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(54) **Variable inductance element**

(57) A meandering inductor pattern (4) is formed on the upper surface of an insulating substrate (1). The inductor pattern (4) is formed by irradiating a conductor

pattern (2) with a laser beam to form U-shaped trimming grooves (10) in the conductor pattern (2) in such a manner that two island-shape rectangular sections (3) are separated from the conductor pattern.

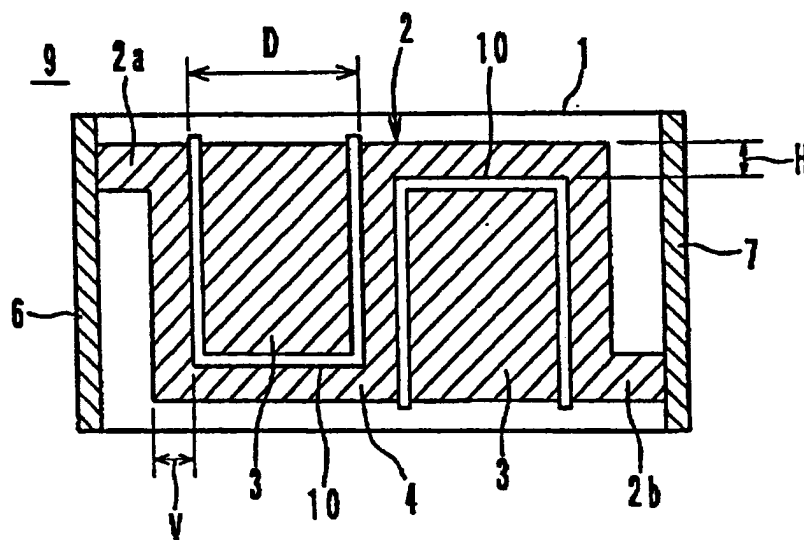


FIG.3

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a variable inductance element, and more particularly to a variable inductance element especially for use in a mobile communications device such as a mobile telephone or the like.

2. Description of the Related Art

[0002] In recent years, mobile communications devices such as portable telephones or the like have been remarkably miniaturized, and demands for reducing the size of electronic components for use in the devices have been strong. Further, as higher frequencies are employed in the mobile communications devices, the circuits of the devices become more complicated, and moreover, electronic components to be mounted in the devices are required to have uniform characteristics and high precision.

[0003] However, even if electronic components each having parameters with uniform characteristics and high precision are employed for formation of a circuit, the deviation in the parameters of the respective mounted electronic components have an overall/combined effect, so that in some cases, a desired function cannot be performed. Hence, some of the parameters of the electronic components constituting an electronic circuit are made variable, if necessary. By finely adjusting the parameters of some of the electronic components, a desired function of the circuit can then be performed.

[0004] FIG. 8 shows an example of such a conventional type of fine adjustment method. According to the fine adjustment method, a trimming area 34 to function as an inductance element is formed between signal patterns 31 and 32. The trimming area 34 is irradiated with a laser beam emitted from a laser trimming machine (not shown) while the beam is linearly moved. The trimming area 34 is partially removed corresponding to the movement track of the laser beam, so that a linear trimming groove 35 is formed. Accordingly, the area of the trimming area 34 is changed so that the inductance of the trimming area 34 is finely adjusted.

[0005] In the conventional variable inductance element, if the area of the trimming area 34 is small, the variable range of the inductance becomes narrow, so that the circuit cannot be finely adjusted. Therefore, the trimming area 34 is made to have a large area. On the other hand, when a high precision laser trimming machine is employed, the groove width (trimming width) of the trimming groove 35 formed by one pass of the trimming laser is generally thin. For this reason, in the case where a wide trimming width is required, irradiation with a laser beam must be repeated while the irradiation po-

sition is moved in parallel, as shown in FIG. 9. Hence, there arises the problem that it takes much time to carry out the fine adjustment.

5 SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide a variable inductance element having a high Q factor, and in which the inductance can be finely adjusted efficiently.

[0007] To achieve the above object, according to the present invention, there is provided a variable inductance element which comprises (a) an insulating substrate, and (b) a substantially meandering inductor pattern defined by trimming a conductor provided on the surface of the insulating substrate such that predetermined island-shaped sections are separated from the inductor pattern.

[0008] With the above configuration, by changing the shape and size of a trimming pattern, the number and area of the island-shaped sections, and the space between island-shaped sections are changed. By this, the width and the number of meanders of the inductor pattern are changed, causing the inductance to change. Preferably, by setting the pattern width of the substantially meandering inductor pattern at a substantially constant value, and setting the distance between neighboring portions of the substantially meandering inductor pattern to be at least two times as long as the pattern width of the inductor pattern, the distance between magnetic fields generated in the respective neighboring portions is large, and the magnetic fields can be prevented from interfering with each other.

[0009] Further features and advantages of the present invention will become clear from the following description of preferred embodiments thereof, given by way of example, and illustrated by the accompanying drawings, in which:

40 BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a perspective view showing the appearance of a variable inductance element according to a first embodiment of the present invention;

FIG. 2 is a perspective view illustrating a method of varying the inductance of the variable inductance element of FIG. 1;

FIG. 3 is a plan view of a meandering inductor pattern of the variable inductance element of FIG. 1;

FIG. 4 is a plan view showing the conductor pattern of a variable inductance element according to a second embodiment of the present invention;

FIG. 5 is a plan view showing the meandering inductance pattern of the variable inductance element of FIG. 4;

FIG. 6 is a plan view showing a modified example

of the meandering inductor pattern;

FIG. 7 is a plan view showing a further modified example of the meandering inductor pattern;

FIG. 8 illustrates a method of adjusting the inductance value of a conventional variable inductance element; and

FIG. 9 illustrates a problem of the method of adjusting the inductance value of the conventional variable inductance element.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] Hereinafter, embodiments of the variable inductance element of the present invention will be described with reference to Figs. 1 to 7 of the accompanying drawings.

First Embodiment

[0012] As shown in FIG. 1, after the upper face of an insulating substrate 1 is polished to have a smooth surface, a conductor pattern 2 having a wide area is formed on the upper face of the insulating substrate 1 by a thick-film printing method or a thin-film forming method such as photolithography or the like. According to the thick-film printing method, a mask having an opening in a desired pattern is made to cover the upper surface of the insulating substrate 1, and electrically conductive paste is coated from above the mask, whereby a conductor having a relatively large thickness is formed in the desired pattern (in the case of the first embodiment, the conductor pattern 2) on the upper surface of the insulating substrate 1 exposed through the opening of the mask.

[0013] An example of photolithography will be described below. A relatively thin conductive film is formed on substantially the whole upper surface of the insulating substrate 1. After this, a resist film (for example, a photosensitive resin or the like) is formed on substantially the whole of the conductive film by spin coating or printing. Next, a mask film having a predetermined image pattern is placed to cover the upper surface of the resist film, and the desired part of the resist film is hardened by irradiation of UV rays or the like. After this, the resist film is removed, with the hardened part thereof remaining, and the exposed part of the conductive film is removed, whereby a conductor is formed in the desired pattern, and thereafter, the hardened resist film is also removed.

[0014] Further, according to another photolithographic method, photosensitive conductive paste may be coated onto the upper surface of the insulating substrate 1, and a mask film having a predetermined image pattern formed therein covers the photosensitive conductive paste, followed by exposure and development. The conductive pattern 2 is provided on substantially the whole of the insulating substrate 1.

[0015] One end 2a of the conductor pattern 2 is led out to the rear portion of the left-side, as viewed in FIGS. 1, 2 and 3, of the insulating substrate 1, while the other end 2b is led out to the front portion of the right-side, as viewed in FIGS. 1, 2 and 3, of the insulating substrate 1. As materials for the insulating substrate 1, glass, glass ceramic, alumina, ferrite, or other suitable material may be used. As materials for the conductor pattern 2, Ag, Ag-Pd, Cu, Au, Ni, Al, or other suitable material may be employed.

[0016] Moreover, a liquid insulating material (polyimide or the like) is coated onto the whole of the upper surface of the insulating substrate 1 by spin coating, printing or the like, and is dried, whereby an insulating protection film (not shown) covering the conductor pattern 2 is formed.

[0017] Next, external input-output electrodes 6 and 7 are provided on each end portion of the insulating substrate 1 in the longitudinal direction, respectively. The external input-output electrode 6 is electrically connected to the end portion 2a of the conductor pattern 2, and the external input-output electrode 7 is electrically connected to the end portion 2b of the conductor pattern 2. The external input-output electrodes 6 and 7 are formed by coating and baking conductive paste of Ag, Ag-Pd, Cu, Ni, NiCr, NiCu, or other suitable material, by dry or wet plating, or by a combination of the coating and baking, and the plating.

[0018] A variable inductance element 9 obtained as described above is mounted onto a printed circuit board or the like, and the conductor pattern 2 is trimmed. In particular, as shown in FIG. 2, the upper surface of the variable inductance element 9 is irradiated with a pulsed laser beam L while the beam L is being moved, so that U-shaped trimming grooves 10 are formed in the variable inductance element 9. The two trimming grooves 10 separate two island-shaped rectangular sections 3 from the conductor pattern 2 to form a meandering inductor pattern 4, as shown in FIG. 3. The ends 2a and 2b of the meandering inductor pattern 4 are electrically connected to the external input-output electrodes 6 and 7, respectively.

[0019] By changing the shapes and sizes of the patterns of the trimming grooves 10, the number and area of the island-shaped sections 3 (in this embodiment, the number is 2), and the space between the sections 3 are changed. By this, the width of the meandering inductor pattern 4 and the number of the meanders are changed, so that the inductance of the meandering inductor pattern 4 can be continuously varied over a wide range, and can be efficiently and finely adjusted to a desired inductance. At this time, the inductance element 9 can be provided with a Q factor required for a high frequency circuit.

[0020] By forming the U-shaped trimming grooves 10 in the conductor pattern 2 so as to form the meandering inductor pattern 4, adjustment of the inductance is possible over a wider range as compared with that by the

conventional linear trimming. For example, in the case of a variable inductance element having a size of 2.0 mm × 1.25 mm, the adjustment is possible only over a range of about 0.15 nH by conventional linear trimming. On the other hand, by trimming in a U-shaped pattern as in the first embodiment, the adjustment range is about 1.0 nH (a range about 6.7 times as wide as that of the conventional trimming method).

[0021] Further, in the first embodiment of the present invention, the pattern width V of a portion of the inductor pattern 4 extending in parallel to the width direction of the insulating substrate 1 is equal to the pattern width H of a portion thereof extending in parallel to the longitudinal direction of the insulation substrate 1, and the distance D between the leg portions of each U-shaped trimming groove 10 is set to be at least two times as long as the pattern width V (or the pattern width H). By this, the pattern width of the inductor pattern 4 is substantially constant over the whole length thereof. The distance between neighboring portions of the inductor pattern 4 is at least two times as long as the pattern width. As a result, the distance between magnetic fields generated in neighboring portions of the inductor pattern 4 is large, which prevents the magnetic fields from interfering with each other. Hence, the Q factor of the inductance element 9 can be further enhanced. Concretely, the Q factor can be enhanced by about 40% as compared with that of a conventional variable inductance element.

[0022] Trimming of the conductor pattern 2 is not restricted to a method using a laser beam, and may be carried out by any method such as sand blasting or the like. Further, it is not necessary to provide the trimming grooves 10. Provided that the conductor pattern 2 is electrically cut, the trimming grooves 10 do not have to be formed in a physical sense.

Second Embodiment

[0023] In the second embodiment of the present invention, a conductor pattern 22 is directly formed on a printed circuit board 21. The conductor pattern 22 which functions as an inductance element 20 is provided between signal patterns 28 and 29. As shown in FIG. 5, the conductor pattern 22 is irradiated with a pulsed laser beam while the beam is moved, so that the part of the conductor pattern 22 irradiated with the laser beam is removed, due to the laser energy, to form U-shaped trimming grooves 27 in the conductor pattern 22. The trimming grooves 27 separate two island-shape rectangular sections 23 from the conductor pattern 22 to form a meandering inductor pattern 24. The ends of the zig-zag inductor pattern 24 are electrically connected to the signal patterns 28 and 29, respectively.

[0024] By changing the shapes and sizes of the patterns of the trimming grooves 27, the width and the number of meanders of the meandering inductor pattern 24 are changed, and the inductance value of the meandering inductor pattern 24 can be continuously changed

over a wide range. Thus, the inductance can be efficiently and finely adjusted to a desired value.

Other Embodiments

[0025] The variable inductance element of the present invention is not restricted to the above-described embodiments. Changes and modifications may be made without departing from the present invention as defined in the annexed claims.

[0026] The above embodiments are described in the production of an individual variable inductance element. In the case of efficiently mass-producing variable inductance elements, a mother substrate (wafer) provided with a plurality of variable inductance elements is produced, and in the final process, the wafer is cut to a product size by a technique such as dicing, scribe-break, laser cutting, or the like. Further, the inductor pattern may have a meandering shape in outline. For example, the pattern may have a shape containing a sinusoidal curve.

[0027] Further, in the variable inductance element, the trimming groove 10 may be formed in such a manner that one island-shape section 3 (see FIG. 6) is produced. Also, the trimming grooves 10 may be formed so as to produce three island-shape sections 3 (see FIG. 7), or more.

[0028] As seen in the above-description, according to the present invention, by changing the shape and size of a trimming pattern, the width and the number of meanders of a substantially meandering inductor pattern are changed to vary the inductance of the inductor pattern. Hence, the inductance can be finely adjusted continuously and efficiently over a wide range. A high precision variable inductance element having a desired inductance and a high Q factor can be provided.

[0029] Preferably, by setting the pattern width of the substantially meandering inductor pattern at a substantially constant value, and by setting the distance between neighboring portions of the substantially meandering inductor pattern to be at least two times as long as the pattern width, the distance between magnetic fields generated in the neighboring portions is long, which can prevent the magnetic fields from interfering with each other. Thus, the Q factor of the inductance element can be further enhanced.

Claims

1. A variable inductance element (9) comprising:

an insulating substrate (1); and
a substantially meandering inductor pattern (4) defined by trimming a conductor (2) provided on the surface of said insulating substrate such that predetermined island-shaped sections (3) are separated from the inductor pattern.

2. A variable inductance element (9) according to claim 1, wherein the pattern width (V/H) of said substantially meandering inductor pattern (4) is substantially constant, and the distance (D) between neighboring portions of said substantially meandering inductor pattern (4) is at least two times as long as the pattern width (V/H).

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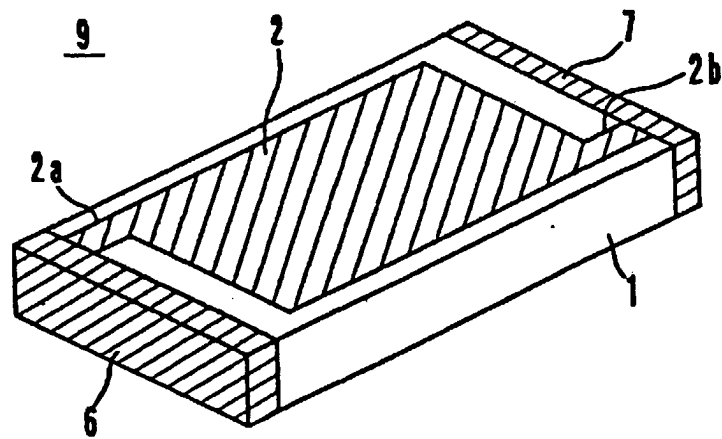


FIG.1

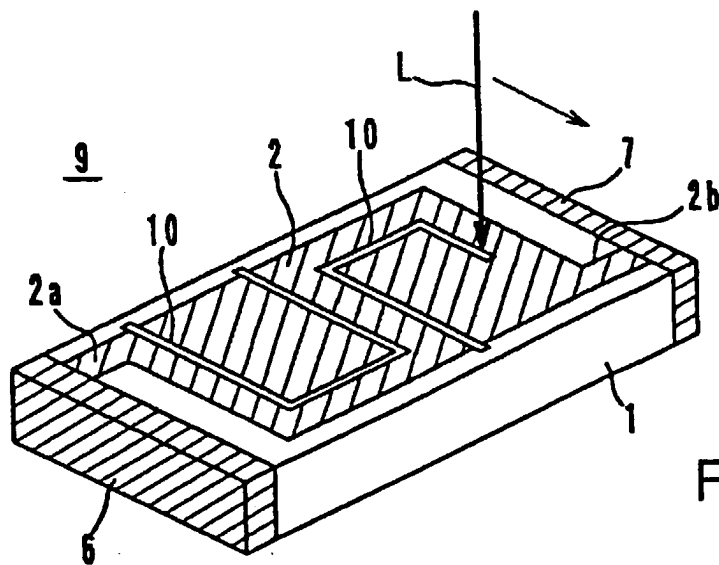


FIG.2

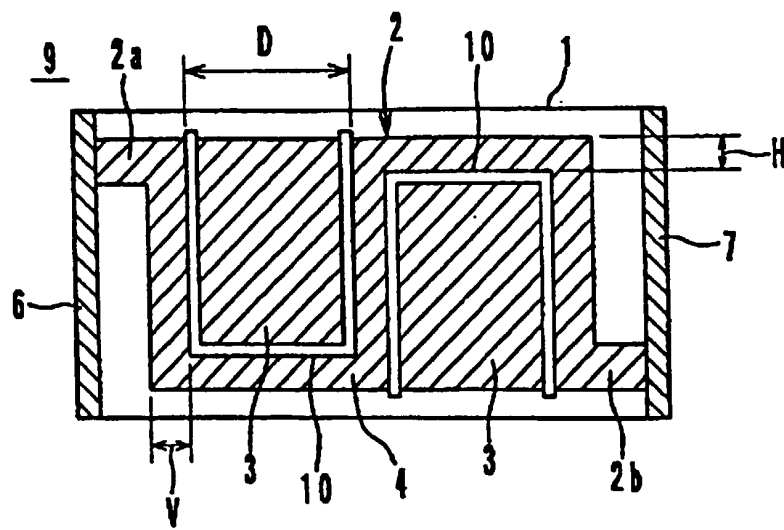


FIG.3

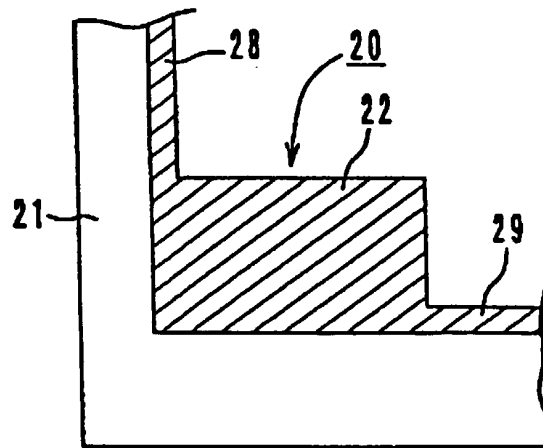


FIG.4

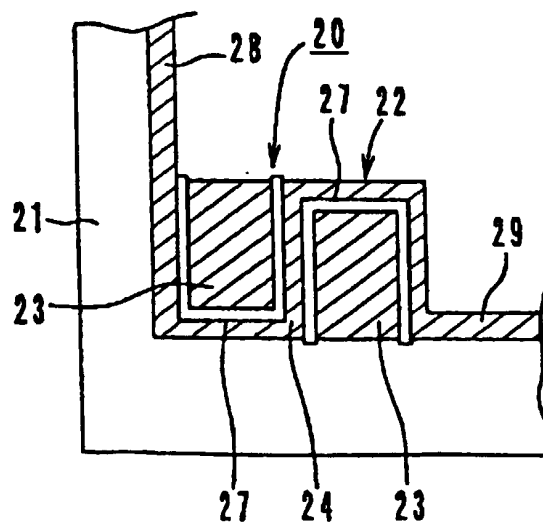


FIG.5

