



(22) Date de dépôt/Filing Date: 2014/01/13
(41) Mise à la disp. pub./Open to Public Insp.: 2014/09/15
(45) Date de délivrance/Issue Date: 2020/12/15
(62) Demande originale/Original Application: 2 839 334
(30) Priorité/Priority: 2013/03/15 (US13/832,181)

(51) Cl.Int./Int.Cl. *C23F 15/00* (2006.01),
C08J 5/12 (2006.01), *C09K 3/10* (2006.01)
(72) Inventeur/Inventor:
ERICKSON, MARCUS ALEXANDER, US
(73) Propriétaire/Owner:
THE BOEING COMPANY, US
(74) Agent: SMART & BIGGAR LLP

(54) Titre : STRUCTURE HYBRIDE ET PROCEDES DE FORMATION DE CELLE-CI
(54) Title: HYBRID STRUCTURE AND METHODS FOR FORMING THE SAME

(57) **Abrégé/Abstract:**

A method for forming a hybrid structure is disclosed. The method involves applying a sealant to a first component fabricated from a first material, and coupling an isolation sheet to the sealant, the isolation sheet is fabricated from a second material that is different from the first material, the isolation sheet exposed for receiving a second component directly thereon when forming the hybrid structure. A method for use in forming an assembly is also disclosed. The method involves forming a sub-assembly that includes a first component fabricated from a first material, a sealant applied to the first component, and an isolation sheet coupled to the sealant. The isolation sheet is fabricated from a second material that is different than the first material, the isolation sheet being exposed for receiving a second component directly thereon when forming the assembly, installing the sub-assembly in the assembly.

ABSTRACT OF THE DISCLOSURE

A method for forming a hybrid structure is disclosed. The method involves applying a sealant to a first component fabricated from a first material, and coupling an isolation sheet to the sealant, the isolation sheet is fabricated from a second material that is different from the first material, the isolation sheet exposed for receiving a second component
5 directly thereon when forming the hybrid structure. A method for use in forming an assembly is also disclosed. The method involves forming a sub-assembly that includes a first component fabricated from a first material, a sealant applied to the first component, and an isolation sheet coupled to the sealant. The isolation sheet is fabricated from a second material that is different than the first material, the isolation sheet being exposed for receiving a second component
10 directly thereon when forming the assembly, installing the sub-assembly in the assembly.

HYBRID STRUCTURE AND METHODS FOR FORMING THE SAME

BACKGROUND

The present disclosure relates generally to hybrid structures and, more specifically, to methods for use in reducing galvanic corrosion within hybrid structures.

Galvanic corrosion refers to an electrochemical process where in electrons are transferred between materials in electrical contact that have different electrode potentials. A galvanic cell generally includes an anode, a cathode, and an electrolyte that couples the anode and cathode together in electrical contact. During operation, electrons from the material with the more active electrode potential (i.e., the anode) are transferred to the material with the less active electrode potential (i.e., the cathode) via the electrolyte. As such, corrosion occurs when the anode material dissolves in the electrolyte and deposits on the cathode.

Recently, at least some known aircraft components have increasingly been fabricated from composite materials such as carbon-fiber-reinforced polymer (CFRP) in combination with metallic materials such as aluminum, titanium, and/or steel. As used herein, the term “metallic” may refer to a single metallic material or a metallic alloy material. The composite materials generally reduce the weight of the aircraft resulting in an increase in the fuel efficiency of the aircraft. In such assemblies, certain metallic materials have a more active electrode potential than the conductive carbon fibers dispersed within the composite materials.

In at least some known aircraft assemblies, metallic components are coupled to CFRP components via a plurality of fasteners. In one known assembly, CFRP-metallic hybrid structures are formed in a process where the metallic components are aligned with the CFRP parts in a predetermined position, and hole locations are drilled based on the predetermined position. The metallic component is then coupled to the CFRP components with fasteners. In such structures, galvanic corrosion may occur if moisture is introduced between the metallic and CFRP components.

Preventing galvanic corrosion generally requires either eliminating and/or suppressing at least one of the elements of the galvanic cell. When the electrolyte is water, one known method to prevent galvanic corrosion is to apply a water resistant sealant between the anode and cathode to substantially prevent the ingress of the electrolyte therebetween. When

forming CFRP-metallic hybrid structures, the sealant is generally applied after the hole locations have been determined, which requires the metallic component to be removed in an intermediate step. However, the process described above that includes alignment of the metallic components, fastener hole formation, removal of the metallic components, sealant application, and re-
5 alignment of the metallic components is an inefficient and time-consuming task, and changes in the ambient conditions after the holes have been formed may cause the parts to distort making re-alignment of holes in the metallic parts with the drill holes difficult.

SUMMARY

In accordance with one disclosed aspect there is provided a method for forming a hybrid structure. The method involves applying a sealant to a first component fabricated from a first
10 material, coupling an isolation sheet to the sealant, the isolation sheet being fabricated from a second material that is different from the first material. The first material has an electrode potential that is different than an electrode potential of the second material, and the first material includes a carbon fiber material and the second material includes a metallic material. The method also involves coupling a second component, fabricated from the second material, to the
15 isolation sheet, a surface area of the isolation sheet being less than a whole surface area of the first component, and the surface area of the isolation sheet being greater than a surface area covered by the second component.

The carbon fiber material may include a carbon-fiber-reinforced polymer material.

Applying the sealant may involve coupling an isolating layer to a surface of the first
20 component before applying the sealant, and applying the sealant directly to the isolating layer, the applied sealant having a smaller area than the isolating layer.

Coupling the isolation sheet to the sealant may involve bonding the isolation sheet to the first component with the sealant.

Applying the sealant may involve covering the first component with the sealant, and
25 applying a pressure to the isolation sheet to cause microvoids between the isolation sheet and the first component to be substantially filled by the sealant, the sealant being operable to prevent ingress of moisture between the isolation sheet and the first component.

Applying the sealant may involve applying the sealant that has moisture resistance properties to restrict ingress of moisture between the first component and the isolation sheet.

Coupling the isolation sheet to the sealant may involve applying pressure to the isolation sheet to facilitate removing excess sealant from between the isolation sheet and the first component.

Coupling the second component to the isolation sheet may involve aligning the second component with the isolation sheet in a predetermined orientation, determining bore hole locations on the isolation sheet with at least one of holes defined in the second component and a drill jig, forming bore holes through the isolation sheet, the sealant, and the first component at the hole locations, and using at least one fastener to couple the second component to the isolation sheet.

The method may involve substantially maintaining alignment of the second component relative to the isolation sheet while the bore holes may be formed.

Coupling the second component to the isolation sheet may involve aligning the second component with the isolation sheet such that the second component remains separated from the first component.

In accordance with another disclosed aspect there is provided a method for use in forming an assembly. The method involves forming a sub-assembly that includes a first component fabricated from a first material, a sealant applied to and covering less than a whole surface area of the first component, and an isolation sheet coupled to the sealant. A surface area covered by the sealant is greater than a surface area of the isolation sheet. The isolation sheet is fabricated from a second material that is different than the first material, the isolation sheet being exposed for receiving a second component, fabricated from the second material, directly thereon when forming the assembly. The first material has an electrode potential that is different than an electrode potential of the second material, and the first material includes a carbon fiber material and the second material includes a metallic material. The method further involves installing the sub-assembly in the assembly.

The method may involve coupling the second component to the isolation sheet.

Coupling the second component to the isolation sheet may involve aligning the second component with the isolation sheet in a predetermined orientation, determining bore hole locations on the isolation sheet with at least one of holes defined in the second component and a drill jig, forming bore holes through the sub-assembly at the bore hole locations, and using at least one fastener to couple the second component to the sub-assembly.

Using the at least one fastener may involve applying a second sealant to at least one of the bore holes and the at least one fastener before using the at least one fastener.

The isolation sheet may be coupled to the sealant by applying a pressure to the isolation sheet to cause microvoids between the isolation sheet and the first component to be substantially filled by the sealant, the sealant being operable to prevent ingress of moisture between the isolation sheet and the first component.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of an exemplary hybrid structure.

Figure 2 is illustrates a series of assembly steps for forming the hybrid structure shown in Figure 1.

Figure 3 is a flow diagram of an exemplary method for forming the hybrid structure shown in Figure 1.

Figure 4 is a flow diagram of an exemplary method that may be completed to form an assembly that may be used with the hybrid structure shown in Figure 1.

DETAILED DESCRIPTION

The present disclosure relates to hybrid structures fabricated from components of different materials, and methods for forming hybrid structures to facilitate preventing galvanic corrosion of the components therein. The hybrid structures described herein include a sub-assembly formed from a first component fabricated from a first material, a sealant applied to the first component, and an isolation sheet fabricated from a second material that is coupled to the sealant. A second component fabricated from the second material is coupled to the isolation sheet to form the hybrid structure. In the exemplary implementation, the first material and the second material have different electrode potentials such that galvanic corrosion may occur if the second component were directly coupled to the first component in the presence of an electrolyte.

As such, in the exemplary implementation, the sealant and the isolation sheet facilitate separating the first component from the second component to substantially prevent the formation of a galvanic cell in the hybrid structure.

In some implementations, the sub-assembly described herein may be fabricated and installed in an assembly, and the second component may then be coupled to the sub-assembly. More specifically, in some implementations, the second component may be coupled to the sub-assembly by aligning the second component with the sub-assembly, determining drill
5 hole locations in the sub-assembly based on holes defined in the second component and/or with a drill jig, and coupling the second component to the sub-assembly with fasteners. Because the sealant and isolation sheet are pre-installed in the sub-assembly, the second component does not need to be removed from alignment after the drill hole locations are determined, and a sealant does not need to be applied to the first component after removal of the second component. As
10 such, manufacturing times may be substantially reduced and difficulties resulting from temperature distortion in the drilled parts may be substantially eliminated as compared to other known manufacturing processes.

Figure 1 is a perspective view of an exemplary hybrid structure 100. In the exemplary implementation, hybrid structure 100 includes a first component 102, an isolating
15 layer 104, a sealant 106 applied to isolating 104, an isolation sheet 108 coupled to sealant 106, and a second component 110 coupled to isolation sheet 108. As such, second component 110 is separated from first component 102 by isolation sheet 108, sealant 106, and in some implementations, isolating layer 104 such that galvanic corrosion is facilitated to be prevented.

First component 102, second component 110, and isolation sheet 108 may be
20 fabricated from any suitable material that enables hybrid structure 100 to function as described herein. In some implementations, first component 102 is fabricated from a first material having a first electrode potential, and second component 110 and isolation sheet 108 are fabricated from a second material having a second electrode potential that is different than the first electrode potential. For example, in the exemplary implementation, the difference between the first and
25 second electrode potentials would enable galvanic corrosion to occur if first component 102 and second component 110 were coupled directly to each other in the presence of an electrolyte (not shown). For example, in some implementations, the first material is a carbon fiber material and the second material is a metallic material. Exemplary first materials include, but are not limited to, carbon-fiber-reinforced polymer (CFRP) and a titanium material, and an exemplary second
30 material includes, but is not limited to, an aluminum material. In the exemplary implementation,

the first material is a carbon-fiber-reinforced polymer (CFRP) and the second material is an aluminum alloy.

At least some known materials have different levels of electrode potentials that position each material in varying positions on the Anodic index. The Anodic index is used to determine the likelihood of a material to be anodic or cathodic based on the electrode potential of each material used in a galvanic cell. Generally, materials having a less active electrode potential are more likely to be cathodic, and materials having a more active electrode potential are more likely to be anodic. Further, the larger the difference in electrode potential between two materials, the more likely it is for galvanic corrosion to occur if the materials are used in the presence of an electrolyte. In alternative implementations, any first and second materials that have differing electrode potentials may be used to fabricate hybrid structure **100** as described herein.

As described above, materials having different electrode potentials are used to fabricate hybrid structure **100**. As such, sealant **106** and isolating layer **104** are used to facilitate preventing galvanic corrosion from occurring within hybrid structure **100**. For example, in the exemplary implementation, sealant **106** and isolating layer **104** facilitate preventing galvanic corrosion between isolation sheet **108** and first component **102** by substantially preventing the ingress of moisture therebetween. Further, galvanic corrosion is substantially prevented between isolation sheet **108** and second component **110** because they are fabricated from materials that have substantially similar electrode potentials. As such, in such an implementation, galvanic corrosion would not occur between isolation sheet **108** and second component **110** even if an electrolyte were introduced therebetween.

In the exemplary implementation, sealant **106** may include any suitable material that enables hybrid structure **100** to function as described herein. For example, in the exemplary implementation, sealant **106** has moisture resistance properties that facilitate substantially preventing the ingress of moisture between first component **102** and isolation sheet **108**. Further, curing sealant **106** facilitates coupling isolation sheet **108** to first component **102**. Exemplary sealant materials include, but are not limited to, a polysulfide material. In some implementations, sealant **106** is fabricated from commercially available aerospace integral fuel tank sealant. For example, the sealant material may have elastomeric properties that don't degrade when exposed

to fuel and/or hydraulic fluids, may cure at ambient conditions, may have a service temperature range of between about -65 °F (-54 °C) and 275 °F (135 °C), and may have biocidal properties.

In the exemplary implementation, isolating layer **104** is coupled to a surface **116** of first component **102**. In an alternative implementation, isolating layer **104** may be omitted from hybrid structure **100**, and sealant **106** may then be applied directly to first component **102**. Isolating layer **104** may be fabricated from any suitable material that facilitates preventing galvanic corrosion from occurring within hybrid structure **100**. An exemplary material that may be used to fabricate isolating layer **104** includes, but is not limited to, a fiberglass material. For example, in the exemplary implementation, isolating layer **104** is fabricated from a fiberglass material. In some implementations, the electrode potential of the material used to fabricate isolating layer **104** may not be relevant to facilitating preventing formation of a galvanic cell in hybrid structure **100**.

In the exemplary implementation, second component **110** has a smaller area than isolation sheet **108**, isolation sheet **108** has a smaller area than the applied sealant **106**, the applied sealant **106** has a smaller area than isolating layer **104**, and isolating layer **104** has a smaller area than first component **102**. Moreover, each component of hybrid structure **100** is substantially aligned to ensure second component **110** is physically and/or galvanically separated from first component **102**. As such, second component **110** is substantially prevented from being directly coupled to first component **102** and thus, formation of a galvanic cell within hybrid structure **100** is substantially prevented.

Figure **2** illustrates a series of assembly steps for forming hybrid structure **100**. As illustrated, first component **102** is provided and isolating layer **104** is coupled to first component **102**. For example, in the exemplary implementation, first component **102** is fabricated from CFRP, and isolating layer **104** is positioned on surface **116** of first component **102**. Sealant **106** is then applied directly to isolating layer **104** and thus indirectly to first component **102**. In an alternative implementation, hybrid structure **100** does not include isolating layer **104**, and sealant **106** may be applied directly to surface **116** of first component **102**.

Isolation sheet **108** is then applied to sealant **106** and pressure is applied to isolation sheet **108** to remove excess sealant **106** from between isolation sheet **108** and first component **102**. Pressure may be applied to isolation sheet **108** by any suitable method such as, but not limited to, a mechanical clamping method, and a vacuum bagging method. Applying

pressure to isolation sheet **108** also enables sealant **106** to fill microvoids (not shown) defined within surfaces of isolation sheet **108** and first component **102**, which substantially prevents the ingress of moisture between isolation sheet **108** and first component **102**. Pressure is applied to isolation sheet **108** while sealant **106** cures, which enables isolation sheet **108** to be coupled to first component **102**. In some implementations, first component **102**, isolating layer **104**, sealant **106**, and isolation sheet **108** may form a sub-assembly **120**, which may be installed in any suitable assembly (not shown) before second component **110** is coupled to isolation sheet **108**. An exemplary assembly includes, but is not limited to, an aircraft assembly, where sub-assembly **120** may be installed as part of a carbon fiber fuselage and second component **110** may be a wing portion of the aircraft assembly.

After isolation sheet **108** has been coupled to first component **102** with sealant **106**, second component **110** may be aligned with isolation sheet **108** in a predetermined position. In the exemplary implementation, second component **110** includes a plurality of holes **112** defined therein. When second component **110** is aligned with isolation sheet **108** in the predetermined position, holes **112** may be used to determine bore hole locations (not shown) in isolation sheet **108** based on the position of holes **112** defined in second component **110**. In an alternative implementations, the bore hole locations may be determined using a drill jig. Bore holes may then be defined in sub-assembly **120** at the determined bore hole locations using any suitable method such as, but not limited to, drilling.

In some implementations, second component **110** is substantially maintained in the predetermined position while bore holes are drilled in sub-assembly **120**. Fasteners **114** may then be inserted through holes **112** and the bore holes defined in sub-assembly **120** to couple second component **110** to isolation sheet **108**. In some implementations, fasteners **114** are installed using a wet installation. As used herein, the term “wet installation” refers to a process of applying a sealant either to fasteners **114** during installation and/or to each bore hole before inserting a fastener **114** therethrough. Wet installation substantially prevents the ingress of moisture between fasteners **114** and the components of sub-assembly **120** to substantially prevent galvanic corrosion from occurring within hybrid structure **100**.

Figure **3** is a flow diagram of an exemplary method **200** for use in forming a hybrid structure, such as structure **100**. In the exemplary implementation, a sealant is applied **202** to a first component, such as component **102**, and an isolation sheet, such as isolation sheet **108**,

is then coupled **204** to the sealant, such as sealant **106**. In some implementations, the sealant may be cured to facilitate bonding the isolation sheet to the first component. The second component, such as component **110**, is then coupled **206** to the isolation sheet. In the exemplary implementation, the first component is fabricated from a first material and the isolation sheet and
5 the second component are fabricated from a second material.

In some implementations, the second component is coupled **206** to the isolation sheet by aligning the second component in a predetermined orientation, and determining bore hole locations on the isolation sheet based on holes defined in the second component. Bore holes may then be formed through the isolation sheet, the sealant, and the first component at the desired
10 hole locations, and at least one fastener may be used to couple **206** the second component to the isolation sheet. For example, the at least one fastener may be inserted through the holes defined in the second component and the formed bore holes to couple **206** the second component to the isolation sheet.

Figure **4** is a flow diagram of an exemplary method **300** that may be implemented
15 to form an assembly, such as an aircraft assembly. In the exemplary implementation, a sub-assembly, such as sub-assembly **120**, is formed **302** and installed **304** in the assembly. After the sub-assembly is installed **304** in the assembly, the second component, such as component **110**, is then coupled **306** to the sub-assembly.

In some implementations, the sub-assembly is installed **304** as part of an aircraft
20 assembly. In the exemplary implementation, the sub-assembly includes a first component, such as component **102**, that is fabricated from a carbon fiber material, and the second component coupled **306** to the sub-assembly is fabricated from a metallic material. Moreover, in some implementations, the second component is coupled **306** to the sub-assembly by aligning the second component in a predetermined orientation, and determining bore hole locations in the sub-
25 assembly based on holes defined in the second component. Bore holes may then be formed through the sub-assembly at the desired hole locations, and at least one fastener may be used to couple **306** the second component to the sub-assembly. As described above, a sealant and an isolation sheet are pre-installed in the sub-assembly, and the second component does not need to be removed from alignment after the bore hole locations are determined. As such, coupling **306**
30 the second component to the sub-assembly may be simplified, which may be useful in processes that include fabricating structures of increasing sizes.

The hybrid structures and associated methods of forming described herein substantially prevent galvanic corrosion from occurring within the hybrid structure. More specifically, components of the hybrid structure are fabricated from materials having different electrode potentials. First and second components of the hybrid structure remain separated within the completed structure by the isolating layer, the sealant, and the isolation sheet. As such, even in the presence of an electrolyte such as moisture, the isolating layer, the sealant, and the isolation sheet substantially prevent a galvanic cell from being formed within the hybrid structure. Further, in some implementations, the first component, the isolating layer, the sealant, and the isolation sheet may be formed into a sub-assembly that is then installed in an assembly. The second component may then be coupled to the sub-assembly after installation of the sub-assembly. Post-installation coupling of the second component to the sub-assembly may facilitate reducing manufacturing times for assemblies that use the hybrid structure described herein. Moreover, difficulties associated with temperature distortion and fastener installation may be substantially prevented in applications that require installation of a large number of fasteners.

This written description uses examples to disclose various implementations, including the best mode, and also to enable any person skilled in the art to practice the various implementations, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for forming a hybrid structure, the method comprising:

5 applying a sealant to a first component fabricated from a first material;

 coupling an isolation sheet to the sealant, wherein the isolation sheet is fabricated from a second material that is different from the first material, wherein the first material has an electrode potential that is different than an electrode potential of the second material, and wherein the first material comprises a carbon fiber material and the

10 second material comprises a metallic material; and

 coupling a second component, fabricated from the second material, to the isolation sheet, wherein a surface area of the isolation sheet is less than a whole surface area of the first component, and the surface area of the isolation sheet is greater than a surface area covered by the second component.

15 **2.** The method in accordance with claim **1**, wherein the carbon fiber material comprises a carbon-fiber-reinforced polymer material.

3. The method in accordance with claim 1 wherein applying the sealant comprises:

 coupling an isolating layer to a surface of the first component before applying the sealant; and

20 applying the sealant directly to the isolating layer, wherein the applied sealant has a smaller area than the isolating layer.

4. The method in accordance with claim **1**, wherein coupling the isolation sheet to the sealant comprises bonding the isolation sheet to the first component with the sealant.

5. The method in accordance with claim **1**, wherein applying the sealant comprises:

covering the first component with the sealant; and

applying a pressure to the isolation sheet to cause microvoids between the isolation sheet and the first component to be substantially filled by the sealant, the sealant being operable to prevent ingress of moisture between the isolation sheet and the first component.

6. The method in accordance with claim 1, wherein applying the sealant comprises applying the sealant that has moisture resistance properties to restrict ingress of moisture between the first component and the isolation sheet.

7. The method in accordance with claim 1, wherein coupling the isolation sheet to the sealant comprises applying pressure to the isolation sheet to facilitate removing excess sealant from between the isolation sheet and the first component.

8. The method in accordance with claim 1 wherein coupling the second component to the isolation sheet comprises:

aligning the second component with the isolation sheet in a predetermined orientation;

determining bore hole locations on the isolation sheet with at least one of holes defined in the second component and a drill jig;

forming bore holes through the isolation sheet, the sealant, and the first component at the hole locations; and

using at least one fastener to couple the second component to the isolation sheet.

9. The method in accordance with claim 8, further comprising substantially maintaining alignment of the second component relative to the isolation sheet while the bore holes are formed.

10. The method in accordance with claim 8, wherein coupling the second component to the isolation sheet comprises aligning the second component with the isolation sheet such that the second component remains separated from the first component.

11. A method for use in forming an assembly, said method comprising:

forming a sub-assembly that includes a first component fabricated from a first material,
a sealant applied to and covering less than a whole surface area of the first component,
and an isolation sheet coupled to the sealant, wherein a surface area covered by the
sealant is greater than a surface area of the isolation sheet, wherein the isolation sheet
is fabricated from a second material that is different than the first material, wherein
the isolation sheet is exposed for receiving a second component, fabricated from the
second material, directly thereon when forming the assembly, wherein the first
material has an electrode potential that is different than an electrode potential of the
second material, and wherein the first material comprises a carbon fiber material and
the second material comprises a metallic material; and

installing the sub-assembly in the assembly.

12. The method in accordance with claim **11**, further comprising coupling the second component
to the isolation sheet.

13. The method in accordance with claim **12**, wherein coupling the second component to the
isolation sheet comprises:

aligning the second component with the isolation sheet in a predetermined orientation;

determining bore hole locations on the isolation sheet with at least one of holes defined
in the second component and a drill jig;

forming bore holes through the sub-assembly at the bore hole locations; and

using at least one fastener to couple the second component to the sub-assembly.

14. The method in accordance with claim **13**, wherein using the at least one fastener comprises
applying a second sealant to at least one of the bore holes and the at least one fastener before
using the at least one fastener.

15. The method in accordance with claim **11**, wherein the isolation sheet is coupled to the sealant

by applying a pressure to the isolation sheet to cause microvoids between the isolation sheet and the first component to be substantially filled by the sealant, the sealant being operable to prevent ingress of moisture between the isolation sheet and the first component.

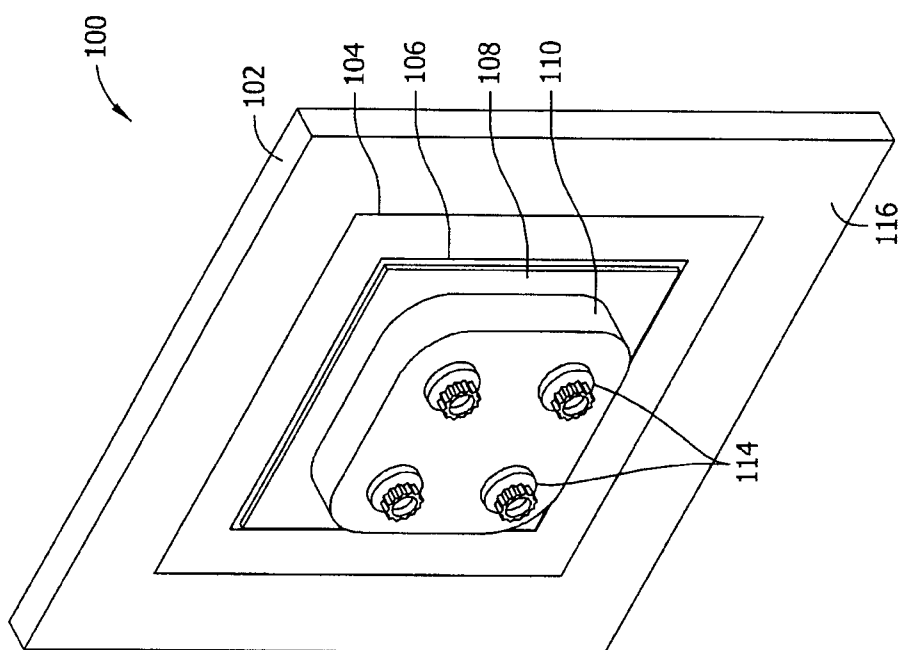


FIG. 1

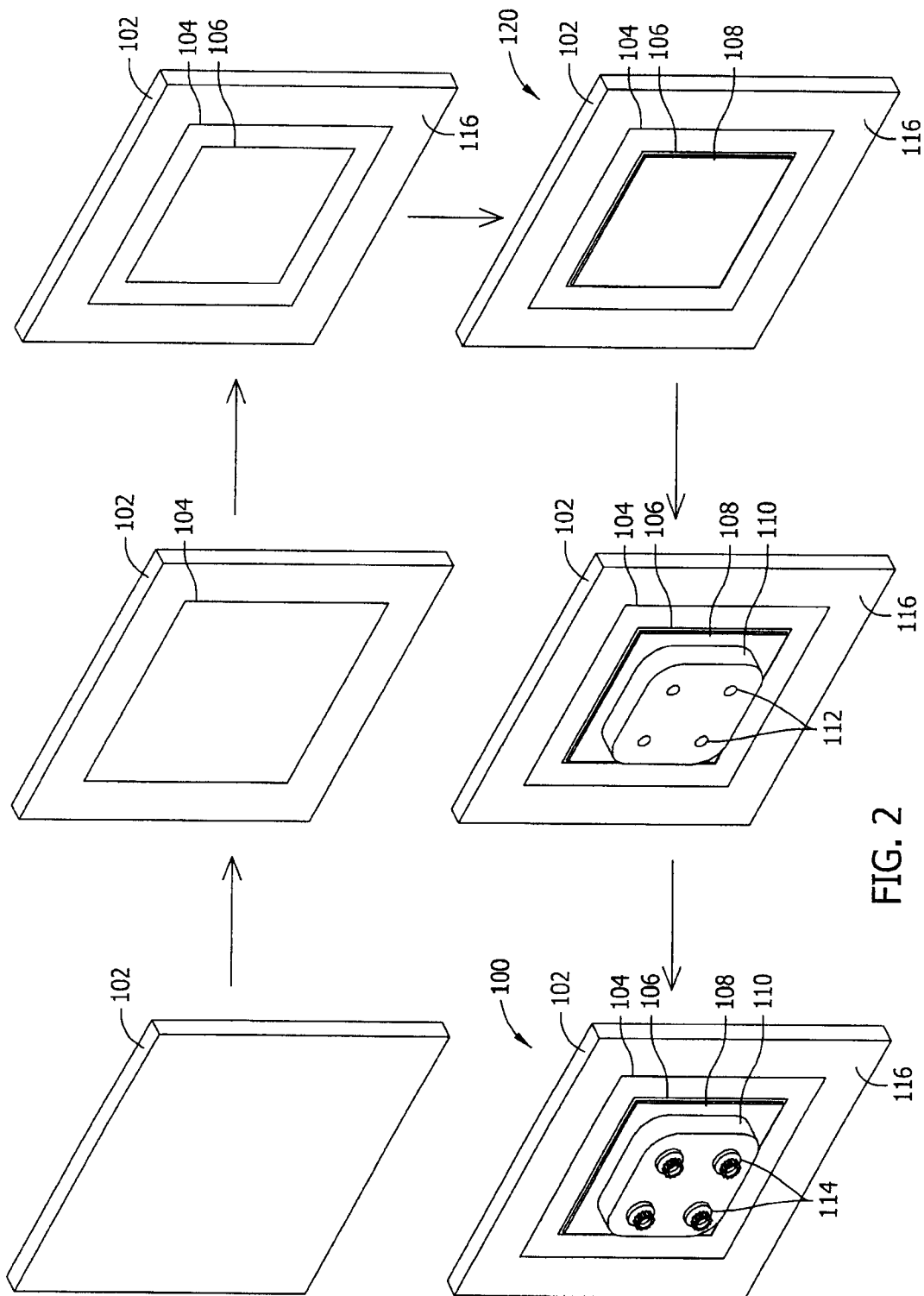


FIG. 2

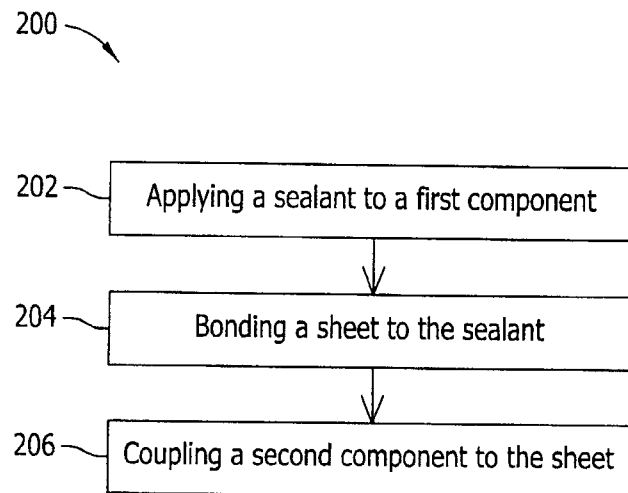


FIG. 3

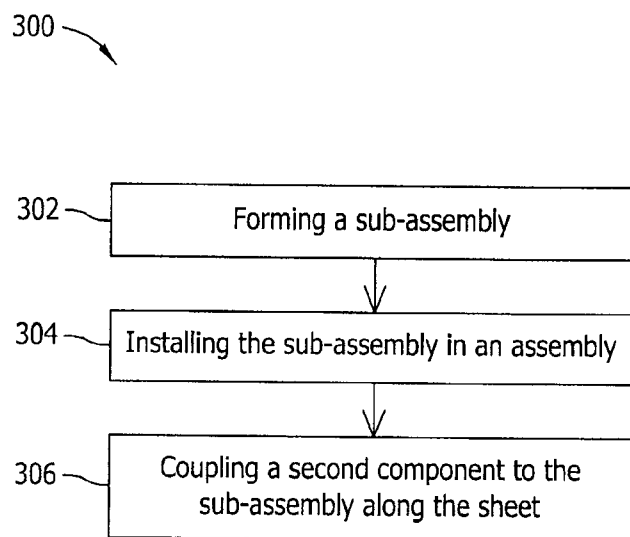


FIG. 4