than a width dimension, and the second shield is arranged so as to shield electromagnetic waves leaking from a gap between the plurality of first elongated holes.
6. The high-frequency circuit according to claim 1, further comprising: a cover film applied to a surface of at least one of the first electric conductor layer and the second electric conductor layer.

7. The high-frequency circuit according to claim 1, wherein the first transmission line is surrounded by electromagnetic wave shields on four sides in a plan view.
8. The high-frequency circuit according to claim 1, wherein the adhesive is between side edges of the first transmission line and side edges of the ground pattern.
9. The high-frequency circuit according to claim 1, wherein the interval is smaller than ¼ of a wavelength of high-frequency waves transmitted by the first transmission line.
10. The high-frequency circuit according to claim 1, wherein the interval is smaller than ⅛ of a wavelength of high-frequency waves transmitted by the first transmission line.
11. A high-frequency circuit comprising: a first dielectric layer; a circuit layer disposed on the first dielectric layer and including a first transmission line of a high-frequency signal and a ground pattern disposed around the first transmission line; a second dielectric layer disposed such that the circuit layer is located between the first dielectric layer and the second dielectric layer; a first electric conductor layer disposed such that the first dielectric layer is located between the circuit layer and the first electric conductor layer; a second electric conductor layer disposed such that the second dielectric layer is located between the circuit layer and the second electric conductor layer; and an electromagnetic wave shield disposed around the first transmission line, wherein the second electric conductor layer includes a second transmission line, the second transmission line is electrically connected to the first transmission line and is an external connection terminal for the first transmission line, the electromagnetic wave shield includes a ground electric conductor on inner surfaces of a plurality of holes continuously extending through the first dielectric layer, the ground pattern, the second dielectric layer, the first electric conductor layer, and the second electric conductor layer, the plurality of holes are a plurality of elongated holes spaced apart by an interval between edges of the holes in a direction in which the first transmission line is surrounded, in each of the plurality of elongated holes, a longitudinal dimension in the direction in which the first transmission line is surrounded is larger than a width dimension, and the longitudinal dimension of the holes is larger than the interval between holes.
12. The high-frequency circuit according to claim 11, wherein the interval is smaller than ¼ of the wavelength of high-frequency waves transmitted by the first transmission line.
13. The high-frequency circuit according to claim 11, wherein the interval is smaller than ⅛ of the wavelength of high-frequency waves transmitted by the first transmission line.