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(71) Applicant: **TRXMEMS AB**
197 91 Bro (SE)

(72) Inventor: **Bauer, Tomas**
19791 Bro (SE)

(54) A MULTI-LAYER WAVEGUIDE ARRANGEMENT

(57) The present disclosure relates to a waveguide arrangement comprising a first outer layer (109) and at least two intermediate layers (111a, 111b, 111c) comprising a first intermediate layer 111a) and a third intermediate layer (111c). The first intermediate layer 111a) is bonded to the third intermediate layer (111c) and the first outer layer 109 is bonded to the first intermediate layer (111a). At least one first probe part (114a, 114'a) is formed in the first intermediate layer (111a), at least one respective probe post (113, 113') connected to the first probe part (114a, 114'a) is formed in the third intermediate layer (111c), and at least one second probe part (114b, 114'b) is formed in the first outer layer (109). Each second probe part (114b, 114'b) protrudes via a respective probe aperture (115, 115') and constitutes a continuation of the respective first probe part (114a, 1 14'a). The layers are at least partly metallized, where a first waveguide conductor part (102) is formed in the first intermediate layer (111a) and a third waveguide conductor part (104) is formed in the third intermediate layer (111c). The waveguide arrangement comprises a dielectric material (140, 141) positioned between the second probe part (114b, 114'b) and a corresponding outer coaxial conductor (121, 121').

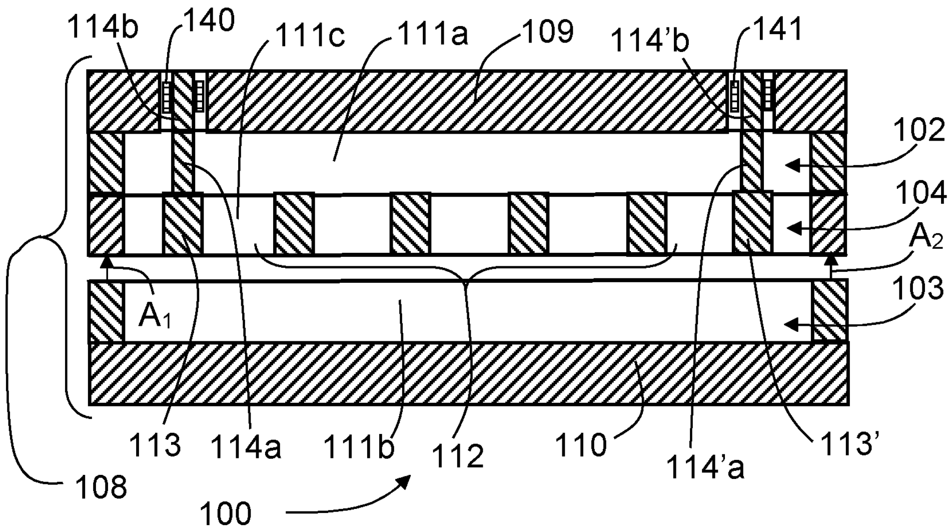

FIG. 4F

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a waveguide arrangement comprising at least one waveguide port, where at least one waveguide port comprises a coaxial probe. The waveguide arrangement is formed in a multilayer structure.

BACKGROUND

[0002] Traditionally, microwave radios and radars are using waveguide components due to the low losses. There are waveguide ports used as interfaces to receivers, to transmitters and to antennas. These waveguide components are often injection molded, 3D printed in polymers, or manufactured in milled metal or cast metal. For all these examples, the materials are often surface-treated with silver, gold or copper to lower the insertion losses. Some materials such as for example aluminum may work to a sufficient extent without surface treatment. These solutions are common on S-, C-, X-, Ku- and Ka-bands. It is common that there are H- or E-bends in the design to connect the waveguide ports to the rest of the waveguide ports. Sometimes filters are realized using so-called comb elements in the form of posts within the waveguide, one example is a so-called interdigital filter or combline filter.

[0003] A waveguide arrangement typically consists of a trench embodiment introduced into, or through, a substrate, eventually completed by a top and bottom substrate to seal the waveguide cavity. A silicon-based waveguide arrangement will often be realized by defining the waveguide trench by means of etching. Such an etching process will inherently carry a manufacturing error relating to the etch angle. The deeper the trench that is etched, the larger the potential error in the manufacturing process.

[0004] The waveguide arrangement is normally accessed electrically by means of one or more waveguide ports, and such a port can for example be constituted by a coaxial port. This means that in this context, the term "waveguide port" should be interpreted broadly and encompass different types of ports that connect to a waveguide conductor, for example coaxial ports.

[0005] A coaxial port, integrated in a waveguide arrangement, having a probe that extends through an aperture is difficult to manufacture in an accurate, repeatable and reliable manner, in particular at higher frequencies exceeding for example 10GHz, where the probe and other parts become very small and therefore fragile. It is also desired to provide an enhanced stability for the formed probe.

[0006] It is therefore desired to provide at least one coaxial port in a waveguide arrangement and a manufacturing method that provides an accurate and repeatable process for such a coaxial port.

SUMMARY

[0007] The above object is achieved by means of waveguide arrangement comprising a first outer layer and at least two intermediate layers comprising a first intermediate layer and a third intermediate layer. The first intermediate layer is bonded to the third intermediate layer, where the first outer layer is bonded to the first intermediate layer. At least one first probe part is formed in the first intermediate layer, at least one respective probe post connected to the first probe part is formed in the third intermediate layer, and at least one second probe part is formed in the first outer layer. Each second probe part protrudes via a respective probe aperture and constitutes a continuation of the respective first probe part. The layers are at least partly metallized, where a first waveguide conductor part is formed in the first intermediate layer and a third waveguide conductor part is formed in the third intermediate layer. The at least one first probe part, the at least one respective probe post and the at least one second probe part are formed by removing material. The waveguide arrangement comprises a dielectric material positioned between each second probe part and a corresponding outer coaxial conductor.

[0008] This structure enables a probe that extends through an aperture to be formed in an accurate, repeatable and reliable manner, in particular at higher frequencies exceeding for example 10GHz, where the probe and other parts become very small and therefore fragile. Many different parts can be attached to the third intermediate layer, for example a PCB, a metal plate, antenna elements and/or other types of active and passive microwave structures. Furthermore, a rigid support for the second probe parts.

[0009] According to some aspects, the waveguide arrangement further comprises a second intermediate layer and a second outer layer, where the second intermediate layer comprises a second waveguide conductor part. The second outer layer is bonded to the second intermediate layer and the second intermediate layer is bonded to the third intermediate layer such that the third intermediate layer is positioned between the first intermediate layer and the second intermediate layer.

[0010] This means that a waveguide is formed and connected to a least one coaxial probe.

[0011] The present disclosure enables creating a desired waveguide arrangement with at least one integrated coaxial probe by means of stacking multiple micro-structured substrates. With such a coaxial probe integrated in the waveguide, a cost-effective integration of the waveguide arrangement can be achieved by direct mounting of the waveguide arrangement with an integrated coaxial port to a printed circuit board for example, without need for wire bonding.

[0012] The above object is also achieved by means of methods associated with the above advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The present disclosure will now be described more in detail with reference to the appended drawings, where:

Figure 1A	shows a perspective view of a waveguide arrangement according to a first example;
Figure 1B	shows a cross-section side view of the waveguide arrangement according to the first example;
Figure 2	shows an exploded view of the waveguide arrangement according to the first example;
Figure 3	shows a perspective view of a two layers bonded to each other;
Figure 4A	shows a cross-section view of Figure 3;
Figure 4B	shows a cross-section view of Figure 3 where material has been removed;
Figure 4C	shows a view of a first outer layer after metallization;
Figure 4D	shows Figure 4B with a further layer added and bonded;
Figure 4E	shows Figure 4C where material has been removed;
Figure 4F	shows Figure 4D with final layers added and bonded;
Figure 4G	shows a partial top view of Figure 4F;
Figure 5A-5B	show a flowchart illustrating methods according to the present disclosure; and
Figure 6	shows an alternative waveguide arrangement.

DETAILED DESCRIPTION

[0014] Aspects of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings. The different devices, systems, computer programs and methods disclosed herein can, however, be realized in many different forms and should not be construed as being limited to the aspects set forth herein. Like numbers in the drawings refer to like elements throughout.

[0015] The terminology used herein is for describing aspects of the disclosure only and is not intended to limit the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0016] With reference to Figure 1A, Figure 1B and Figure 2, illustrating a first example, there is a waveguide arrangement 100 comprising a first waveguide port 101, a second waveguide port 101' and a waveguide conductor 102, 103, 104 that extends between the waveguide ports 101, 101'. The waveguide conductor 102, 103, 104 has a longitudinal extension L and comprises at least one electrically conducting inner wall 104, 105, 106, 107, in this example four electrically conducting inner walls 104, 105, 106, 107, the waveguide conductor 102, 103, 104 having a rectangular cross-section. According to some aspects, the layers mainly run along an H-plane of the waveguide conductor 102, 103, 104.

[0017] The ports 101, 101' are both in the form of coaxial ports that face a perpendicular direction versus the longitudinal extension L. The coaxial ports 101, 101' will be discussed more in detail later.

[0018] The waveguide arrangement is formed in a multilayer structure 108 comprising two outer layers 109, 110, a first outer layer 109 and a second outer layer 110. The multilayer structure 108 comprises a first intermediate layer 11 1a, a second intermediate layer 111b and a third intermediate layer 111c that is positioned between the first intermediate layer 111a and the second intermediate layer 111b. The intermediate layers 111a, 111b, 111c are positioned between the two outer layers 109, 110.

[0019] The layers 109, 110, 111a, 111b, 111c are individually formed and bonded together to form the waveguide conductor 102, 103, 104. According to some aspects, and as in particular shown in Figure 2, the internal structures comprised in the third intermediate layer 111c comprise posts 112a, 112b, 112c, 112d that extend along a waveguide inner width w_i, the posts extending from one inner wall 104, 105 and ending before the opposite inner wall 105, 104. Here, four posts 112a, 112b, 112c, 112d are shown, but of course there can be less or more posts.

[0020] According to some aspects, the posts 112a, 112b, 112c, 112d run between the inner walls 104, 105 in an alternating manner as shown in Figure 2.

[0021] By means of these posts 112a, 112b, 112c, 112d, a combline filter or interdigital filter can be formed in the waveguide arrangement 100 in a reliable and uncomplicated manner. The volume formed between the posts can hereby be reduced, such that a combline filter becomes smaller than traditional cavity filters.

[0022] The posts 112; 112a, 112b, 112c, 112d are an example of internal structures that can be formed in the intermediate layers 111a, 111b, 111c, other types of internal structures are of course possible.

[0023] The two outer layers 109, 110 are plates that in this example, form a respective top and bottom of the waveguide arrangement 100 that seal a vertical dimension of the waveguide arrangement 100 that is perpendicular to the longitudinal extension L, while the intermediate layers 111a, 111b, 111c comprise corresponding inner conductor parts that form the waveguide conductor 102, 103, 104. Two or more intermediate layers 111a, 111b, 111c may of course comprise internal structures. According to some aspects, the two outer layers 109, 110 may also comprise internal structures and/or conductor parts.

[0024] At least one waveguide port 101, 101' is in the form of a coaxial port, where the internal structures of at least one intermediate layer 111a, 111c comprise at least one coaxial probe arrangement 113, 114; 113', 114'. This means that in this context, the term "waveguide port" should be interpreted broadly and encompass different types of ports that connect to the waveguide conductor 102, 103, 104, for example the coaxial ports described here. Each coaxial probe arrangement comprises a probe post 113, 113' and a coaxial probe 114, 114' that extends from the respective probe post 113, 113' and is adapted to extend via a corresponding probe aperture 115, 115' in the first outer layer 109. In this example, both waveguide ports 101, 101' are in the form of coaxial ports. There is thus a first coaxial port that comprises a first probe post 113 and a first coaxial probe 114, and a second coaxial port that comprises a second probe post 113' and a second coaxial probe 114'. According to some aspects, the probe posts 113, 113' can be a part of a combline filter or interdigital filter together with the other posts 112a, 112b, 112c, 112d described.

[0025] This means that delicate internal structures such as posts that end before reaching an opposite inner wall and coaxial probe arrangements can be made in a reliable and repeatable manner.

[0026] In Figure 2, the coaxial probes 114, 114' are shown as being part of the third intermediate layer 111c,however, the coaxial probes 114, 114' can in practice be formed in two or more layers as will be described in the following.

[0027] With reference to Figure 3 and Figure 4A-4F, a procedure for forming coaxial ports will be described for the waveguide arrangement 100. The completed waveguide arrangement 100 is illustrated in Figure 4F. With reference to Figure 3, the first intermediate layer 111a and the third intermediate layer 111c are bonded together, and a section is shown in Figure 4A. Figure 4B and 4D-4E show the same section as the layers are processed and more layers added to form the multi-layer waveguide arrangement 108.

[0028] Figure 4B illustrates how material has been removed from the first intermediate layer 111a and the third intermediate layer 111c such that a first port first probe part 114a and a second port first probe part 114'a have been formed in the first intermediate layer 111a, and how a plurality of posts 112; 112a, 112b, 112c, 112d not connected to a probe, a first probe post 113 connected to the first port first probe part 114a and a second probe post 113' connected to the second port first probe part 114'a have been formed in the third intermediate layer 111c. Furthermore, a first waveguide conductor part 102 is formed in the first intermediate layer 111a and a third waveguide conductor part 104 is formed in the third intermediate layer 111c. The first waveguide conductor part 102 comprises the first probe parts 114a, 114'a and the third waveguide conductor part 104 comprises the posts 112a, 112b, 112c, 112d, 113, 113'. Then, the first intermediate layer 111a and the third intermediate layer 111c are metallized.

[0029] In Figure 4C, the side of the first outer layer 109 that is intended to face the first intermediate layer 111a has been metallized such that a metal layer 120 is formed, and thereafter metal has been removed R1, R2 where material later is to be removed. In this way, metal end parts E1, E2 are formed which are intended to contact the first port first probe part 114a and the second port first probe part 114'a.

[0030] In Figure 4D, the first outer layer 109 has been bonded to the first intermediate layer 111a.

[0031] In Figure 4E, material has been removed from the first outer layer 109, for example from the side that faces away from the first intermediate layer 111a, such that a first port second probe part 114b and a second port second probe part 114'b have been formed in the first outer layer 109, the first port second probe part 114b being a continuation of the first port first probe part 114a and the second port second probe part 114'b being a continuation of the second port first probe part 114'a. The first outer layer 109 is now metallized again such that electrical contact is made along the probe parts 114a, 114b; 114'a, 114'b that have been formed. Also, all other surfaces of the first outer layer 109 are metallized such that a corresponding outer coaxial conductor 121, 121' is formed.

[0032] The at least one first probe part 114a, 114'a, the at least one respective probe post 113, 113' and the at least one second probe part 114b, 114'b are formed by removing material.

[0033] This method enables a probe that extends through an aperture to be formed in an accurate, repeatable and reliable manner, in particular at higher frequencies exceeding for example 10GHz, where the probe and other parts become very small and therefore fragile. At this stage, many different parts can be attached to the third intermediate layer 111c, for example a PCB, a metal plate, antenna elements and/or other types of active and passive microwave structures.

[0034] In this example, a completed waveguide arrangement according to the one shown in Figure 1A will be formed. In Figure 4F, the waveguide arrangement 100 comprising the layer structure 108 is shown just before the second intermediate layer 111b and the second outer layer 110 are added, as indicated with arrows A_1, A_2.

[0035] This addition can be performed in several ways, for example the second intermediate layer 111b and the second outer layer 110 are completed and bonded together separately, before being bonded to the rest of the waveguide arrangement 100 as indicated in Figure 4F.

[0036] This means that the second intermediate layer 111b can be bonded to the second outer layer 110, and then material is removed from the second intermediate layer 111b and the layers 110, 111b metallized such that a second waveguide conductor part 103 formed before bonding the second intermediate layer 111b to the third intermediate layer 111c. The second intermediate layer 111b and the second outer layer 110 form a U-shape or a "bathtub-shape". The second intermediate layer 111b and the second outer layer 110 can be formed in an SOI (Silicon on Insulator) wafer as a starting material provided as two bonded silicon wafers with an oxide separation.

[0037] Other orders of assembly are of course conceivable, for example the second intermediate layer 111b is bonded to the third intermediate layer 111c, and the second outer layer 110 is then bonded to the second intermediate layer 111b. Some steps include that material is removed from the second intermediate layer 111b and the layers 111b, 111c are metallized such that a second waveguide conductor part 103 is formed, where these steps are performed before the second intermediate layer 111b is bonded to the third intermediate layer 111c. According to some aspects, material can be removed from the second intermediate layer 111b before the second intermediate layer 111b is bonded to the third intermediate layer 111c.

[0038] The posts 112a, 112b, 112c, 112d are not necessary, and are shown for illustrative purposes. Other internal structures such as for example a plurality of ridges extending across at least a part of the entire waveguide inner width W_i, can also be included in one of the intermediate layers 111a, 111b, 111c.

[0039] The bonding makes the layers 109, 110, 111a, 111b, 111c to be rigidly attached to each other, and the removal of material can be performed in many ways, for example by means of etching of the material that form the layers 109, 111a, 111b, 111c in which structures are formed. Material may be removed from a layer before or after that layer has been bonded to another layer. The procedure disclosed does not have to take place in the order described, but may be performed in any suitable order.

[0040] Metallization of the waveguide arrangement 100 may be performed layer-wise, between bonding steps, when two or more layers are bonded together, and/or when the complete layer structure 108 has been formed. In the case of Silicon-based waveguide arrangement, the metallization itself may be used to attach the layers together.

[0041] According to some aspects, each layer 109, 110, 111a, 111b, 111c is formed in one piece of silicon and is at least partly metallized. This means that the waveguide arrangement 100 with the internal structures can be made by using well-known etching and metallization techniques.

[0042] According to some aspects, generally, each intermediate layer 111a, 111b, 111c comprises a waveguide conductor 102, 103, 104.

[0043] With reference to Figure 5A and Figure 5B, the present disclosure also relates to a method for forming a waveguide arrangement 100 with at least one coaxial port. With reference first to Figure 5A, the method comprises providing S100 a first outer layer 109 and at least two intermediate layers 111a, 111b, 111c. These intermediate layers comprise a first intermediate layer 111a and a third intermediate layer 111c. The method further comprises bonding S200 the first intermediate layer 111a to the third intermediate layer 111c, as shown in Figure 4A, removing S300 material from the first intermediate layer 111a and the third intermediate layer 111c such that at least one first probe part 114a, 114' a is formed in the first intermediate layer 111a, and at least one respective probe post 113, 113' connected to the first probe part 114a, 114'a is formed in the third intermediate layer 111c, as shown in Figure 4B, and at least partly metallizing S400 the intermediate layers 111a, 111c. Here there is a first probe post 113, a second probe post 113', a first probe first probe part 114a and a second probe first probe part 114'a.

[0044] The method also comprises providing S500 metallization to the first outer layer 109 such that at least one metal end parts E1, E2 is formed, intended to contact a corresponding first probe part. Here, there is a first metal end part E1 intended to contact the first probe first probe part 114a and a second metal end part E1 intended to contact the second port first probe part 114'a as shown in Figure 4C. The method also comprises bonding S600 the first outer layer 109 to the first intermediate layer 111a as shown in Figure 4D. The method further comprises removing S700 material R1, R2 from the first outer layer 109 such that at least one second probe part 114b, 114'b is formed in the first outer layer 109, each second probe part 114b, 114'b protruding via a respective probe aperture 115, 115' and constituting a continuation of the respective first probe part 114a, 114'a. The method furthermore comprises at least partly metallizing S800 the layers 109, 111a, 111c and the acquired result is shown in Figure 4E. Here, material R1, R2 has been removed such that a first probe second probe part 114b and second probe second probe part 114'b are formed. The method also comprises providing S800B a dielectric material 140, 141 between the second probe parts 114b, 114'b and a corresponding outer coaxial conductor 121, 121'.

[0045] According to some aspects, with reference also to Figure 5B and Figure 4F, optionally, the method further comprises providing S900 a second intermediate layer 111b and a second outer layer 110, and bonding S1000 the second intermediate layer 111b to the second outer layer 110.

[0046] The method comprises removing S 1100 material from the second intermediate layer 111b and metallizing S1200 the second intermediate layer 111b and the second outer layer 110 such that a waveguide conductor part is formed. The method further comprises bonding S1300 the second intermediate layer 111b to the third intermediate layer 111c, this corresponds to Figure 4F that shows an example of an almost completed waveguide arrangement 100.

[0047] According to some aspects, the layers 109, 110, 111a, 111b, 111c are formed in a substrate material. According to some further aspects, each layer 109, 110; 111a, 111b, 111c is separately formed in one layer of a silicon wafer substrate.

[0048] The method above may be performed in different ways, according to some aspects such that some steps can be performed in different orders. For example, metallizing the layers 109, 110, 111a, 111b, 111c can take place before or after bonding two or more layers together.

[0049] The present disclosure also relates to a waveguide arrangement comprising a first outer layer 109 and at least two intermediate layers 111a, 111b, 111c comprising a first intermediate layer 111a and a third intermediate layer 111c. The first intermediate layer 111a is bonded to the third intermediate layer 111c, where the first outer layer 109 is bonded to the first intermediate layer 111a, where at least one first probe part 114a, 114'a is formed in the first intermediate layer 111a, at least one respective probe post 113, 113' connected to the first probe part 114a, 114'a is formed in the third intermediate layer 111c, and at least one second probe part 114b, 114'b is formed in the first outer layer 109. Each second probe part 114b, 114'b protrudes via a respective probe aperture 115, 115' and constitutes a continuation of the respective first probe part 114a, 114'a. The layers are at least partly metallized, where a first waveguide conductor part 102 is formed in the first intermediate layer 111a and a third waveguide conductor part 104 is formed in the third intermediate layer 111c.

[0050] This structure enables a probe that extends through an aperture to be formed in an accurate, repeatable and reliable manner, in particular at higher frequencies exceeding for example 10GHz, where the probe and other parts become very small and therefore fragile. Many different parts can be attached to the third intermediate layer, for example a PCB, a metal plate, antenna elements and/or other types of active and passive microwave structures.

[0051] According to some aspects, the waveguide arrangement further comprises a second intermediate layer 111b and a second outer layer 110, where the second intermediate layer 111b comprises a second waveguide conductor part 103. The second outer layer 110 is bonded to the second intermediate layer 111b and the second intermediate layer 111b is bonded to the third intermediate layer 111c such that the third intermediate layer 111c is positioned between the first intermediate layer 111a and the second intermediate layer 111b.

[0052] This means that a waveguide is provided and connected to a least one coaxial probe.

[0053] Furthermore, as shown in Figure 4F and Figure 4G, the waveguide arrangement comprises a dielectric material 140, 141 positioned between each second probe part 114b, 114'b and a corresponding outer coaxial conductor 121, 121'. This provides an increased stability for the second probe parts 114b, 114'b. The dielectric material 140, 141 thus at least partly fills the space between the second probe parts 114b, 114'b and the corresponding outer coaxial conductor 121, 121', and is according to some aspects annular. According to some aspects, the dielectric material 140, 141 is formed in at least one of the materials resin, glue, epoxy, plastic and PTFE (polytetrafluoroethylene).

[0054] With reference to Figure 6, that corresponds to Figure 4F, another way to provide an increased stability for the second probe parts 114b, 114'b is to realize the coax feedthrough without creating an air gap between pin and ground. The ground ring for the coax would need to be made with at least one narrow gap 600, 601 to keep material in place during processing. The second probe parts 114b, 114'b are thus formed as metallization of etched cavities in the substrate material such that the metallized pin 602, and ground rings, 603, 604 are formed.

[0055] An alternative solution would be to make the top layer in Figure 6 as a glass substrate with integrated feedthroughs. Glass is more difficult to etch or laser drill than silicon but the benefit is that in such case excellent RF properties will be achieved for the feedthrough.

[0056] The present disclosure enables creating a desired waveguide arrangement with at least one integrated coaxial probe by means of stacking multiple micro-structured substrates. With such a coaxial probe integrated in the waveguide, a cost-effective integration of the waveguide arrangement can be achieved by direct mounting of the waveguide arrangement with an integrated coaxial port to a printed circuit board for example, without need for wire bonding.

[0057] According to some aspects, each layer is formed in one piece of silicon.

[0058] The present disclosure is not limited to the above, but may vary freely within the scope of the appended claims. For example, one or more probes can be combined with any other suitable internal structure formed in one or more of the intermediate layers, or internal structures other than those relating to the coaxial ports can be omitted.

[0059] Ridges, posts and coaxial probe arrangements have been shown as examples of internal structures; these can of course be combined in any manner, and many other types of internal structures are of course conceivable in this multi-layer waveguide arrangement 108. This is the case for all examples described.

[0060] The waveguide arrangement according to the present disclosure is normally a part of a larger assembly, and several waveguide arrangements may be stacked and/or connected in serial with intermediate components.

[0061] By means of the present disclosure, relatively complicated coaxial waveguide ports that previously have been difficult to manufacture, can now be formed in a relatively uncomplicated an inexpensive manner using commercially available manufacturing equipment with an increased degree of accuracy.

[0062] All Figures are of a schematic character, only being intended to illustrate the present invention, and not being intended to suggest actual proportions and/or measures.

[0063] According to some aspects, the waveguide arrangement can be regarded as a waveguide arrangement that is formed in a multilayer structure.

Claims

1. A method for forming a waveguide arrangement (100) with at least one coaxial port (101, 101'), the method comprising

    providing (S100) a first outer layer (109) and at least two intermediate layers (111a, 111b, 111c) comprising a first intermediate layer (111a) and a third intermediate layer (111c);
    bonding (S200) the first intermediate layer (111a) to the third intermediate layer (111c);
    removing (S300) material from the first intermediate layer (111a) and the third intermediate layer (111c) such that at least one first probe part (114a, 114'a) is formed in the first intermediate layer (111a), and at least one respective probe post (113, 113') connected to the first probe part (114a, 114'a) is formed in the third intermediate layer (111c);
    at least partly metallizing (S400) the intermediate layers (111a, 111c).
    providing (S500) metallization to the first outer layer (109) such that at least one metal end parts (E1, E2) is formed, intended to contact a corresponding probe part (114a, 114'a);
    bonding (S600) the first outer layer (109) to the first intermediate layer (111a);
    removing (S700) material (R1, R2) from the first outer layer (109) such that at least one second probe part (114b, 114'b) is formed in the first outer layer (109), each second probe part (114b, 114'b) protruding via a respective probe aperture (115, 115') and constituting a continuation of the respective first probe part (114a, 1 14'a);
    at least partly metallizing (S800) the layers (109, 111a, 111c); and
    providing (S800B) a dielectric material (140, 141) between the second probe parts (114b, 114'b) and a corresponding outer coaxial conductor (121, 121').

2. The method according to claim 1, the method further comprising

    providing (S900) a second intermediate layer (111b) and a second outer layer (110);
    bonding (S1000) the second intermediate layer (111b) to the second outer layer (110);
    removing (S1100) material from the second intermediate layer (111b);
    metallizing (S1200) the second intermediate layer (111b) and the second outer layer (110) such that a waveguide conductor part is formed; and
    bonding (S1300) the second intermediate layer (111b) to the third intermediate layer (111c).

3. The method according to any one of the claims 1 or 2, wherein each layer (109, 110; 111a, 111b, 111c) is formed in one piece of silicon.

4. A waveguide arrangement comprising a first outer layer (109) and at least two intermediate layers (111a, 111b, 111c) comprising a first intermediate layer (111a) and a third intermediate layer (111c), where the first intermediate layer (111a) is bonded to the third intermediate layer (111c) and the first outer layer (109) is bonded to the first intermediate layer (111a), where at least one first probe part (114a, 114'a) is formed in the first intermediate layer (111a), at least one respective probe post (113, 113') connected to the first probe part (114a, 114'a) is formed in the third intermediate layer (111c), and at least one second probe part (114b, 114'b) is formed in the first outer layer (109), each second probe part (114b, 114'b) protruding via a respective probe aperture (115, 115') and constituting a continuation of the respective first probe part (114a, 114'a), the layers being at least partly metallized, where a first waveguide conductor part (102) is formed in the first intermediate layer (111a) and a third waveguide conductor part (104) is formed in the third intermediate layer (111c), where the at least one first probe part (114a, 114'a), the at least one respective probe post (113, 113') and the at least one second probe part (114b, 114'b) are formed by removing material, and where the waveguide arrangement comprises a dielectric material (140, 141) positioned between each second probe part (114b, 114'b) and a corresponding outer coaxial conductor (121, 121').

5. The waveguide arrangement according to claim 4, further comprising a second intermediate layer (111b) and a second outer layer (110), where the second intermediate layer (111b) comprises a second waveguide conductor part (103), where the second outer layer (110) is bonded to the second intermediate layer (111b) and the second intermediate layer (111b) is bonded to the third intermediate layer (111c) such that the third intermediate layer (111c) is positioned between the first intermediate

layer (111a) and the second intermediate layer (111b) .

6. The waveguide arrangement according to any one of the claims 4 or 5, wherein each layer (109, 110; 111a, 111b, 111c) is formed in one piece of silicon.

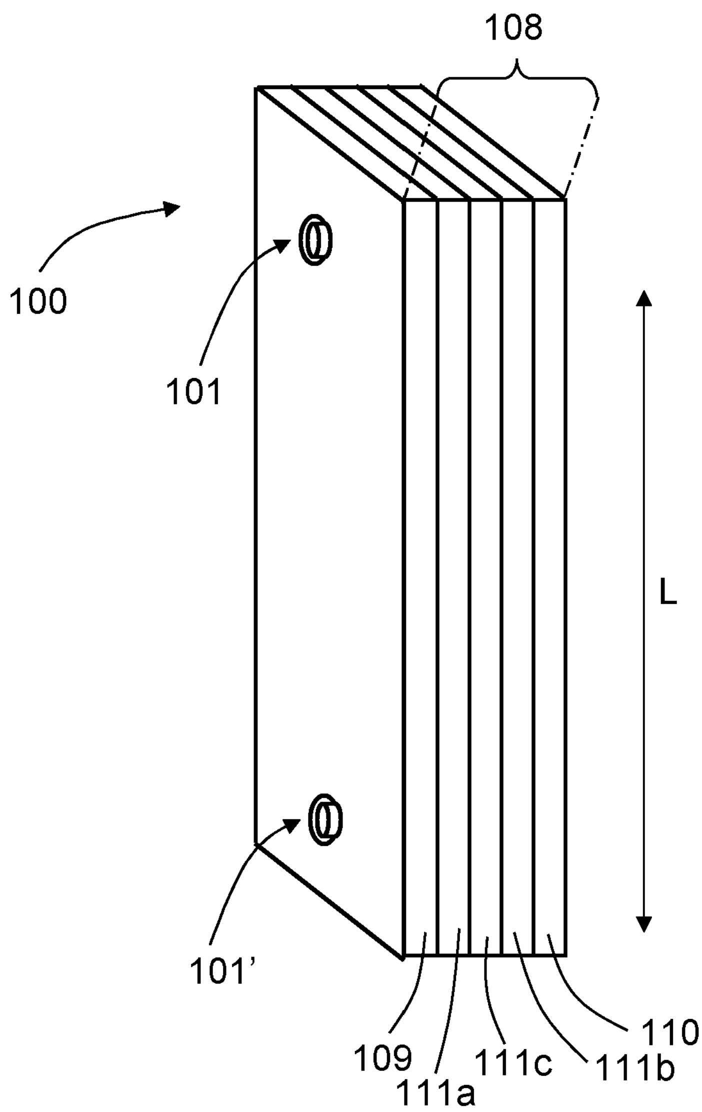

108
100
101
L
101'
110
109
111c
111b
111a

FIG. 1A

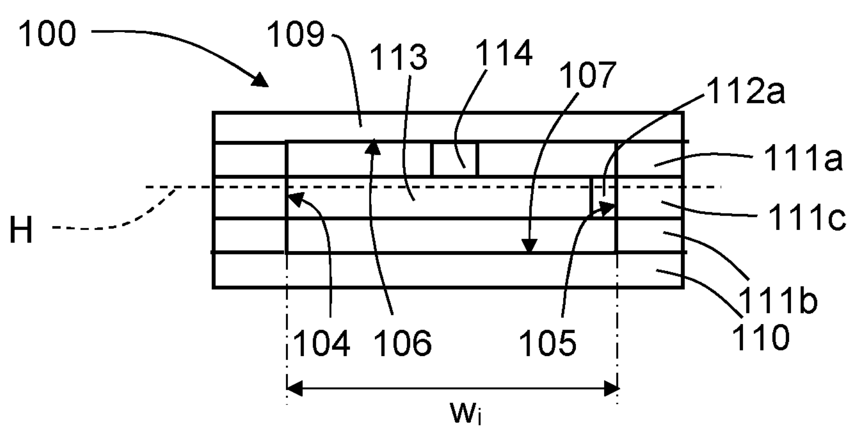

100
109
113
114
107
112a
111a
H
111c
111b
104
106
105
110
Wi

FIG. 1B

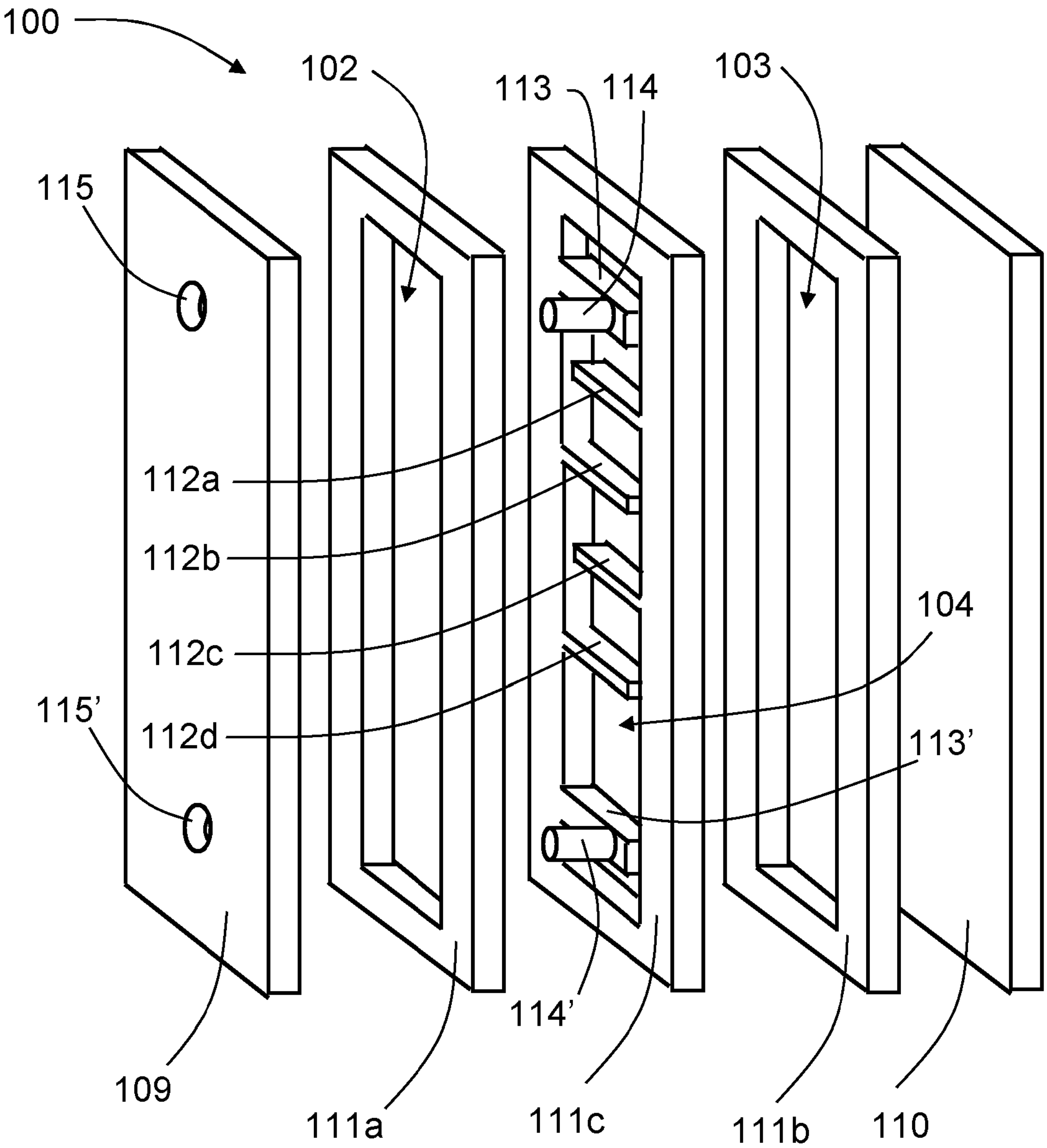

100
102
113
114
103
115
112a
112b
112c
104
115'
112d
113'
114'
109
111a
111c
111b
110

FIG. 2

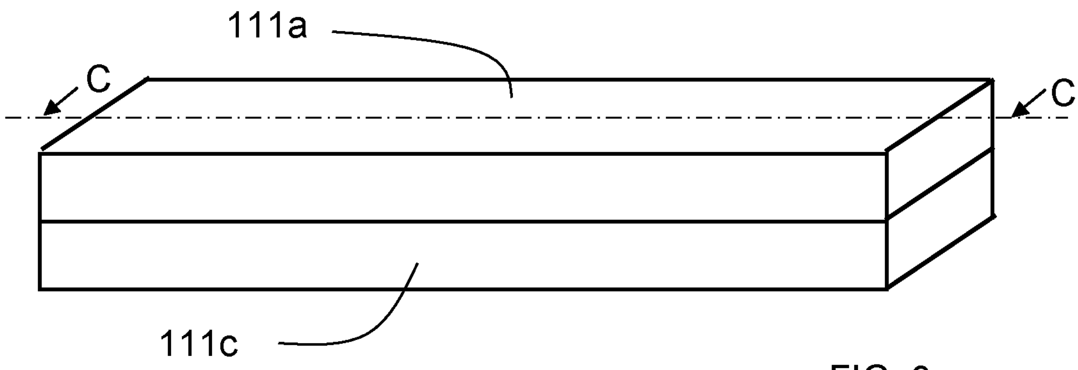
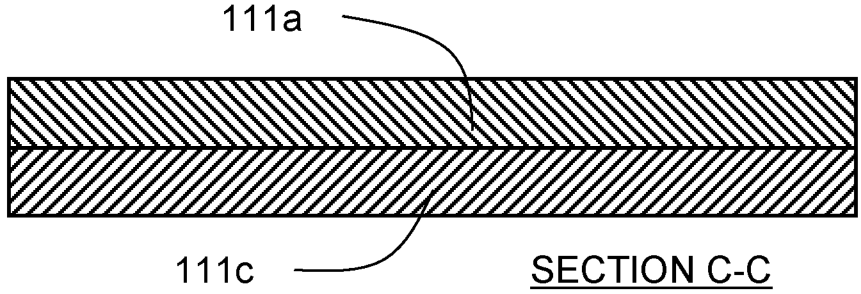


FIG. 3



SECTION C-C

FIG. 4A

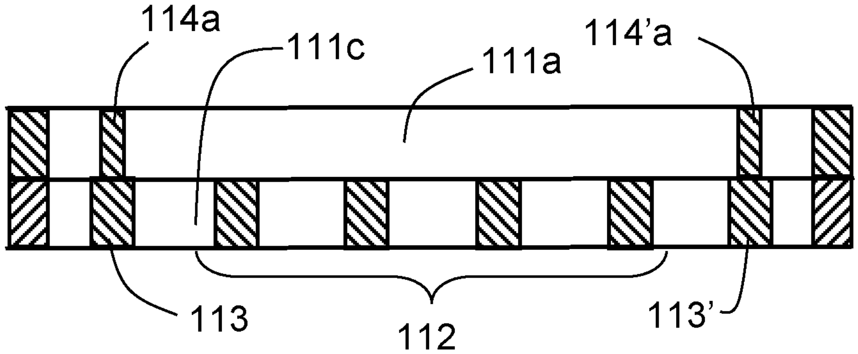


FIG. 4B

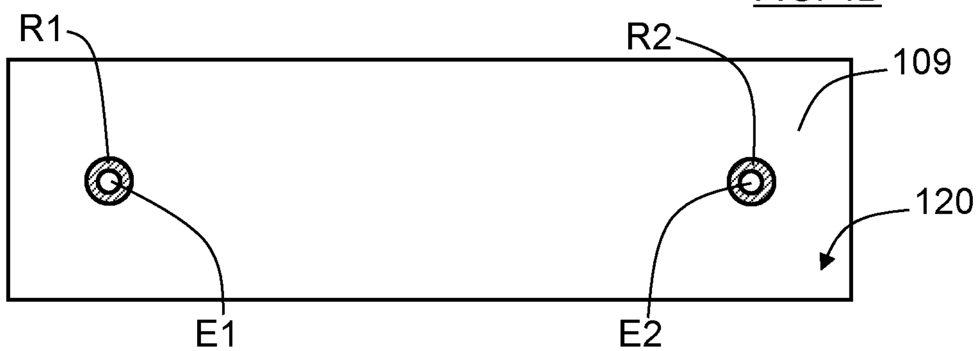


FIG. 4C

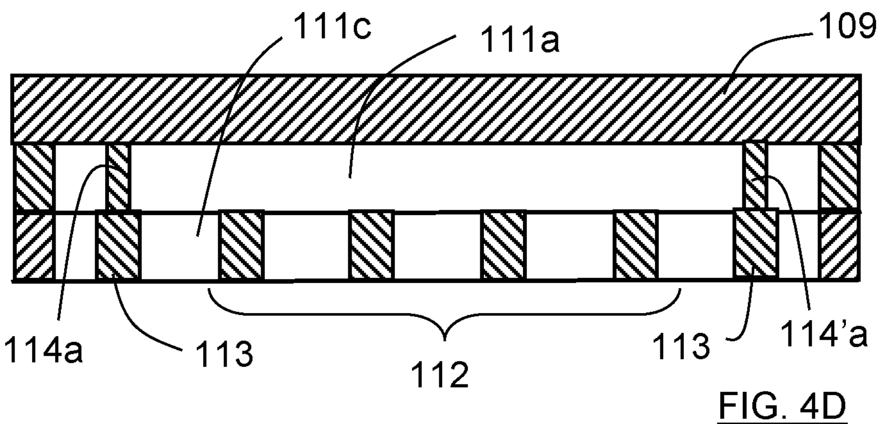


FIG. 4D

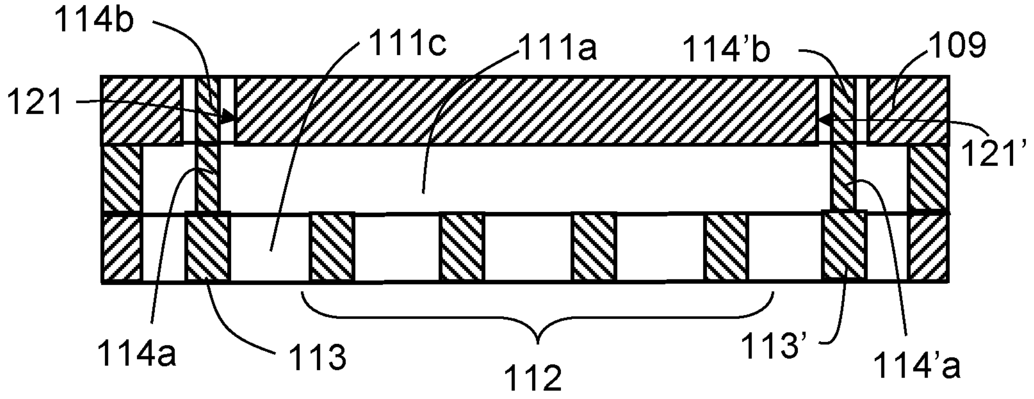


FIG. 4E

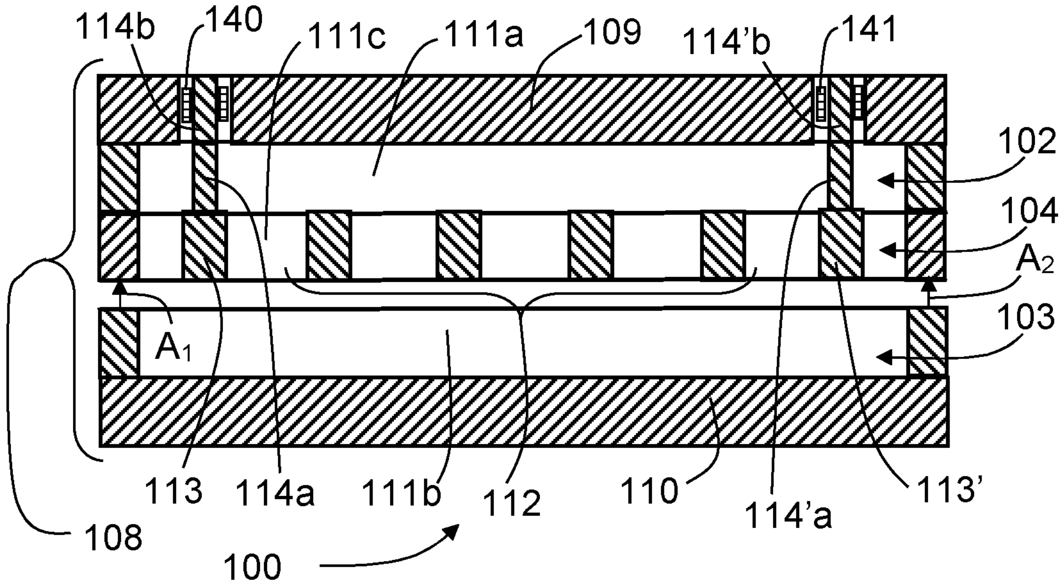


FIG. 4F

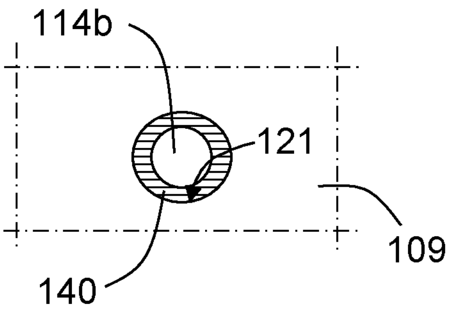

114b
121
109
140

FIG. 4G

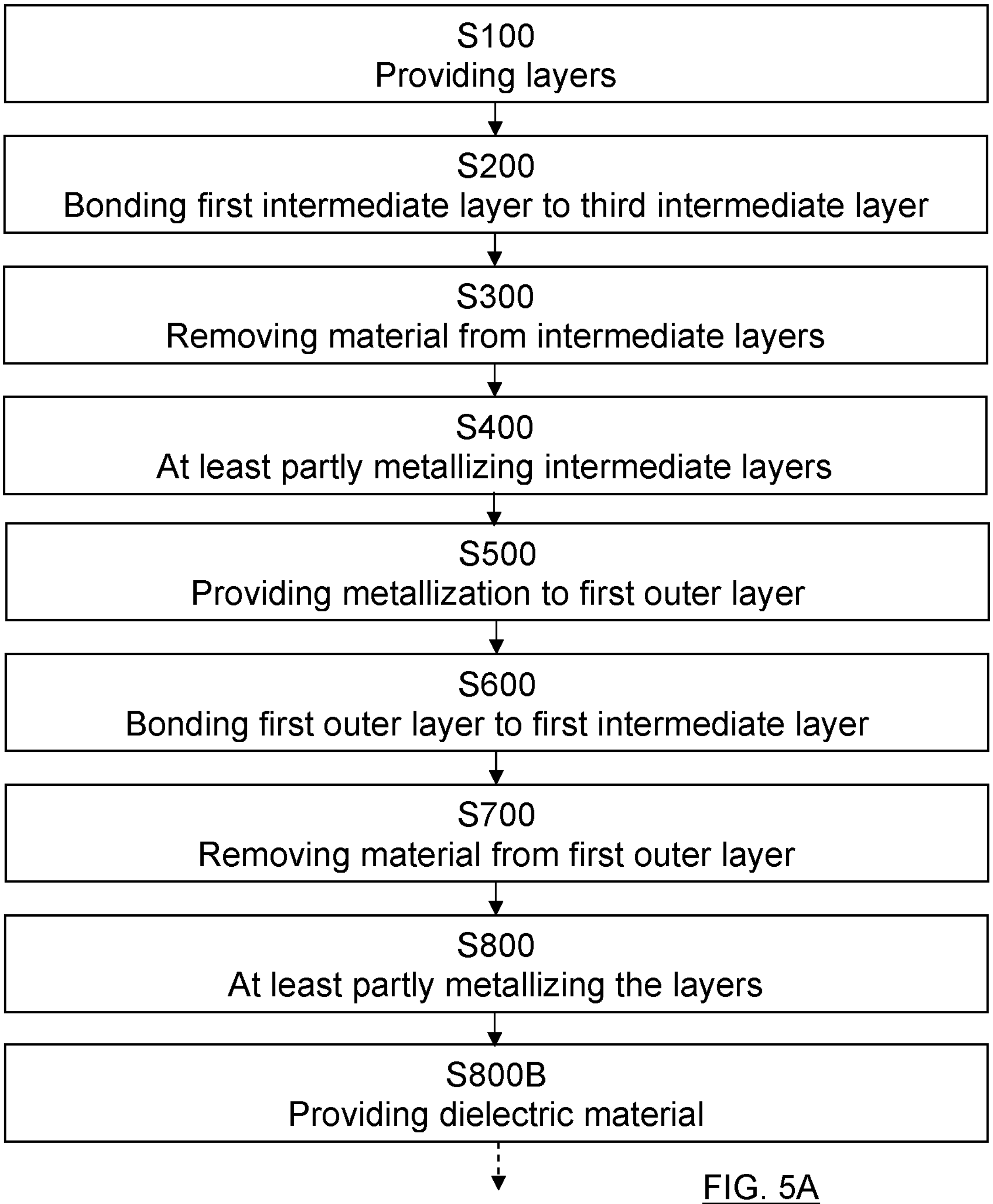

S100
Providing layers
S200
Bonding first intermediate layer to third intermediate layer
S300
Removing material from intermediate layers
S400
At least partly metallizing intermediate layers
S500
Providing metallization to first outer layer
S600
Bonding first outer layer to first intermediate layer
S700
Removing material from first outer layer
S800
At least partly metallizing the layers
S800B
Providing dielectric material

FIG. 5A

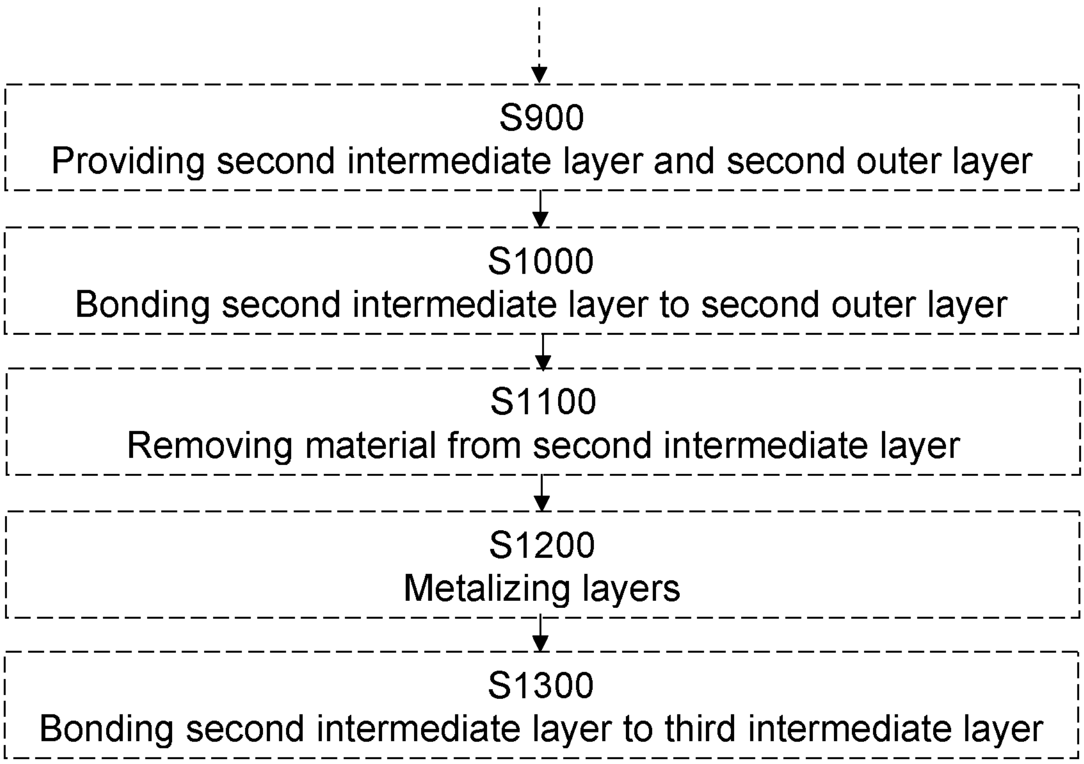
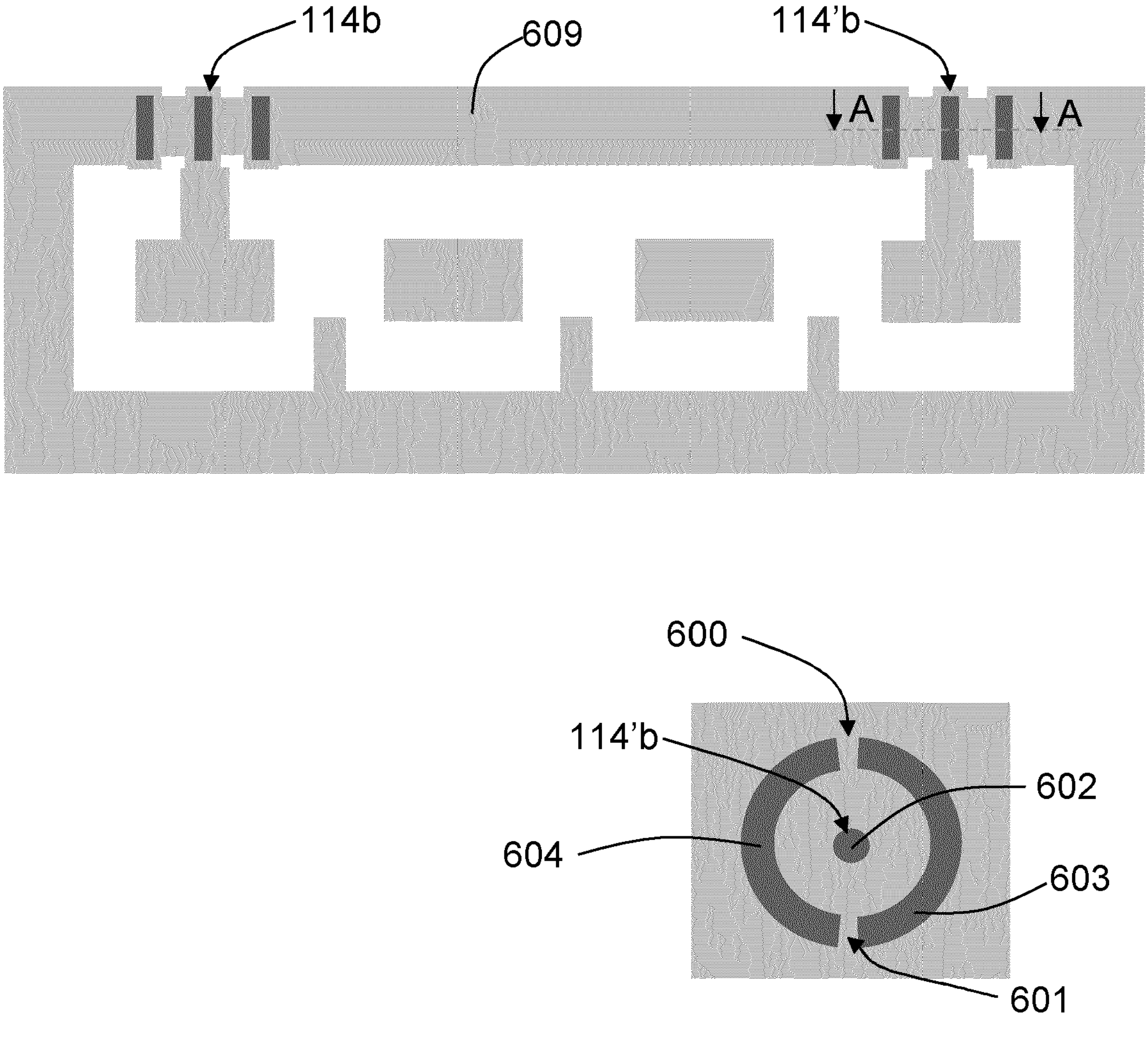

S900
Providing second intermediate layer and second outer layer
S1000
Bonding second intermediate layer to second outer layer
S1100
Removing material from second intermediate layer
S1200
Metalizing layers
S1300
Bonding second intermediate layer to third intermediate layer

FIG. 5B



SECTION A-A

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 24 22 2056

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2017/125871 A1 (ISHIBASHI DAIJIRO [JP]) 4 May 2017 (2017-05-04) * paragraph [0046] - paragraph [0058] * * figure 3 * * paragraph [0073] * * figure 8B * * paragraph [0091] - paragraph [0114] * * paragraph [0117] * * figures 13-20 * * paragraph [0140] - paragraph [0143] * * figure 24 * -----	1-6	INV. H01P11/00 H01P3/12 H01P5/103 H01P1/203
A	CN 102 790 248 A (CN ELECT TECH NO 26 RES INST) 21 November 2012 (2012-11-21) * paragraph [0023] - paragraph [0042] * * figures 1-5 * -----	1-6	
A	US 2017/019994 A1 (WU SHIH-HSIEN [TW]) 19 January 2017 (2017-01-19) * paragraph [0059] - paragraph [0066] * * figure 1 * -----	1-6	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01P

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 April 2025	Culhaoglu, Ali

CATEGORY OF CITED DOCUMENTS

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15-04-2025

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