

(51) International Patent Classification:
G02B 7/04 (2006.01)(21) International Application Number:
PCT/IB2016/054909(22) International Filing Date:
16 August 2016 (16.08.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/207,161 19 August 2015 (19.08.2015) US(71) Applicant: **SABIC GLOBAL TECHNOLOGIES B.V.**
[NL/NL]; Plasticslaan 1, 4612 PX Bergen Op Zoom (NL).(72) Inventors: **CHO, Bradly Younghoon**; 20F, Donghoon Tower, 702-19, Yeoksam-Dong, Kangnam-Ku, Seoul, Seoul 135-513 (KR). **JUNG, Jinju**; 7138-3, Taepyung 1-dong, Sujeong-gu, Gyeonggi-do, Gyeonggi-do 461-824 (KR). **CHOI, Jong-Min**; 7138-3, Taepyung 1-dong, Sujeong-gu, Gyeonggi-do, Gyeonggi-do 461-824 (KR). **LIM, Jae-Kook**; 20F, Donghoon Tower, 702-19, Yeoksam-Dong, Kangnam-Ku, Seoul, Seoul 135-513 (KR).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

Published:

- with international search report (Art. 21(3))

(54) Title: CAMERA MODULE HAVING TRACES FORMED BY LASER DIRECT STRUCTURING

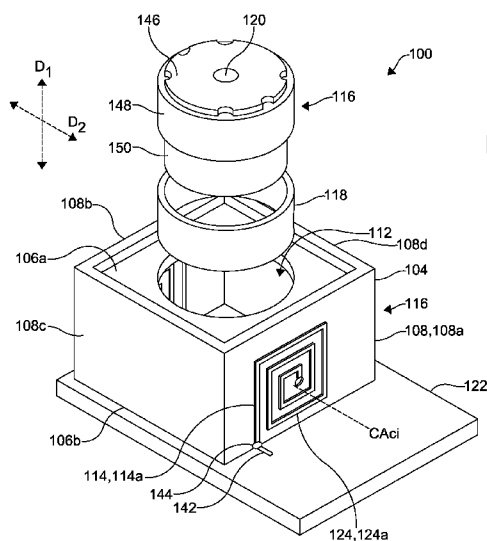


FIG. 1

(57) **Abstract:** In one aspect, a camera module includes a housing and a lens barrel. A body of the housing defines a first end, an opposed second end spaced from the first end along a first direction, a side extending from the first end to the second end, and a cavity that extends between the first and second ends along the first direction. An electrically conductive trace, which is formed on the side by, for example, laser direct structuring, defines an electromagnetic coil. The lens barrel is disposed in the cavity and includes a magnet and an optical lens supported by the magnet. When a current is applied to the coil, a magnetic flux of the magnet responds to the current so as to create a Lorentz force that urges the magnet to translate the lens from a first position to a second position along the first direction.

CAMERA MODULE HAVING TRACES FORMED BY LASER DIRECT STRUCTURING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Patent Application No. 62/207,161, filed August 19, 2015, which is hereby incorporated herein by reference in its entirety.

BACKGROUND

[0002] In the mobile phone industry, a current trend has been to make mobile phones increasingly slimmer. This, in turn, has led to a need to make the components within phones, such as the rear camera module, smaller. However, due to its complexity, the rear camera module has proven difficult to miniaturize. Therefore, there is a need for miniaturized camera modules and methods of making the same.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The foregoing summary, as well as the following detailed description, is better understood when read in conjunction with the appended drawings. There is shown in the drawings example embodiments, and the present invention is not intended to be limited to the specific embodiments and methods disclosed.

[0004] Fig. 1 shows a partially-exploded perspective view of a camera module according to one embodiment;

[0005] Fig. 2 shows a cross-sectional view of the camera module of Fig. 1;

[0006] Fig. 3 shows a cross-sectional perspective view of the housing of the camera module of Fig. 1;

[0007] Fig. 4 shows a plan view of a first side surface of a first side of the housing of the camera module of Fig. 1;

[0008] Fig. 5 shows a plan view of a second side surface of the first side of the housing of the camera module of Fig. 4, opposite the first side surface;

[0009] Fig. 6 shows a plan view of a first side surface of a second side of the housing of the camera module of Fig. 1;

[0010] Fig. 7 shows a plan view of a second side surface of the second side of the housing of the camera module of Fig. 4, opposite the first side surface;

[0011] Fig. 8 shows a partially-exploded perspective view of a camera module according to another embodiment;

[0012] Fig. 9 shows a perspective view of a camera module according to another embodiment;

[0013] Fig. 10 shows an exploded perspective view of a camera module according to another embodiment; and

[0014] Fig. 11 shows a perspective bottom view of a housing of the camera module of Fig. 10.

DETAILED DESCRIPTION

[0015] Certain terminology is used in the following description for convenience only and is not limiting. The words “right”, “left”, “upper,” and “lower” designate directions in the drawings to which reference is made. The words “inward”, “inwardly”, “outward”, “outwardly,” “upward,” “upwardly,” “downward,” and “downwardly” refer to directions toward and away from the geometric center of the device and/or designated parts thereof. The terminology intended to be non-limiting includes the above-listed words, derivatives thereof and words of similar import.

[0016] Fig. 1 shows a partially-exploded perspective view of a camera module 100 according to one embodiment, and Fig. 2 shows a cross-sectional view of the camera module 100. In general, the camera module 100 includes a housing 102 that includes a housing body 104. The camera module can also include a substrate 122 such as a printed circuit board onto which the housing 102 is mounted using a surface-mount technology. The housing 102 also includes at least one electrically conductive trace 114 formed on the housing body 104 using laser direct structuring as will be described in further detail below or insert molding, where the at least one electrically conductive trace 114 defines at least one electromagnetic coil 124. The camera module 100 also includes a lens barrel 116 that is disposed in a cavity 112 of the housing body 104 when the camera module 100 is assembled. The lens barrel 116 includes a magnet 118 and an optical lens 120

supported by the lens barrel 116, and consequently supported by the magnet 118. When an electrical current is applied to the at least one electrically conductive trace 114, a magnetic flux of the magnet 118 responds to the current so as to create a Lorentz force that urges the magnet 118 to translate the optical lens 120 from a first position to a second position, different from the first position, along the first direction D_1 . Thus, the magnet 118 and electromagnetic coil 124 operate together as a voice coil motor.

[0017] The housing body 104 defines a rectangular cuboid, although alternative embodiments may have any other suitable shape such as a cube or a cylinder. The housing body 104 defines a first end 106a, an opposed second end 106b spaced from the first end 106a along a first direction D_1 , and at least one side 108, such as four sides 108a to 108d, extending from the first end 106a to the second end 106b. Each side 108 of the housing body 104 can define a first or outer surface 110a and an opposed second or inner surface 110b. Each outer surface 110a and/or each inner surface 110b can be substantially parallel to the first direction D_1 . Further, the inner surface or surfaces 110b of the housing body 104 can define a cavity 112 that extends between the first and second ends 106a and 106b along the first direction D_1 . The cavity 112 extends through the first end 106a and the second end 106b, although in alternative embodiments, the cavity 112 may extend through only one of the first and second ends 106a and 106b.

[0018] The housing body 104 can be formed from a plastic material that is doped with a conductive additive such as (without limitation) a metal-plastic additive, and can be formed by injection molding the plastic material into the shape of the housing body 104. The plastic material can have a heat deflection temperature that is higher than a reflow temperature of solder that is used to mount the camera module 100 to a substrate 122 (shown in Fig. 1). The at least one electrically conductive trace 114 can be formed on the at least one side 108 of the housing body 104 by applying a laser to the at least one side 108 of the housing body 104. As the laser draws the pattern for the at least one electrically conductive trace 114, the laser activates the conductive additive so as to define a micro-rough track 154 on the at least one side 108. As shown in Detail 2 of Fig. 2, the micro-rough track 154 can be defined in a recess or pocket that extends from one of the first and second surfaces 110a and 110b toward, but not to, the other of the first and second surfaces 110a and 110b. The metal particles of the micro-rough track can form a base, and one or more layers of metal or metal alloy 156 can be created on the base so as to form the at least one electrically conductive trace

114. For example, the housing body 104 can be bathed in an electroless bath of metal or metal alloy such that an additional layer of metal or metal alloy is formed on the micro-rough track each time the housing body 104 is dipped in the bath. The metal or metal alloy can include (without limitation) copper, nickel, and/or gold. Further, the one or more layers 156 can be formed so as to be recessed from (as shown in Detail 2), flush with, or raised from the one of the first and second surfaces 110a and 110b on which the micro-rough track is formed. Thus, the electrically conductive trace 114 is formed directly on the housing body 104, such that the electrically conductive trace 114 is integral to and inseparable from the housing body 104. Further, one or more layers of a protective coating (not shown) may be formed on the exposed surfaces of the at least one electrically conductive trace 114.

[0019] According to alternative embodiments, the at least one electrically conductive trace 114 can be pre-formed using, for example, a wire, and the housing 102 can be formed by insert molding the housing body 104 and the pre-formed at least one electrically conductive trace 114. According to further alternative embodiments, the at least one electrically conductive trace 114 can be formed in part by insert molding and in part using laser direct structuring.

[0020] Referring to Figs. 2 to 5, the at least one electrically conductive trace 114 comprises a first electrically conductive trace 114a that is formed on the first side 108a of the housing body 104. The first electrically conductive trace 114a comprises an electromagnetic coil 124a, a first current transfer portion 126a, and a second current transfer portion 128a, where each of the first and second current transfer portions 126a and 128a are configured to transfer current between the electromagnetic coil 124a and a substrate 122 (shown in Fig. 1). Accordingly, the first electrically conductive trace 114a defines a closed conductive loop that extends from the substrate 122, through the first current transfer portion 126a, through the electromagnetic coil 124a, and through the second current transfer portion 128a back to the substrate 122, or vice versa.

[0021] The electrically conductive trace 114a is formed on the first side surface 110a of the first side 108a and on the second side surface 110b of the first side 108a, opposite the first side surface 110a. In particular, the electromagnetic coil 124a and the first current transfer portion 126a are formed on the first side surface 110a and the second current transfer portion 128a is formed on the second side surface 110b. The side 108a also includes an internal surface 130a that defines an aperture 132a extending from the first side surface 110a to the second side surface 110b. Further,

the electrically conductive trace 114a comprises a connecting portion 134a formed on the internal surface 130a that extends from the electromagnetic coil 124a on the first side surface 110a to the second current transfer portion 128a on the second side surface 110b so as to electrically connect the electromagnetic coil 124a and the second current transfer portion 128a. Thus, the connecting portion 134a completes a conductive path between the first side surface 110a and the second side surface 110b.

[0022] As shown in Fig. 2, the aperture 132a can have a conical shape that tapers inward as it extends from the first side surface 110a to the second side surface 110b, or can have another suitable shape. The aperture 132a extends along a second direction D_2 that is perpendicular to first direction D_1 , and the internal surface 130a extends at an angle θ_a with respect to the second direction D_2 . Stated differently, the aperture 132a defines a central aperture axis CA_{A1} that extends along the second direction, and the internal surface 130a extends at the angle θ_{A1} with respect to the central aperture axis CA_{A1} . In at least some embodiments, the angle θ_{A1} can be at least substantially 30 degrees, and in at least some of these embodiments, the angle can be at least 45 degrees.

[0023] In alternative embodiments, the electrically conductive trace 114a can be formed entirely on only one of either the first and second side surfaces 110a and 110b. Thus, the electromagnetic coil 124a, and the first and second current transfer portions 126a can be formed entirely on the first side surface 110a or the second side surface 110b. In such embodiments, the closed conductive loop can be formed with the substrate 122 on the one of the first and second side surfaces 110a and 110b, and the aperture 132a and the connecting portion 134a can be omitted. Further, in alternative embodiments, the aperture 132a can taper outward as it extends from the first side surface 110a to the second side surface 110b. Yet further, in alternative embodiments, the electrically conductive trace 114a can be formed such that the electromagnetic coil 124a and the first current transfer portion 126a are formed on the second side surface 110b, and the second current transfer portion 128a is formed on the first side surface 110a. Accordingly, the electromagnetic coil 124a can be formed on either the outer side surface 110a or the inner side surface 110b. Even yet still further, the electrically conductive trace 114a can include a first electromagnetic coil formed on the first side surface 110a and a second electromagnetic coil formed on the second side surface

110b, where the second electromagnetic coil can be electrically isolated from or electrically coupled to the first electromagnetic coil.

[0024] The electromagnetic coil 124a includes a first coil end 136a, a second coil end 138a spaced from the first coil end 136a, and an elongate line 140a that extends continuously around a central coil axis CA_{C1} of the electromagnetic coil 124a from the first coil end 136a to the second coil end 138a. The central coil axis CA_{C1} extends in the second direction D_2 as shown in Fig. 1, and the elongate line 140a forms at least one ring about the central coil axis CA_C from the first coil end 136a to the second coil end 138a. The central coil axis CA_{C1} is spaced from the central aperture axis CA_{A1} ; however, in alternative embodiments they may be coaxial. The first coil end 136a is spaced closer to the central coil axis CA_{C1} than the second coil end 138a, and the elongate line 140a extends around the central coil axis CA_{C1} from the first coil end 136a to the second coil end 138a so as to form a spiral comprising a plurality of concentric rings. In this embodiment, the electromagnetic coil 124a defines two full rings or turns and one partial ring or turn; however, in alternative embodiments, the electromagnetic coil may define as few as one ring or more than two full and one partial ring. Further, in this embodiment, the rings turn at right angles such that each ring has a substantially rectangular or square shape. However, in alternative embodiments each ring can have another suitable shape such as a substantially circular shape and can even extend along multiple sides 108 of the housing 102.

[0025] Each concentric ring of the plurality of concentric rings is spaced from an immediately adjacent ring of the plurality of concentric rings in a radial direction by a distance A_1 . In at least some embodiments, the distance A_1 can be greater than or equal to substantially 100 μm . The elongate line 140a extends in a clockwise direction from the first coil end 136a to the second coil end 140a as viewed in the second direction D_2 from the electromagnetic coil 124a toward the cavity 112. However, in alternative embodiments, the elongate line 140a can extend in a counter clockwise direction from the first coil end 136a to the second coil end 138a as viewed in the second direction D_2 from the electromagnetic coil 124a toward the cavity 112.

[0026] Referring to Figs. 2, 6, and 7, the at least one electrically conductive trace 114 can include a second electrically conductive trace 114b, although in alternative embodiments, the at least one electrically conductive trace 114 can include as few as one or more than two electrically conductive traces 114. The second electrically conductive trace 114b can be formed on the second side

108b of the housing body 104, opposite the first side 108a, or on a side of the housing body 104 other than the first and second sides 108a and 108b. The second electrically conductive trace 114b is similar to the first electrically conductive trace 114a, although as described below, the electromagnetic coil 124b of the second electrically conductive trace 114b is formed on the second or inner side surface 110b, rather than on the outer side surface 110a.

[0027] The second electrically conductive trace 114b comprises an electromagnetic coil 124b, a first current transfer portion 126b, and a second current transfer portion 128b, where each of the first and second current transfer portions 126b and 128b are configured to transfer current between the electromagnetic coil 124b and the substrate 122 (shown in Fig. 1). Accordingly, the second electrically conductive trace 114b defines a closed conductive loop that extends from the substrate 122, through the first current transfer portion 126b, through the electromagnetic coil 124b, and through the second current transfer portion 128b back to the substrate 122, or vice versa.

[0028] The second electrically conductive trace 114b is formed on the first side surface 110a of the second side 108b and on the second side surface 110b of the second side 108b, opposite the first side surface 110a. In particular, the electromagnetic coil 124b and the first current transfer portion 126b are formed on the second or inner side surface 110b and the second current transfer portion 128b is formed on the first or outer side surface 110a. The second side 108b also includes an internal surface 130b that defines an aperture 132b extending from the first side surface 110a to the second side surface 110b. Further, the second electrically conductive trace 114b comprises a connecting portion 134b formed on the internal surface 130b that extends from the electromagnetic coil 124b on the second side surface 110b to the second current transfer portion 128b on the first side surface 110a so as to electrically connect the electromagnetic coil 124b and the second current transfer portion 128b. Thus, the connecting portion 134b completes a conductive path between the first side surface 110a and the second side surface 110b.

[0029] The aperture 132b can have a conical shape that tapers inward as it extends from the first side surface 110a to the second side surface 110b, or can have another suitable shape. The aperture 132b extends along the second direction D_2 and the internal surface 130b extends at an angle θ_b with respect to the second direction D_2 . Stated differently, the aperture 132b defines a central aperture axis CA_{A2} that extends along the second direction, and the internal surface internal surface 130b extends at the angle θ_{A2} with respect to the central aperture axis CA_{A2} . In at least some

embodiments the angle θ_{A2} can be at least substantially 45 degrees. Further, in at least some embodiments, the central aperture axis CA_{A2} of the aperture 132b can be coaxial with the central aperture axis CA_{A1} of the aperture 132a.

[0030] In alternative embodiments, the second electrically conductive trace 114b can be formed entirely on only one of either the first and second side surfaces 110a and 110b. Thus, the electromagnetic coil 124b, and the first and second current transfer portions 126b can be formed entirely on the first side surface 110a or the second side surface 110b. In such embodiments, the closed conductive loop can be formed with the substrate 122 on the one of the first and second side surfaces 110a and 110b of the second side 108b, and the aperture 132b and the connecting portion 134b can be omitted. Further, in alternative embodiments, the aperture 132b can taper outward as it extends from the first side surface 110a to the second side surface 110b. Yet further, in alternative embodiments, the second electrically conductive trace 114b can be formed such that the electromagnetic coil 124b and the first current transfer portion 126b are formed on the first or outer side surface 110a, and the second current transfer portion 128b is formed on the second or inner side surface 110b. Accordingly, the electromagnetic coil 124b can be formed on either the outer side surface 110a or the inner side surface 110b. Even yet still further, the second electrically conductive trace 114b can include a first electromagnetic coil formed on the first side surface 110a and a second electromagnetic coil formed on the second side surface 110b, where the second electromagnetic coil can be electrically isolated from or electrically coupled to the first electromagnetic coil.

[0031] The electromagnetic coil 124b includes a first coil end 136b, a second coil end 138b spaced from the first coil end 136b, and an elongate line 140b that extends continuously around a central coil axis CA_{C2} of the electromagnetic coil 124b from the first coil end 136b to the second coil end 138b. The central coil axis CA_{C2} extends in the second direction D_2 as shown in Fig. 1, and the elongate line 140b forms at least one ring about the central coil axis CA_{C2} from the first coil end 136b to the second coil end 138b. In particular, the first coil end 136b is spaced closer to the central coil axis CA_{C2} than the second coil end 138b, and the elongate line 140b extends around the central coil axis CA_{C2} from the first coil end 136b to the second coil end 138b so as to form a spiral comprising a plurality of concentric rings. In this embodiment, the electromagnetic coil 124b defines two full and one partial ring; however, in alternative embodiments, the electromagnetic coil may define as few as one ring or more than two full and one partial ring. Further, in this

embodiment, the rings turn at right angles such that each ring has a substantially rectangular or square shape. However, in alternative embodiments each ring can have another suitable shape such as a substantially circular shape and can even extend along multiple sides 108 of the housing 102. Each concentric ring of the plurality of concentric rings is spaced from an immediately adjacent ring of the plurality of concentric rings in a radial direction by a distance A_2 . In at least some embodiments, distance A_2 can be greater than or equal to substantially 100 μm . Further, in at least some embodiments, the distance A_2 can be substantially equal to the distance A_1 or can be different from distance A_1 . The elongate line 140b extends in a clockwise direction from the first coil end 136b to the second coil end 140b as viewed in the second direction D_2 from the electromagnetic coil 124b away from the cavity 112. However, in alternative embodiments, the elongate line 140b can extend in a counter clockwise direction from the first coil end 136b to the second coil end 138b as viewed in the second direction D_2 from the electromagnetic coil 124b away from the cavity 112.

[0032] As shown in Fig. 3, the first electromagnetic coil 114a can be formed on the outer surface 110a of the first side 108a, and the second electromagnetic coil 114b can be formed on the inner surface 110b of the second side 108b. Alternatively, the first electromagnetic coil 114a can be formed on the inner surface 110b of the first side 108a, and the second electromagnetic coil 114b can be formed on the outer surface 110a of the second side 108b. Alternatively still, both the first and second electromagnetic coils 114a and 114b can be formed on the inner surfaces 110b of the first and second sides 108a and 108b, respectively, or both the first and second electromagnetic coils 114a and 114b can be formed on the outer surfaces 110a of the first and second sides 108a and 108b, respectively.

[0033] Turning again to Figs. 1 and 2, the housing body 104 can be mounted onto the substrate 122 via a surface-mount technology. In particular, the substrate 122 can include one or more electrically conductive paths 142, and the housing body 104 can be mounted onto the substrate via the surface mount technology such that the at least one electrically conductive trace 114 is in electrical communication with the one or more electrically conductive paths 142. For example, the at least one electrically conductive trace 114 can be physically and electrically coupled to the one or more electrically conductive paths 142 by reflowing solder balls or solder paste 144 such that the solder balls or solder paste 144 bond to the at least one electrically conductive trace 114 and the one or more electrically conductive paths 142. To further support mounting of the housing body, a

recess 158 can be formed in the respective side 108 of the housing body 104 as shown in Detail 1 of Fig. 2, where the recess 158 can receive the solder ball or solder paste 144. The recess 158 can have any suitable shape such as (without limitation) a quarter of a sphere.

[0034] The lens barrel 116 includes a lens barrel body 146 having a first cylindrically-shaped portion 148 having a first diameter, and a second cylindrically-shaped portion 150 extending from the first cylindrically-shaped portion along the first direction D_1 . The second cylindrically-shaped portion 150 can be coaxial with the first portion 148 and has a second diameter D_2 , smaller than the first diameter D_1 . It will be understood that the body 146 can have any other suitable shape. The lens barrel 116 also includes the magnet 118 and at least one optical lens 120. The magnet 118 can be removably attachable to the body 146 as shown. For example, the magnet 118 can have a tubular shape and can include an inner surface that defines a third diameter that is substantially equal to the second diameter such that the magnet 118 can be press fit around the second cylindrically-shaped portion 150. Note that, in alternative embodiments, the magnet 118 can have another suitable shape and/or can be attached to the body 146 by a method other than or in addition to press fitting such as by an adhesive. Further, the lens barrel 116 can include a plurality of magnets 118. Yet further, the lens barrel body 146 can be integrally formed with the magnet 118 or formed from a magnetic material such that the magnet 118 is integral to and inseparable from the lens barrel body 146.

[0035] In operation, an electrical current is applied to each of the at least one electromagnetic coil 114. The current can be applied to each so as to flow from one of the first current transfer portion and the second current transfer portion of the electrically conductive trace 114 through the coil to the other of the first current transfer portion and the second current transfer portion. The magnetic flux of the magnet 118 responds to the electrical current and urges the magnet 118 to translate the optical lens from a first position to a second position along the first direction. Stated differently, the optical lens can translate along a central axis of the lens barrel CA_{LB} from the first position to the second position, where the central axis is parallel to the first direction. In the first position, the optical lens 120 can be closer to the second end 106b of the housing 104 than in the second position such that the optical lens 120 moves upward when the current is applied. Alternatively, the optical lens 120 can be closer to the second end 106b of the

housing 104 in the second position than in the first position such that the optical lens 120 moves downward when the current is applied.

[0036] To return the optical lens substantially to the first position, the electrical current can be reversed so as to flow from the other of the first current transfer portion and the second current transfer portion to the one of the first current transfer portion and the second current transfer portion. Alternatively, the camera module 100 can include at least one spring, such as two leaf springs 152a and 152b, which can apply a spring force to the lens barrel 116 when the electrical current is removed such that the spring force returns the optical lens 120 substantially to the first position.

[0037] Fig. 8 shows a partially-exploded perspective view of a camera module 800 according to another embodiment. As will be described in further detail below, the camera module 800 is similar to the camera module 100 of Fig. 1 with a few notable exceptions. For example, the camera module 800 has a housing 802 that includes a cylindrically-shaped housing body 804, and the electromagnetic coil 824 has a central coil axis CA_C that extends along the first direction D_1 , rather than the second direction D_2 . Like camera module 100, the camera module 800 can include a substrate 822 such as a printed circuit board onto which the housing 802 is mounted using a surface-mount technology. The housing 802 also includes an electrically conductive trace 814 formed on the housing body 804 using laser direct structuring or insert molding, where the electrically conductive trace 814 defines the electromagnetic coil 824. The camera module 800 also includes a lens barrel 816 that is disposed in the cavity when the camera module 800 is assembled. The lens barrel 816 includes a magnet 818 and an optical lens 820 supported by the lens barrel 816, and consequently supported by the magnet 818. When an electrical current is applied to the electrically conductive trace 814, a magnetic flux of the magnet 818 responds to the current so as to create a Lorentz force that urges the magnet 818 to translate the optical lens 820 from a first position to a second position, different from the first position, along the first direction D_1 . Thus, the magnet 818 and electromagnetic coil 824 operate together as a voice coil motor.

[0038] The housing body 804 defines a first end 806a, an opposed second end 806b spaced from the first end 806a along a first direction D_1 , and a side 808 extending circumferentially around a central axis of the body CA_B from the first end 806a to the second end 806b. The side 108 of the housing body 804 defines a first or outer surface 810a and an opposed second or inner surface 810b. The outer surface 810a and/or the inner surface 810b can be substantially parallel to the first

direction D_1 . Further, the inner surface 810b of the housing body 804 can define a cavity 812 that extends between the first and second ends 806a and 806b along the first direction D_1 . The cavity 812 extends through the first end 806a and the second end 806b, although in alternative embodiments, the cavity 812 may extend through only one of the first and second ends 806a and 806b.

[0039] The housing body 804 can be formed in a manner similar to that of housing body 104 of Fig. 1. In particular, the housing body 804 can be formed from a plastic material that is doped with a conductive additive such as (without limitation) a metal-plastic additive, and can be formed by injection molding the plastic material into the shape of the housing body 804. The plastic material can have a heat deflection temperature that is higher than a reflow temperature of solder that is used to mount the camera module 800 to a substrate 822. The electrically conductive trace 814 can be formed on the side 808 of the housing body 804 by applying a laser to the side 808 of the housing body 804. As the laser draws the pattern for the electrically conductive trace 814, the laser activates the conductive additive so as to define a micro-rough track on the side 808. The metal particles of the micro-rough track can form a base, and one or more layers of metal or metal alloy can be created on the base so as to form the electrically conductive trace 814. For example, the housing body 804 can be bathed in an electroless bath of metal or metal alloy, wherein an additional layer of metal or metal alloy is formed on the micro-rough track each time the housing body 804 is dipped in the bath. The metal or metal alloy can include (without limitation) copper, nickel, and/or gold. Further, the one or more layers can be formed so as to be recessed from (such as shown in Detail 2 of Fig. 2), flush with, or raised from the one of the first and second surfaces 810a and 810b on which the micro-rough track is formed. Thus, the electrically conductive trace 814 is formed directly on the housing body 804, such that the electrically conductive trace 814 is integral to and inseparable from the housing body 804. Further, one or more layers of a protective coating (not shown) may be formed on the exposed surfaces of the at least one electrically conductive trace 114.

[0040] According to alternative embodiments, the electrically conductive trace 814 can be pre-formed using, for example, a wire, and the housing 802 can be formed by insert molding the housing body 804 and the pre-formed electrically conductive trace 814. According to further alternative embodiments, the at least one electrically conductive trace 114 can be formed in part by insert molding and in part using laser direct structuring.

[0041] The electrically conductive trace 814, which is formed on the first side 808 of the housing body 804, comprises an electromagnetic coil 824, a first current transfer portion 826, and a second current transfer portion 828, where each of the first and second current transfer portions 826 and 828 are configured to transfer current between the electromagnetic coil 824 and a substrate 822. Accordingly, the electrically conductive trace 814 defines a closed conductive loop that extends from the substrate 822, through the first current transfer portion 826, through the electromagnetic coil 824, and through the second current transfer portion 828 back to the substrate 822, or vice versa.

[0042] The electrically conductive trace 814 is formed at least partially on the first or outer side surface 810a of the side 808 and at least partially on the second or inner side surface 810b of the side 808, opposite the first side surface 810a. In particular, the electromagnetic coil 824 and the first current transfer portion 826 are formed on the first side surface 810a and the second current transfer portion 828 is formed on the second side surface 810b. The side 808 also includes an upper surface 810c that extends from the outer surface 810a to the inner surface 810b. Further, the electrically conductive trace 814 comprises a connecting portion 834 formed on the upper surface 810c that extends from the electromagnetic coil 824 on the first side surface 810a to the second current transfer portion 828 on the second side surface 810b so as to electrically connect the electromagnetic coil 824 and the second current transfer portion 828. Thus, the connecting portion 834 completes a conductive path between the first side surface 810a and the second side surface 810b.

[0043] Note that, according to alternative embodiments, the connecting portion 834 can extend through an aperture (not shown) in the side 808 similar to the aperture 132a of camera module 100. Further, according to alternative embodiments, the electrically conductive trace 814 can be formed such that the electromagnetic coil 824 and the first current transfer portion 826 are formed on the second side surface 810b, and the second current transfer portion 828 is formed on the first side surface 810a. Accordingly, the electromagnetic coil 824 can be formed on either the outer side surface 810a or the inner side surface 810b. Yet further, the electrically conductive trace 814 can include a first electromagnetic coil formed on the first side surface 810a and a second electromagnetic coil formed on the second side surface 810b, where the second electromagnetic coil can be electrically isolated from or electrically coupled to the first electromagnetic coil.

[0044] The electromagnetic coil 824 includes a first coil end 836, a second coil end 838 spaced from the first coil end 836, and an elongate line 840 that extends continuously around a

central coil axis CA_C of the electromagnetic coil 824 from the first coil end 836 to the second coil end 838. The central coil axis CA_C extends in the first direction D_1 , and in at least some embodiments can be coaxial with a central axis CA_B of the lens barrel 816. The elongate line 840 forms at least one ring about the central coil axis CA_C from the first coil end 836 to the second coil end 838. In particular, the elongate line 840 extends around the central coil axis CA_{C1} from the first coil end 836 to the second coil end 838 so as to form a helix comprising a plurality of concentric rings between the first and second ends 806a and 806b of the housing body 804. In Fig. 8, eleven rings are shown, although in alternative embodiments, the camera module 800 can have as few as one ring or greater than eleven rings. Each concentric ring of the plurality of concentric rings is spaced from an immediately adjacent ring of the plurality of concentric rings in a radial direction by a distance A_3 . In at least some embodiments, the distance A_3 can be greater than or equal to substantially 100 μm . The elongate line 840 extends in a counter clockwise direction from the first coil end 836 to the second coil end 840 as viewed in the first direction D_1 from the first end 806a toward the second end 806b. However, in alternative embodiments, the elongate line 140a can extend in a clockwise direction from the first coil end 836 to the second coil end 838 as viewed in the first direction D_1 from the first end 806a toward the second end 806b.

[0045] The housing body 804 can be mounted onto the substrate 822 via a surface-mount technology. In particular, the substrate 822 can include one or more electrically conductive paths 842, and the housing body 804 can be mounted onto the substrate via the surface mount technology such that the electrically conductive trace 814 is in electrical communication with the one or more electrically conductive paths 842. For example, the electrically conductive trace 814 can be physically and electrically coupled to the one or more electrically conductive paths 842 by reflowing solder balls or solder paste 844 such that the solder balls or solder paste 844 bond to the electrically conductive trace 814 and the one or more electrically conductive paths 842.

[0046] The lens barrel 816 can be configured in a manner similar to that of lens barrel 116 of Fig. 1. In particular, the lens barrel 816 can include a lens barrel body 846 having a first cylindrically-shaped portion 848 having a first diameter, and a second cylindrically-shaped portion 850 extending from the first cylindrically-shaped portion along the first direction D_1 . The second cylindrically-shaped portion 850 has a second diameter D_2 , smaller than the first diameter D_1 . In alternative embodiments, the body 846 can have any other suitable shape. The lens barrel 816 also

includes the magnet 818 and at least one optical lens 820. The magnet 818 can be removably attachable to the body 846 as shown. For example, the magnet 818 can have a tubular shape and can include an inner surface that defines a third diameter D_3 that is substantially equal to the second diameter D_2 such that the magnet 818 can be press fit around the second cylindrically-shaped portion 850. Note that, in alternative embodiments, the magnet 818 can have another suitable shape. Further, in alternative embodiments, the magnet 818 can be attached to the body 846 by a method other than or in addition to press fitting such as by an adhesive. Further, the lens barrel 816 can include a plurality of magnets 818, and the lens barrel body 846 can be integrally formed with the magnet 818 or formed from a magnetic material such that the magnet 818 is integral to and inseparable from the lens barrel body 846.

[0047] In operation, an electrical current is applied the electromagnetic coil 814. The current can be applied so as to flow from one of the first current transfer portion 826 and the second current transfer portion 828 of the electrically conductive trace 814 through the coil 824 to the other of the first current transfer portion 826 and the second current transfer portion 828. The magnetic flux of the magnet 818 responds to the electrical current and urges the magnet 818 to translate the optical lens 820 from a first position to a second position along the first direction. Stated differently, the optical lens 820 can translate along the central axis CA_{LB} of the lens barrel 816 from the first position to the second position, where the central axis is parallel to the first direction. In the first position, the optical lens 820 can be closer to the second end 806b of the housing 804 than in the second position such that the optical lens 820 translates upward when the current is applied. Alternatively, the optical lens 820 can be closer to the second end 806b of the housing 804 in the second position than in the first position such that the optical lens 820 translates downward when the current is applied.

[0048] To return the optical lens substantially to the first position, the electrical current can be reversed so as to flow from the other of the first current transfer portion 826 and the second current transfer portion 828 to the one of the first current transfer portion 826 and the second current transfer portion 828. Alternatively, the camera module 800 can include at least one spring (not shown in Fig. 8) similar to the leaf springs 152a and 152b of Fig. 2, which can apply a spring force to the lens barrel 816 when the electrical current is removed such that the spring force returns the optical lens 820 substantially to the first position.

[0049] Fig. 9 shows a perspective view of a camera module 900 according to another embodiment. The camera module 900 can comprise a housing 102 and a lens barrel 116 that are constructed as described above in relation to Figs. 1 to 7, and the housing 102 can be surface mounted onto a substrate 122 as described above. Further, the camera module 900 can comprise one or more electrical components 902 that are surface mounted onto a surface of the housing 102. Although Fig. 9 shows the component 902 mounted onto an upper surface of the housing, the one or more components 902 can be mounted to any surface of the housing.

[0050] The housing 902 can include one or more electrically conductive traces, such as electrically conductive traces 904a and 904b that provide an electrical path between the one or more electrical components 902 and the substrate 122. The one or more electrical components 902 can be electrically and mechanically coupled to the one or more electrically conductive traces 904a and 904b via solder balls or solder paste 908a and 908b, and the one or more electrically conductive traces 904a and 904b can be electrically and mechanically coupled to traces on the substrate 122 via solder balls or solder paste 906a and 906b.

[0051] The one or more electrically conductive traces 904a and 904b can be formed on a surface of the housing 102 by applying a laser to the surface. As the laser draws the pattern for the one or more electrically conductive traces 904a and 904b, the laser activates the conductive additive of the housing 102 so as to define a micro-rough track on the surface. The metal particles of the micro-rough track can form a base, and one or more layers of metal or metal alloy can be created on the base so as to form the one or more electrically conductive traces 904a and 904b. For example, the housing 102 can be bathed in an electroless bath of metal or metal alloy as discussed above. Thus, the one or more electrically conductive traces 904a and 904b are formed directly on the housing body 104, such that the one or more electrically conductive traces 904a and 904b are integral to and inseparable from the housing body 104. Further, one or more layers of a protective coating (not shown) may be formed on the exposed surfaces of the at least one electrically conductive trace 114.

[0052] According to alternative embodiments, the one or more electrically conductive traces 904a and 904b can be pre-formed using, for example, a wire, and the housing 902 can be formed by insert molding the housing body 904 and the pre-formed electrically conductive traces

904a and 904b. According to further alternative embodiments, the at least one electrically conductive trace 114 can be formed in part by insert molding and in part using laser direct structuring.

[0053] Fig. 10 shows an exploded perspective view of a camera module 1100 according to another embodiment, and Fig. 11 shows a perspective bottom view of a housing 1102 of the camera module 1100. In general, the camera module 1100 includes the housing 1102, a lens barrel 1116, and a liquid lens module 1222. The camera module can also include a substrate (not shown) such as a printed circuit board onto which the housing 1102 is mounted using a surface-mount technology. The lens barrel 1116 includes an optical lens 1120 supported by the lens barrel 1116. Further, the housing 1102 includes at least one electrically conductive trace 1114, such as four electrically conductive traces 1114a to 1114d, formed on at least one surface of the housing body 1104 using laser direct structuring in a manner similar to that described above in relation to electrically conductive traces 904a and 904b of Fig. 9. The at least one electrically conductive trace 1114 extends from the substrate to the liquid lens module 1222 to provide an electrically conductive path between the substrate and the liquid lens module 1222. When an electrical current is provided via the at least one electrically conductive trace 1114 to the liquid lens module 1222, the electrical current causes a wettability of the liquid within the liquid lens module 1222 to change, thereby causing a curvature of the liquid to change to focus on an object. According to alternative embodiments, the at least one electrically conductive trace 1114 can be pre-formed using, for example, a wire, and the housing 1102 can be formed by insert molding the housing body 1104 and the pre-formed at least one electrically conductive trace 1114. According to further alternative embodiments, the at least one electrically conductive trace 114 can be formed in part by insert molding and in part using laser direct structuring.

[0054] The housing body 1104 defines a rectangular cuboid, although alternative embodiments may have any other suitable shape such as a cube or a cylinder. The housing body 1104 defines a first end 1106a, an opposed second end 1106b spaced from the first end 1106a along a first direction D_1 , and at least one side 1108, such as four sides 1108a to 1108d, extending from the first end 1106a to the second end 1106b. Each side 1108 of the housing body 1104 can define a first or outer surface 1110a and an opposed second or inner surface 1110b. The first end 1106a can define an upper or outer surface 1108e and can define an interior surface 1114 having a plurality of threads disposed thereon that are configured to mate with corresponding threads 1118 on the lens

barrel 1116. Further, the inner surface or surfaces 1110b of the housing body 1104 can define a cavity 1112 that extends between the first and second ends 1106a and 1106b along a first direction D_1 . The cavity 1112 extends through the first end 1106a and the second end 1106b, although in alternative embodiments, the cavity 1112 may extend through only one of the first and second ends 1106a and 1106b.

[0055] The housing body 1104 can be formed from a plastic material that is doped with a conductive additive such as (without limitation) a metal-plastic additive, and can be formed by injection molding the plastic material into the shape of the housing body 1104. The plastic material can have a heat deflection temperature that is higher than a reflow temperature of solder that is used to mount the camera module 1100 to a substrate. The at least one electrically conductive trace 1114 can be formed on the at least one side 1108 of the housing body 1104 by applying a laser to the at least one side 1108 of the housing body 1104. For example, the at least one electrically conductive trace 1114 can be formed on an inner surface of the side 1110b and on an inner surface of the first end 1106a such that the at least one electrically conductive trace 1114 extends from the first end 1106b to the inner surface 1114 of the first end 1106a. Alternatively, the at least one electrically conductive trace 1114 can be formed on an outer surface of the side 1110b and an outer surface of the first end 1106a. As the laser draws the pattern for the at least one electrically conductive trace 1114, the laser activates the conductive additive so as to define a micro-rough track on the at least one side 1108. The metal particles of the micro-rough track can form a base, and one or more layers of metal or metal alloy can be created on the base so as to form the at least one electrically conductive trace 1114. For example, the housing body 1104 can be bathed in an electroless bath of metal or metal alloy in a manner similar to that described above. Further, the one or more layers can be formed so as to be recessed from (as shown in Detail 2 of Fig. 2), flush with, or raised from the one of the first and second surfaces 1110a and 1110b on which the micro-rough track is formed. Thus, the at least one electrically conductive trace 1114 is formed directly on the housing body 1104, such that the at least one electrically conductive trace 1114 is integral to and inseparable from the housing body 1104.

[0056] The housing body 1104 can be mounted onto a substrate via a surface-mount technology. In particular, the substrate can include one or more electrically conductive paths, and the housing body 1104 can be mounted onto the substrate via the surface mount technology such

that the at least one electrically conductive trace 1114 is in electrical communication with the one or more electrically conductive paths of the substrate. For example, the at least one electrically conductive trace 1114 can be physically and electrically coupled to the one or more electrically conductive paths of the substrate by reflowing solder balls or solder paste (not shown) such that the solder balls or solder paste bond to the at least one electrically conductive trace 1114 and the one or more electrically conductive paths of the substrate.

[0057] In operation, an electrical current is applied the liquid lens module 1122 via the at least one electrically conductive trace 1114. The current charges a substrate on which the liquid of the liquid lens module 1122 is disposed, causing a wettability of the liquid in the liquid lens module 1122 to change. This in turn, causes the curvature of the liquid in the liquid lens module 1122 to change so as to focus on an object. To return the liquid to its initial state, the electrical current is removed.

[0058] It should be appreciated that the present disclosure can include at least any one up to all of the following examples:

Example 1. A camera module comprising:

a housing including:

a housing body defining a first end, an opposed second end spaced from the first end along a first direction, and at least one side extending from the first end to the second end, the housing body defining a cavity that extends between the first and second ends along the first direction; and

at least one electrically conductive trace formed on the at least one side, the at least one electrically conductive trace defining an electromagnetic coil; and

a lens barrel disposed in the cavity, the lens barrel including a magnet and an optical lens supported by the magnet, wherein a magnetic flux of the magnet is responsive to a current applied to the electromagnetic coil so as to create a Lorentz force that urges the magnet to translate the optical lens from a first position to a second position, different from the first position, along the first direction.

Example 2. The camera module of example 1, wherein the housing body includes a plastic material doped with a conductive additive.

Example 3. The camera module of example 2, wherein the plastic material has a heat deflection temperature that is higher than a solder reflow temperature.

Example 4. The camera module of any of examples 2 and 3, wherein the housing body includes at least one micro-rough track formed by activating the conductive additive with a laser.

Example 5. The camera module of example 4, wherein the at least one electrically conductive trace comprises at least one layer of electrically conductive material formed on the at least one micro-rough track.

Example 6. The camera module of any of examples 1 to 5, comprising a substrate having one or more electrically conductive paths, and the housing body is mounted onto the substrate via a surface mount technology such that the at least one electrically conductive trace is in electrical communication with the one or more electrically conductive paths.

Example 7. The camera module of example 6, wherein the at least one electrically conductive trace is soldered to the one or more electrically conductive paths.

Example 8. The camera module of any of examples 1 to 7, wherein the at least one side comprises at least two sides, and the at least one electrically conductive trace includes at least two electrically conductive traces, each formed on a different one of the at least two sides of the housing.

Example 9. The camera module of any of examples 1 to 8, wherein the at least one side defines an outer surface, and at least a portion of the at least one electrically conductive trace is formed on the outer surface.

Example 10. The camera module of any of examples 1 to 8, wherein the at least one side defines an inner surface, and at least a portion of the at least one electrically conductive trace is formed on the inner surface.

Example 11. The camera module of any of examples 1 to 8, wherein the at least one side defines an inner surface and an outer surface, and at least a portion of the at least one electrically conductive trace is formed on the inner surface and at least another portion of the at least one electrically conductive trace is formed on the outer surface.

Example 12. The camera module of any of examples 1 to 8, wherein the at least one side defines an inner surface and an outer surface, and the at least one electrically conductive trace comprises at least two electrically conductive traces, each defining an electromagnetic coil, wherein the electromagnetic coil of a first of the at least two electrically conductive traces is formed on the

inner surface and the electromagnetic coil of a second of the at least two electrically conductive traces is formed on the outer surface.

Example 13. The camera module of any of examples 1 to 12, wherein the at least one electrically conductive trace comprises the electromagnetic coil and first and second current transfer portions, each of the first and second current transfer portions configured to transfer current between the electromagnetic coil and a substrate.

Example 14. The camera module of example 13, wherein the at least one electrically conductive trace is formed on opposed first and second side surfaces of the at least one side such that the first current transfer portion and the electromagnetic coil are formed on the first side surface and the second current transfer portion is formed on the second side surface.

Example 15. The camera module of example 14, wherein the at least one side includes an internal surface that defines an aperture extending from the first side surface to the second side surface, and the at least one electrically conductive trace comprises a connecting portion formed on the internal surface that extends from the electromagnetic coil on the first side surface to the second current transfer portion on the second side surface.

Example 16. The camera module of example 15, wherein the aperture has a conical shape that tapers as it extends from the first side surface to the second side surface.

Example 17. The camera module of example 15, wherein the aperture has a conical shape that tapers as it extends from the second side surface to the first side surface.

Example 18. The camera module of any of examples 16 and 17, wherein the aperture extends along a second direction that is perpendicular to first direction, and the internal surface extends at an angle with respect to the first direction that is at least substantially 45 degrees.

Example 19. The camera module of example 13, wherein the at least one electrically conductive trace is formed entirely on a single side surface of the at least one side such that the first current transfer portion, the electromagnetic coil, and the second current transfer portion are formed on the single side surface.

Example 20. The camera module of any of examples 1 to 19, wherein the at least one electromagnetic coil is formed on a first side surface of the at least one side, the at least one side surface being substantially parallel to the first direction.

Example 21. The camera module of any of examples 1 to 20, wherein the electromagnetic coil includes a first coil end, a second coil end spaced from the first coil end, and an elongate line that extends continuously around a central coil axis of the electromagnetic coil from the first coil end to the second coil end.

Example 22. The camera module of example 21, wherein the central coil axis extends in a second direction substantially perpendicular to the first direction, and the elongate line forms at least one ring about the central coil axis from the first coil end to the second coil end.

Example 23. The camera module of example 22, wherein the first coil end is spaced closer to the central coil axis than the second coil end, and the elongate line extends around the central coil axis from the first coil end to the second coil end so as to form a spiral comprising a plurality of concentric rings.

Example 24. The camera module of examples 22, wherein each concentric ring of the plurality of concentric rings is spaced from an immediately adjacent ring of the plurality of concentric rings in a radial direction by a distance that is greater than or equal to substantially 100 μm .

Example 25. The camera module of any of examples 21 to 24, wherein the elongate line extends in a clockwise direction from the first coil end to the second coil end as viewed in the second direction from the electromagnetic coil toward the cavity.

Example 26. The camera module of any of examples 21 to 24, wherein the elongate line extends in a counter clockwise direction from the first coil end to the second coil end as viewed in the second direction from the electromagnetic coil toward the cavity.

Example 27. The camera module of example 21, wherein the central coil axis extends in the first direction, and the elongate line forms at least one ring about the central coil axis from the first coil end to the second coil end.

Example 28. The camera module of example 27, wherein first coil end is spaced closer to the first end of the housing body than the second coil end, and the elongate line extends continuously around the central coil axis from the first coil end to the second coil end so as to form a helix comprising a plurality of concentric rings between the first and second ends of the housing body.

Example 29. The camera module of example 28, wherein the coil extends in a clockwise direction from the first coil end to the second coil end as viewed in the first direction from the first end toward the second end.

Example 30. The camera module of example 28, wherein the coil extends in a counter clockwise direction from the first coil end to the second coil end as viewed in the first direction from the first end toward the second end.

Example 31. The camera module of any of examples 1 to 30, comprising a spring configured to return the lens barrel from the second position to the first position along the direction when the application of the current to the electromagnetic coil is terminated.

Example 32. The camera module of any of examples 1 to 30, wherein reversal of the current applied the electromagnetic coil causes the magnet to translate the lens barrel with the optical lens from the second position to a third position along a direction opposite the direction.

Example 33. The camera module of any of examples 1 to 32, wherein the lens barrel includes a lens barrel body and the magnet is attached to the lens barrel body.

Example 34. The camera module of any of examples 1 to 32, wherein the lens barrel includes a lens barrel body that is formed at least partially from a magnetic material.

Example 35. A method of manufacturing a camera module, the method comprising:
applying a laser to at least one side of a housing body of the camera module to define a micro-rough track on the at least one side;

creating at least one electrically conductive trace on the micro-rough track so as to define an electromagnetic coil; and

positioning a lens barrel in an interior cavity of the housing body such that a magnetic flux of a magnet of the lens barrel is responsive to electrical current applied to the electromagnetic coil so as to create a Lorentz force that urges a lens supported by the magnet to translate in a first direction from a first position to a second position, different from the first position.

Example 36. The method of example 35, comprising forming the housing body for the camera module by injection molding a plastic material doped with a conductive additive.

Example 37. The method of any of examples 35 and 36, wherein creating the at least one electrically conductive trace comprises plating the at least micro-rough track with at least one layer

of an electrically conductive material so as to form at the least one electrically conductive trace on the at least one side.

Example 38. The method of any of examples 36 and 37, wherein the plastic material has a heat deflection temperature that is higher than a solder reflow temperature.

Example 39. The method of any of examples 35 to 38, comprising mounting the housing body onto a substrate having one or more electrically conductive paths via a surface mount technology such that the at least one electrically conductive trace is in electrical communication with the one or more electrically conductive paths.

Example 40. The method of example 39, wherein the mounting comprises soldering the at least one electrically conductive trace to the one or more electrically conductive paths.

Example 41. The method of any of examples 35 to 40, comprising performing the laser direct structuring on at least two sides of the housing body to form an electrically conductive trace on each of the at least two sides.

Example 42. The method of any of examples 35 to 41, comprising forming at least a portion of the at least one electrically conductive trace on an outer surface of the at least one side of the housing body.

Example 43. The method of any of examples 35 to 42, comprising forming at least a portion of the least one electrically conductive trace on an inner surface of the at least one side of the housing body.

Example 44. The method of any of examples 35 to 41, comprising forming at least a portion of the at least one electrically conductive trace on the inner surface of the at least one side of the housing body and forming at least another portion of the at least one electrically conductive trace on an outer surface of the at least one side of the housing body.

Example 45. The method of any of examples 35 to 44, comprising forming a first electromagnetic coil of the at least one electrically conductive trace on an inner surface of the at least one side of the housing body and forming a second electromagnetic coil of the at least one electrically conductive trace on an outer surface of the at least one side of the housing body.

Example 46. The method of any of examples 35 to 45, comprising forming a first current transfer portion and the electromagnetic coil of the electrically conductive trace on a first side

surface of the at least one side and forming a second current transfer portion on a second side surface of the at least one side.

Example 47. The method of example 46, comprising forming an aperture through the at least one side, and forming a connecting portion of the electrically conductive trace through the aperture from the electromagnetic coil on the first side surface to the second current transfer portion on the second side surface.

Example 48. The method of any of examples 35 to 43, comprising forming the at least one electrically conductive trace entirely on a single side surface of the at least one side.

Example 49. The method of any of examples 35 to 48, comprising forming the at least one electromagnetic coil on a first side surface of the at least one side, the first side surface being substantially parallel to the first direction.

Example 50. The method of any of examples 35 to 48, comprising forming the electromagnetic coil continuously around a central coil axis of the electromagnetic coil that extends in a second direction substantially perpendicular to the first direction such that the electromagnetic coil forms at least one ring about the central coil axis.

Example 51. The method of any of examples 35 to 48, comprising forming the electromagnetic coil continuously around a central coils axis that extends in the first direction such that the electromagnetic coil forms at least one ring about the central coil axis.

Example 52. The method of any of examples 35 to 51, comprising attaching the magnet to a lens barrel body of the lens barrel.

Example 53. The method of any of examples 35 to 51, comprising at least partially forming a lens barrel body of the lens barrel from a magnetic material.

Example 54. A method of operating the camera module of any one of examples 1 to 34, the method comprising:

applying an electrical current to the at least one electromagnetic coil formed on the at least one side of the housing body;

causing a magnetic flux of the magnet to the electrical to respond to the electrical current so as to urge the magnet to translate the optical lens from the first position to the second position along the first direction.

Example 55. The method of example 54, comprising applying a spring force to the lens barrel when the electrical current is removed such that the spring force returns the optical lens substantially to the first position.

[0059] The embodiments described in connection with the illustrated embodiments have been presented by way of illustration, and the present invention is therefore not intended to be limited to the disclosed embodiments. Furthermore, the structure and features of each the embodiments described above can be applied to the other embodiments described herein. Accordingly, those skilled in the art will realize that the invention is intended to encompass all modifications and alternative arrangements included within the spirit and scope of the invention, as set forth by the appended claims.

CLAIMS

What is Claimed:

1. A camera module comprising:
a housing including:
a housing body defining a first end, an opposed second end spaced from the first end along a first direction, and at least one side extending from the first end to the second end, the housing body defining a cavity that extends between the first and second ends along the first direction; and
at least one electrically conductive trace formed on the at least one side, the at least one electrically conductive trace defining an electromagnetic coil; and
a lens barrel disposed in the cavity, the lens barrel including a magnet and an optical lens supported by the magnet, wherein a magnetic flux of the magnet is responsive to a current applied to the electromagnetic coil so as to create a Lorentz force that urges the magnet to translate the optical lens from a first position to a second position, different from the first position, along the first direction.
2. The camera module of claim 1, wherein the housing body includes a plastic material doped with a conductive additive.
3. The camera module of claim 2, wherein the plastic material has a heat deflection temperature that is higher than a solder reflow temperature.
4. The camera module of claim 2, wherein the housing body includes at least one micro-rough track formed by activating the conductive additive with a laser.
5. The camera module of claim 4, wherein the at least one electrically conductive trace comprises at least one layer of electrically conductive material formed on the at least one micro-rough track.
6. The camera module of claim 1, comprising a substrate having at least one electrically conductive path, and wherein the housing body is mounted onto the substrate via a surface mount

technology to place the at least one electrically conductive trace in electrical communication with the at least one electrically conductive path.

7. The camera module of claim 6, wherein the at least one electrically conductive trace is soldered to the at least one electrically conductive path.

8. The camera module of any one of claims 1-7, wherein the at least one side defines an outer surface, and at least a portion of the at least one electrically conductive trace is formed on the outer surface.

9. The camera module of any one of claims 1-8, wherein the at least one side defines an inner surface, and at least a portion of the at least one electrically conductive trace is formed on the inner surface.

10. The camera module of any one of claims 1-8, wherein the at least one side defines an inner surface and an outer surface, and at least a portion of the at least one electrically conductive trace is formed on the inner surface and at least another portion of the at least one electrically conductive trace is formed on the outer surface.

11. The camera module of any one of claims 1-8, wherein the at least one side defines an inner surface and an outer surface, and the at least one electrically conductive trace comprises at least two electrically conductive traces, each defining an electromagnetic coil, wherein the electromagnetic coil of a first of the at least two electrically conductive traces is formed on the inner surface and the electromagnetic coil of a second of the at least two electrically conductive traces is formed on the outer surface.

12. The camera module of any one of claims 1-8, wherein the at least one side includes an internal surface that defines an aperture extending from the first side surface to the second side surface, and the at least one electrically conductive trace comprises a connecting portion formed on

the internal surface that extends from the electromagnetic coil on the first side surface to the second current transfer portion on the second side surface.

13. The camera module of claim 12, wherein the aperture has a conical shape that tapers as it extends from the first side surface to the second side surface.

14. A method of manufacturing a camera module, the method comprising:
applying a laser to at least one side of a housing body of the camera module to define a micro-rough track on the at least one side; and
creating at least one electrically conductive trace on the micro-rough track so as to define an electromagnetic coil.

15. The method of claim 14, wherein creating the at least one electrically conductive trace comprises plating the at least micro-rough track with at least one layer of an electrically conductive material so as to form at the least one electrically conductive trace on the at least one side.

16. The method of any one of claims 14-15, further comprising positioning a lens barrel in an interior cavity of the housing body such that a magnetic flux of a magnet of the lens barrel is responsive to electrical current applied to the electromagnetic coil so as to create a Lorentz force that urges a lens supported by the magnet to translate in a first direction from a first position to a second position, different from the first position.

17. The method of any one of claims 14-16, further comprising forming the housing body for the camera module by injection molding a plastic material doped with a conductive additive.

18. The method of claim 17, wherein the plastic material has a heat deflection temperature that is higher than a solder reflow temperature.

19. The method of any one of claims 14-19, further comprising mounting the housing body onto a substrate having one or more electrically conductive paths via a surface mount technology such

that the at least one electrically conductive trace is in electrical communication with the one or more electrically conductive paths.

20. A method of operating the camera module of claim 1, the method comprising:

applying an electrical current to the at least one electromagnetic coil formed on the at least one side of the housing body;

causing a magnetic flux of the magnet to the electrical to respond to the electrical current so as to urge the magnet to translate the optical lens from the first position to the second position along the first direction.

1/7

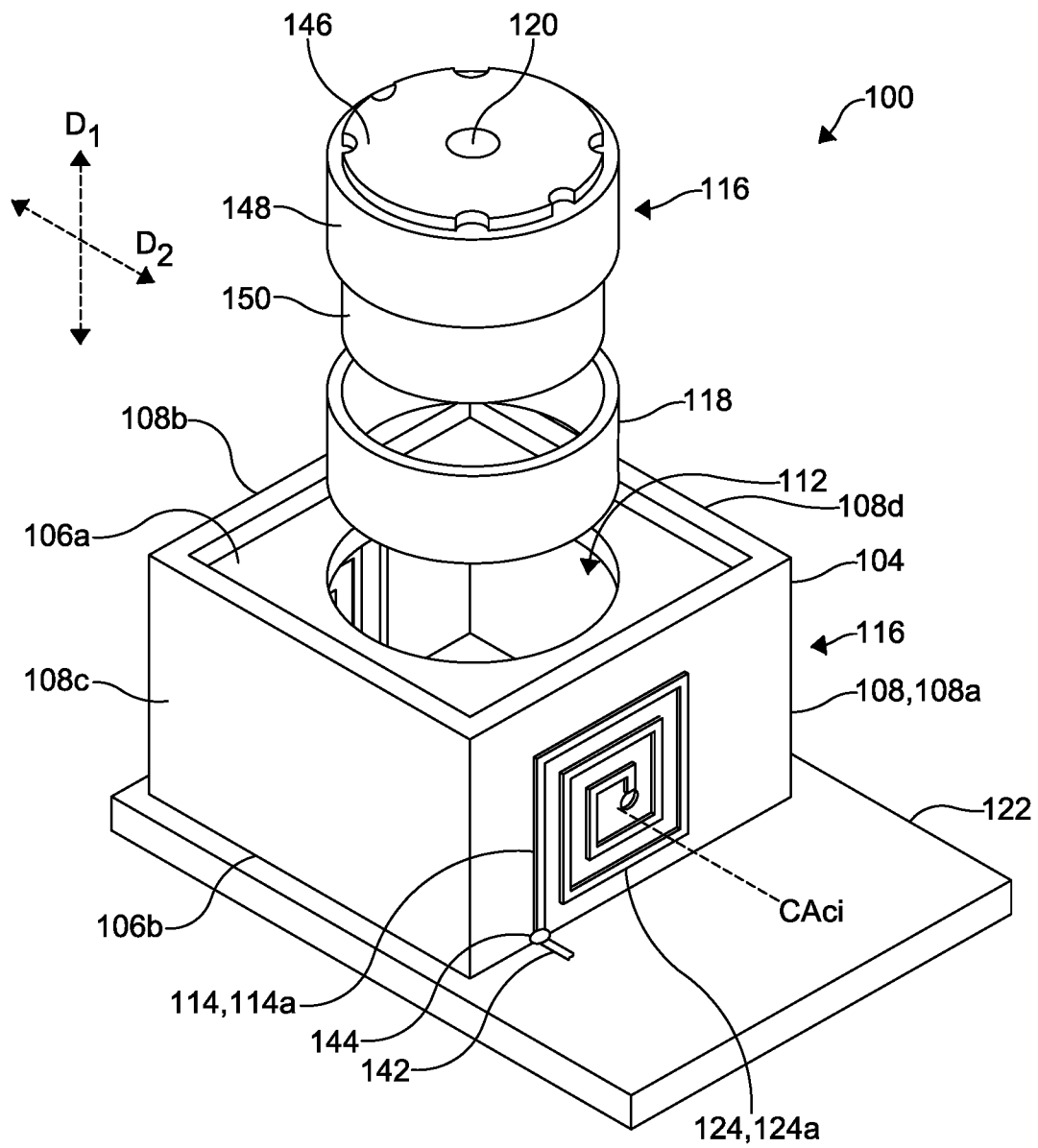


FIG. 1

2/7

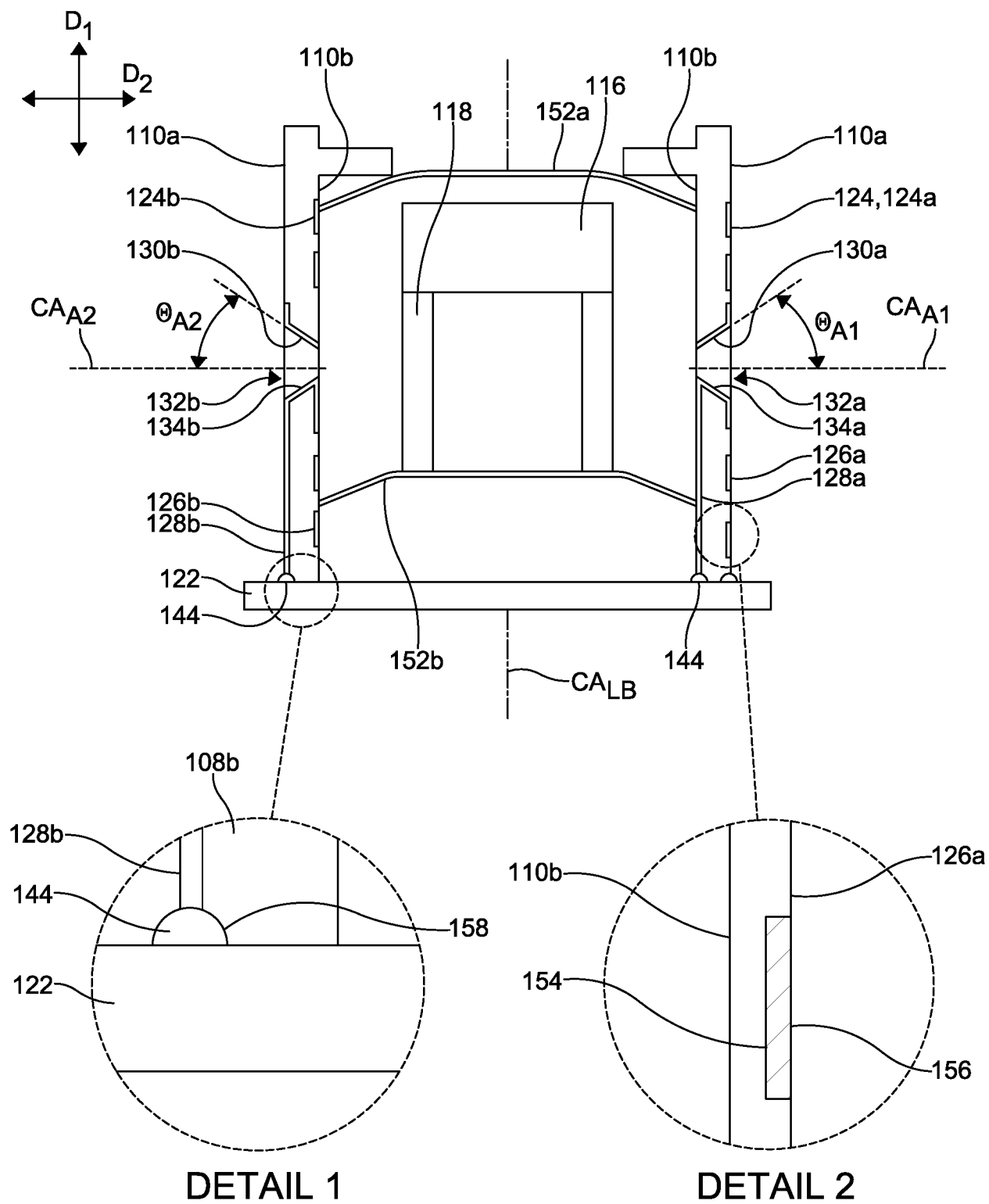


FIG. 2

3/7

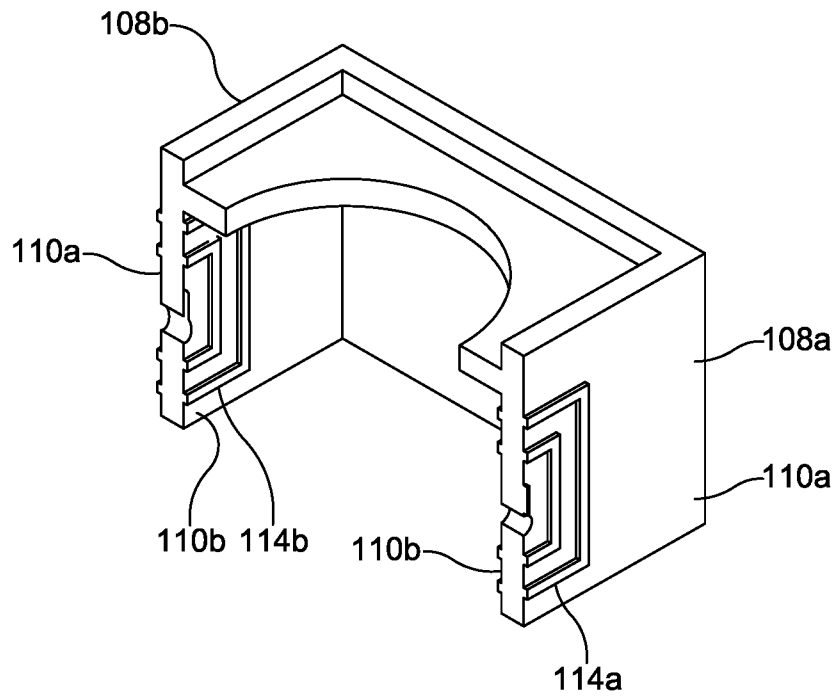


FIG. 3

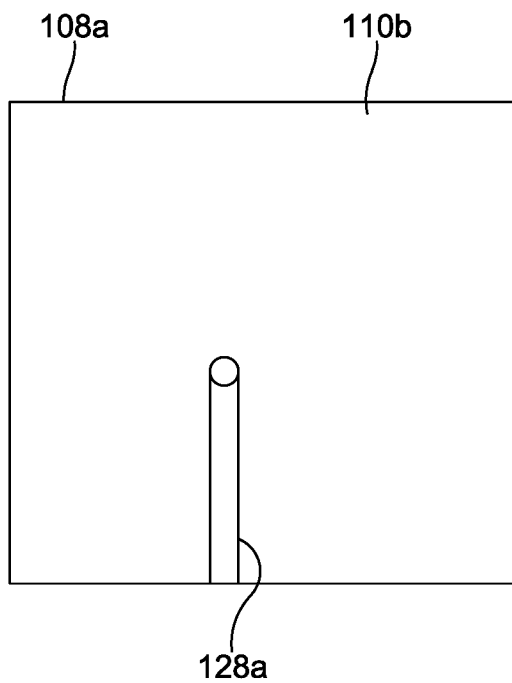


FIG. 4

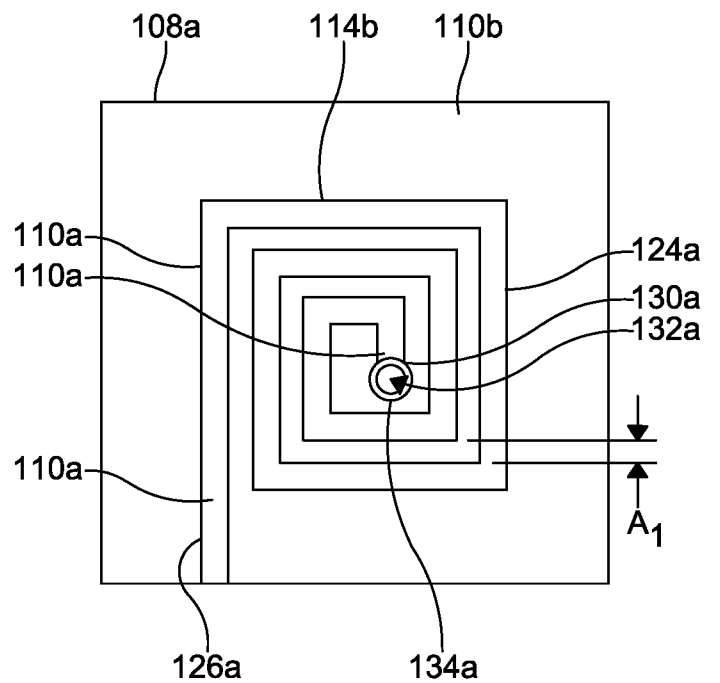


FIG. 5

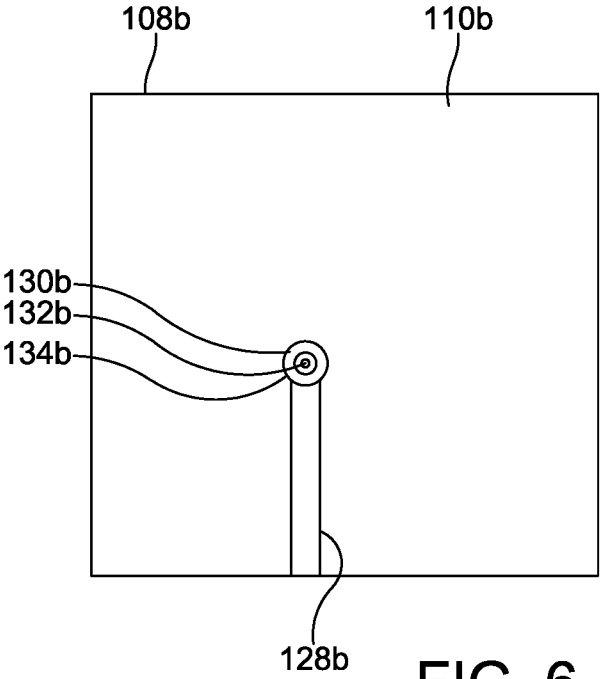


FIG. 6

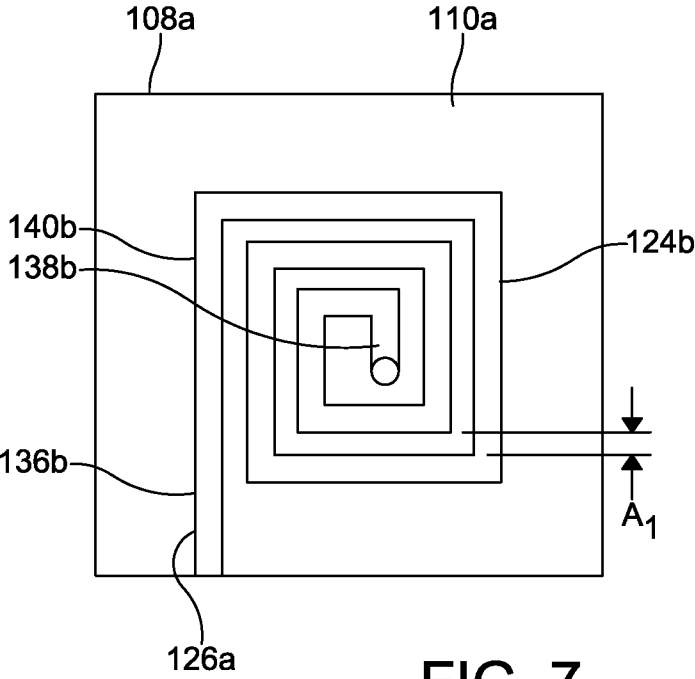
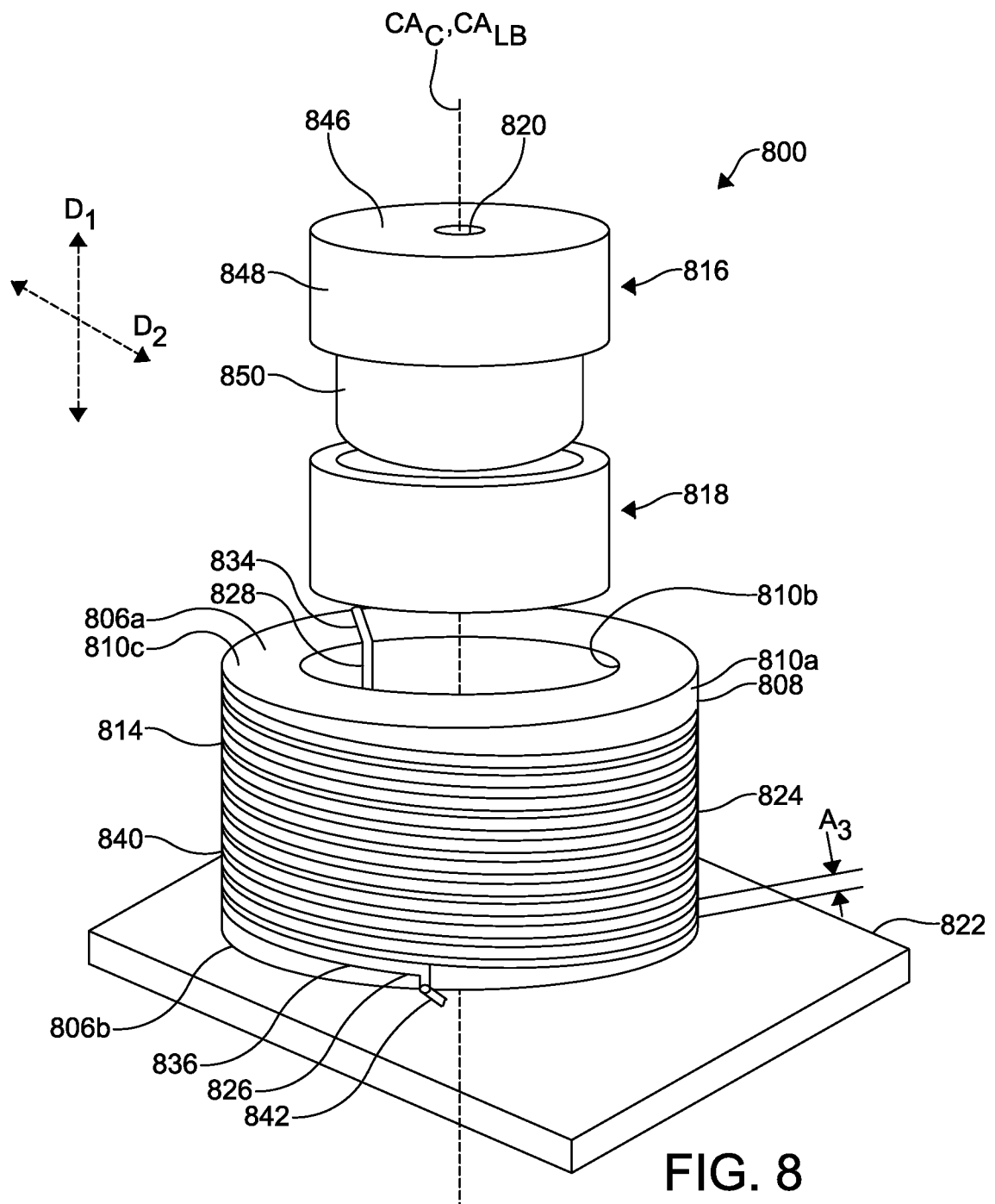
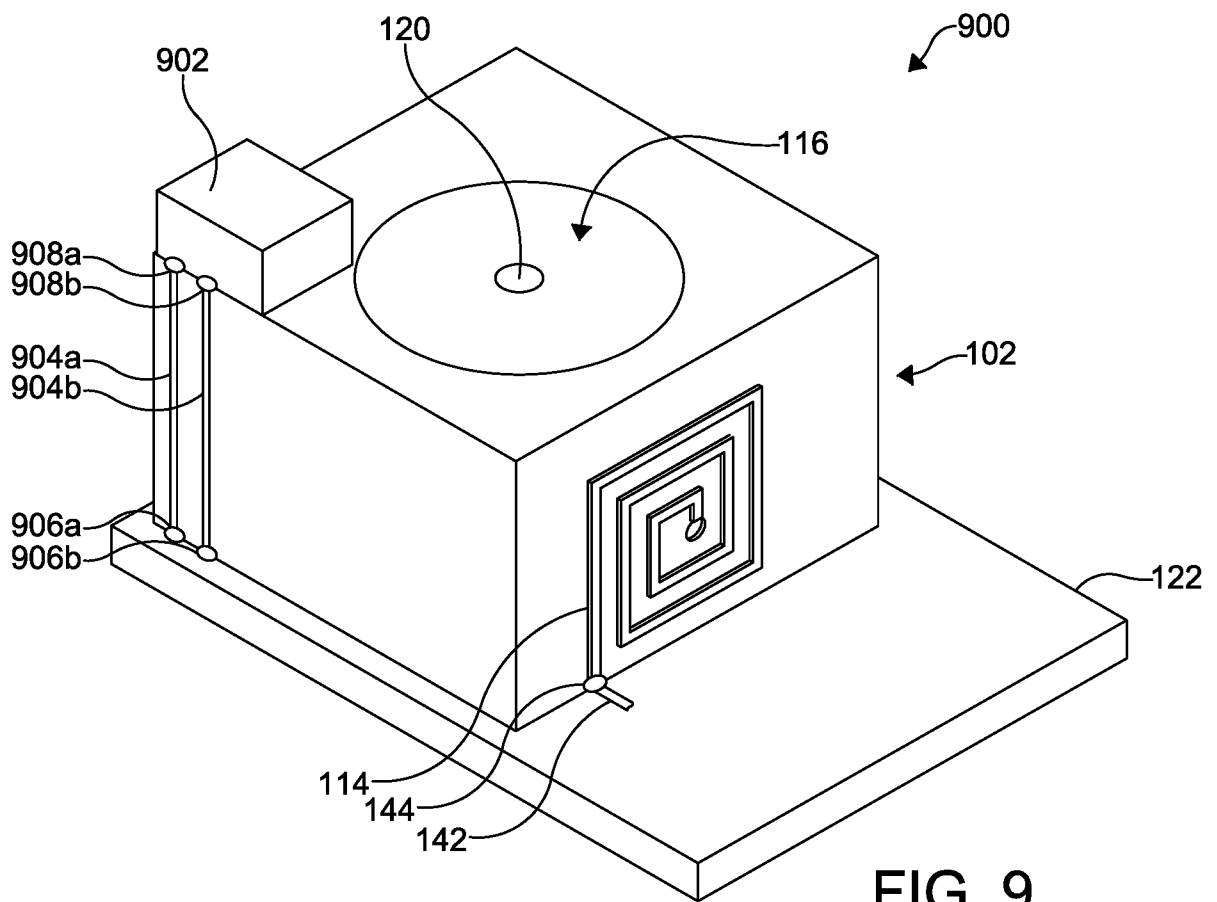


FIG. 7

5/7



6/7



7/7

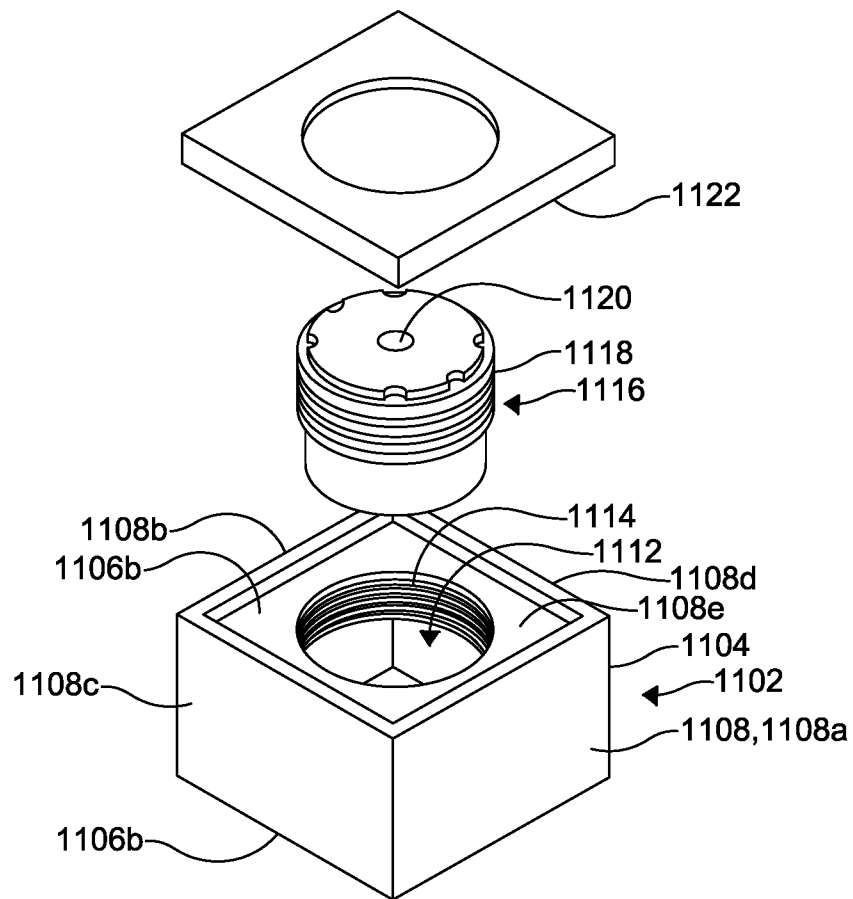


FIG. 10

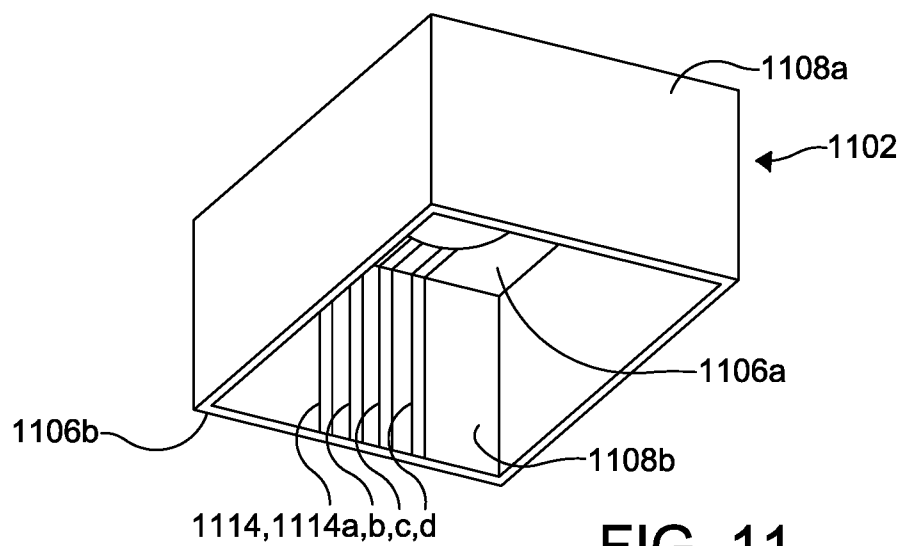


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2016/054909

A. CLASSIFICATION OF SUBJECT MATTER

INV. G02B7/04

ADD.

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)

G02B

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/098434 A1 (BAIK JAE HO [KR] ET AL) 10 April 2014 (2014-04-10)	1,3,6-13
Y	paragraphs [0017], [0035]; figures 1-4	2,4,5, 12-20
X	----- JP 2011 133661 A (OLYMPUS CORP) 7 July 2011 (2011-07-07)	1
A	the whole document	2-20
Y	----- US 2014/050469 A1 (SONG XIAO JUN [CN]) 20 February 2014 (2014-02-20)	2,4,5, 14-20
Y	----- KR 2009 0062890 A (KOREA MACH & MATERIALS INST [KR]) 17 June 2009 (2009-06-17) abstract; figures 2,3	2,4,5, 14-20
	----- -/--	

☒ 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

"&" document member of the same patent family

Date of the actual completion of the international search

24 October 2016

Date of mailing of the international search report

02/11/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2

NL - 2280 HV Rijswijk

Tel. (+31-70) 340-2040,

Fax: (+31-70) 340-3016

Authorized officer

Elflein, Wilhelm

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2016/054909

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	W0 2015/005712 A1 (LG INNOTEK CO LTD [KR]) 15 January 2015 (2015-01-15) paragraphs [0022], [0027]; figure 5 -----	6,7,19
Y	W0 2014/025167 A1 (3HVISION CO LTD [KR]) 13 February 2014 (2014-02-13) abstract; figures 1-5 paragraph [0048] -----	5,12-20
A	US 2012/008220 A1 (LEE SEONGMIN [KR] ET AL) 12 January 2012 (2012-01-12) abstract; figure 2 -----	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2016/054909

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014098434 A1	10-04-2014	CN 103728709 A KR 101328301 B1 US 2014098434 A1	16-04-2014 14-11-2013 10-04-2014
JP 2011133661 A	07-07-2011	NONE	
US 2014050469 A1	20-02-2014	CN 202837644 U TW M449282 U US 2014050469 A1	27-03-2013 21-03-2013 20-02-2014
KR 20090062890 A	17-06-2009	NONE	
WO 2015005712 A1	15-01-2015	CN 105324710 A KR 20150007672 A US 2016173744 A1 WO 2015005712 A1	10-02-2016 21-01-2015 16-06-2016 15-01-2015
WO 2014025167 A1	13-02-2014	CN 104541199 A KR 101314178 B1 WO 2014025167 A1	22-04-2015 02-10-2013 13-02-2014
US 2012008220 A1	12-01-2012	CN 102315748 A CN 105048760 A US 2012008220 A1 US 2014103747 A1 US 2016043622 A1	11-01-2012 11-11-2015 12-01-2012 17-04-2014 11-02-2016