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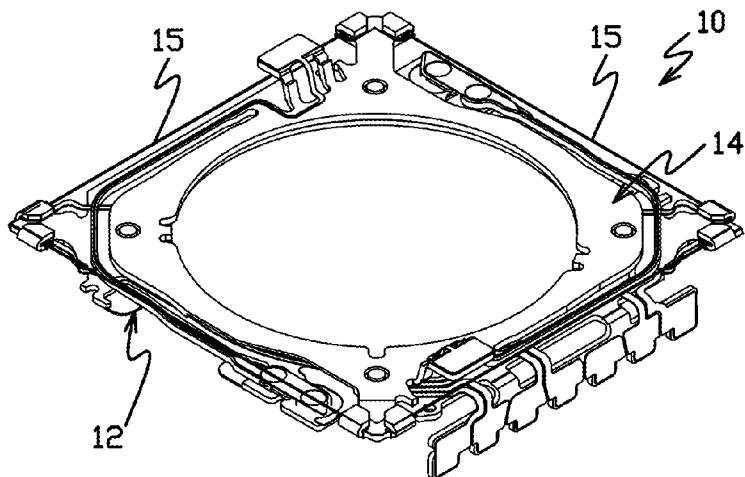


FIG. 1A

(57) Abstract: A suspension assembly for a camera lens element includes a support member with a wire attach structure and a moving member coupled to the support member. The moving member includes a plate, flexure arms extending from the plate and coupled to the support member, and a wire attach structure. A bearing supports the plate of the moving member for movement with respect to the support member. The bearing includes a spacer portion extending from one of the support member and the plate of the moving member, and a polymer interface surface portion slidably engaged with the other of the support member and the plate of the moving member. A smart memory alloy wire is coupled to and extends between the wire attach structures of the support member and the moving member.

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## CAMERA LENS SUSPENSION WITH POLYMER BEARINGS

### CROSS REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of the following U.S. Provisional Applications, both which are incorporated herein by reference in their entirety and for all purposes: No. 62/086,595, filed on December 2, 2014, entitled Improvements to Optical Image Stabilization (OIS) Camera Lens Suspension, and No. 62/129,562, filed on March 6, 2015, entitled Two-Piece Camera Lens Suspension with Integrated Electrical Leads.

### FIELD OF THE INVENTION

**[0002]** The invention relates generally to camera lens suspensions such as those incorporated into mobile phones. In particular, the invention relates to bearings between relatively movable components of such suspensions.

### BACKGROUND

**[0003]** PCT International Application Publication Nos. WO 2014/083318 and WO 2013/175197 disclose a camera lens optical image stabilization (OIS) suspension system that has a moving assembly (to which a camera lens element can be mounted) supported by a flexure element or spring plate on a stationary support assembly. The moving assembly is supported for movement on the support assembly by plural balls. The flexure element, which is formed from metal such as phosphor bronze, has a moving plate and flexures. The flexures extend between the moving plate and the stationary support assembly and function as springs to enable the movement of the moving assembly with respect to the stationary support assembly. The balls allow the moving assembly to move with little resistance. The moving assembly and support assembly are coupled by shape memory alloy (SMA) wires extending between the assemblies. Each of the SMA wires has one end attached to the support assembly, and an opposite end attached to the moving assembly. The suspension is actuated by applying electrical drive signals to the SMA wires. The above-identified PCT publications are incorporated herein by reference for all purposes.

**[0004]** There remains a continuing need for improved lens suspensions. Suspension structures of these types that are highly functional, robust and efficient to manufacture would be particularly desirable.

## SUMMARY

**[0005]** Embodiments of the invention include a suspension assembly with improved bearings. In embodiments, the suspension assembly comprises a support member including a wire attach structure, and a moving member coupled to the support member. The moving member includes a plate, flexure arms extending from the plate and coupled to the support member, and a wire attach structure. Low friction polymer material defining a sliding bearing interface is between the support member and the plate of the moving member. A smart memory alloy wire is coupled to and extends between the wire attach structures of the support member and the moving member. Embodiments include a plurality of the bearing interfaces, each of which can include a polymer surface portion having a perimeter.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** FIG. 1A is a top isometric view of a suspension including bearings in accordance with embodiments of the invention.

**[0007]** FIG. 1B is a top plan view of the suspension shown in FIG. 1A.

**[0008]** FIG. 2A is a top isometric view of the support member of the suspension shown in FIG. 1A.

**[0009]** FIG. 2B is a bottom plan view of the support member shown in FIG. 2A.

**[0010]** FIG. 3A is a detailed top isometric view of a mount region of the support member shown in FIG. 2A.

**[0011]** FIG. 3B is a detailed bottom isometric view of the mount region of the support member shown in FIG. 2A.

**[0012]** FIG. 4A is a top isometric view of the moving member of the suspension shown in FIG. 1A.

**[0013]** FIG. 4B is a bottom plan view of the moving member shown in FIG. 4A.

**[0014]** FIG. 5 is a detailed top isometric view of a flexure arm mount region and a wire attach of the moving member shown in FIG. 4A.

**[0015]** FIG. 6 is a detailed top isometric view of a flexure arm mounting region and a wire attach of the moving member shown in FIG. 4A.

**[0016]** FIG. 7 is a detailed top isometric view of a support member mount region and a flexure arm mount region of the suspension shown in FIG. 1A.

**[0017]** FIG. 8 is a detailed isometric view of one of the bearings shown in FIG. 2A.

**[0018]** FIG. 9 is a top isometric view of a suspension in accordance with embodiments of the invention.

**[0019]** FIG. 10 is an exploded isometric view of the suspension shown in FIG. 9.

[0020] FIG. 11 is a sectional view of the suspension shown in FIG. 9.

[0021] FIGs. 12-18 are annotated illustrations of suspensions that can include the bearings in accordance with embodiments of the invention.

[0022] FIGs. 19-20 describe features of bearings in accordance with embodiments of the invention.

[0023] FIGs. 21-25 are annotated illustrations of suspensions including bearings in accordance with embodiments of the invention.

[0024] FIG. 26A is a top isometric view of a suspension including a limiter in accordance with embodiments of the invention.

[0025] FIG. 26B is a top plan view of the suspension shown in FIG. 1A.

[0026] FIG. 27 is a top isometric view of the support member of the suspension shown in FIG. 26A.

[0027] FIG. 28A is a top isometric view of the moving member of the suspension shown in FIG. 26A.

[0028] FIG. 28B is a bottom plan view of the moving member shown in FIG. 28A.

[0029] FIG. 29 is a detailed isometric view of a portion of the suspension shown in FIG. 26A, illustrating embodiments of the limiter.

[0030] FIG. 30 is a detailed side view of a portion of the suspension shown in FIG. 26A, illustrating embodiments of the limiter.

## DESCRIPTION OF THE INVENTION

**[0031]** FIGs. 1A and 1B illustrate a suspension assembly 10 including bearings 100 and sliding bearing interfaces (shown in FIGs. 2A and 8) in accordance with embodiments of the invention. As shown, the suspension assembly 10 includes a flexible printed circuit (FPC) or support member 12 and a spring crimp circuit or moving member 14 that is coupled to the support member. Smart memory alloy (SMA) wires 15 extend between the support member 12 and the moving member 14, and can be electrically actuated to move and control the position of the moving member with respect to the support member. In embodiments, the suspension assembly 10 is a camera lens optical image stabilization (OIS) device that can be incorporated, for example, into mobile phones, tablets, laptop computers.

**[0032]** FIGs. 2A, 2B, 3A and 3B illustrate the support member 12 in greater detail. As shown, the support member 12 includes a base layer 16 and a plurality of conductive traces 18 such as traces 18a-18d in a conductor layer on the base layer. A layer of dielectric 20 is located between the conductive traces 18 and the base layer 16 to electrically insulate the traces from the base layer. A plurality of wire attach structures such as crimps 24 (i.e., static crimps; four are shown in the illustrated embodiment) are located on the base layer 16. In the illustrated embodiment the crimps 24 are organized as two pairs of adjacent structures that are integrally formed on a ledge 25 in the base layer 16 at a level spaced (e.g., in a z-direction) from a major planar surface portion 26 of the base layer. Other embodiments (not shown) include other wire attach structures (e.g., solder pads) and/or wire attach structures that are organized in other arrangements (e.g., singly rather than in pairs).

**[0033]** In embodiments, bearings 100, which are described in greater detail below, extend from the support member 12 (e.g., from portion 26 of base layer 16) and engage a bottom side of the moving member 14 (i.e., the side shown in Fig. 4B) to movably support the moving member with respect to the support member. The bearings 100 cooperate with the plate 60 of the moving member 14 to provide slidable polymer interfaces between the moving member and the support member 12. In other embodiments, the bearings are mounted to and extend from the moving member 14 to slidably engage the support member 12. Although three bearings 100 are shown in the illustrated embodiments, other embodiments have more or fewer bearings.

**[0034]** Traces 18 include terminals 30 and contact pads 32 in the conductor layer on the base layer 16. Each of the traces 18 couples a terminal 30 to a contact pad 32. For example, contact pads 32a and 32b are at a first mount region 33 of the support member 12, and traces 18a and 18b couple terminals 30a and 30b to pads 32a and 32b, respectively. Contact pads 32 at a second mount region 35 are similarly coupled to terminal 30 by traces 18. A contact pad 32 is located at each of the crimps 24 in the illustrated embodiment, and each of the contact pads is

coupled by a separate trace to a separate terminal 30 (e.g., trace 18d couples terminal 30d to pad 32d). The portion of the base layer 16 on which the terminals 30 are located is formed out of the plane of the major surface portion 26 (e.g., perpendicular to the plane of the major surface portion in the illustrated embodiment).

**[0035]** FIGs. 3A and 3B illustrate in greater detail embodiments of the mount region 33 of the support member 12. As shown, the mount region 33 includes first and second mounting pads 40 and 42. Mounting pad 42 includes an island or pad portion 44 in the base layer 16 that is electrically isolated from other portions of the base layer. The island pad portion 44 can be supported in part from adjacent portions of the base layer 16 by areas of dielectric 20 that extend between the island pad portion and adjacent portions of the base layer. Trace 18a and contact pad 32a extend to the island pad portion 44, and in embodiments are electrically connected to the island pad portion 44 by an electrical connection such as a plated or other via 46 that extends through the dielectric 20 at the mounting pad 42. Other embodiments include other electrical connections in place of or in addition to via 46, such as, for example, conductive adhesive that extends between the contact pad 32a and island pad portion 44 over the edges of the dielectric 20. Mounting pad 40 is adjacent to mounting pad 42, and includes a pad portion 48 in the base layer 16 (that in embodiments functions as an electrical ground or common structure), and an electrical connection such as via 50 that connects the contact pad 32b to the pad portion 48. The mount region 35 can be similar to mount region 33.

**[0036]** FIGs. 4A, 4B, 5, 6 and 7 illustrate embodiments of the moving member 14 in greater detail. As shown, the moving member 14 includes a plate 60 and spring or flexure arms 62 extending from the plate 60. In the illustrated embodiments, the plate 60 is a rectangular member, and each flexure arm 62 is an elongated member having first and second portions 64 and 66 that extend along two sides of the periphery of the plate. The plate 60 and flexure arms 62 are formed in a spring metal base layer 68 such as stainless steel. Moving member 14 also includes SMA wire attach structures such as crimps 70 (moving crimps; four are shown in the illustrated embodiment, organized in pairs). In the illustrated embodiment, the crimps 70 are unitary with and formed from the same spring metal base layer 68 as the plate 60 (i.e., on ends of arms 72 extending from the plate). Moving member 14 is configured differently in other embodiments. For example, in other embodiments (not shown) the flexure arms 62 can be shaped differently, be different in number, organized differently, and/or can extend from other locations on the plate 60. In still other embodiments (not shown), the crimps 70 can be formed as separate structures that are attached to the plate 60 (i.e., not unitary with the plate). Other embodiments (not shown) include other types of wire attach structures (e.g., solder pads) and/or wire attach structures that are organized in other arrangements (e.g., singly rather than in pairs).

**[0037]** The end portions of the flexure arms 62 have mount regions 74 that are configured to be mounted to the mount regions 33 and 35 of the support member 12. Conductive traces 76 on the base layer 68 extend on the flexure arms 62 from the mount regions 74. In embodiments, the traces 76 also extend on the base layer 68 over portions of the plate 60. In the illustrated embodiment, the traces 76 also extend to contact pads 77 on the arms 72 on the plate 60. In the illustrated embodiment, the contact pads 77 are on platforms extending out of the major planar surface of the plate 60. The contact pads are at other locations (e.g., on the plate 60) in other embodiments (not shown). A layer of dielectric 78 is located between the conductive traces 76 and the base layer 68 to electrically insulate the traces from the base layer. Mount regions 74 include first and second mounting pads 80 and 82. Each mounting pad 82 includes an island or pad portion 84 in the base layer 68 that is electrically isolated from other portions of the base layer. Each trace 76 extends from the mounting pad 82, over (and electrically insulated from) the mounting pad 80. In the illustrated embodiment, the portions of traces 76 extending between the mounting pads 80 and 82 are enlarged over the portions of the traces on the flexure arms 62 to provide support for the island pad portions 84 in the base layer 68. The traces 76 extend to the island pad portions 84, and in embodiments are electrically connected to the island pad portions by electrical connections such as a plated or other via 86 that extends through the dielectric 78 at the mounting pad 82. Other embodiments include other electrical connections in place of or in addition to vias 86, such as conductive adhesive that extends between the trace 76 and island pad portion 84 over the edges of the dielectric 78. Mounting pad 80 includes a pad portion 90 in the base layer 68 that is electrically isolated from the trace 76 by the dielectric 78. In the illustrated embodiments, the portions of the traces 76 over the mounting pads 80 and 82 are circular and open in the center, but take other forms in other embodiments (not shown).

**[0038]** As perhaps best shown in FIGs. 1A and 7, the mount regions 74 of the moving member flexure arms 62 are mechanically attached to the mount regions 33 and 35 of the support member 12. The traces 76 on the flexure arms 62 are electrically connected to the associated traces 18 on the support member 12. In embodiments, the mechanical connections are made by welds between the pad portions 84 and 90 in the base layer 68 of the moving member 14 and the corresponding pad portions 44 and 48 in the base layer 16 of the support member 12. The welds can, for example, be made through the openings in the traces 76 at the pad portions 84 and 90. The welds also enable electrical connections between the pad portions 84 and 90 of the moving member 14 and the corresponding pad portions 44 and 48 of the support member 12. By these electrical connections, the metal base layer 68 of the moving member 14, and thereby the moving crimps 70, are electrically connected in common to an associated trace 18 (i.e., such as

18b through via 50). Similarly, each flexure arm trace 76 is electrically connected to an associated trace 18 (i.e., such as 18a through via 46). Other embodiments of the invention (not shown) have other structures for mechanically mounting the flexure arms 62 to the support member 12, and/or for electrically connecting the traces 76 on the flexure arms to the associated traces 18 on the support member. In the illustrated embodiment, conductive metal regions 94 are located directly on the metal base layer 68 of the moving member 14 at the crimps 70 (i.e., there is no dielectric or other insulating material between the conductive metal regions and the metal base layer) to enhance the electrical connections between the metal base layer and the SMA wires 15 engaged by the crimps.

**[0039]** As described in greater detail below, the support member 12 and moving member 14 can be formed from additive and/or subtractive processes. Base layers 16 and/or 68 are stainless steel in embodiments. In other embodiments the base layers 16 and/or 68 are other metals or materials such as phosphor-bronze. Traces 18 and 76, terminals 30 and contact pads 32 can be formed from copper, copper alloys or other conductors. Polyimide or other insulating materials can be used as the dielectric 20 and 78. Other embodiments of the support member 12 and/or moving member 14 (not shown) have more or fewer traces 18 and 76, and the traces can be arranged in different layouts. Structures other than crimps 24, such as welds, can be used to attach the SMA wires 15 to the base layer 16. Other embodiments of the invention (not shown) have more or fewer crimps 24 and 70, and the crimps can be at different locations on the support member 12 and moving member 14, respectively.

**[0040]** FIG. 8 is a detailed illustration of a portion of the support member 12 including a bearing 100. As shown, the bearing 100 includes a spacer portion 102 and a polymer surface region or portion 104. The spacer portion 102 extends from the base layer 16 of the support member 12 to position the surface portion 104 at a height with respect to the support member 12 that will allow the portion of the moving member 14 engaged by the surface portion (e.g. plate 60) to slide on the bearing 100 (e.g., a height of 25-200  $\mu\text{m}$  in embodiments). The spacer portion 102 and the polymer surface portion 104 can be a one-piece polymer member in embodiments. Properties of the polymer surface portion 104 (and optionally the spacer portion 102) can include relatively low friction, relatively low wear and/or relatively high stiffness. In one embodiment, spacer portion 102 and polymer surface portion 104 are formed from materials such as POM (polyoxymethylene). Surface portion 104 is formed from other polymers such as fluoropolymers (e.g., Teflon) in other embodiments. Bearing 100 can be fixedly attached to the support member 12 by adhesive 106 (e.g., thermoset adhesive, 5-25  $\mu\text{m}$  thick in embodiments). In other embodiments, the bearing 100 is attached to support member 12 by other methods or structures such as by welding. In the illustrated embodiment the bearing 100 is attached to the

support member 12 in a partial-etched pocket 108 in the base layer 16. In yet other embodiments the bearing 100 is attached to a surface portion of the base layer 16 that is free from a pocket such as 108.

**[0041]** In still other embodiments, the spacer portion 102 can be formed from other materials such as metal, and the surface portion 104 can be a layer or coating of polymer on the metal spacer portion. For example, in embodiments the spacer portion 102 can be a formed dimple in the metal base layer 16. In other embodiments the spacer portion 102 is a separate metal or polymer member that is attached, for example by adhesive or welding, to the support member 12. In still other embodiments, the bearings 100 can extend from the moving member 14 (e.g., from the base layer 68), and slidably engage the support member 12 (e.g., at the base layer 16). Surface portion 104, which has a perimeter, can be generally flat as shown in the embodiment of FIG. 8. In other embodiments the surface portion 104 has other shapes such as a convex shape. The surfaces engaged by the bearing can be metal, and can be processed by laser polishing, electro polishing or other methods to provide a low surface roughness and further reduce friction at the sliding bearing interface. Yet other embodiments include lubricant such as Xylan at the sliding bearing interface.

**[0042]** Bearings such as 100 provide important advantages. For example, in addition to providing a high-quality, reliable, low friction sliding bearing interface, they can be manufactured and assembled relatively efficiently, and enable relatively close spacing between the support member 12 and moving member 14 (i.e., relatively thin suspensions).

**[0043]** FIGs. 9-11 illustrate a suspension assembly 110 having bearings 200 in accordance with embodiments of the invention. As shown, suspension assembly 110 includes a can base 111, flexible printed circuit (FPC) or support member 112, bearing race 113, moving member 114 and moving crimp 115. Features of suspension assembly 110 can be similar to those of suspension assembly 10 described above. Support member 112 includes a plurality of wire attach structures such as static crimps 124. Bearing race 113 can be a polymer member and has polymer bearing plate surface portions 203. The bearing race 113 is fixedly attached to can base 111 and/or support member 112 (e.g., by adhesive or welds). Properties of the polymer surface portions 203 (and optionally other portions of the bearing race 113) can include relatively low friction, relatively low viscosity, relatively low wear and/or relatively high stiffness. In one embodiment, bearing race 113 and polymer surface portions 203 are formed from materials such as POM (polyoxymethylene). Bearing race 113 and/or surface portions 203 are formed from other polymers such as fluoropolymers (e.g., Teflon) in other embodiments. As shown in FIG. 11, a screening can 117 can be attached to the can base 111 and enclose portions of the suspension assembly 110.

**[0044]** Moving member 114 includes a plate 160 and spring or flexure arms 162 extending from the plate. Plate 160 and flexure arms 162 are formed from a spring metal layer such as stainless steel. End portions of the flexure arms 162 have mount regions 174 configured to be mounted to mount regions 133 of the support member 112. Moving crimp 115 includes wire attach structures such as crimps 170, and is attached (e.g., by welding) to the plate 160 of moving member 114 to become part of the moving member. Although not shown in FIGs. 9-11, SMA wires are attached to and extend between associated crimps 124 on the support member 112 and crimps 170 on the moving crimp 115.

**[0045]** Bearings 200 include a spacer portion 202 and have a surface region or portion 204. The spacer portion 202 extends from the plate 160 of the moving member 114, and the surface portion 204 engages a polymer surface portion 203 on the bearing race 113 to define a sliding bearing interface that will allow the moving member 114 to slide with respect to the bearing race and the support member 112. Properties of the spacer portion 202 and surface portion 204 can include relatively low friction, relatively low viscosity, relatively low wear and/or relatively high stiffness. In the illustrated embodiment, the spacer portion 202 is a formed dimple in the plate 160. In other embodiments the spacer portion 202 is a separately manufactured member (e.g., from metal, polymer or ceramic) that is attached to the plate 160 (e.g., by adhesive or welding). In embodiments, for example, the spacer portion 202 and surface portion 204 are formed from polyoxymethylene. In embodiments, the surface portion 204 can be a coating on the spacer portion 202. Examples of materials that can be used as coatings for surface portion 204 include ceramic, and polymers such as polyoxymethylene and fluoropolymers (e.g. Teflon). Although three bearings 200 are shown in FIG. 10, other embodiments have fewer or more bearings. Surface portions 203 and/or 204 can be processed, for example by laser polishing or coining, to enhance the smoothness of the surfaces. Bearings 200 offer advantages similar to those of bearings 100 described above.

**[0046]** FIGs. 12-18 are annotated illustrations of an improved camera lens suspension assembly in accordance with embodiments of the invention. The suspension assembly has two primary components – a base or support member (referred to in FIGs. 12-18 as a static FPC (flexible printed circuit)), and a moving/spring member (referred to in the FIGs. 12-18 as a spring crimp circuit). Both the static FPC (base member) and the spring crimp circuit (moving member) are integrated lead structures in the illustrated embodiments, in that they have electrical structures such as leads, contact pads and terminals (e.g. in a copper “Cu” or copper alloy layer) formed on the base metal (stainless steel (SST) in the illustrated embodiments). A layer of insulator (e.g., polyimide or “poly”) separates the portions of the electrical structures that are to be electrically isolated from the SST (other portions of the Cu layer are connected to or directly

on the SST layer). At some locations, the electrical structures can be electrically connected to the SST layer by electrical connections (e.g., “vias”) extending from the Cu trace or lead layer to the SST layer through openings in the poly layer. In embodiments, a lens can be mounted to the spring crimp circuit. In yet other embodiments, an autofocus system supporting the lens can be mounted to the spring crimp circuit.

**[0047]** As noted above, the static FPC and spring crimp circuit can be formed from overlaying layers of base metal (e.g., a spring metal such as SST), poly and Cu (i.e., the “trace” layer). An insulating covercoat can be applied over all or portions of the Cu. Corrosion resistant metals such as gold (Au) and/or nickel (Ni) can be plated or otherwise applied to portions of the trace layer to provide corrosion resistance. Conventional additive deposition and/or subtractive processes such as wet (e.g., chemical) and dry (e.g., plasma) etching, electro plating and electroless plating and sputtering processes in connection with photolithography (e.g., use of patterned and/or unpatterned photoresist masks), as well as mechanical forming methods (e.g., using punches and forms) can be used to manufacture the static FPC and spring crimp circuit in accordance with embodiments of the invention. Additive and subtractive processes of these types are, for example, known and used in connection with the manufacture of disk drive head suspensions, and are disclosed generally in the following U.S. patents, all of which are incorporated herein by reference for all purposes: Bennin et al. U.S. patent 8,885,299 entitled Low Resistance Ground Joints for Dual Stage Actuation Disk Drive Suspensions, Rice et al. U.S. patent 8,169,746 entitled Integrated Lead Suspension with Multiple Trace Configurations, Hentges et al. U.S. patent 8,144,430 entitled Multi-Layer Ground Plane Structures for Integrated Lead Suspensions, Hentges et al. U.S. patent 7,929,252 entitled Multi-Layer Ground Plane Structures for Integrated Lead Suspensions, Swanson et al. U.S. patent 7,388,733 entitled Method for Making Noble Metal Conductive Leads for Suspension Assemblies, Peltoma et al. U.S. patent 7,384,531 entitled Plated Ground Features for Integrated Lead Suspensions.

**[0048]** The static FPC is a one-piece member in the illustrated embodiment, and has two static crimps (attachment structures) on each of two diagonal corners of the member (4 static crimps in total). A terminal pad section includes terminal pads in the trace layer that are connected to traces that extend over the surface of the member. As shown for example, a separate trace extends to each of the four static crimps. At each of the static crimps is an electrical contact or terminal formed by the trace and poly layers. Formed dimples extending from the upper surface of the static FPC member engage the back surface of the spring crimp circuit member, and function as sliding interface bearings to enable low friction movement of the spring crimp circuit member with respect to the static FPC. The traces on the static FPC also couple terminal pads to electrical pad locations on the static FPC that are electrically and

mechanically coupled to the spring crimp circuit member (e.g., to provide electrical signals to an auto focus (AF) assembly and to provide a common or ground signal path to the SST layer of the spring crimp circuit member. Vias couple the respective traces on the static FPC to portions of the SST layer that are connected to the feet.

**[0049]** The spring crimp circuit is a one-piece member in the illustrated embodiments and includes a central member for supporting a lens or auto focus system, and one or more spring arms (two in the illustrated embodiment) extending from the central member. The spring crimp member has two moving crimps on each of two diagonal corners of the member (4 moving crimps in all). Pedestals or feet in the SST layer (on the ends of the spring arms opposite the central member in the illustrated embodiment) are configured to be welded or otherwise attached to corresponding locations on the static FPC. Traces on the spring crimp member are configured to be electrically coupled to traces on the static FPC (e.g., through the feet) and couple signals to terminal pads such as the auto focus (AF) terminal pads. In the illustrated embodiment, the SST layer of the spring crimp circuit is used as a signal path to the ends of the SMA wires attached to the moving crimps. Electrical connection between the corresponding terminal pad and trace on the static FPC to the SST layer of the spring crimp circuit is provided by the connection between the feet of the spring arms and the SST layer of the static FPC (i.e., the SST layers of the two members are electrically coupled, and are at a common ground potential in embodiments).

**[0050]** Suspensions in accordance with the invention having traces on the moving member flexure arms offer important advantages. They can for example, be efficiently fabricated and assembled. The traces are effective structures for coupling electrical signals to structures mounted to the plate or other portions of the moving member.

**[0051]** FIGs. 26A, 26B, 27, 28A, 28B and 29-30 illustrate a suspension assembly 10' that includes a crash stop or limiter 200 in accordance with embodiments of the invention. Other than the limiter 200, features of suspension 10' can be similar to or the same as other embodiments of the invention, including suspension 10 described above. Limiter 200 can also be incorporated in any or all other described embodiments of the invention.

**[0052]** As shown, the limiter 200 includes an engaged structure such as opening 202 on or in the plate 60' of the moving member 14', and a stop 204 on the support member 12' (e.g., on a planar portion of the support member). An engagement portion 206 of the stop 204 is fixedly positioned with respect to the support member 12' and extends into the opening 202. A first diameter of the opening 202 is greater than a second diameter of the engagement portion 206, allowing a limited range of motion of the moving member 14' with respect to the support member 12' (e.g., in directions generally parallel to the major planar surfaces of the moving

member and support member). Features of limiter 200 such as the shapes, sizes and locations of the opening 202 and stop 204 are configured to prevent displacement of the moving member 14' with respect to the support member 12' that might cause damage to the suspension 10' components or other components, such as a lens, mounted to the suspension. The engagement portion 206 can move within a predetermined range of movement, but engages the engaged structure such as the wall portions of the plate 60' defining the opening 202 to limit the range of relative movement.

**[0053]** In embodiments, the engagement portion 206 is on a spacer portion 208. The spacer portion 208, which can be integral with and/or formed from the same material as the engagement portion 206, is larger than the engagement portion in embodiments, and provides a base for the engagement portion to extend or otherwise position the engagement portion away from the major planar surface of the support member 12'. The engagement portion 206 is on an end of the spacer portion 208 opposite the major planar surface of the support member 12'. In embodiments, the stop 204 can be a separately manufactured polymer member that is attached to the support member 12' (e.g., by adhesive). In other embodiments the stop 204 can be a metal member formed from one or more layers of the support member 12' (e.g., from the base layer 16'), or a separately manufactured member that is attached to the support member during assembly (e.g., by welding). In still other embodiments the stop 204 can be integral with other suspension components such as the bearing such as that shown at 100. Although two limiters 200 are shown in the illustrated embodiment, other embodiments have more or fewer limiters. Opening 202 can be a through hole as shown in the illustrated embodiment, or a recess or pocket (e.g., formed by partial etching). In still other embodiments the opening 202 can be on the support member 12' and the stop 204 can be on the moving member 14'. Limiters such as 200 provide important advantages. For example, they can prevent damage to the suspension or components mounted thereto (e.g., when the device in which it is incorporated is dropped). Suspensions including the limiters can also be efficiently manufactured.

**[0054]** In embodiments, the suspension assembly comprises: (1) a support member including a wire attach structure; (2) a moving member coupled to the support member, including: (i) a plate; (ii) flexure arms extending from the plate and coupled to the support member; and (iii) a wire attach structure; (3) a bearing supporting the plate of the moving member for movement with respect to the support member; (4) a smart memory alloy wire coupled to and extending between the wire attach structures of the support member and the moving member; and (5) a limiter to limit a range of movement of the moving member with respect to the support member, the limiter including: (i) an opening in one of the moving member plate and the support member, wherein the opening has a first diameter; and (ii) a stop on the other of the moving member plate

and the support member, the stop including an engagement portion extending into the opening, wherein the engagement portion has a second diameter that is less than the first diameter. In embodiments, the stop further includes a spacer portion, and wherein the engagement portion is on an end of the spacer portion. In embodiments, the spacer portion is formed from the support member. In embodiments, the spacer portion is formed as a member separate from the support member, and is mounted to the support member. In embodiments, the opening is a through hole in the plate of the moving member.

**[0055]** Although the invention has been described with reference to preferred embodiments, those of skill in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the invention. For example, although the illustrated embodiments include the traces on the sides of the flexure arms opposite the support member (i.e., on the top side of the traces), other embodiments can alternatively or in addition include traces on the sides of the flexure arms facing the moving member (i.e., on the bottom side of the traces). Although described in connection with certain suspension assembly embodiments, bearings 200 and 100 can be incorporated in other suspension assembly embodiments. Bearings in accordance with embodiments of the invention can be used in combination, and/or in connection with or as an alternative to ball bearings to provide for relative movement between suspension components. Features of bearings 100 and 200 can be combined with each other.

## CLAIMS

What is claimed is:

1. A suspension assembly, comprising:
  - a support member including a wire attach structure;
  - a moving member coupled to the support member, including:
    - a plate;
    - flexure arms extending from the plate and coupled to the support member; and
    - a wire attach structure;
  - a bearing supporting the plate of the moving member for movement with respect to the support member, the bearing including:
    - a spacer portion extending from one of the support member and the plate of the moving member; and
    - a polymer interface surface portion slidably engaged with the other of the support member and the plate of the moving member; and
  - a smart memory alloy wire coupled to and extending between the wire attach structures of the support member and the moving member.
2. The suspension assembly of claim 1, further comprising a plurality of the bearings.
3. The suspension assembly of claim 2, wherein the polymer interface surface portions of the bearings include one of polyoxymethylene and fluoropolymers such as Teflon and Xylan
4. The suspension assembly of claim 3 wherein the spacer portions of the bearings comprise metal.
5. The suspension assembly of claim 4 wherein:
  - the plate of the moving member comprises metal; and
  - the spacer portions of the bearings include formed dimples in the metal of the moving member plate.
6. The suspension assembly of claim 2 wherein:
  - the support member comprises a metal base layer; and

the spacer portions are attached to and extend from the metal base layer of the support member.

7. The suspension assembly of claim 6 wherein the spacer portions of the bearings comprise polymer, optionally polyoxymethylene.

8. The suspension assembly of claim 7 and further including layers of adhesive joining the polymer spacer portions to the metal base layer of the support member.

9. The suspension assembly of claim 8 wherein:  
the metal base layer of the support member further includes partial etched pockets; and  
the bearings are attached to and extend from the metal base layer in the partial etched pockets of the support member.

10. The suspension assembly of claim 8, wherein the polymer interface surface portions of the bearing include polyoxymethylene.

11. The suspension assembly of claim 7, wherein the polymer interface surface portions of the bearing include polyoxymethylene.

12. The suspension assembly of claim 6 wherein the spacer portions of the bearings comprise the same polymer as the polymer interface portions.

13. The suspension assembly of claim 1 wherein the polymer interface surface portion of the bearing includes one of polyoxymethylene and a fluoropolymer such as Teflon and Xylan

14. The suspension assembly of claim 13 wherein the spacer portion of the bearing comprises metal.

15. The suspension assembly of claim 14 wherein:  
the plate of the moving member comprises metal; and  
the spacer portion of the bearing includes a formed dimple in the metal of the moving member plate.

16. The suspension assembly of claim 1 wherein:  
the support member comprises a metal base layer; and  
the spacer portion of the bearing is attached to and extends from the metal base layer of  
the support member.

17. The suspension assembly of claim 16 wherein the spacer portion of the bearing  
comprises polymer, optionally polyoxymethylene.

18. The suspension assembly of claim 17 and further including a layer of adhesive  
joining the polymer spacer portion to the metal base layer of the support member.

19. The suspension assembly of claim 18 wherein:  
the metal base layer of the support member further includes a partial etched pocket; and  
the bearing is attached to and extends from the metal base layer in the partial etched  
pocket of the support member.

20. The suspension assembly of claim 19, wherein the polymer interface surface  
portion of the bearing includes polyoxymethylene.

21. The suspension assembly of claim 17, wherein the polymer interface surface  
portions of the bearing include polyoxymethylene.

22. The suspension assembly of claim 16 wherein the spacer portion of the bearing  
comprises the same polymer as the polymer interface portions.

23. The suspension assembly of claim 16 and further including a layer of adhesive  
joining the polymer spacer portion to the metal base layer of the support member.

24. A suspension assembly, comprising:  
a support member including a wire attach structure;  
a moving member coupled to the support member, including:  
a plate;  
flexure arms extending from the plate and coupled to the support member; and  
a wire attach structure;

low friction polymer material defining a sliding bearing interface between the support member and the plate of the moving member; and  
a smart memory alloy wire coupled to and extending between the wire attach structures of the support member and the moving member.

25. The suspension assembly of claim 24 wherein the sliding bearing interface comprises a plurality of spaced-apart low friction polymer regions, wherein each low friction polymer region has a perimeter.

26. The suspension assembly of claim 25 wherein the low friction polymer regions are fixedly mounted to the moving member plate.

27. The suspension assembly of claim 26 and further including spacer portions attached to and extending from the moving member plate, and wherein the low friction polymer regions are on the spacer portions.

28. The suspension assembly of claim 25 wherein the low friction polymer regions are polymer cylinders mounted to the support member, optionally by adhesive.

29. The suspension assembly of claim 24 wherein the sliding bearing interface includes a spacer portion extending from the support member, and wherein the spacer portion optionally includes a formed dimple in the support member.

30. A suspension assembly, comprising:

a support member including a wire attach structure;

a moving member coupled to the support member, including:

a plate;

flexure arms extending from the plate and coupled to the support member; and  
a wire attach structure;

a bearing supporting the plate of the moving member for movement with respect to the support member, the bearing including:

a spacer portion extending from the support member; and

a polymer interface surface portion slidably engaged with the plate of the moving member; and

a smart memory alloy wire coupled to and extending between the wire attach structures of the support member and the moving member.

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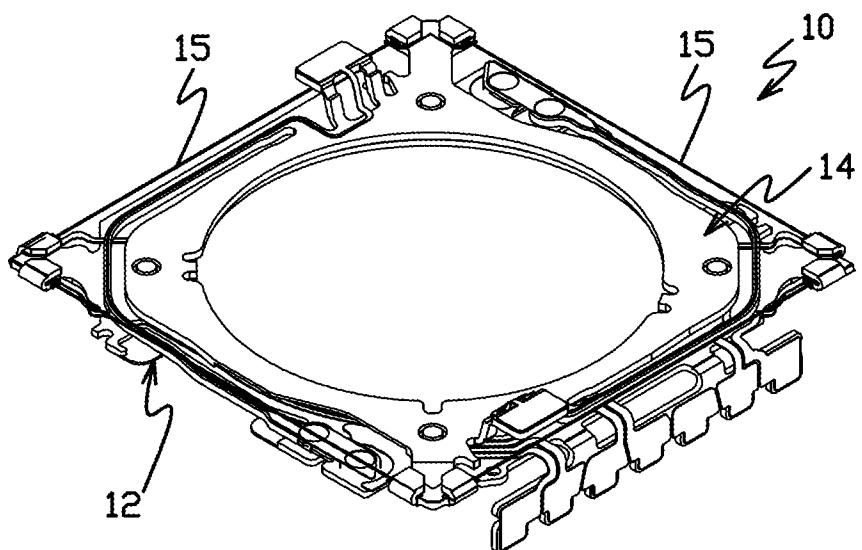


FIG. 1A

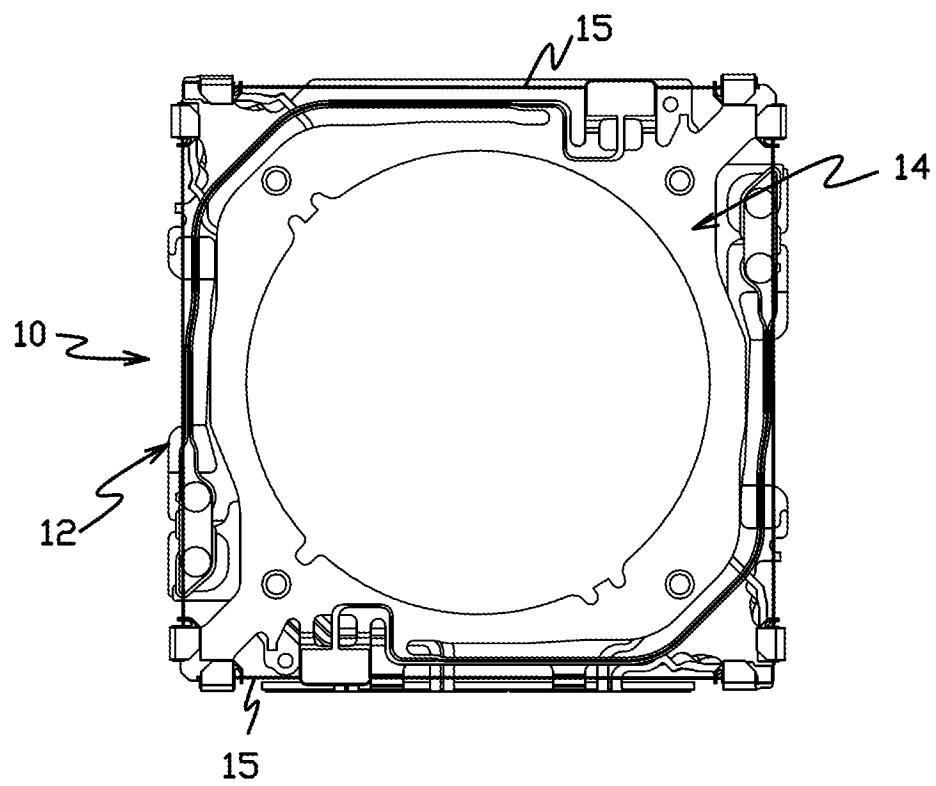
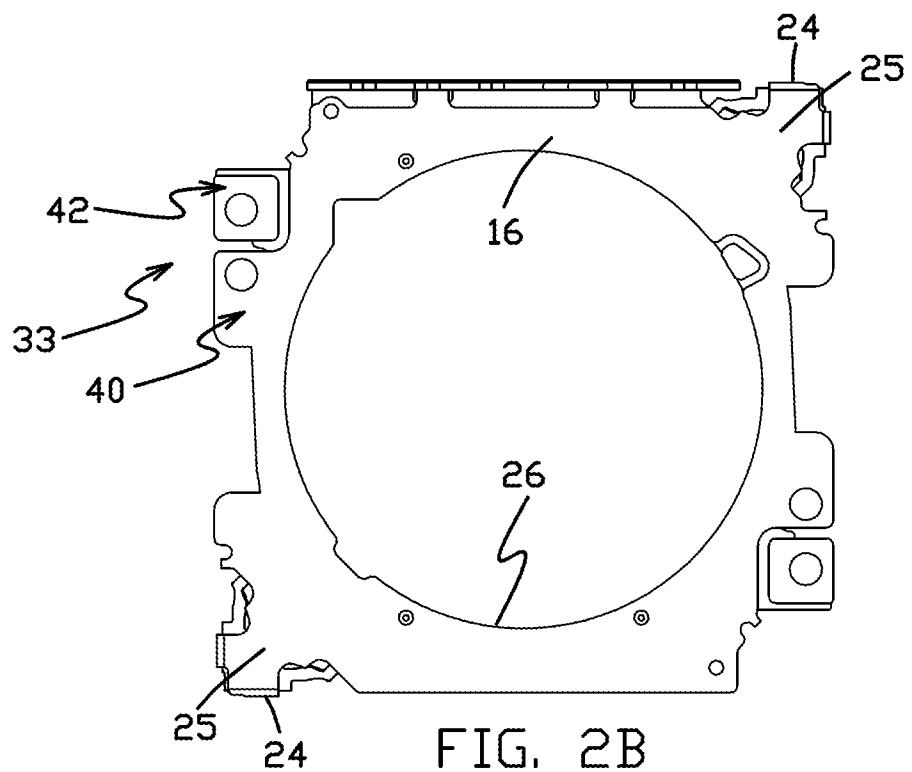
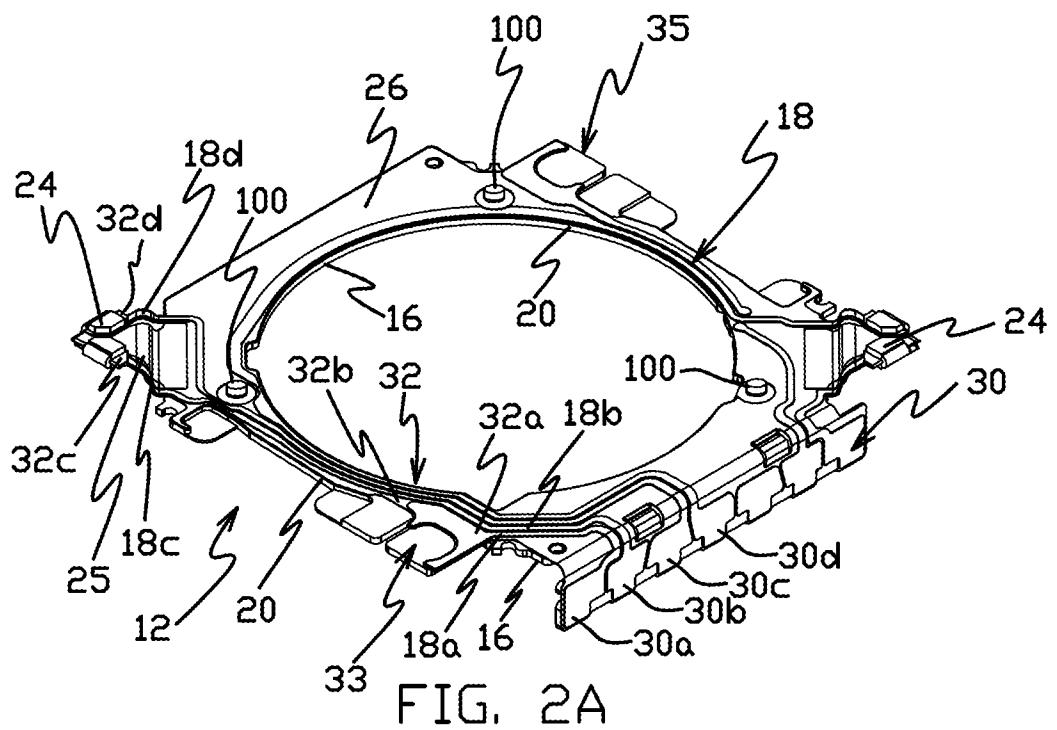
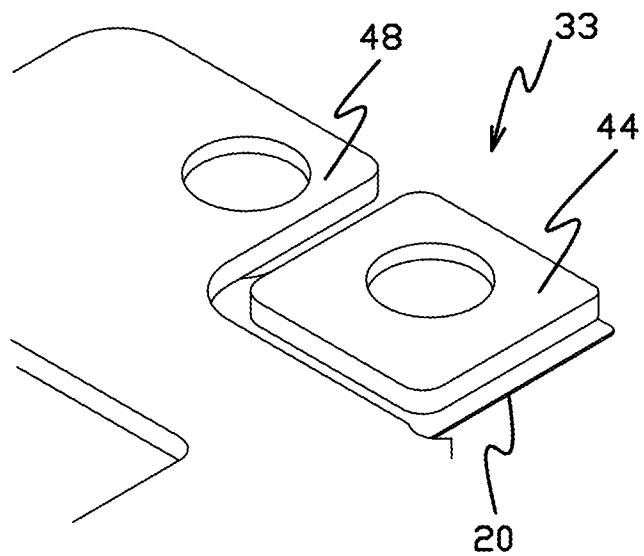
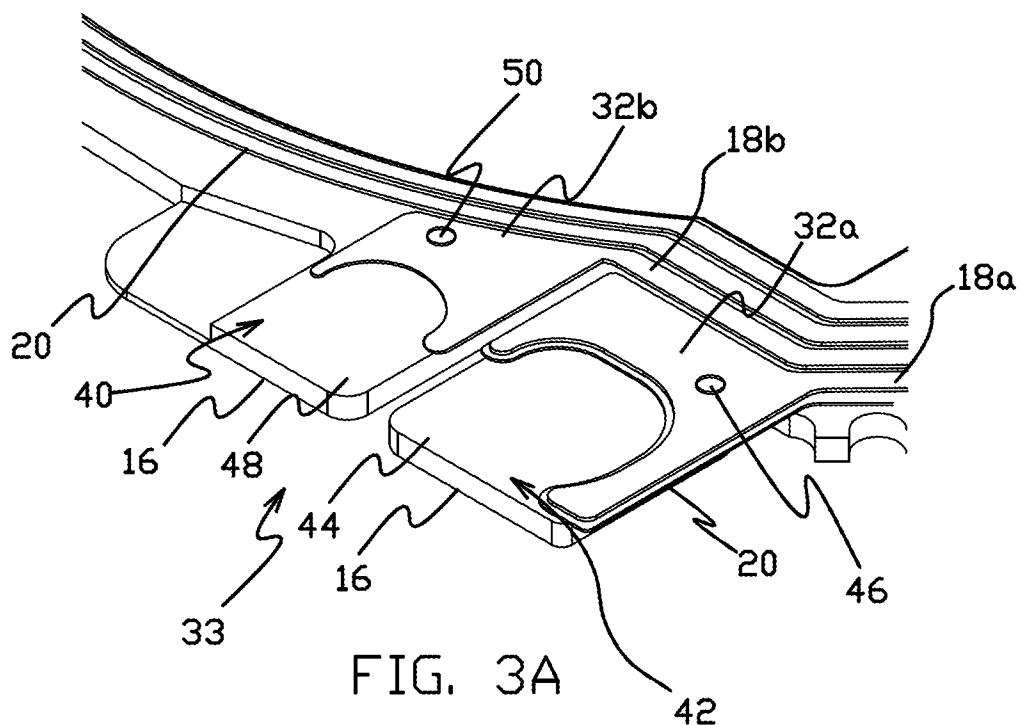


FIG. 1B

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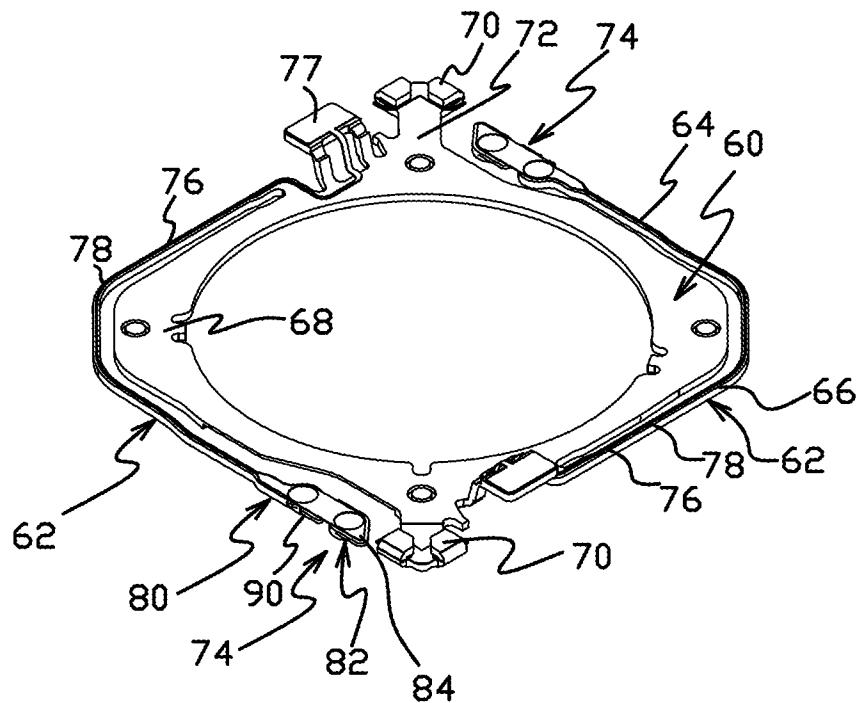


FIG. 4A

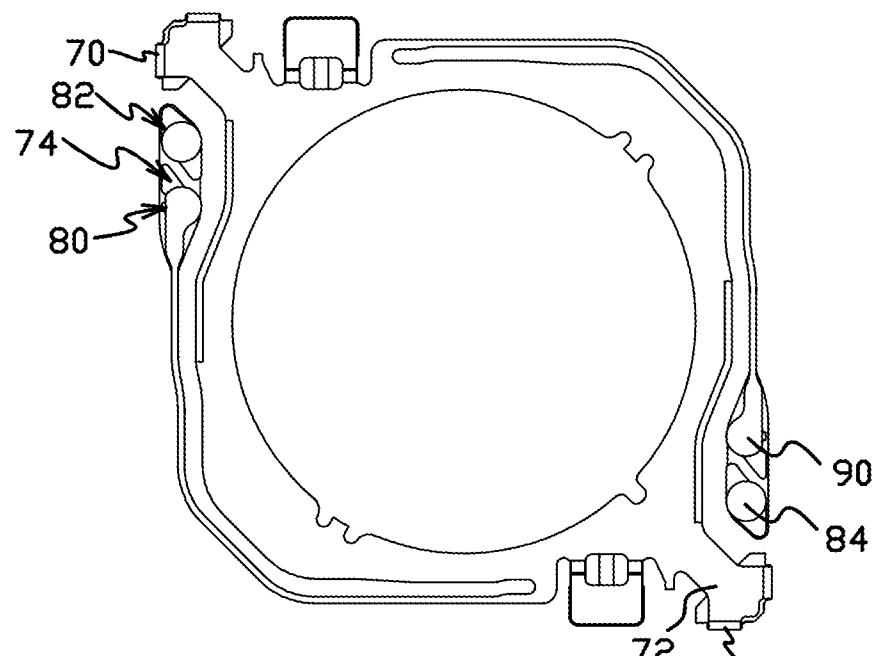


FIG. 4B

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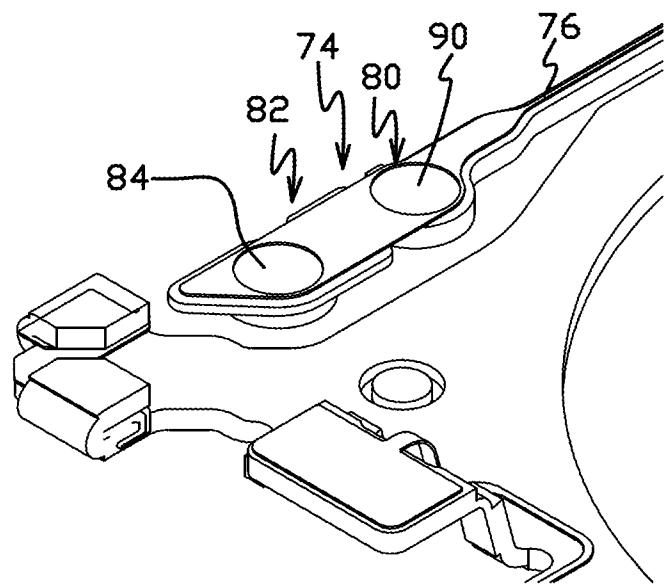


FIG. 5

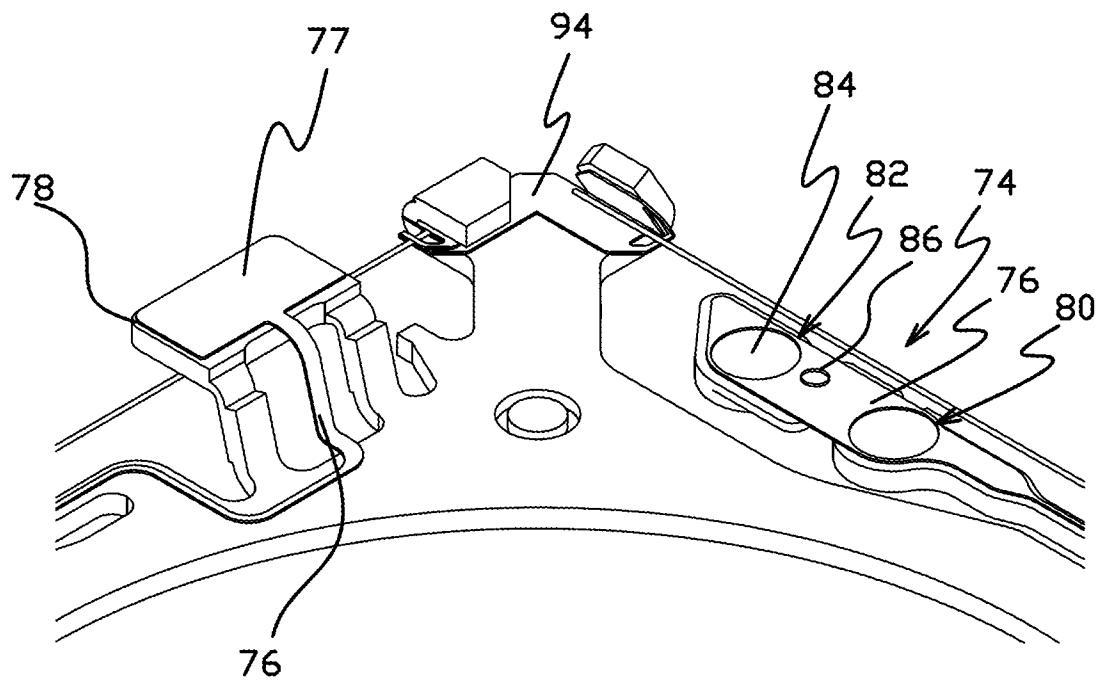


FIG. 6

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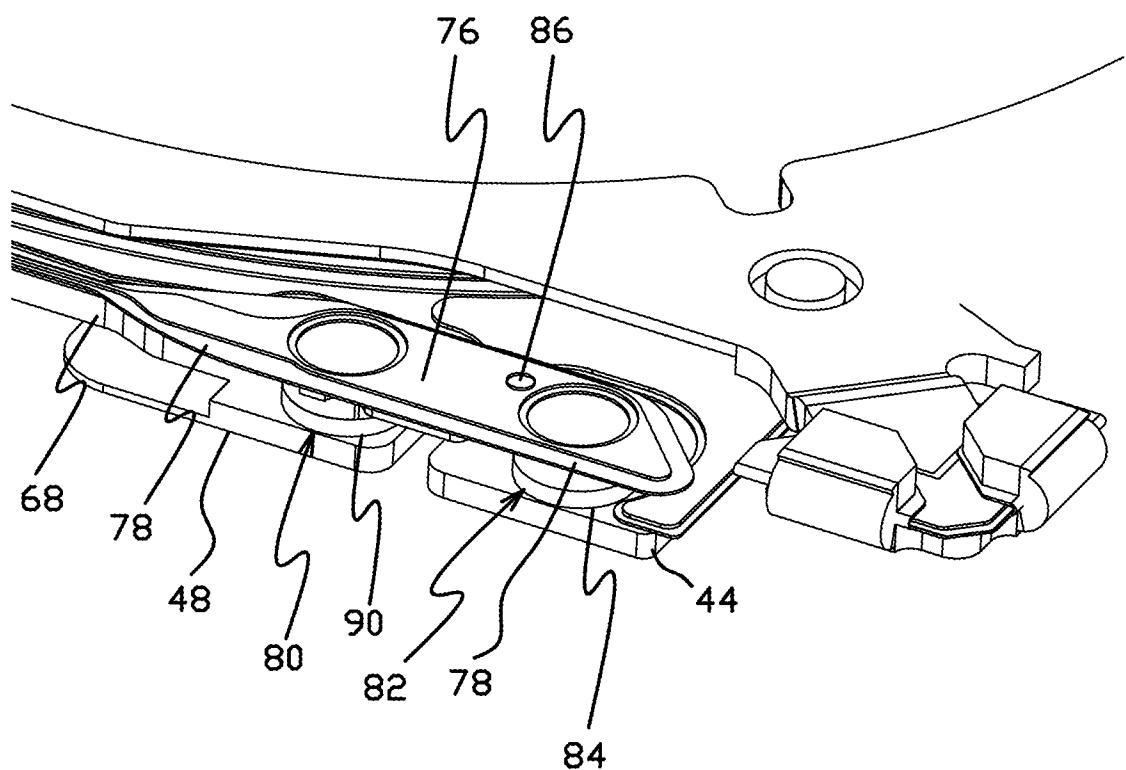


FIG. 7

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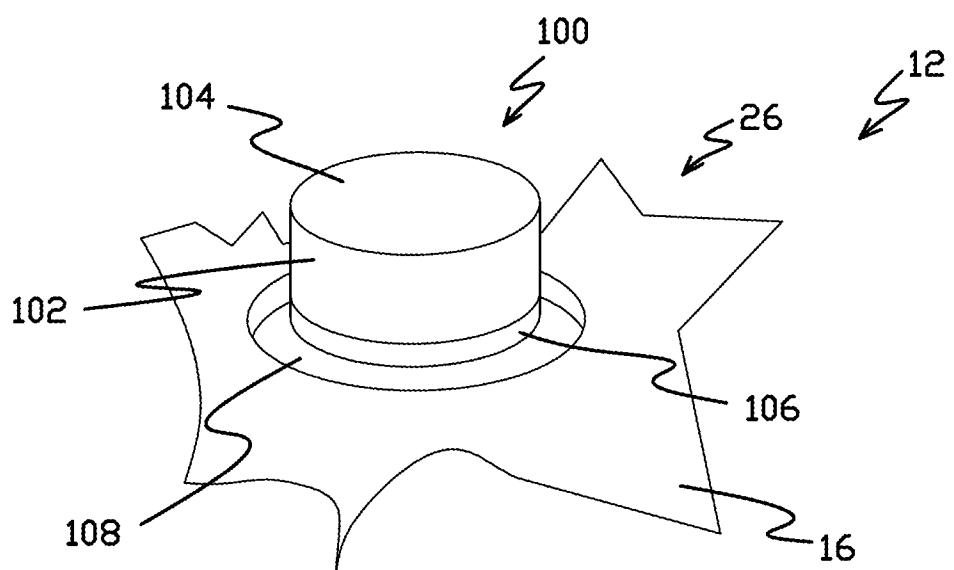
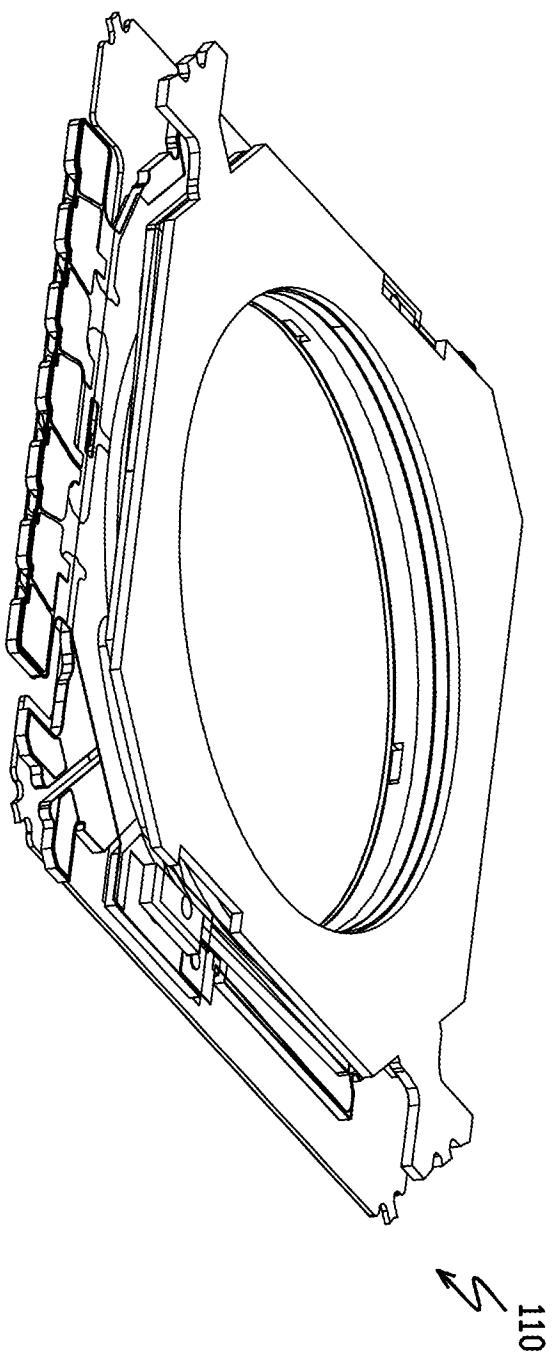


FIG. 8

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FIG. 9



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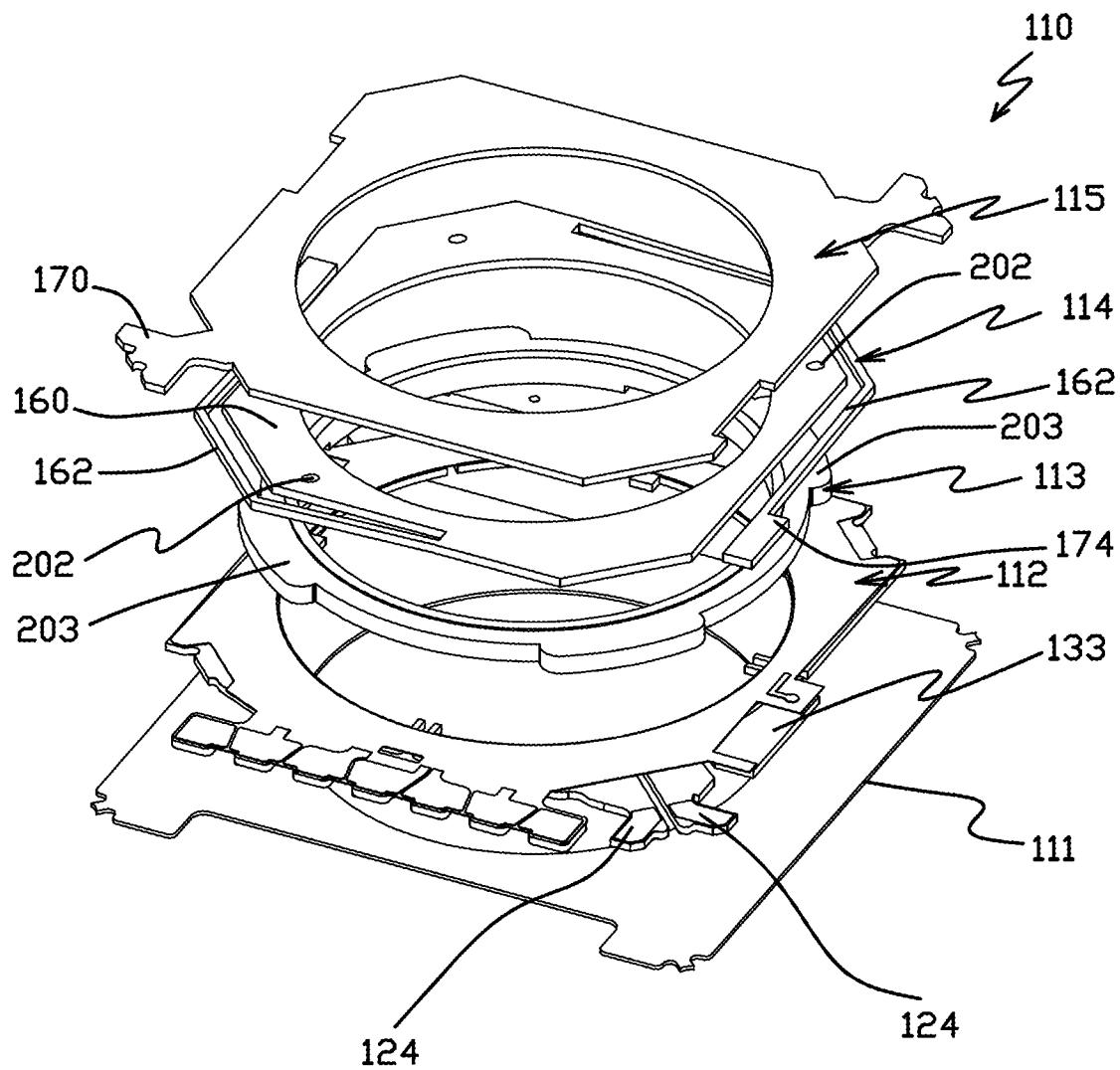


FIG. 10

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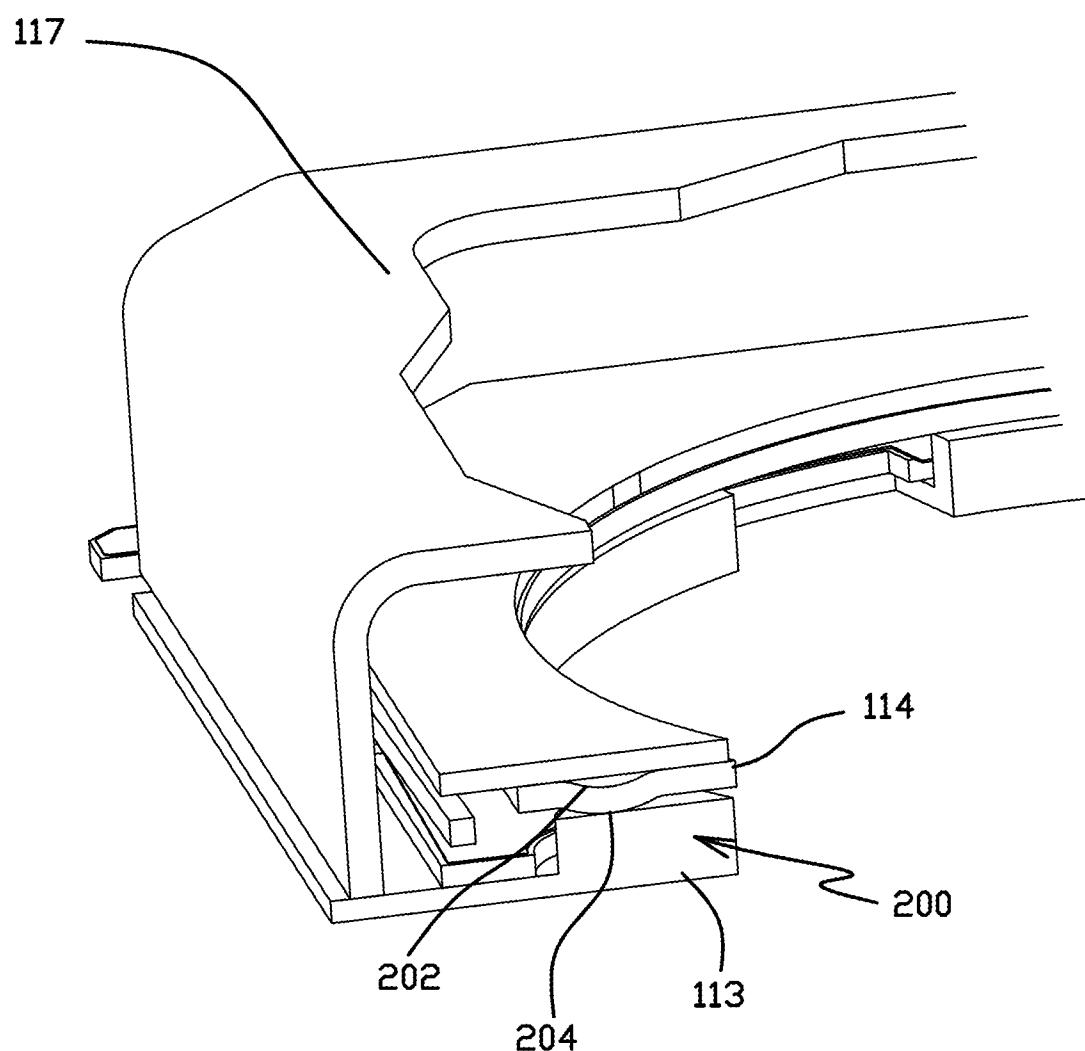
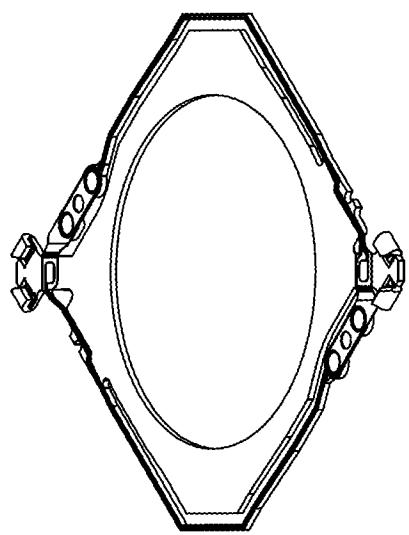


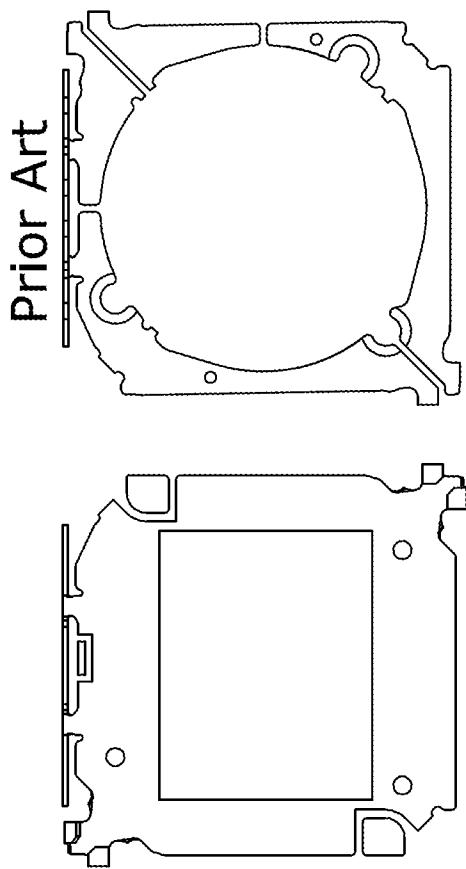
FIG. 11

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**Enable integrated full hard SST (stainless steel) spring and moving crimp**

- Use poly and copper to take up any spring back of full hard SST after crimp for high wire pull strength

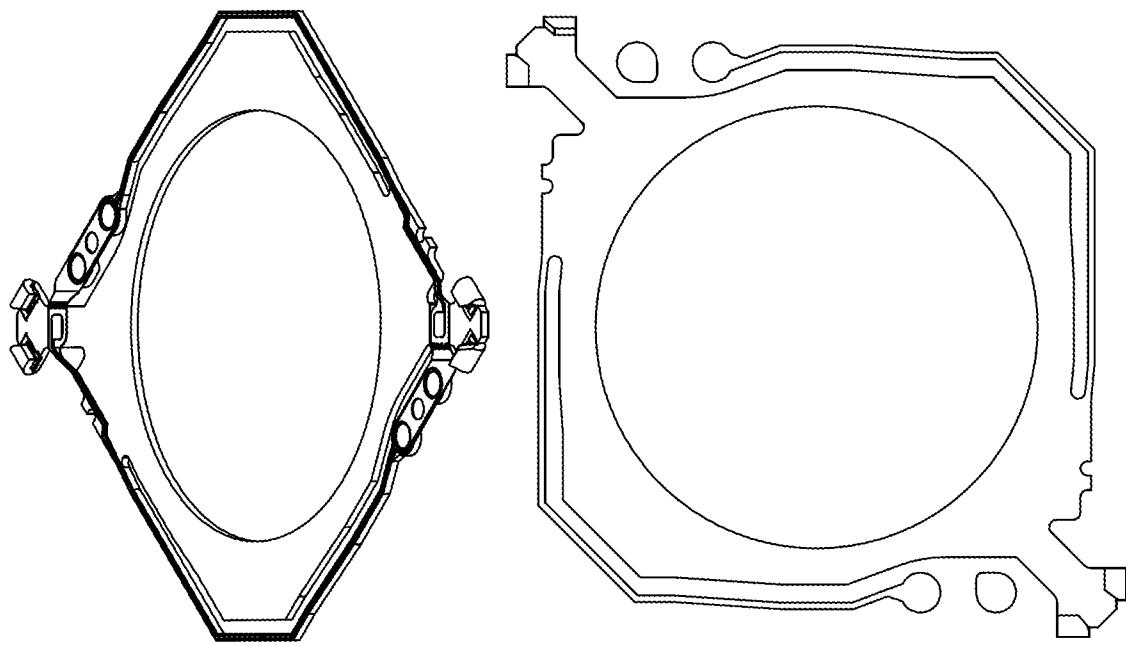


**Enable solid FPC (flexible printed circuit) SST layer**

- Enables thin 2-piece welded OIS
- Enable OIS\_COMMON to be FPC SST layer for strong weld connection

FIG. 12

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### Integrated spring and crimps

- Use poly and copper to take up any spring back of full hard SST after crimp for high wire pull strength
- Poly and copper will not damage the wire like full hard metal could during the crimp process

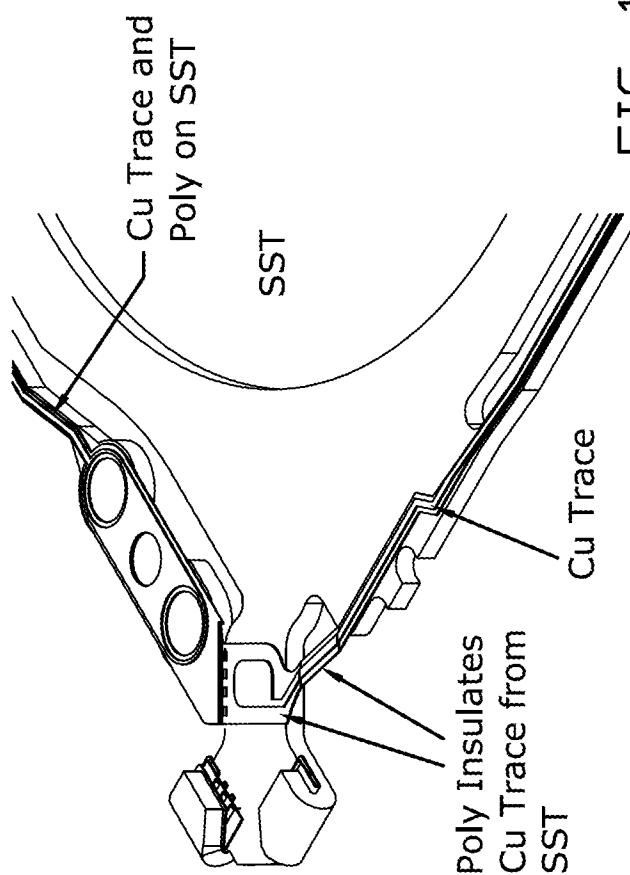
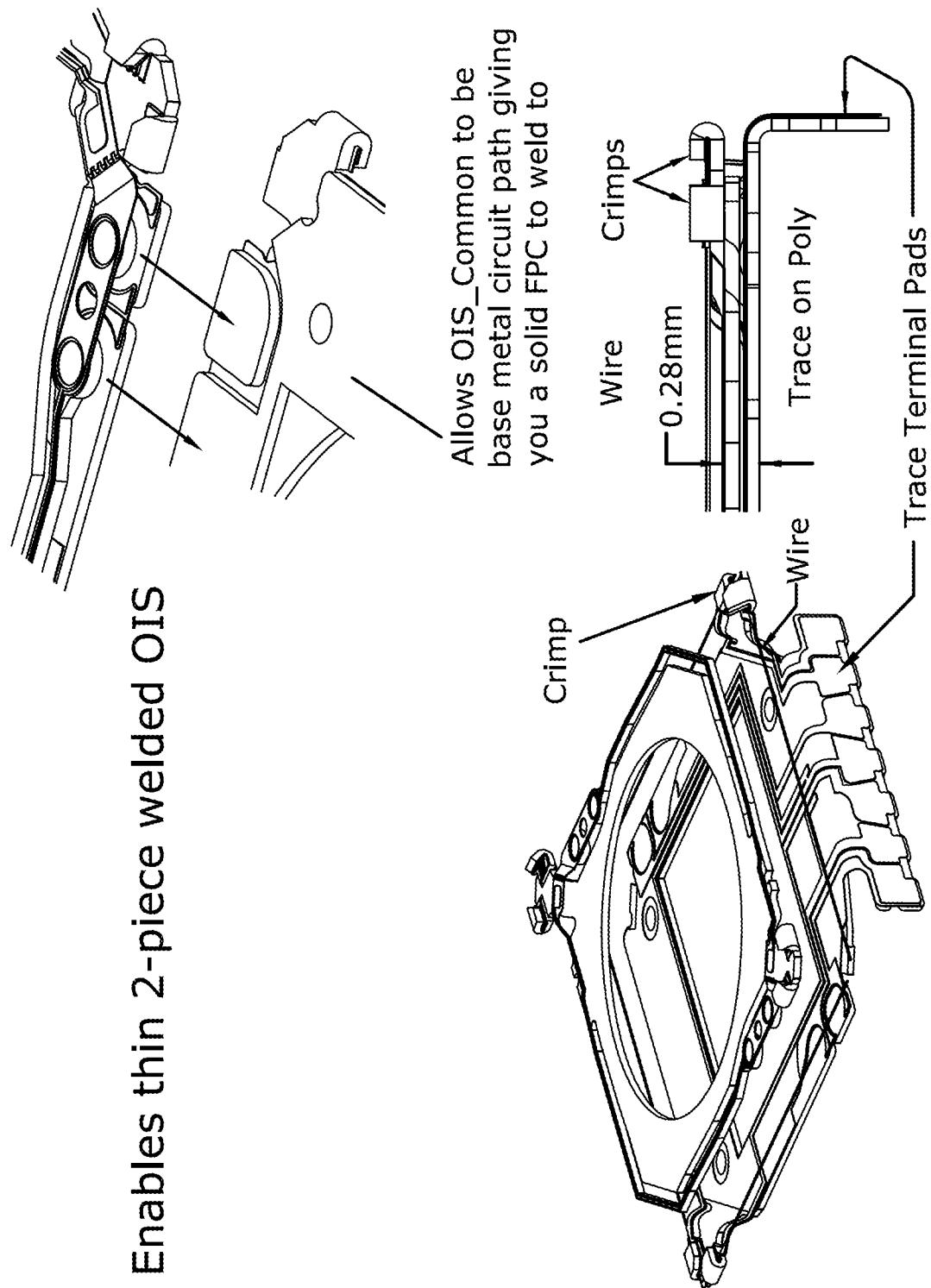
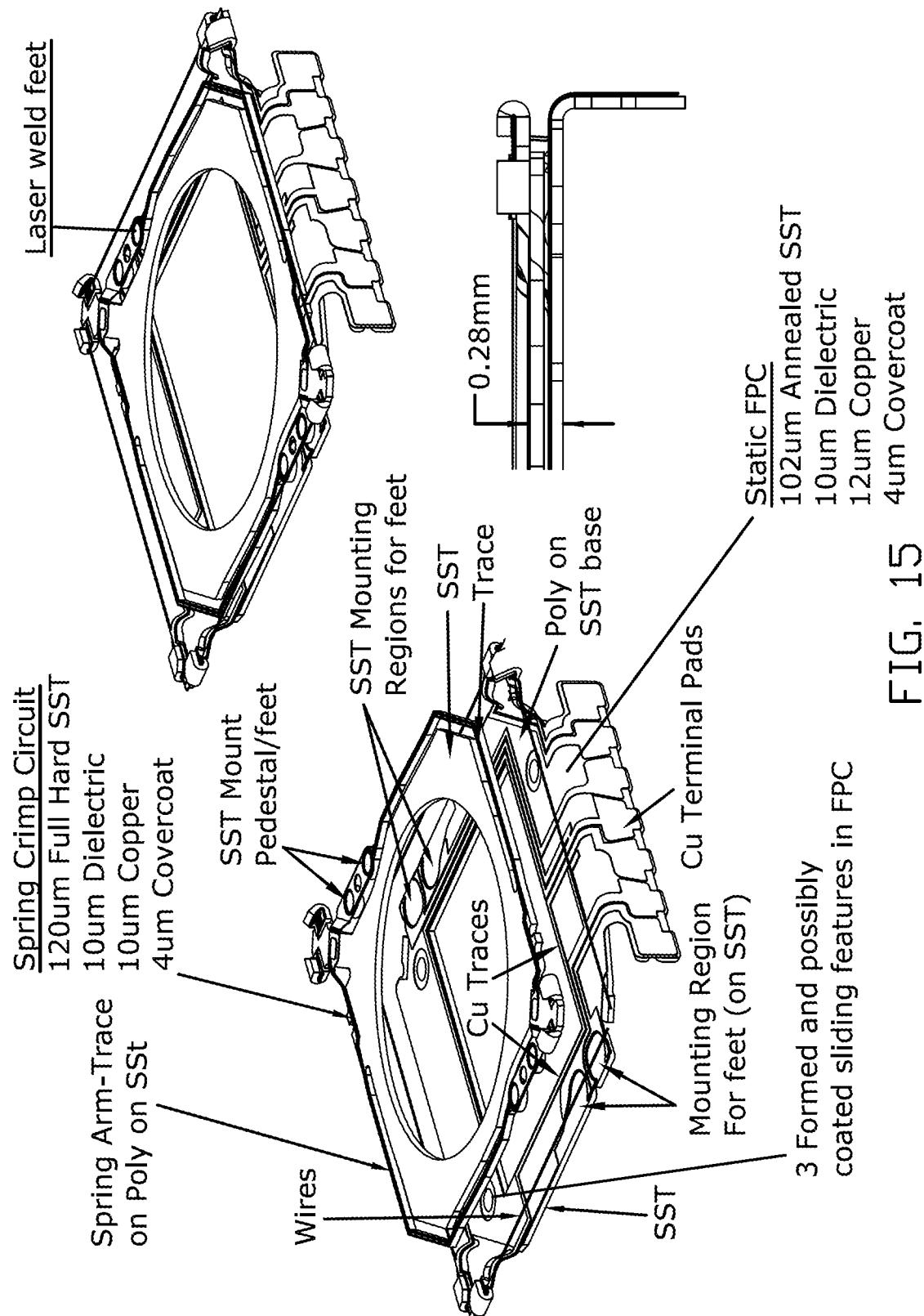


FIG. 13

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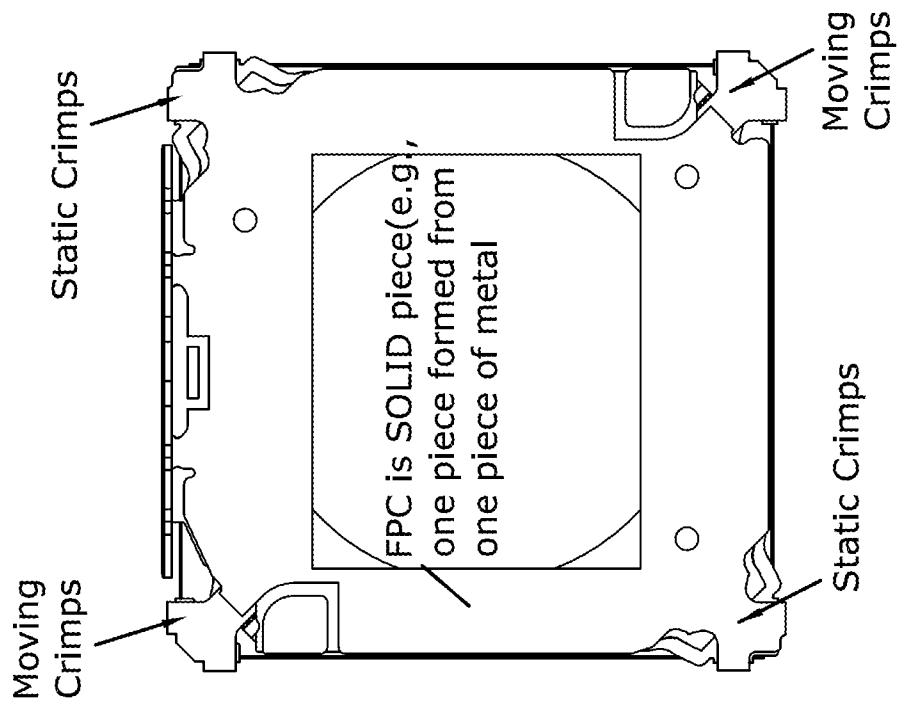


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Bottom Side View



Top Side View

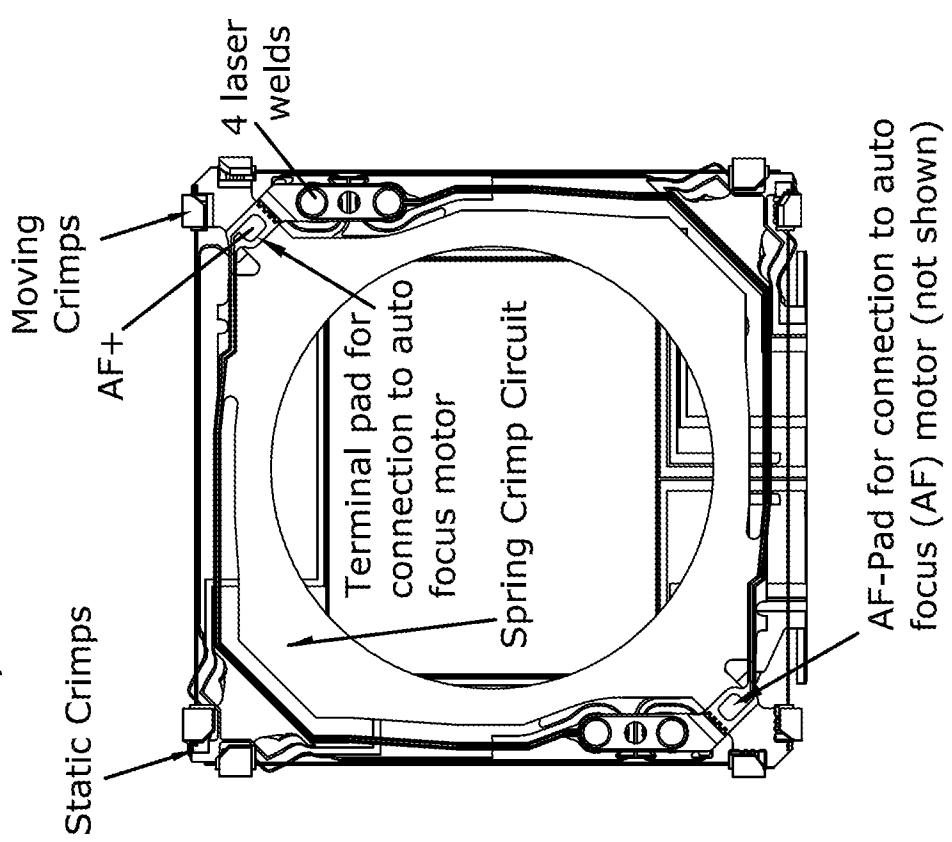


FIG. 16

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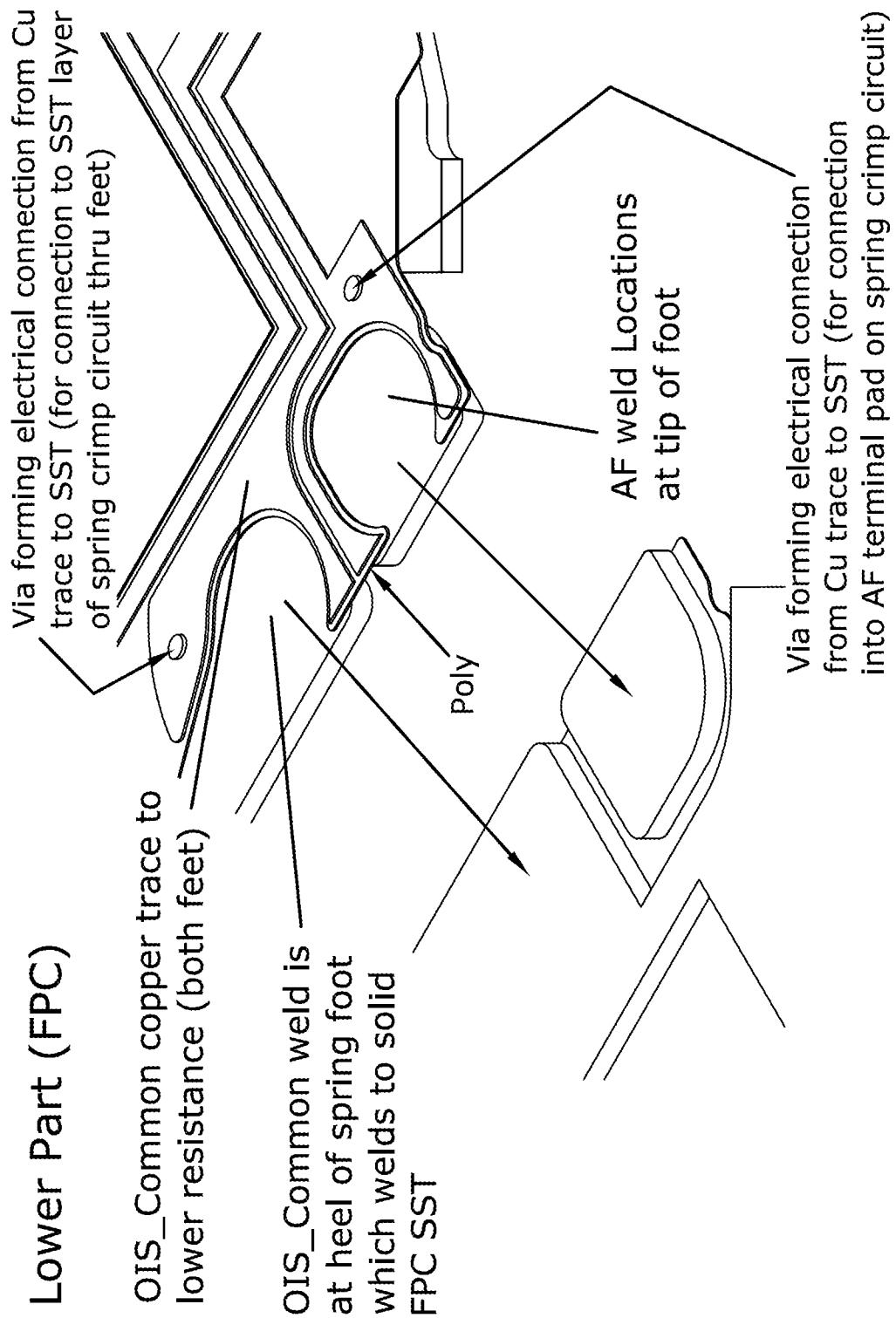


FIG. 17

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## Upper Part (Spring\_Crimp)

- Full Hard SST (120um)
- Poly (10um)
- CU (10um)
- CL (4um)

Break free at assembly weld

Enables pre form of spring feet, but keeps feet in plane for weld locating

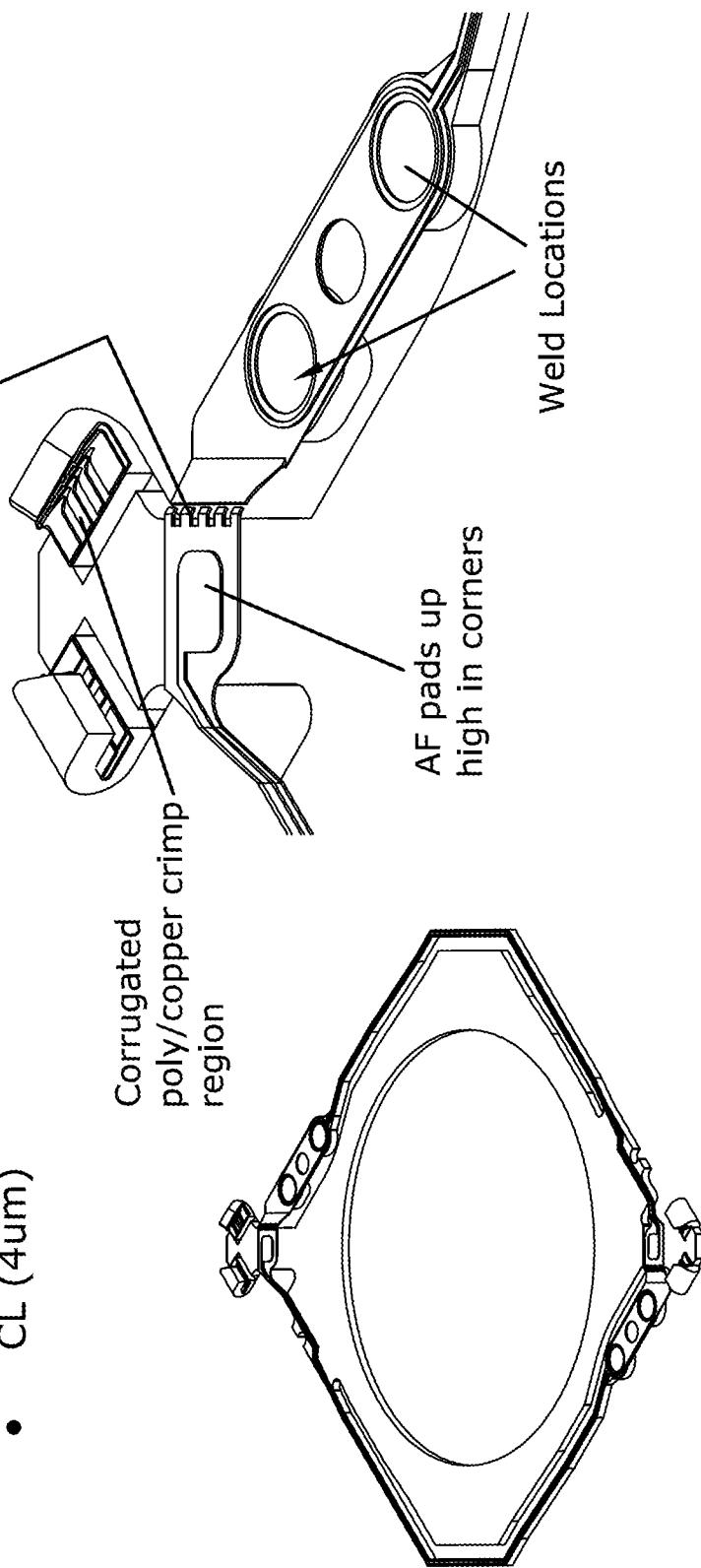


FIG. 18

## Benefits of Innovation

- **Lower material cost**
  - Forming dimples is much cheaper than buying small ball bearings. Approximately 10% the cost per OIS part.
- **Improved assembly cost**
  - Forming dimples is one simple operation on relatively simple equipment, whereas picking and placing 3 ball bearings requires many operations using expensive equipment.
- **Improved reliability**
  - It has proven difficult to keep the 3 small ball bearings from ejecting during internal manufacturing and customer assembly processes. Formed dimples do not have this issue.

FIG. 19

- OIS that uses formed or plated dimples instead of ball bearings.
  - Optimum is 3 dimples to replace the 3 ball bearings
  - Optimum dimple material could be SST with laser polish and/or coining operation
  - Optional dimple material could be high stiffness smooth plastic (example: polyoxymethylene, trade name Delrin)
  - Another material could be ceramic coated metal or a ceramic dot
- Dimples interface with a low friction surface with good wear properties.
  - Optimum may be plastic (polyoxymethylene, trade name Delrin) with a low  $R_a$  surface of 0.1  $\mu\text{m}$  max.
  - May also be metal or plastic layer with low friction coating applied or laser polish or coining.
- Example of a low friction coating could be the application of Xylan on the contact surface to reduce friction and improve wear

FIG. 20

# DIMPLE OIIS CONCEPT - 1

Design Features:

- NO Balls- 3 Dimples formed in spring layer and rides on plastic race.

- Dimple Race = The plastic material (red) the dimple rides on.

- Dimple Race is on bottom and 3 elevated areas protrude through the circuit to contact with the dimples.

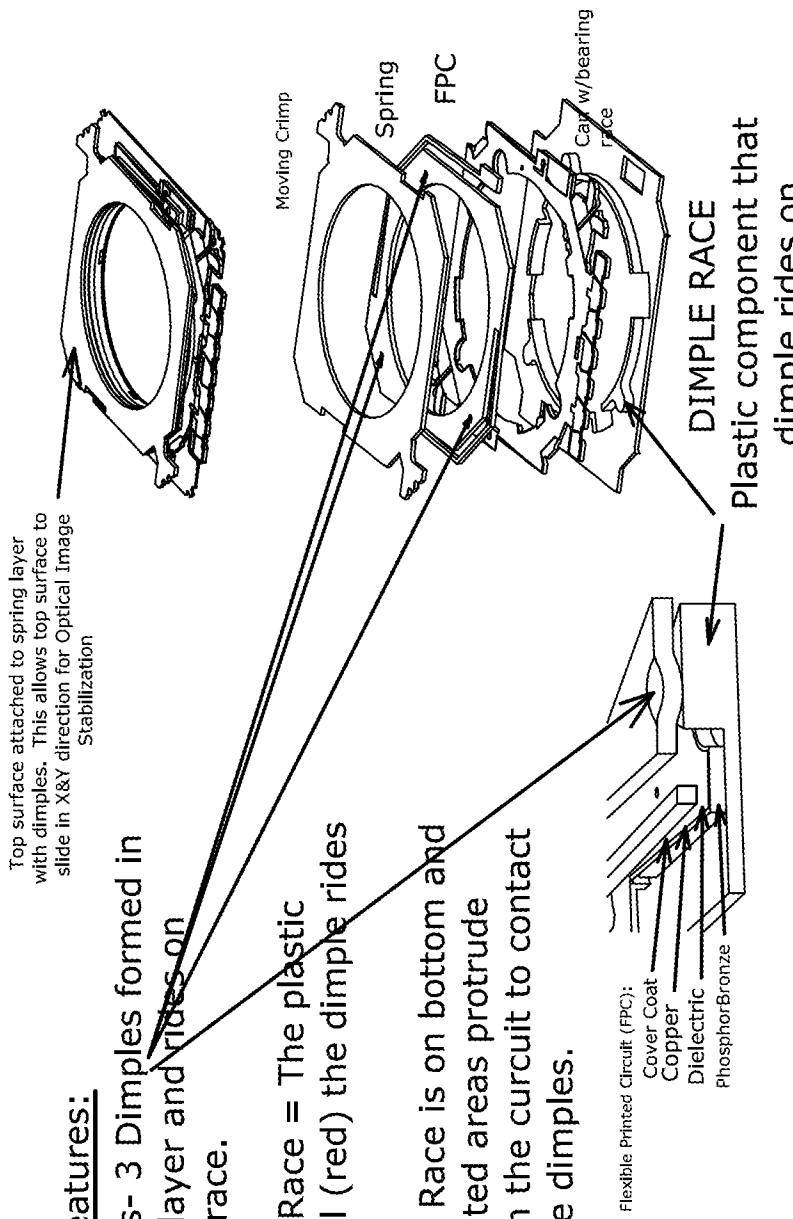


FIG. 21

# DIMPLE DIS CONCEPT\_2

## Design Features:

- NO Balls- 3 Dimples formed into spring layer and rides on plastic race.
- Dimple Race is a simple ring that sits on top of the circuit on which the dimples contact

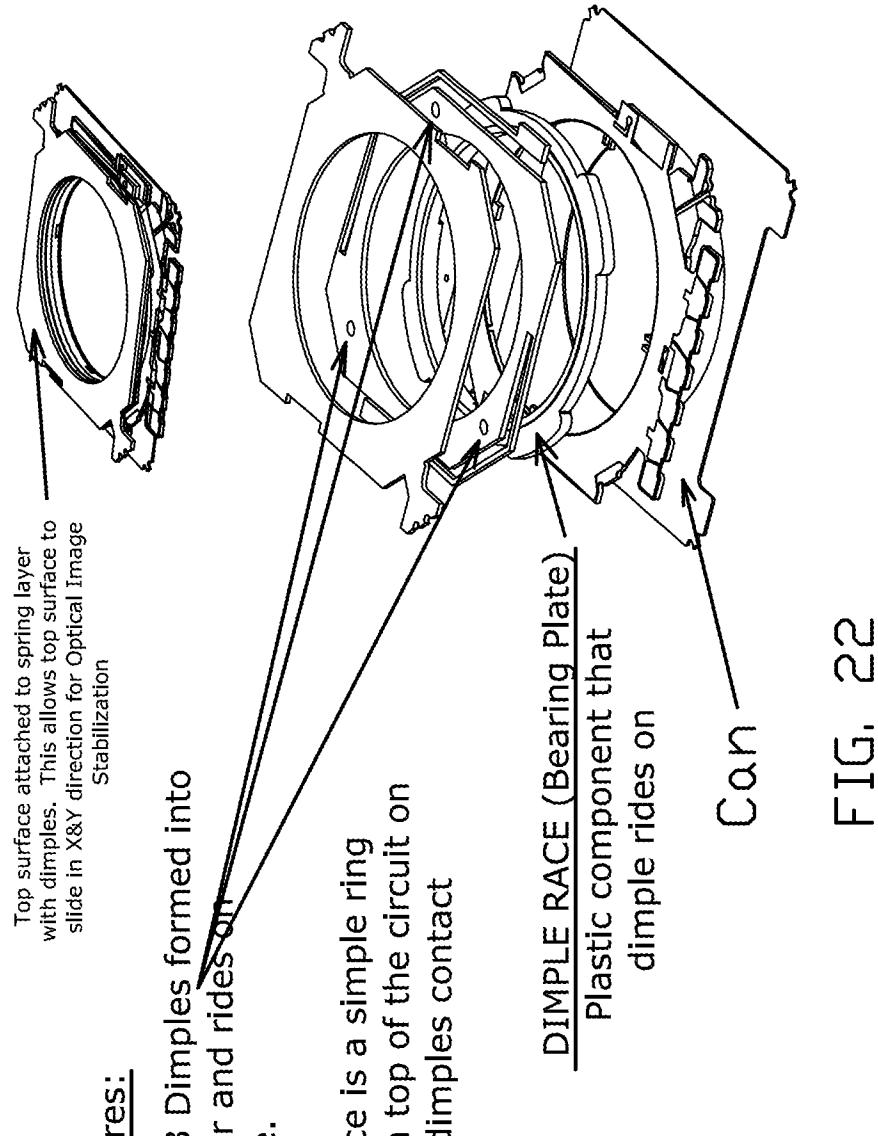


FIG. 22

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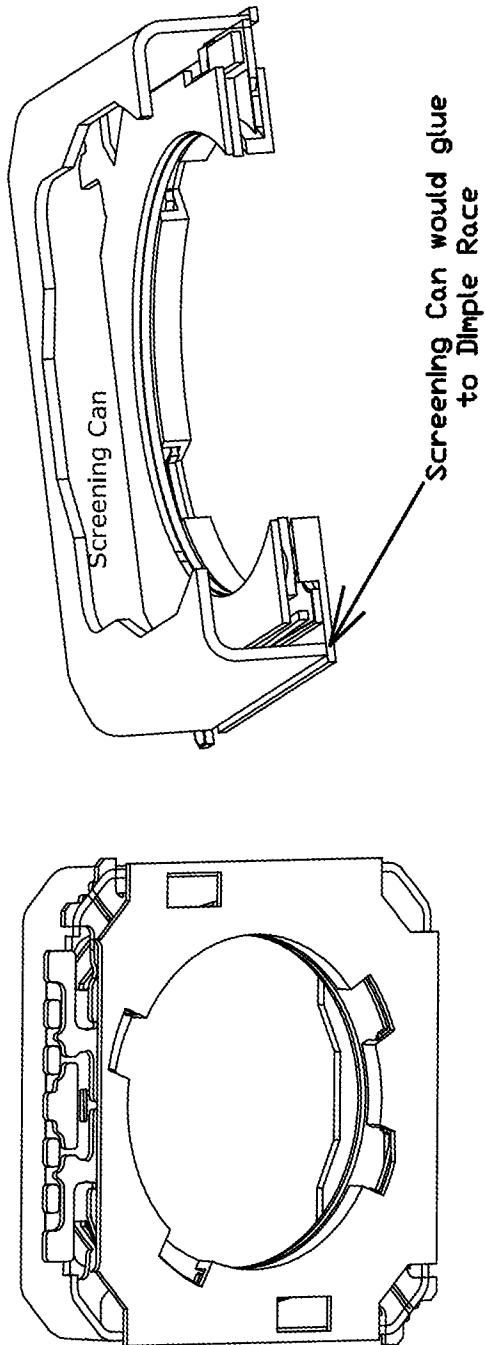
**CONCEPT\_1 WITH SCREENING\_CAN**

FIG. 23

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## CONCEPT\_1 DIMPLE\_RACE ATTACHED TO CIRCUIT

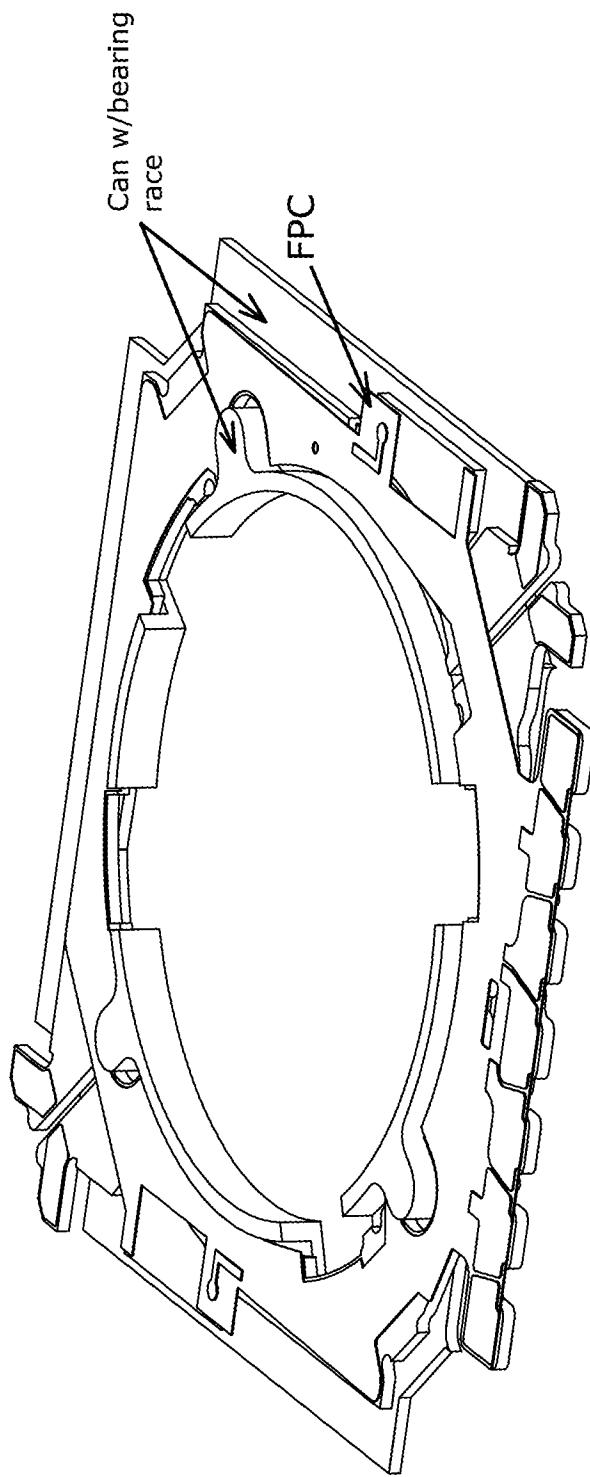


FIG. 24

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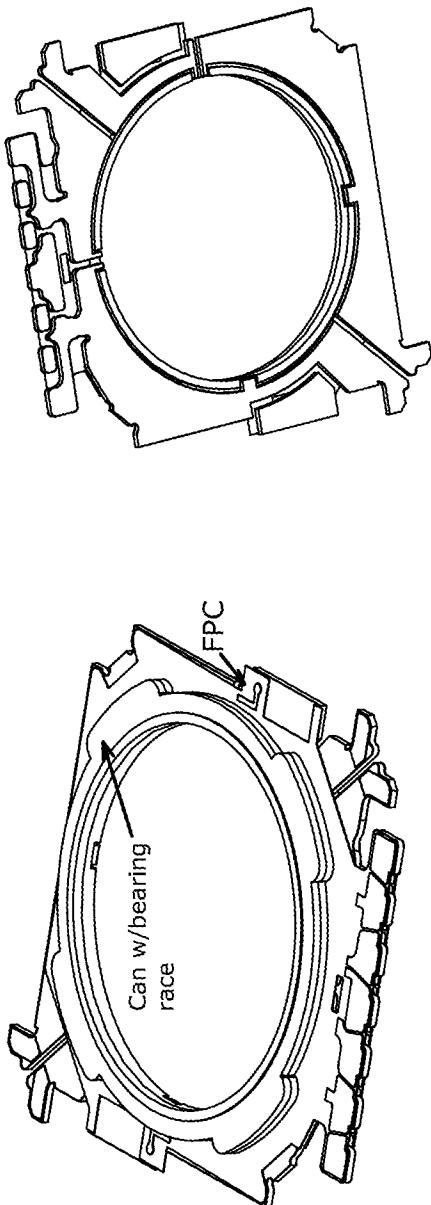
**CONCEPT\_2: DIMPLE\_RACE ATTACHED TO CIRCUIT**

FIG. 25

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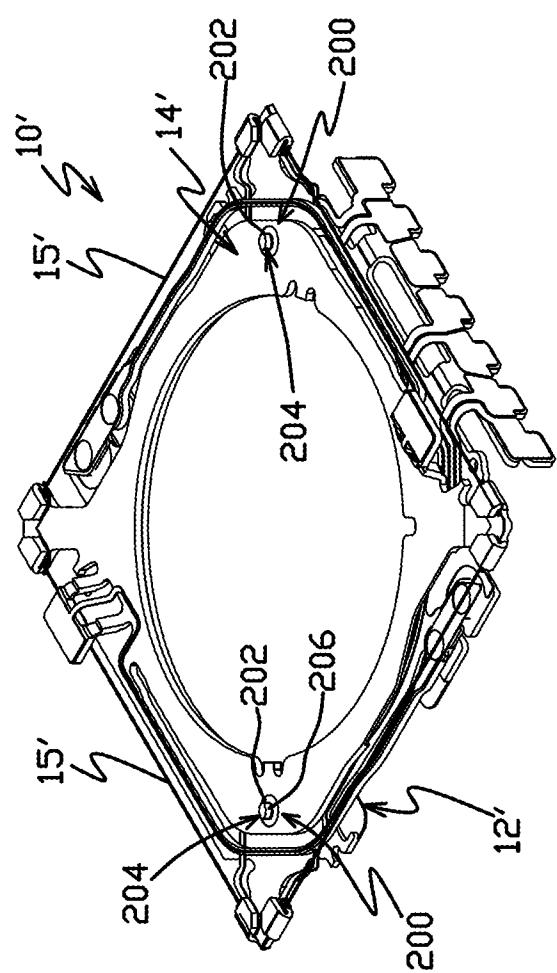


FIG. 26A

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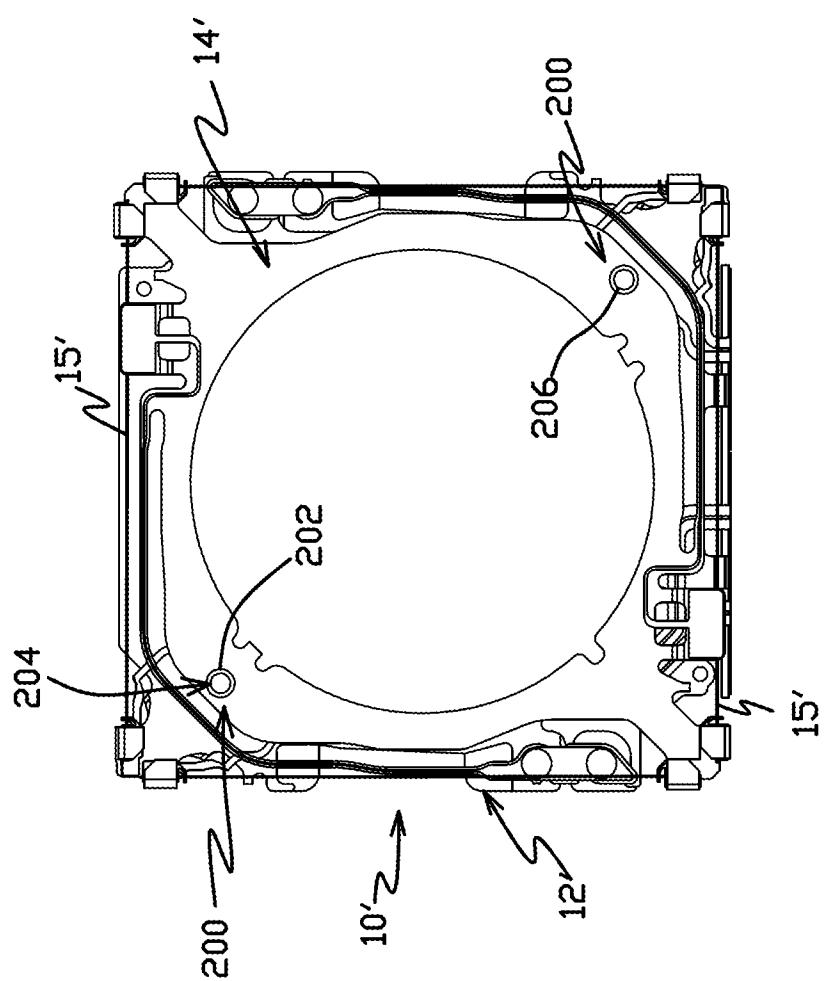


FIG. 26B

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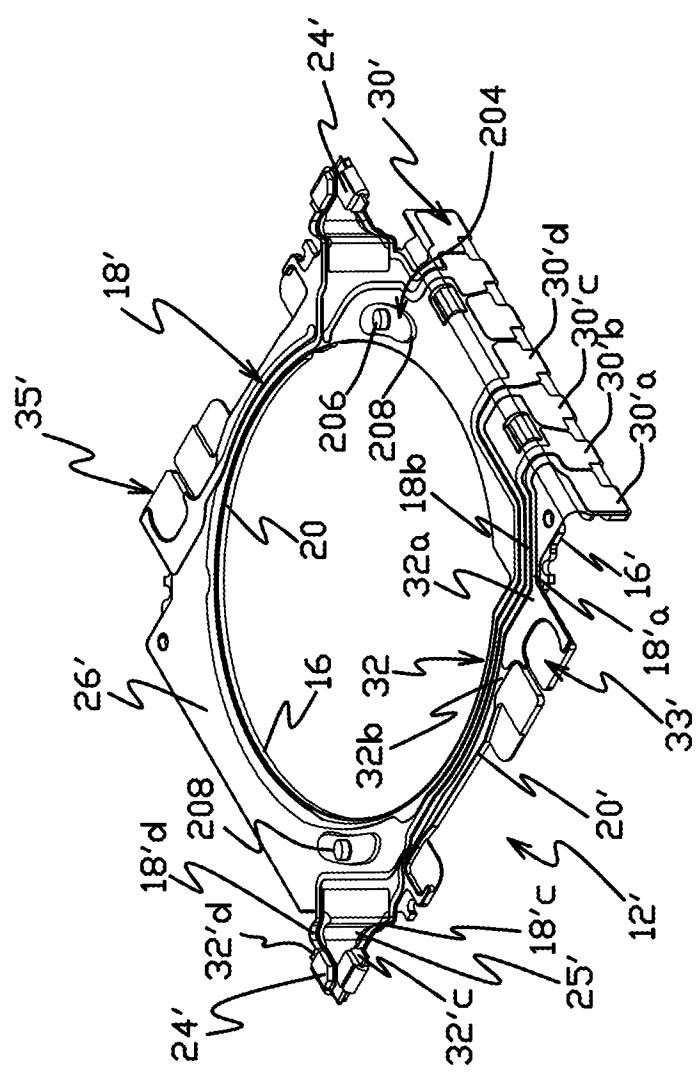


FIG. 27

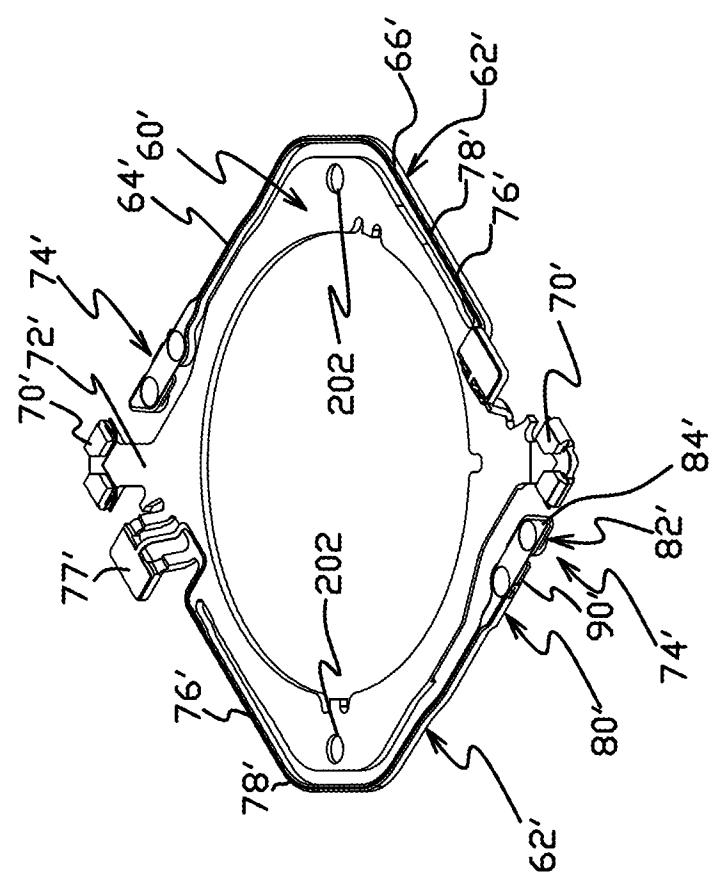


FIG. 28A

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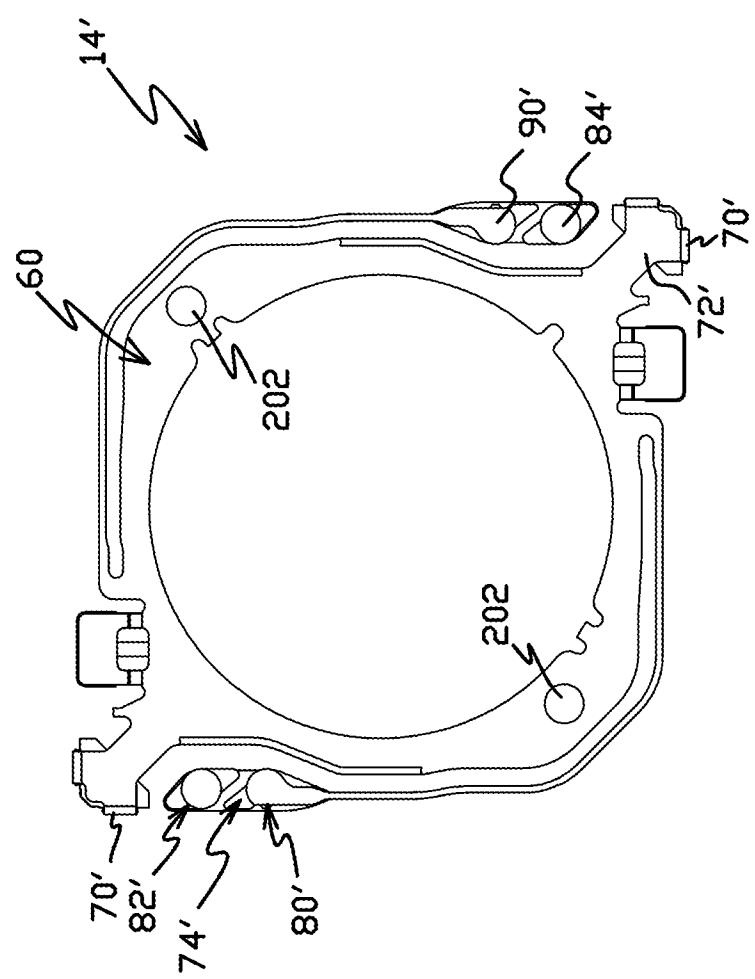


FIG. 28B

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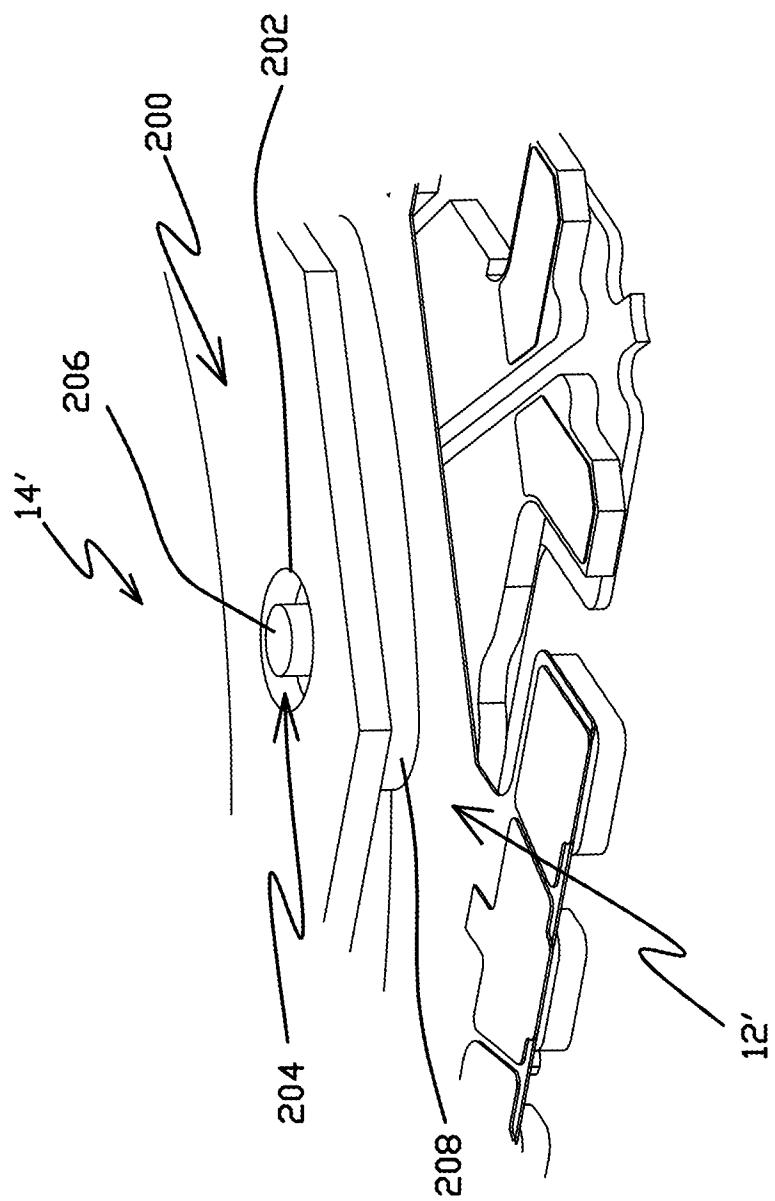


FIG. 29

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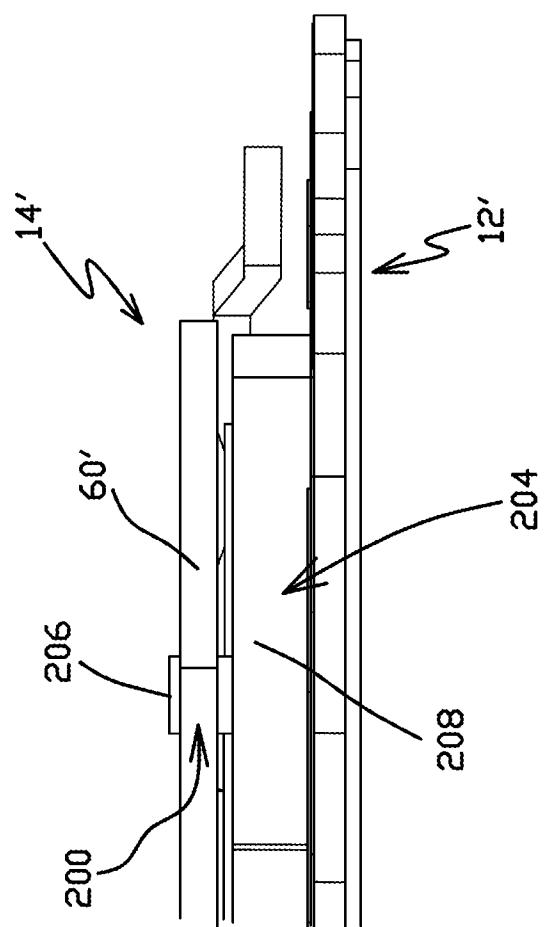


FIG. 30

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US2015/062713

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(8) - G02B 27/64 (2016.01)

CPC - G02B 27/646 (2015.12)

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - F03G 7/06; G02B 7/02, 27/64; G03B 3/00, 5/00, 13/18, 17/00 (2016.01)

CPC - F03G 7/065; G02B 7/023, 7/026, 13/001, 27/646; G03B 13/34, 2205/0053, 2205/076 (2015.12)

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

USPC - 348/208.11, 357, 374; 359/819; 396/73, 75, 89, 90, 554 (Keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar, Google

Search terms used: camera, lens, suspension, assembly, stabilize, polymer, layer, base, attach, crimp, spacer, bearing, wire, memory, alloy, metal, flex, support, static, moving, plate, arms, interface

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014083318 A1 (CAMBRIDGE MECHATRONICS LIMITED) 05 June 2014 (05.06.2014) entire document	1-4, 13, 14, 24, 25, 30
Y	US 3,587,432 A (KOCH) 28 June 1971 (28.06.1971) entire document	1-4, 13, 14, 24, 25, 30
A	US 8,570,384 B2 (BROWN) 29 October 2013 (29.10.2013) entire document	1-30
A	US 20120154614 A1 (MORIYA et al) 21 June 2012 (21.06.2012) entire document	1-30
A	US 8,848,064 B2 (TOPLISS et al) 30 September 2014 (30.09.2014) entire document	1-30

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published 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; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

17 January 2016

Date of mailing of the international search report

02 MAR 2016

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