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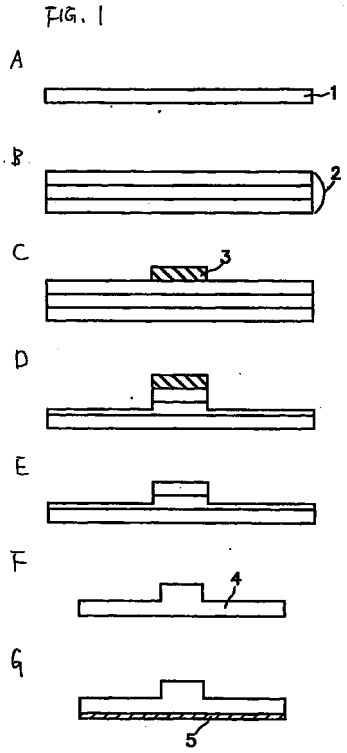
(54) Method of producing a dielectric strip line

(57) The present invention provides a method of producing a dielectric line which is capable of producing a dielectric line at low cost with causing neither cracks nor chips in processing and high precision of each dimension of a dielectric strip. The method of producing a dielectric line having a dielectric strip provided between a plurality of substantially parallel conductive planes includes the step of forming a resist material on a green sheet containing at least an inorganic powder and an organic binder; the step of removing a desired amount of the green sheet corresponding to an aperture of the resist material used as a mask; the step of removing the resist material; and the step of burning the green sheet.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a method of producing transmission line used in the milli-wave or microwave band, and a dielectric line suitable for integrated circuits.

2. Description of the Related Art

[0002] A conventional dielectric line comprises a dielectric strip provided between substantially parallel two conductive planes so that electromagnetic waves are propagated along the dielectric strip. Particularly, a non radiative dielectric waveguide (referred to as a "NRD guide" hereinafter) has been developed as a transmission line with less propagation loss, in which the distance between the two dielectric planes is set to a half wavelength or less of a propagated wave to form a cut-off region, for avoiding radiation of electromagnetic waves from the dielectric strip. The electromagnetic wave transmission modes of such a NRD guide include LSM and LSE modes; the LSM mode causing less loss is generally used.

[0003] Figs. 2 and 3 are sectional views respectively showing two constructions of conventional NRD guides. Fig. 2 shows the construction of a normal type NRD guide comprising a dielectric strip 53 provided two conductive plates 51 and 52 arranged in parallel, which is disclosed in, for example, Japanese Examined Patent Publication No. 62-35281. Fig. 3 shows the construction of a so-called winged type NRD guide in which conductors 59 and 60 are formed on the outer planes of dielectric strips 57 and 58 having wings 55 and 56, respectively, by an evaporation method or a method of baking silver paste, the dielectric strips being opposed to each other, as disclosed in Japanese Unexamined Patent Publication No. 6-260814. The winged type NRD guide has the advantages that the conductors and the dielectric strips can easily be aligned, and that characteristics have excellent reproducibility, as compared with the normal type NRD guide. As the material of the dielectric strips, a synthetic resin such as Teflon (registered trademark of U.S. Dupont) and the like, dielectric ceramics are used. By using a dielectric ceramic as the constituent material of the dielectric strips, it is possible to decrease a bend loss in a curved line, and attempt to reduce the size because its dielectric constant is generally lower than synthetic resins. Therefore, at present, the development of dielectric strips using dielectric ceramics is progress. The width w of each of the dielectric strips 57 and 58, and the thickness t of each of the wings 55 and 56 are defined by the dielectric constant of the dielectric material used, and the frequency of the electromagnetic wave used. Generally, the width w and thickness t decrease as the dielectric constant and the frequency used increase.

[0004] In producing the winged type NRD guide shown in Fig. 3 by using a dielectric ceramic, a previously burned ceramic flat plate is cut, or a green sheet laminated product formed by laminating a plurality of green sheets each having an aperture is burned to produce a NRD guide comprising dielectric strips having a desired shape, as disclosed in Japanese Unexamined Patent Publication No. 10-224120.

[0005] However, since burned ceramics are very hard, and thus have a problem in that much time and labor are required for cutting the ceramic flat plate in a desired shape after burning. There is also the problem of readily causing cracks or chips in the cutting process because the wings have a thin thickness t.

[0006] In the method of laminating green sheets each having an aperture, it is very difficult to precisely cut each of the green sheets to the width w of the dielectric strips, and precisely align the green sheets, thereby causing the problem of deteriorating workability (in the NRD guide frequently used as a high-frequency transmission line, the dielectric strips are required to have high dimensional precision).

SUMMARY OF THE INVENTION

[0007] Accordingly, it is an object of the present invention to provide a method of producing a dielectric line which exhibits low production cost and neither cracking nor chipping in processing, and which is capable of producing a dielectric strip with high dimensional precision.

[0008] As a result of intensive research in consideration of the above-described problems, the inventors found that the problems can be resolved by forming a resist material on a green sheet containing an inorganic powder and an organic binder, removing a predetermined amount of the green sheet at a position corresponding to an aperture of the resist material used as a mask, removing the resist material, and then burning the green sheet, leading to the achievement of the present invention.

[0009] A method of producing a dielectric line of the present invention comprising a dielectric strip provided between substantially parallel two conductive planes, comprises the step of forming a resist material on a green sheet containing an inorganic powder and an organic binder, the step of removing a predetermined amount of the green sheet at a position corresponding to an aperture of the resist material used as a mask, the step of removing the resist material, and the step of burning the green sheet.

[0010] In the present invention, unlike in conventional examples, a hard ceramic flat plate after burning is not cut, but an unnecessary portion of the green sheet is removed in the state of the green sheet, thereby processing within a short time with causing neither

cracking nor chipping. Also, unlike conventional examples, the dielectric strip is formed not by laminating a plurality of patterned thin green sheets, and thus accurate alignment of green sheets, which is required in conventional examples, is made unnecessary, simplifying the process of producing a dielectric line. In addition, since a photolithographic technique capable of precise patterning can be applied to patterning of the resist material, each of the dimensions of the dielectric line can precisely be defined, and the dimensional precision can be significantly improved, as compared with cases in which a dimensional value is defined by cutting.

[0011] In order to remove the green sheet, any of various methods such as sand blasting, wet etching, chemical milling, ion milling, RIE, etc. can be used. Particularly, from the viewpoints that a processing method using a vacuum process is relatively unsuitable for finely processing the green sheet containing moisture and organic components, and that high dimensional precision can be realized in relatively deep etching of 0.2 to 1.0 mm, which is required for producing the dielectric strip, the sand blasting process is most preferably used.

[0012] The step of removing the resist material and the step of burning the green sheet may be performed simultaneously. Namely, in burning the green sheet at high temperature, at the same time, the resist material may be removed by pyrolysis. This can further simplify the process.

[0013] In removing the green sheet by sand blasting or the like, from the viewpoints of improvement in workability, prevention of deformation of the green sheet in the removing step, etc., it is preferable to place the green sheet on a hard ceramic substrate which is previously burned, and then burn the green sheet. In this case, the ceramic substrate is left as a wing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Fig. 1 is a sectional view showing the steps of a method of producing a dielectric line of the present invention;

Fig. 2 is a sectional view showing the structure of an example of conventional dielectric lines; and

Fig. 3 is a sectional view showing the structure of another example of conventional dielectric lines.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] Fig. 1 shows a method of producing a dielectric line of the present invention.

[0016] First, a ceramic green sheet 1 comprising an inorganic powder and an organic binder is prepared (Fig. 1A). As the inorganic powder used, ceramics such as alumina, cordierite, forsterite, spinel, and the like, and glass can be used, and any inorganic powder can be used as long as no problem occurs in processing precision and propagation properties. An inorganic material having a relative dielectric constant of 4 or more is preferably used because it permits miniaturization as compared with used of a synthetic resin such as Teflon (registered trade mark of U.S. Dupont) or the like. As the organic binder, butyral resins, acrylic resins, urethane resins, epoxy resins, vinyl resins, and the like can be used, and any resin can be used as long as it can more easily be ground than the resist material used in the step of removing the green sheet. In order to improve adhesion and bonding workability of a plurality of ceramic green sheets 1, a plasticizer such as DOP, DBP, α-turpeneol, or the like may be added to the inorganic powder and the organic binder. As the method of producing the green sheet 1, a doctor blade method, a comma coating method, a roll coating method, a casting method, and the like can be used. In producing the green sheet 1, the thickness of the green sheet 1 is previously controlled to several μm to several mm in the stage of the green sheet so that a desired thickness (which permits propagation of electromagnetic waves as a dielectric strip) is obtained after burning. However, the thickness may be controlled in the step of laminating and compressing a plurality of the green sheets 1 to form a green sheet laminated product (referred to as a "laminated product" hereinafter) 2, as shown in Fig. 1B.

[0017] Next, a resist is coated on the laminated product 2 so that a resist material 3 functioning as a mask in a predetermined region is formed by photolithography (Fig. 1C). Although the resist material 3 may be formed by a printing method or the like, the photolithographic technique is preferably used because a mask having excellent dimensional precision can be formed. As the resist material, any material can be used as long as it has sufficient resistance in removal of the ceramic green sheets in the subsequent step. More specifically, polyvinyl alcohol, polymethacrylate, cellulose resins, poly-α-methyl styrene, urethane resins, and the like can be used.

[0018] Then, a predetermined amount of the ceramic green sheets is removed by, for example, a sand blasting method or the like using the resist material 3 formed on the laminated product 2 as a mask (Fig. 1D). As the sand blasting method, a dry blasting method in which abrasive grains are blown together with a gas to remove a portion of the green sheet corresponding to an aperture, or a wet blasting method in which abrasive grains are blown together with a liquid to remove a portion of the green sheet can be used. In the sand blasting method, alumina, silicon carbide, carbon, rigid plastic, and the like can be used as the abrasive grains, air, nitrogen, argon, and the like can be used as the gas, and water, ethyl alcohol, isopropyl alcohol, and the like can be used as the liquid.

[0019] After the predetermined amount of the green sheets was removed, the resist material 3 is removed (Fig. 1E). Conceivable methods of removing the resist material 3 include a method of immersing the resist

material 3 in a solvent to dissolve the resist material, a method of pyrolytically burning the resist material 3 in the step of burning the laminated product 2, and the like. Any method may be used as long as there is no possibility of causing deformation of the green sheets.

[0020] Next, the laminated product 2 is burned after removal of the resist material 3 (or the resist material 3 is removed by combustion at the same time as the step of burning the laminated product 2) to obtain a burned product 4 of dielectric ceramic (Fig. 1F). Burning can be carried out by using a general belt furnace, batch furnace, or the like in either a nonoxidizing atmosphere or an oxidizing atmosphere.

[0021] Then, a conductor 5 is formed over the entire surface of the lower plane of the ceramic burned product 4 by evaporation (Fig. 1G), and furthermore, a pair of the ceramic burned products 4 each having the conductor 5 formed on the back surface thereof are arranged so that the dielectric strips thereof are opposed to each other to obtain a dielectric line having the structure shown in Fig. 3.

[0022] Although, in the above description, the conductor 5 is formed on the back of the burned product 4 by evaporation after the ceramic burned product is formed, the method of forming the conductor 5 is not limited to this. For example, the conductor 5 may be formed by a method comprising forming conductor paste by printing or the like in the state of the green sheet 1 or the green sheet laminated product 2 before burning, and then baking the conductor paste at the same time as burning the laminated product 2, or a printing, sputtering, sol-gel, plating method or the like after burning. The conductor 5 may also be formed by bonding a conductor plate such as a metal plate to the back of the burned product 4.

[0023] The dielectric line produced according to the producing method of the present invention will be described in detail below with reference to examples.

Example 1

[0024] A spinel powder as a inorganic power, butyral resin BM-2 (produced by Sekisui Chemical Co., Ltd.) as an organic binder, DOP as a plasticizer, and ethyl alcohol and toluene as organic solvents were prepared, and predetermined amounts of these materials were weighed and mixed by ball milling in a poly pot. Then, a ceramic green sheet was formed in a thickness of 10 to 100 μm by the doctor blade method. Next, the green sheet was cut into a 70-mm square, and trimmed, and a plurality of square green sheets were compressed by a hydrostatic isotropic press to produce a green sheet laminated product. Next, the green sheet laminated product was heated to 80°C, and dry film resist BF-405 (Tokyo Ohka Kogyo Co., Ltd.) was laminated on the top of the laminated product, followed by exposure to ultraviolet rays through a predetermined pattern mask. Exposure was performed under conditions including 365 nm and 200 mJ/cm^2. Then, spray development was performed by using a 0.3 wt% sodium carbonate aqueous solution at a liquid temperature of 30°C to obtain a resist material having an aperture on the green sheet laminated product.

[0025] Next, a portion of the green sheets corresponding to the aperture of the resist was removed by the sand blasting method using Pneuma-Blaster SC-3 type (Fuji Seisakusho Co., Ltd.) until the thickness t of a wing was a predetermined value. At this time, processing was performed by using fused alumina #1000 as abrasive grains under a discharge pressure of 3 kg/cm^2 at a distance of 8 cm between the nozzle and the green sheets. Then, the laminated product was immersed in a 10 wt% monoethanolamine aqueous solution of a temperature of 45°C to remove the resist material, and the laminated product was burned by using a batch type electric furnace in air at 1600°C for 2 hours to obtain a dielectric strip having a wing.

[0026] The dielectric strip obtained in this example had neither cracks nor chips in the wing, and good width w variation (standard deviation) of 10 μm or less.

Example 2

[0027] A green sheet comprising spinel as an inorganic powder was formed by the same method as Example 1. The green sheet was cut in a 70-cm square, and a plurality of square green sheets were laminated and compressed by the same method as Example 1 to obtain a green sheet laminated product. Then, a resist material having a predetermined pattern (aperture) and made of polyvinyl alcohol was formed on the laminated product by the printing method. Next, a predetermined amount of the green sheet was removed from the aperture of the resist by the sand blasting method using the resist material as a mask. Next, the laminated product was burned by using the batch type electric furnace in air at 1600°C for 2 hours without removal of the resist material with a solvent or the like, and at the same time, the resist material was pyrolyzed to obtain a dielectric strip having a wing. The dielectric strip obtained in this example had neither cracks nor chips in the wing, and good width w variation (standard deviation) of 10 μm or less.

[0028] As described above, the method of producing a dielectric line of the present invention facilitates processing without causing cracks and chips by cutting, permitting production at low cost and production of a dielectric line with high precision. Furthermore, since a green sheet is placed on a previously burned ceramic substrate, and then processed, it is possible to prevent deformation of the green sheet and improve workability, and facilitate production of a dielectric line.

Claims

1. A method of producing a dielectric line comprising a

dielectric strip provided between a plurality of substantially parallel conductive planes, the method comprising:

the step of forming a resist material on a green sheet containing at least an inorganic powder and an organic binder;
the step of removing a desired amount of the green sheet corresponding to an aperture of the resist material used as a mask;
the step of removing the resist material; and
the step of burning the green sheet.

2. A method of producing a dielectric line comprising a dielectric strip provided between a plurality of substantially parallel conductive planes, the method comprising:

the step of placing a green sheet containing at least an inorganic powder and an organic binder on a previously burned ceramic substrate;
the step of forming a resist material on the green sheet;
the step of removing a desired amount of the green sheet corresponding to an aperture of the resist material used as a mask;
the step of removing the resist material; and
the step of burning the green sheet.

3. A method of producing a dielectric line according to Claim 2, wherein the substrate on which the green sheet is placed comprises the same material as the green sheet.

4. A method of producing a dielectric line according to any one of Claims 1 to 3, wherein the desired amount of the green sheet is removed by a sand blasting method.

5. A method of producing a dielectric line according to any one of Claims 1 to 4, wherein the green sheet comprises a green sheet laminated product formed by laminating a plurality of green sheet thin layers.

6. A method of producing a dielectric line according to any one of Claims 1 to 5, wherein the step of removing the resist material is performed at the same time as the step of burning the green sheet.

FIG. 1

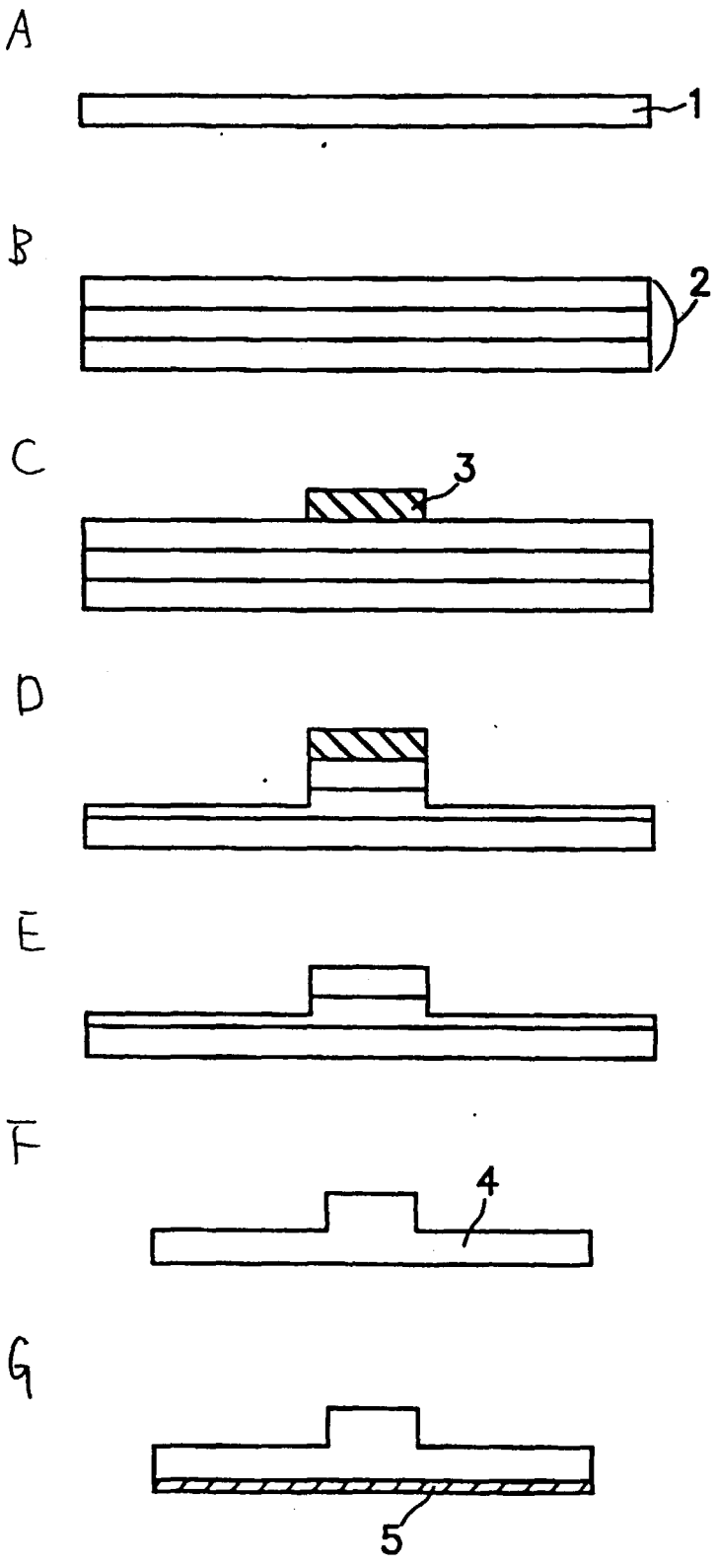

FIG. 2

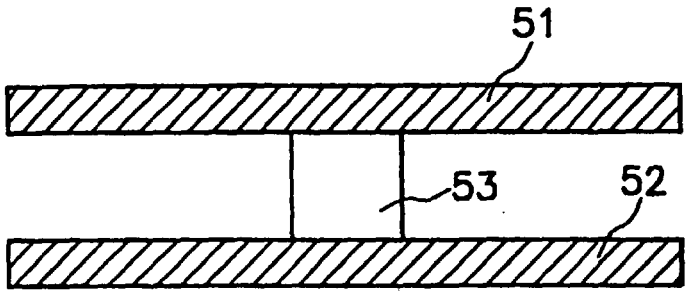

FIG. 3