A thin film structure is provided with the capability of low-power laser tuning and trimming. Trim windows (14) in a plated ground plane (12) are incorporated to allow automated tuning procedures using relatively low-power lasers. The trim windows are conductive, but the heavier layer (25) of plated copper is omitted from those areas, leaving only the titanium/evaporated copper/gold layers (18, 20, 26). The method can also provide for areas (28) of bare substrate if desired.
FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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THIN FILM STRUCTURE FOR CERAMIC SUBSTRATES

Background of the Invention

The present invention relates to the field of metallized substrates for communications applications and, more particularly, to a means of tuning thin film structures such as stripline filters, using automated low-power laser trimming.

Metallization on non-conductive substrates such as ceramics is well known in the art for such circuit components as stripline filters. Such filters typically include a configuration or pattern of conductive elements on one surface of the ceramic plate, these elements interacting with a relatively large area of ground plane on the opposing substrate surface. For electrical reasons, the ground plane is required to be a very low conductivity layer, typically including a heavy (one mil) layer of plated copper. Filters or other such components may require removal of a portion of the conductive ground plane for tuning or other adjustment. Such adjustments have been made by abrasion; i.e., mechanically removing small portions of the ground plane in the appropriate areas, using a diamond grinding wheel or sand trimmer. It will be obvious that such a method does not lend itself to automated trimming procedures, where the circuitry is monitored as it is tuned and the monitoring equipment controls an extremely precise laser beam.

Thick film resistors on substrates can be trimmed
precisely by low-power (1.8 kw input power) laser beams, but that power is not sufficient to trim a heavily plated ground plane.

Summary of the Invention

It is therefore an object of the present invention to provide a means of trimming a ground plane or the like with a low-power laser beam.

It is a particular object to provide such a means utilizing standard process steps.

It is another object to provide additionally for removal of all conductive layers on other portions of the substrate.

These objects, and others which will become apparent, are provided in a structure and accompanying method in accordance with the present invention. On a non-conductive wafer, one or more conductive circuit components are formed on a first surface. A conductive layer or ground plane is formed on a substantial portion of the second surface of the wafer opposite at least one element of a circuit component which requires a fine tuning or trimming adjustment. The ground plane will consist of a thin conductive layer, such as copper evaporated over titanium, a heavy conductive layer such as plated copper, and a thin protective layer of a noble metal such as gold. The heavy copper layer will have an aperture opposite at least a portion of the component to be adjusted. Therefore, tuning or trimming can be accomplished by removing discrete areas of the thinner layers within the aperture in the heavy layer, using a relatively low-power laser beam, such as those used to trim thick film resistors.
Brief Description of the Drawing

Fig. 1 is a bottom view of a stripline filter substrate.

Fig. 2 is a cut-away, perspective view of a portion of the substrate of Fig. 1, along the line 2-2.

Fig. 3 shows the successive steps in one preferred embodiment of the invention.

Fig. 4 shows the successive steps in another embodiment, which provides for areas of bare substrate.

Detailed Description of the Preferred Embodiment

For purposes of clarity, the existing thin film process will be briefly described. On a non-conductive substrate, a very thin layer of titanium is deposited first to provide adhesion for the subsequent layers of metal. Next, a thin layer of copper is evaporated over the titanium. A photo-resist is applied and exposed to ultraviolet light through a mask, the unexposed areas resulting eventually in conductive areas. After the resist is developed, the unhardenened portions are stripped off and a thick layer of copper is plated on the areas of bare copper. A thin layer of gold is plated on over all, then the hardened resist is stripped from the substrate. Etching subsequently removes all thin layers down to the bare substrate in the desired areas.

As may be seen in the drawing, the invention is used for the fine tuning (trimming) of a stripline filter on a substrate 10 (see Figs. 2-4) such as a ceramic wafer. In this example, the visible surface of the substrate is covered by a ground plane 12 having three apertures or "trim windows" 14. The other surface of the substrate 10 has on it (as indicated by dashed lines in Fig. 1) elements 16A, 16B and 16C of the filter circuit.
Stripline filters are well known in the art, and have previously been constructed using a layer of heavy copper throughout the ground plane. Tuning or other fine adjustment has been accomplished by use of an abrasion technique using a diamond grinding wheel. No further description of the circuit aspects of the filter will be given here, since the present invention is only concerned with the capability of fine tuning by the removal of discrete areas of the ground plane with a low-power laser beam.

In the cut-away, perspective view of Fig. 2, the filter of Fig. 1 is shown cut along the line 2-2 with the edges of circuit elements 16A, B and C visible on the lower surface (normally considered the top side of the filter). The ground plane 12 and windows 14 are on the upper side of the ceramic wafer 10 in this view and it is apparent that the copper layer within the window 14 is thinner than it is in the adjacent areas. It is to be noted that no attempt has been made to scale any of the drawing figures; instead, typical dimensions are given as appropriate in the text.

Fig. 3 shows a series of progressive steps in producing the ground plane only of one embodiment of the invention. Fig. 3A shows the bare substrate 10 and Fig. 3B shows a very thin (500 A) added layer 18 of deposited titanium. In Fig. 3C, a thin (10,000 A) layer 20 of copper has been evaporated over the titanium layer 18. In Fig. 3D, a film 22 of a photo-resist (such as that sold commercially as Riston™ 218R) has been added, and a mask 24 is shown in position to expose the area 14' of the photo-resist film 22 for providing one window 14 (Figs. 1 and 2). After the photo-resist has been exposed to ultraviolet light through the mask, and developed, the unhardened areas are removed as shown in Fig. 3E. A heavy (0.7 to 1.2 mils) layer 25 of copper is plated on
all areas except area 14, as shown in Fig. 3F. The hardened resist 22 is then stripped off, as shown in Fig. 3G. As shown in Fig. 3H, a thin (5000 Å) layer 26 of gold is plated over all exposed copper, both thick and thin layers. In the tuning operation, a low-powered laser beam can be manually or automatically controlled to remove as much of the thin layers of gold and copper in any of the windows 14 as is required; e.g., for tuning a stripline filter.

In Fig. 4 is seen the series of progressive steps in an alternate embodiment which can provide both the trim windows 14 as shown in Fig. 3 and areas of bare substrate which may be desired for other purposes than tuning.

Figs. 4A-4D are the same as Figs. 3A-3D except that the mask 24-1 has an area 14' for providing the window or aperture 14 and another area 28' for providing an area 28 (see Fig. 4M) of bare substrate. After the photo-resist 22 has been exposed to ultraviolet light through the mask 24 and developed, the unhardened resist is removed as in Fig. 4E, leaving areas 22-1 and 22-2. The heavy copper layer 25 is then plated on (Fig. 4F) followed by the thin layer 26 of gold (Fig. 4G). The hardened areas of photo-resist 22 are then stripped off as shown in Fig. 4H, and another layer 30 of the photo-resist is applied over all (Fig. 4I). All areas except area 14' of the photo-resist are exposed through a second mask 24-2, then the photo-resist is developed. After the unhardened resist is removed (Fig. 4J); i.e., the portion in the area 14', that area is plated with gold (layer 26) as shown in Fig. 4K. When the hardened resist is removed (Fig. 4L), all exposed surfaces have been plated with gold except for the area 28'. An etching process (Fig. 4M) will remove the thin copper and titanium layer to provide bare substrate in the area 28.
Thus there has been shown and described a means of providing a tunable circuit element on a substrate using only the standard process steps, and of tuning said element with a low-power laser beam. It is intended to cover all modifications and variations which fall within the spirit and scope of the appended claims.

What is claimed is:
Claims

1. An apparatus for use in communications equipment and comprising:
   a non-conductive wafer;
   conductive circuit elements formed on a first surface of said wafer; and
   a conductive element formed on a substantial portion of the second surface of said wafer, positioned opposite at least one of said circuit elements on the first wafer surface, and including a first conductive layer, a superimposed second conductive layer, the second layer being substantially thicker than the first layer and having an aperture opposite the at least one circuit element on the first wafer surface, and a third conductive layer superimposed on the exposed portions of the first and second conductive layers and formed of a noble metal.
2. An apparatus in accordance with claim 1 wherein said first conductive layer is an evaporated layer and said second and third conductive layers are plated layers.

3. An apparatus in accordance with claim 2 wherein said first and second layers are comprised of copper and said third layer is comprised of gold.

4. An apparatus in accordance with claim 1 wherein the conductive elements are formed on a fourth evaporated layer of a conductive material other than the material of said first, second and third conductive layers.

5. An apparatus in accordance with claim 4 wherein the fourth evaporated layer is comprised of titanium.
6. A method of tuning an apparatus for use in communications equipment comprising the steps of:
   providing a non-conductive wafer;
   providing on a first major surface of said wafer at least one conductive circuit element;
   providing on the second major surface of said substrate a relatively large conductive area having generally a first predetermined thickness and having, opposite the at least one circuit element, a portion of a second predetermined thickness, the second predetermined thickness being substantially thinner than the first predetermined thickness; and evaporationg appropriate portions of the thinner portion of the large conductive area by means of a low-power beam.
7. A method in accordance with claim 6 wherein the step of evaporating portions of the large conductive area is performed with a laser beam.
8. A method of processing an apparatus for use in communications equipment comprising the following steps:
   a) providing a non-conductive wafer;
   b) providing conductive circuit elements on a first major surface of the wafer;
   c) evaporating a relatively thin layer of metal onto a second major surface of the wafer;
   d) covering said thin metal layer with a layer of photo-sensitive material;
   e) positioning a mask over said photo-sensitive material;
   f) exposing at least one portion of said photo-sensitive material to radiation through said mask;
   g) developing said photo-sensitive material;
   h) removing the uncured portions of said photo-sensitive material;
   i) plating a relatively heavy layer of metal on those portions of the first metal layer not covered by cured photo-sensitive material;
   j) removing the cured portions of the photo-sensitive material;
   k) plating a layer of noble metal over all exposed metal surfaces; and
   l) tuning the apparatus by evaporating appropriate portions of those areas of metal lacking the relatively heavily plated layer by means of a low-power beam.
9. A method in accordance with claim 8 and wherein the relatively thin layer of metal comprises a layer of titanium and a superimposed layer of copper.

10. A method in accordance with claim 8 wherein the relatively heavy layer of metal is comprised of copper.

11. A method in accordance with claim 8 wherein the noble metal is gold.

12. A method in accordance with claim 8 wherein at least two portions of the layer of photo-sensitive material are exposed to radiation through the first mask and wherein the steps of removing the cured portions of photo-sensitive material and plating with a noble metal are reversed, and further including the steps of:
   k) covering the surface with a second layer of photo-sensitive material;
   l) positioning a second mask over said second layer of photo-sensitive material;
   m) exposing portions of said second layer to radiation through said second mask, said portions excluding at least one area not covered by the heavy layer of metal;
   n) developing said second layer of photo-sensitive material;
   o) removing the uncured portions of said second layer of photo-sensitive material;
   p) plating a second layer of a noble metal over all exposed metal;
   q) removing all cured portions of said second layer of photo-sensitive material; and
   r) removing all thin layers of metal not covered by a noble metal.
13. A method in accordance with claim 12 wherein the step of removing thin layers of metal is done by an etching process.
### INTERNATIONAL SEARCH REPORT

**International Application No:** PCT/US80/01202

**I. CLASSIFICATION OF SUBJECT MATTER**

According to International Patent Classification (IPC) or to both National Classification and IPC:

- **H01P 3/08**
- **US. CL. 333/205**

**II. FIELDS SEARCHED**

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

**III. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Category</th>
<th>Citation of Document, with indication, where appropriate, of the relevant passages</th>
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<td>US, A, 4,157,517 Published 05 June 1979 Kneisel et al.</td>
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<td>A</td>
<td>US, A, 3,605,045 Published 14 September 1971 Ramsbotham</td>
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<td>US, A, 3,792,383 Published 21 June 1974 Knappenberger</td>
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<td>A</td>
<td>US, A, 4,075,757 Published 28 February 1978 Malm et al.</td>
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* Special categories of cited documents:
  - "A" document defining the general state of the art
  - "E" earlier document but published on or after the international filing date
  - "L" document cited for special reason other than those referred to in the other categories
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but on or after the priority date claimed
  - "T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention
  - "X" document of particular relevance

**IV. CERTIFICATION**

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ISA/US, Signature of Authorized Officer

ISA/US, JDSmith
V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claim numbers _______ because they relate to subject matter not required to be searched by this Authority, namely:

2. Claim numbers _______ because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This International Searching Authority found multiple inventions in this international application as follows:

I. Apparatus: Claims 1 to 5
II. Method: Claims 6 to 13

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

   CLAIMS 1-5

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (supplemental sheet (2)) (October 1977)