



TM), European (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, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

MAGNETIC RECORDING HEAD WITH MAGNETIC WALL ANGLE

BACKGROUND

5 Data storage devices store digitally encoded information or data on a magnetic storage media. Data is stored on the storage media using a magnetic recording head. Illustrative magnetic recording heads include a main pole having a pole tip and one or more auxiliary poles. A coil is energized to generate a magnetic flux path in the main pole and the one or more auxiliary poles to
10 magnetically record data on a magnetic storage layer of the storage media. Data can be stored on the magnetic storage layer in a longitudinal or perpendicular pattern. Illustrative data storage media include rotating discs having a plurality of concentric data tracks. Heads are positioned relative to one or more of the plurality of concentric data tracks to encode the data on the magnetic storage
15 layer. Typically heads are orientated at a skew angle relative to the one or more concentric data tracks. Skew is defined as the angle between the head and a center-line of the track. A large skew angle can interfere with recording and contribute to adjacent track erasures. Embodiments of the present application provide solutions to these and other problems, and offer other advantages over
20 the prior art. The above discussion provides background information and is not intended to be used as a basis for determining the scope of the claimed subject matter.

SUMMARY

The application provides a pole tip shield for a pole tip of a write element.
25 The pole tip shield extends along sides of the pole tip to provide a magnetic wall angle or narrower magnetic profile along a leading edge portion of the pole tip. As disclosed, the magnetic wall angle reduces adjacent track erasures or

-2-

interference to compensate for the skew angle of the head. In illustrated embodiments, pole tip shield includes different thickness, width dimensions or magnetic material along side portions thereof. The different dimensions provide different magnetic moments along a length of the pole tip shield to provide the magnetic wall angle to compensate for adjacent track interference ATI or skew angle. In illustrated embodiments, the pole tip shield is generally "U" shaped. In illustrated embodiments, the pole tip shield provides a magnetic wall angle for a rectangular shaped pole tip. In illustrated embodiments, the write element also includes a trailing edge shield separate from the pole tip shield. Other features and benefits that characterize embodiments of the present invention will be apparent upon reading the following detailed description and review of the associated drawings. The claimed subject matter is not limited to implementations that provide advantages or that solves any or all of the problems discussed in the Background section of the application.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of one embodiment of a recording head illustrating an air bearing surface of the head which faces the storage media or disc surface.

FIG. 2 is a cross-sectional view of the recording head as taken along line 2—2 of FIG. 1.

FIGS. 3A-3C schematically illustrate embodiments of a write element of a recording head for encoding data.

FIG. 4 is a schematic illustration of an orientation of a head relative to a data track on a magnetic storage media.

FIG. 5 schematically illustrates an embodiment of a pole tip having a wall angle to compensate for skew of the head relative to data tracks on the magnetic storage media.

-3-

FIGS. 6A-6C schematically illustrate embodiments of a pole tip shield for a pole tip of a write element.

FIG. 7 schematically illustrates a magnetic field profile having a magnetic wall angle to reduce ATI.

5 FIGS. 8A-8B schematically illustrate embodiments of a pole tip shield for a pole tip of a write element having stepped thickness segments.

FIG. 8C is a cross-sectional view taken along line 8C - 8C of FIG. 8B illustrating a profile of the pole tip.

10 FIGS. 8D-8G schematically illustrate embodiments of a pole tip shield having a variable geometry to shape the magnetic wall angle of the pole tip.

FIGS. 9A-9B schematically illustrate embodiments of a pole tip shield for a pole tip of a write element having stepped thickness segments and a contoured pole tip.

15 FIG. 10A-10B schematically illustrate embodiments of a write element including a pole tip shield.

FIGS. 11A-11E schematically illustrate embodiments of a write element including a pole tip shield magnetically connected to an auxiliary pole.

20 FIGS. 12A-12B illustrate embodiments of a write element including a pole tip shield magnetically connected to a first auxiliary pole and a leading edge shield spaced from the pole tip shield and magnetically connected to a second auxiliary pole.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

25 FIGS. 1-2 illustrate an embodiment of a magnetic recording head 106 to write or read data. In the illustrated embodiment, the head 106 includes a write element 120 and a read element 122 formed on a substrate 124, for example, using thin film deposition techniques. As shown, the write element 122 is fabricated

-4-

proximate to a trailing edge 125 of the head spaced from a leading edge 126 of the head and substrate 124. In the illustrated embodiment, the read element 122 includes a sensor 130 that is configured to read the magnetically encoded data from a data storage media or disc. The sensor 130 is disposed between shields
5 132, 134 to isolate the sensor 130 from external magnetic fields that might interfere with read operations. Illustrative sensor elements 130 include magnetoresistive, giant magnetoresistive (GMR), tunneling magnetoresistive (TMR) or other sensors which, read magnetically encoded data.

As shown, the write element 120 includes a main pole 140 and an auxiliary
10 pole 142. The main pole 140 and auxiliary pole 142 are magnetically connected via yoke portion 144 (shown in FIG. 2) to form a magnetic flux path. A conductive coil 146 is wound about the yoke portion 144 to induce a magnetic flux in the main pole 140 and the auxiliary pole 142. An insulating material fills a gap or area between the main pole 140 and auxiliary pole 142 and surrounds the
15 conductive coil 146 to electrically insulate the conductive coil 146 from the main and auxiliary poles 140, 142. Embodiments disclosed herein include a pole tip shield 200 as shown in FIG. 1 and as described more fully herein.

In the illustrated embodiment, the write element 120 and read element 122 are formed along an air bearing surface 147 of the head which faces a surface of
20 the data storage media or disc. In an illustrated embodiment, rotation of the disc creates an air flow path along the air bearing surface 147 of the head. Air flows along the air bearing surface 147 from the leading edge 126 to the trailing edge 125 of the head. For proximity or near proximity recording, the air flow along the air bearing surface 147 is pressurized to provide a lifting force so that the head
25 "floats" above the data storage media or disc 102. In illustrated embodiments, the air bearing surface 147 of the head is patterned using known etching processes to provide an optimum pressure profile and pitch for read and/or write operations.

-5-

As shown in FIGS. 1-2, the main pole 140 has a pole tip 148 along the air bearing surface 147 of the head. Pole tip 148 can be an extension of the main pole 140 (as shown in FIG. 1) or a separate connected element located on either the leading side of the main pole 140 (as shown in FIG. 3A) or the trailing side (as shown in FIG. 3B). Typically, read and write elements 120, 122 are deposited on a wafer and the wafer is sliced to form the etched surfaces of the air bearing surface 147 of the head.

FIGS. 3A-3B are side cross-sectional views illustrating different write element embodiments or structures configured to record or write data to the magnetic storage media or disc 102. In each of the embodiments, the data storage media includes a magnetic recording layer 150 and a magnetic backing layer 152, although application is not limited to the particular storage media shown. For example, in another embodiment, a non-magnetic layer is interposed between the magnetic recording layer 150 and the magnetic backing layer 152. Embodiments disclosed in the application can also be used with an exchange coupled composite (ECC) media. In the illustrated embodiment, coil 146 is energized to induce the magnetic flux. The direction of the current in the coil 146 is reversed to change the direction of the magnetic flux path to record data bits in up and down orientations to perpendicularly encode data on the disc or storage media.

In the illustrated embodiment shown in FIG. 3A, the write element includes main pole 140 having a pole tip 148 and an auxiliary pole 142 spaced from the pole tip 148 in the trailing edge direction. When the coil 146 is energized, a flux path or circuit is formed as shown to perpendicularly record data on the magnetic recording layer 150. In an alternate embodiment shown in FIG. 3B, the pole tip 148 is positioned proximate to the trailing edge of the head 106 and the auxiliary pole 142 is spaced from the pole tip 148 in a direction towards the leading edge. FIG. 3C illustrates another embodiment of a magnetic

-6-

recording head where the write element includes multiple auxiliary poles 142-1, 142-2. Coils 146-1, 146-2 are wound about yokes 144-1, 144-2 connecting the auxiliary poles 142-1, 142-2 to the main pole 140. The coils 146-1, 146-2 are energized to provide multiple flux paths as shown to record data to the magnetic
5 recording layer 150 of the data storage media.

The head 106 is positioned relative to select data tracks via a positioning or actuation device. As schematically illustrated in FIG. 4, the head is positioned on the media such that there is a skew angle 160 between the head and a center-line 164 of the track 166. Since the orientation of the head (and write
10 element) is offset at a skew angle 160 (in this example of approximately 15 degrees) relative to the center-line 164 of track 166, the write element can interfere with data recorded in adjacent tracks 168. In prior designs as shown in FIG. 5, the main pole tip 148 (of the main pole 140) has a trapezoidal shape 170 to provide a wall angle 172 between a leading edge 174 and trailing edge 176 of pole tip 148.
15 The wall angle 172 provides a narrow width profile at the leading edge of the pole tip and a wider profile at the trailing edge to reduce adjacent track interference (ATI) proximate to the leading edge of the pole tip 148.

FIGS. 6A-6C illustrate embodiments of a pole tip shield 200 having application for a write element of a recording head as viewed from the air bearing
20 surface 147 of the head facing the media or disc. In the illustrated embodiments, the pole tip shield 200 is generally "U" shaped and includes a leading edge portion 202 forward of the leading edge 174 of the main pole tip 148 and side portions 204 that extend along sides 205 of the main pole tip 148. In an illustrated embodiment, the main pole tip 148 comprises a ferromagnetic material, such as,
25 but not limited to, iron (Fe), cobalt (Co), and combinations thereof, such as, iron cobalt (Co_xFe_y (where $x \cong 20\text{-}45\%$ and $y \cong 55\text{-}80\%$)), iron nickel (Fe_yNi_x (where $x \cong 55\text{-}95\%$ and $y \cong 5\text{-}45\%$)), cobalt iron nickel ($\text{Co}_x\text{Fe}_y\text{Ni}_z$ (where $x \cong 15\text{-}55\%$, $y \cong 10\text{-}$

-7-

80%, and $z \cong 5-35\%$)) or other ferromagnetic materials. In addition, the write pole tip can be also in a laminated structure or made of only one alloy of those mentioned above.

The pole tip shield 200 in some embodiments is also formed of a ferromagnetic material such iron cobalt (Co_xFe_y (where $x \cong 20-45\%$ and $y \cong 55-80\%$)), iron nickel (Fe_yNi_x (where $x \cong 55-95\%$ and $y \cong 5-45\%$)), or cobalt iron nickel ($\text{Co}_x\text{Fe}_y\text{Ni}_z$ (where $x \cong 15-55\%$, $y \cong 10-80\%$, and $z \cong 5-35\%$)). In one embodiment, both the pole tip 148 and shield 200 are formed of a high moment alloy, such as $\text{Fe}_{60}\text{Co}_{40}$. A gap area 206 between the shield 200 and main pole tip 148 is filled with a non-magnetic and electrically insulating material such as Alumina.

When the write pole is energized to encode data on the media, the write pole tip 148 is close to saturation. In the illustrated embodiments of FIGS. 6A-6C, part of the magnetic flux is shunted into the shield 200 so that an opposite magnetic charge accumulates on a surface of the shield 200 causing a net field decrease and field angle change proximate to the shield 200. The field angle change provides a magnetic wall angle or contour to limit or reduce ATI. The "U" pole tip shield 200 as described is configured to provide a magnetic write bubble 210 in a generally trapezoid shape as shown in FIG. 7. The trapezoidal shape of the magnetic write bubble 210 forms the magnetic wall angle to provide a narrow field width or profile proximate to the leading edge 174 to reduce ATI. The magnetic-write bubble 210 of the pole tip 148 also includes a relatively wider field width profile proximate to the trailing edge 176 with relation to track 166. As described in an illustrated embodiment, the pole tip shield 200 can be formed of different magnetic materials or compositions (including different compositions of the materials discussed above having different x , y or z percentages) to provide variable magnetic moments or properties in the shield 200 to optimize the magnetic wall angle for write operations as described herein.

In the embodiments illustrated in FIG. 6A-6B, side portions 204 of the generally "U" shaped shield 200 extend along the length of sides 205 of the pole tip 148 generally from the leading edge 174 to the trailing edge 176 of the pole tip 148. In the embodiment illustrated in FIG. 6B, the side portions 204 are recessed inward from side edges 203 of the leading edge portion of the pole tip shield 200.

In the embodiment shown in FIG. 6C, the length of the side portions 204 of the shield 200 is shorter than the length of the sides 205 of the pole tip 148. In particular, in the embodiment shown in FIG. 6C, the side portions 204 of the shield 200 extend to about midlength of the pole tip 148.

In illustrated embodiments, the side portions 204 of the "U" shaped pole tip shield 200 are configured to provide a variable magnetic moment along a length of the side portions 204 of the shield 200. In particular, in an illustrated embodiment, the leading edge portion of the pole tip shield 200 has a larger magnetic moment than a trailing edge portion to shape the magnetic wall angle proximate to the leading edge of the pole tip 148. In an illustrated embodiment, the side portions 204 of the "U" shaped pole tip shield 200 can be formed of different magnetic materials or compositions along a length thereof to provide different magnetic moments to optimize magnetization and the write field.

FIGS. 8A-8B illustrate embodiments of a "U" shaped pole tip shield 200 including different thickness dimensions along a length of the pole tip shield 200 to provide different magnetic moments along a length of the side portions 204 of the "U" shaped pole tip shield 200. In the embodiments shown in FIGS. 8A-8B, the different thickness dimensions are formed via stepped thickness segments. Each of the stepped thickness segments provides a different field effect or field angle change along the length of the pole tip 148. In an illustrated embodiment, the different thickness segments can be of different magnetic materials or

-9-

compositions with different magnetic moments to shape the angle or dimension of the magnetic wall angle.

In the illustrated embodiments, the pole tip 148 includes a rectangular shape forming a generally planar surface 222 facing the media to provide optimum write pole tip area at the air bearing surface 147, while, the stepped thickness segments or different thickness dimensions optimize the magnetic field or wall angle to reduce ATI. Illustratively, the pole tip shield 200 is configured to provide a magnetic wall angle of approximately 4-5 degrees, however application is not limited to a specific wall angle dimension. In addition, the rectangular pole enabled by the shield configuration greatly simplifies the writer process especially as the dimensions of the pole tip are reduced to accommodate high areal density.

Specifically, in the embodiment illustrated in FIG. 8A, the pole tip shield 200 includes a leading edge portion 202 having a first thickness segment 220-1 having a thickness dimension t_1 . Side portions 204 of the pole tip shield 200 shown in FIG. 8A include a second thickness segment 220-2 having a second thickness dimension t_2 and a third thickness segment 220-3 having a third thickness dimension t_3 , where $t_3 < t_2 < t_1$.

As shown in FIG. 8A, the larger thickness segments 220-1 and 220-2 provide a larger field angle change or effect to provide a narrow field profile proximate to the leading edge while the smaller thickness segment 220-3 provides a smaller field angle change proximate to the trailing edge. As shown in FIG. 8A, the first, second and third thickness segments 220-1, 220-2, 220-3 are separated by a thickness step, although application is not limited to the specific embodiment illustrated in FIG. 8A. In the illustrated embodiment, thickness steps are orientated so that thickness segments 220-1, 220-2, 220-3 have a common coplanar surface along the air bearing surface 147. In an alternate embodiment, the thickness steps are recessed from the air bearing surface 147. In addition to the

-10-

stepped thickness segments 220-1, 220-2, 220-3 or as an alternative, in illustrated embodiments, the pole tip shield 200 includes different material segments to provide a narrow field profile proximate to the leading edge of the pole tip 148.

FIG. 8B illustrates a pole tip shield 200 including multiple stepped
5 thickness segments 220-1, 220-2, 220-3 similar to the embodiment shown in FIG. 8A. In the embodiment shown in FIG. 8B, the side portions 204 include a shortened length dimension relative to the length of the pole tip 148 between the leading edge 174 and trailing edge 176. In the illustrated embodiments, the main pole tip 148 includes a generally planar surface 222 facing the disc media. As
10 shown in FIG. 8C, the pole tip 148 includes a contoured profile providing a sloped leading edge surface 224 and a sloped trailing edge surface 226 to provide a tapered profile to the planar surface 222 of the pole tip 148 leading up to the air bearing surface 147.

Although in the illustrated embodiments of FIGS. 8A-8B stepped thickness
15 segments 220-1, 220-2, 220-3 are shown, the present invention is not limited to an embodiment having the discrete stepped segments as shown. In illustrated embodiments, the pole tip shield 200 can employ different geometries to vary the magnetic moment along a length of the side portions 204 of the shield 200 to configure the shape of the magnetically induced wall angle to optimize the
20 magnetic field profile. For example, in the embodiment illustrated in FIG. 8D, the side portions 204 have a sloped thickness dimension. As shown, the sloped thickness dimension provides a larger thickness dimension at the leading edge and a smaller thickness dimension proximate to the trailing edge of the side portions 204 of the "U" shaped shield 200 of FIG. 8D. As previously described,
25 the side portions 204 can have a co-planar surface along the air bearing surface 147 or a sloped contour along the air bearing surface 147.

-11-

In alternate embodiments shown in FIGS. 8E and 8F, the side portions 204 of the "U" shaped shield 200 include a tapered width profile. In another embodiment illustrated in FIG. 8G, the "U" shaped shield 200 includes a plurality of stepped width segments 227-1, 227-2 having stepped width dimensions to provide different magnetic moments to shape the angle or dimension of the magnetic wall angle as previously described. In particular, as shown width segments 227-1 has a larger dimension than width segment 227-2 to provide a narrower field profile proximate to the leading edge 174 of the pole tip 148.

FIGS. 9A-9B illustrate an alternate embodiment of a write element. In the embodiment shown in FIG. 9A, the write element includes pole tip shield 200 including a leading edge portion 202 and side portions 204. In the embodiment illustrated in FIG. 9A, the length of the side portions 204 extends along a length of the sides of the pole tip 148 generally from the leading edge 174 to the trailing edge 176 of the pole tip 148. In the illustrated embodiment, the pole tip 148 is shaped or contoured to provide a narrower width dimension at the leading edge 174 and wider width dimension proximate to the trailing edge 176 to enhance the magnetic field profile in combination with the pole tip shield 200. For example, in an illustrative embodiment, the pole tip 148 is contoured to provide a 4-5 degree physical wall angle and the combination of the pole tip contour and pole tip shield 200 (with stepped portions 220-1, 220-2, 220-3 as shown) are designed to provide an effective wall angle of 10+ degrees.

In another embodiment illustrated in FIG. 9B, the side portions 204 of the pole tip shield 200 have a shortened length dimension, smaller than a length dimension of the sides of the pole tip 148 between the leading and trailing edges 174, 176 of the pole tip 148. In each of the illustrated embodiments of FIGS. 9A-9B, the pole tip shields 200 include stepped thickness segments 220-1, 220-2 and 220-3 as previously described with respect to FIGS. 8A-8B. Alternatively, other

-12-

embodiments include embodiments of the "U" shaped pole tip shield as described herein in combination with a contoured pole tip as shown in FIGS. 9A-9B.

FIGS. 10A and 10B illustrate embodiments of a write element including a pole tip shield 200. In the embodiment illustrated in FIG. 10B, the write element includes a trailing edge shield 240 separate from the pole tip shield 200. As shown, the trailing edge shield 240 is spaced from the pole tip shield 200 to form a gap 242 between the pole tip shield 200 and the trailing edge shield 240 along the air bearing surface 147 of the head 106. The gap 242 between the pole tip shield 200 and trailing edge shield 240 along the air bearing surface 147 is filled with a non-magnetic material, such as Alumina. In the embodiment illustrated in FIG. 10A, the pole tip shield 200 has different thickness dimensions in contrast to the pole tip shield 200 illustrated in FIG. 10B. As shown, in FIG. 10A, the different thickness dimensions are formed by stepped thickness segments 220-1, 220-2, 220-3 as shown and previously described. In another embodiment, the pole tip shield 200 of FIG. 10B can include stepped thickness segments 220-1, 220-2, 220-3 as shown in FIG. 10A.

FIGS. 11A-11E illustrate embodiments of write elements including a pole tip shield 200. In the illustrated embodiments shown in FIGS. 11B-11E, the write element includes a trailing edge shield 240 separated from and spaced from the pole tip shield 200 along the air bearing surface 147 of the head 106. In each of the illustrated embodiments, the pole tip shield 200 is magnetically connected to an auxiliary pole 142 to provide a flux connection between the pole tip shield 200 and the auxiliary pole 142 as previously illustrated in FIG. 3B. The auxiliary pole 142 provides a flux path for magnetic charge from the shield 200 to enhance the magnetic wall angle of the pole tip 148.

-13-

In the illustrated embodiments of FIGS. 11A-11C the pole tip shield 200 includes a leading edge portion 202 and side portions 204. In FIGS. 11A-11C, the side portions 204 have an elongate length extending along the sides 205 of the pole tip 148 generally from the leading edge 174 to the trailing edge 176 of the pole tip 148. In the embodiment illustrated in FIG. 11B, the leading edge portion 202 and side portions 204 include stepped thickness segments 220-1, 220-2 to provide different thickness dimensions of the shield 200. In the embodiment illustrated in FIG. 11C, the shield 200 includes stepped thickness segments 220-1, 220-2, 220-3 to form the different thickness dimensions of the shield 200. In each of the embodiments shown in FIGS. 11A-11B, the write element could include a trailing edge shield as in FIG. 11B or not include a trailing edge shield 240 as in FIG. 11A. Illustratively the thickness of the trailing edge shield 240 is similar to the thickness of the leading edge portion of the pole tip shield 200. In illustrated embodiments, auxiliary pole 142 is connected to the pole tip shield 200 to enhance magnetic wall angle. In an exemplary embodiment having a trailing edge shield 240, auxiliary pole 142 can be connected to the trailing edge shield 240.

In FIG. 11D, the pole tip shield 200 includes a leading edge portion 202 and shortened side portions 204. In the illustrated embodiment, the leading edge portion and side portions 204 include different thickness dimensions formed by the stepped thickness segments 220-1, 220-2 similar to embodiments previously described. FIG. 11E illustrates an embodiment of a pole tip shield 200 coupled to the auxiliary pole 142 and a trailing edge shield 240 separated from and spaced from the pole tip shield 200 along the air bearing surface 147. As shown, the pole tip shield 200 includes a leading edge portion 202 spaced forward of the leading edge of the pole tip to provide a magnetic field profile for writing. In each of the illustrated embodiments, alternate features can be employed as described herein to shape the magnetic profile or wall angle of the write element of the head.

FIGS. 12A-12B illustrate embodiments of write elements that include auxiliary poles 142-1, 142-2 connected to the main pole via yokes as previously illustrated in FIG. 3C. Each of the illustrated embodiments in FIGS. 12A and 12B includes a pole tip shield 200 and a trailing edge shield 240. In the illustrated
5 embodiments in FIGS. 12A-12B, the pole tip shield 200 includes a leading edge portion 202 and side portions 204. The shield is magnetically connected to the first auxiliary pole 142-1 forward of the leading edge of the pole tip 148. The trailing edge shield 240 is spaced from the pole tip shield 200 and is magnetically coupled to the second auxiliary pole 142-2 aft of the pole tip 148. As shown, the
10 pole tip shield 200 and trailing edge shield 240 are separated via a non-magnetic gap 242 along the air bearing surface 147 and are magnetically connected through connection of the auxiliary poles 142-1, 142-2 to main pole 140 as previously illustrated in FIG. 3C. In the embodiment illustrated in FIG. 12B, the pole tip shield 200 includes stepped thickness segments 220-1, 220-2, 220-3 as previously
15 described in relation to other embodiments disclosed in the application, although other applications can utilize alternate features described herein.

It is to be understood that even though numerous characteristics and advantages of various embodiments of the invention have been set forth in the foregoing description, together with details of the structure and function of
20 various embodiments of the invention, this disclosure is illustrative only, and changes may be made in detail, especially in matters of structure and arrangement of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, the particular elements may vary
25 depending on the particular application while maintaining substantially the same functionality without departing from the scope and spirit of the present invention. In addition, although the preferred embodiment described herein is directed to a

-15-

particular data storage application, it will be appreciated by those skilled in the art that the teachings of the present invention can be applied to other data storage applications, without departing from the scope and spirit of the present invention.

5 Additionally, although illustrated embodiments disclosure features arranged in a particular combination, other applications or embodiments can incorporate one or more features described herein and application is not limited to the specific combinations or arrangements shown.

WHAT IS CLAIMED IS:

1. A magnetic assembly comprising:
a magnetic pole having a pole tip and the pole tip including a leading edge,
a trailing edge and side edges; and
a generally "U" shaped pole tip shield including a leading edge portion
and side portions and the "U" shaped pole tip shield including a
variable magnetic moment along a length of the side portions of the
generally "U" shaped pole tip shield wherein the variable magnetic
moment decreases in a direction towards the trailing edge of the
pole tip.
2. The assembly of claim 1 wherein the side portions extend along a length of
the pole tip from the leading edge of the pole tip to the trailing edge of the
pole tip.
3. The assembly of claim 1 wherein the generally "U" shaped pole tip shield
includes a plurality of discrete segments along the side portions and the
discrete segments include at least one of different thickness dimensions,
different width dimensions or different magnetic materials to provide the
variable magnetic moment along the length of the side portions of the "U"
shaped pole tip shield.
4. The assembly of claim 3 wherein the plurality of discrete segments include
a plurality of thickness segments comprising a first thickness segment
having a first thickness dimension and a second thickness segment
including a second thickness dimension smaller than the first thickness
dimension in the direction towards the trailing edge of the pole tip.
5. The assembly of claim 1 wherein the side portions of the "U" shaped pole
tip shield include a variable thickness or width dimension along a length of
the side portions of the "U" shaped pole tip shield.

-17-

6. The assembly of claim 1 wherein "U" shaped pole tip shield include a plurality of discrete segments along the side portions of the "U" shaped pole tip shield having different width or thickness dimensions and the plurality of discrete segments include different magnetic materials or compositions.
7. The assembly of claim 1 further comprising at least one auxiliary pole and the "U" shaped pole tip shield is magnetically connected to the at least one auxiliary pole.
8. The assembly of claim 4 and comprising a thickness step between the first thickness segment and the second thickness segment.
9. The assembly of claim 1 wherein the side portions of the "U" shaped pole tip shield include different magnetic material segments along a length of the side portions of the "U" shaped pole tip shield.
10. The assembly of claim 1 wherein the side portions of the "U" shaped pole tip shield have a shortened length dimension relative to a length dimension of the pole tip between the leading edge and the trailing edge of the pole tip.
11. A magnetic assembly comprising:
 - a magnetic pole including a pole tip having a leading edge, a trailing edge and side edges forming a generally rectangular shaped surface along an air bearing surface of the assembly;
 - a coil energizable to induce a magnetic flux path in the pole tip; and
 - a pole tip shield including a leading edge portion connected to side portions having an elongate length dimension extending along the side edges of the pole tip.

-18-

12. The assembly of claim 11 wherein the pole tip shield includes a plurality of segments having different width dimensions, thickness dimensions or magnetic materials.
13. The assembly of claim 11 wherein the side portions of the pole tip shield include variable thickness or width dimensions along the side portions of the pole tip shield.
14. The assembly of claim 11 and comprising an auxiliary pole wherein the pole tip shield is connected to the auxiliary pole through a flux connecting material to provide a flux path through the pole tip shield to the auxiliary pole.
15. The assembly of claim 11 and comprising a first auxiliary pole magnetically connected to the pole tip shield and a second auxiliary pole connected to a trailing edge shield spaced from the pole tip shield and separated from the pole tip shield along the air bearing surface by a non-magnetic gap.
16. A magnetic assembly comprising:
 - a magnetic pole having a pole tip including a leading edge, a trailing edge and side edges;
 - a coil energizable to induce a magnetic flux in the pole tip;
 - a pole tip shield proximate to the pole tip magnetically coupled to an auxiliary pole of the assembly;
 - a trailing edge shield spaced from the pole tip shield; and
 - a non-magnetic gap portion separating the pole tip shield from the trailing edge shield along an air bearing surface of the assembly.
17. The assembly of claim 16 wherein the pole tip shield is generally "U" shaped and the gap portion separates the generally "U" shaped pole tip shield from the trailing edge shield along the air bearing surface.

-19-

18. The assembly of claim 17 wherein the generally "U" shaped pole tip shield includes variable thickness or width dimensions along side portions of the pole tip shield.
19. The assembly of claim 17 wherein the generally "U" shaped pole tip shield includes a leading edge portion and opposed side portions and the side portions extend along a length of the sides of the pole tip to the trailing edge of the pole tip.
20. The assembly of claim 16 further comprising a second auxiliary pole magnetically connected to the trailing edge shield.

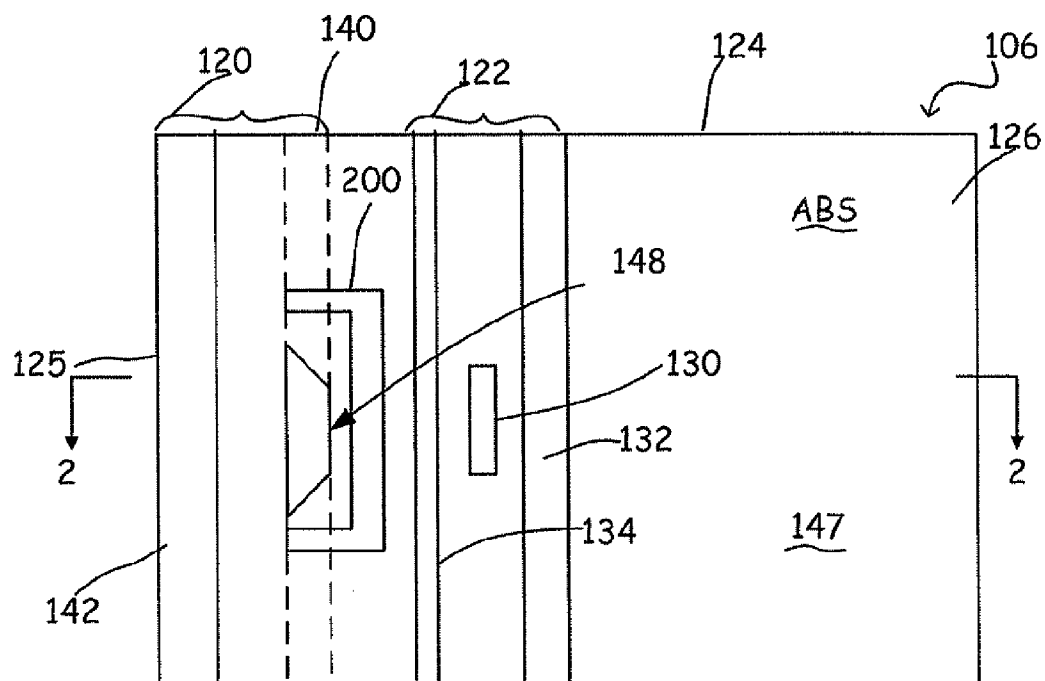


FIG. 1

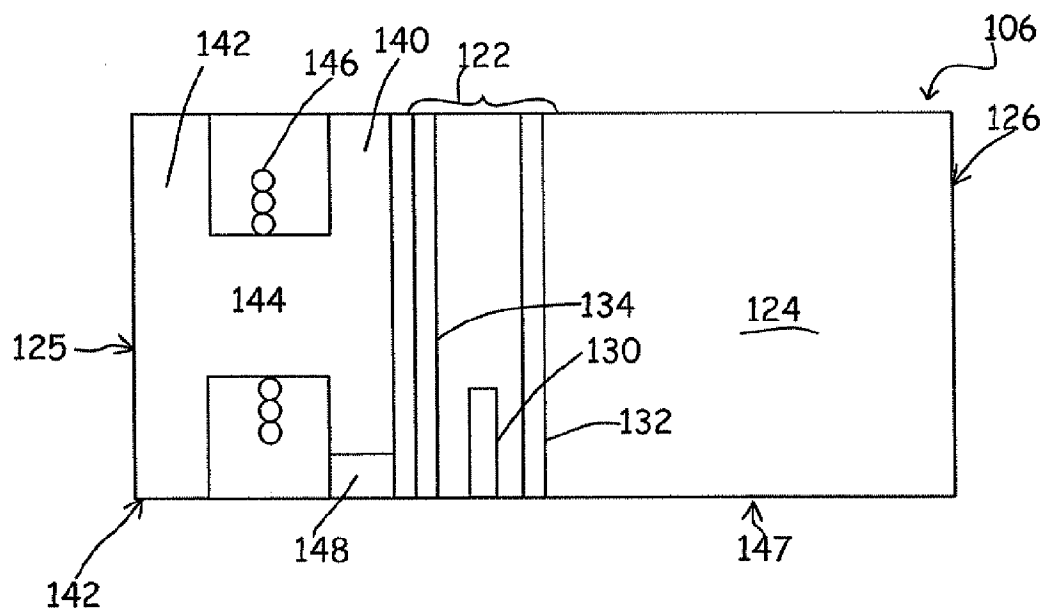


FIG. 2

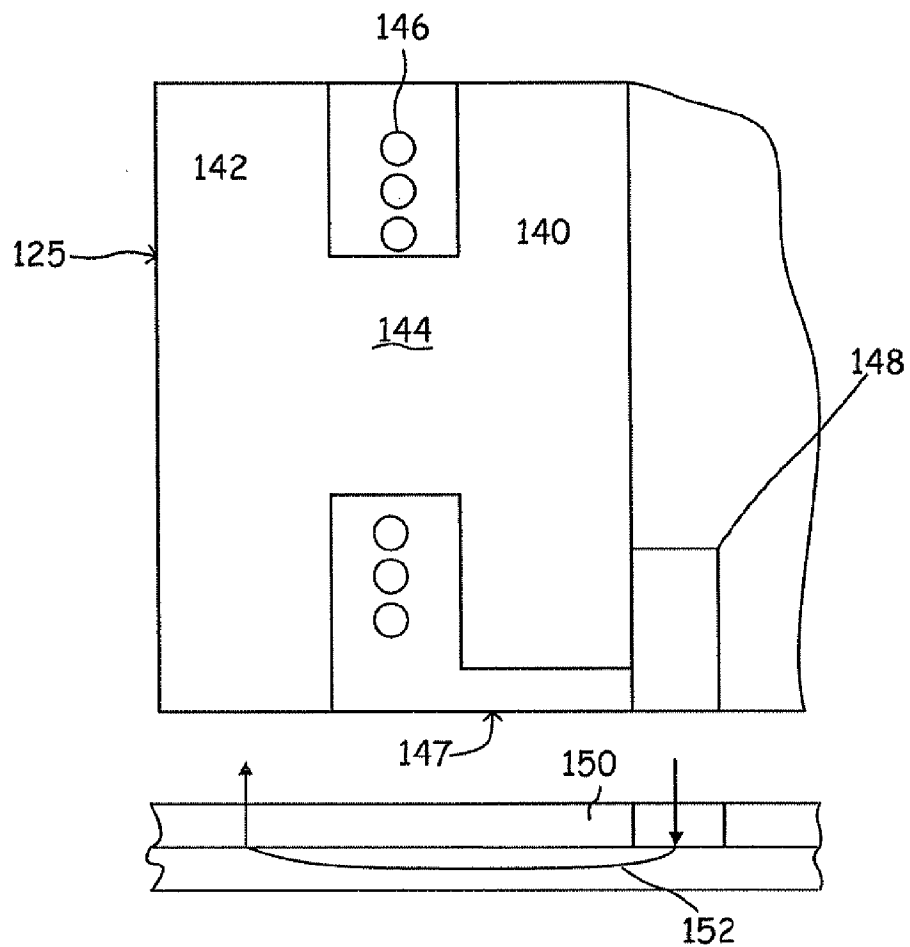


FIG. 3A

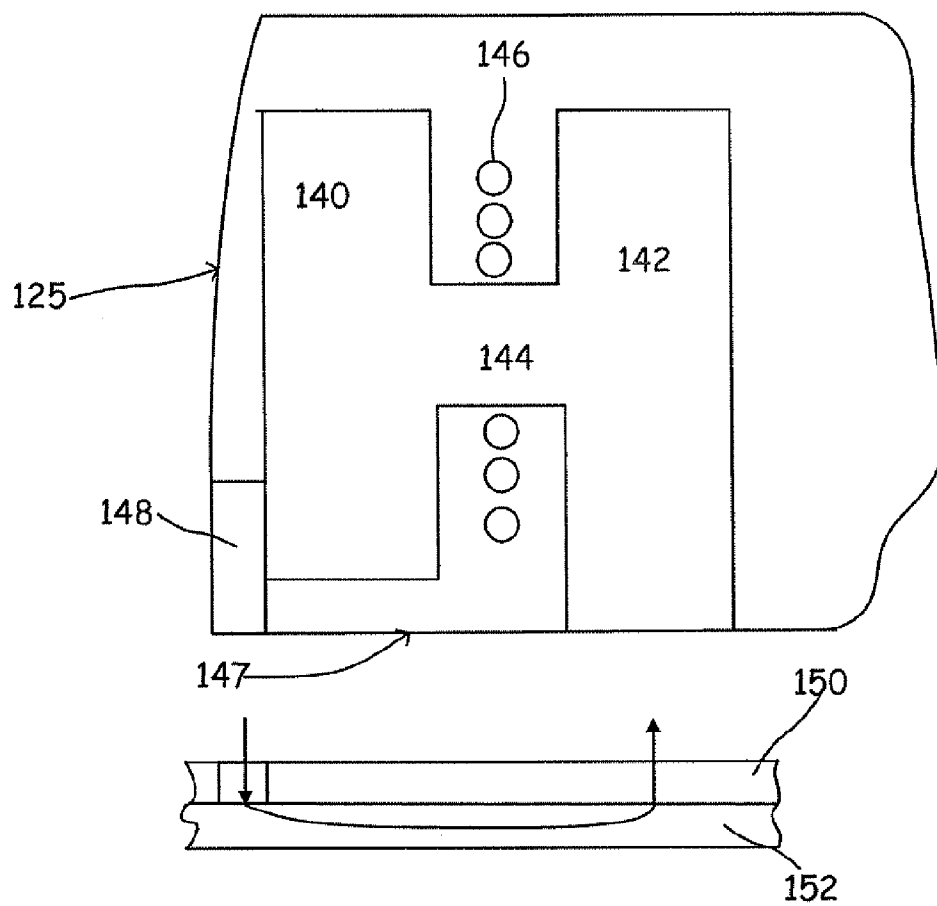


FIG. 3B

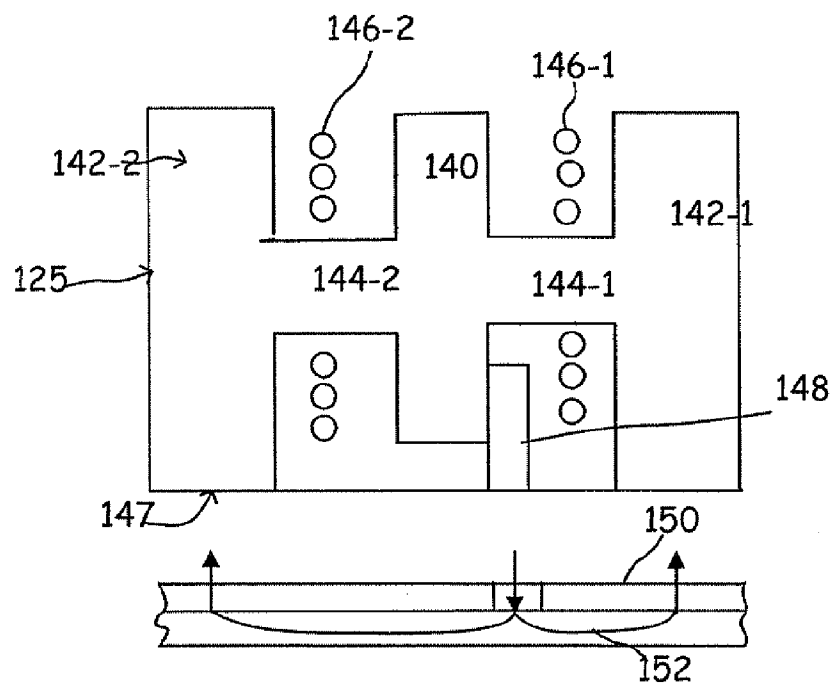


FIG. 3C

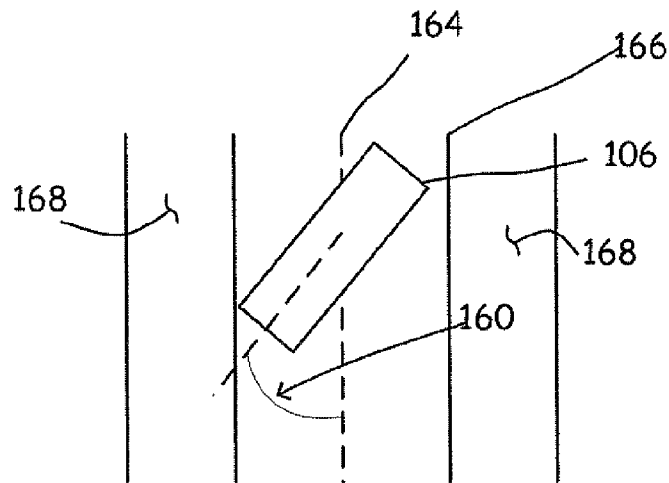


FIG. 4

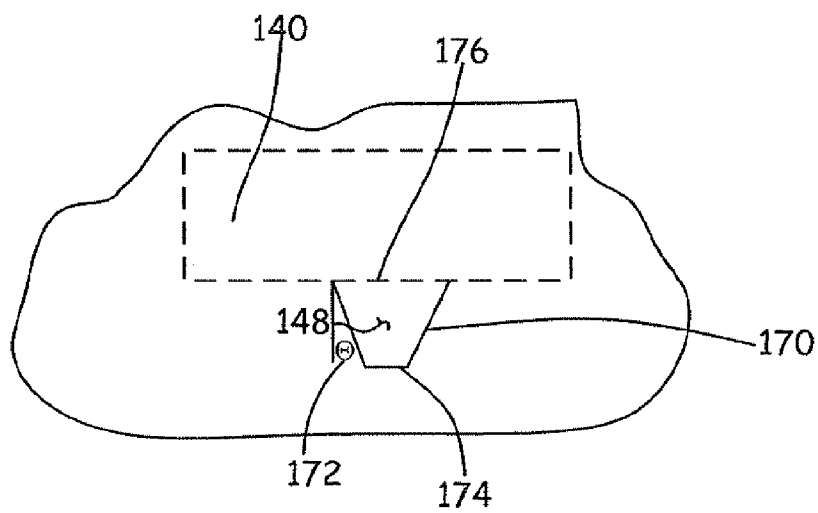


FIG. 5

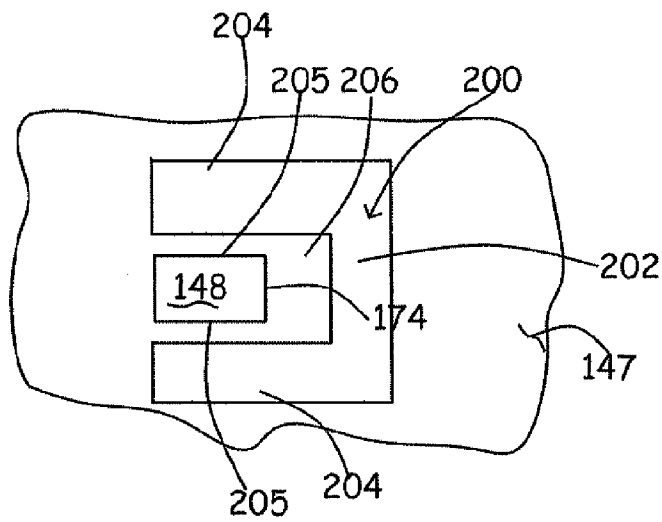


FIG. 6A

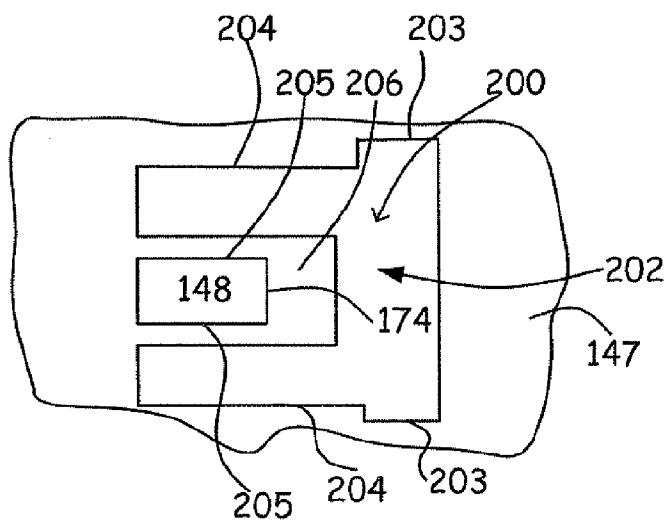


FIG. 6B

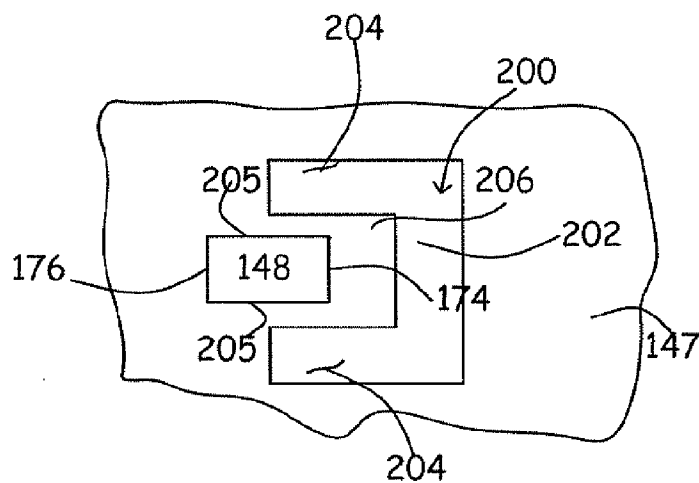


FIG. 6C

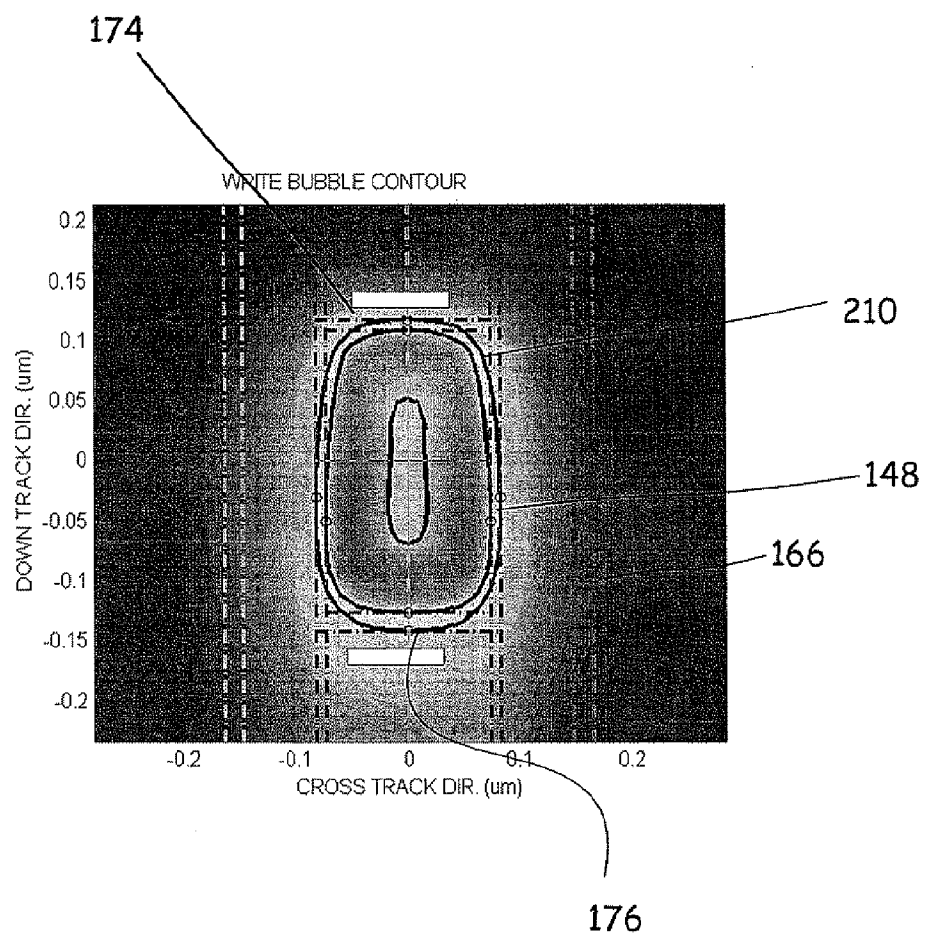


FIG. 7

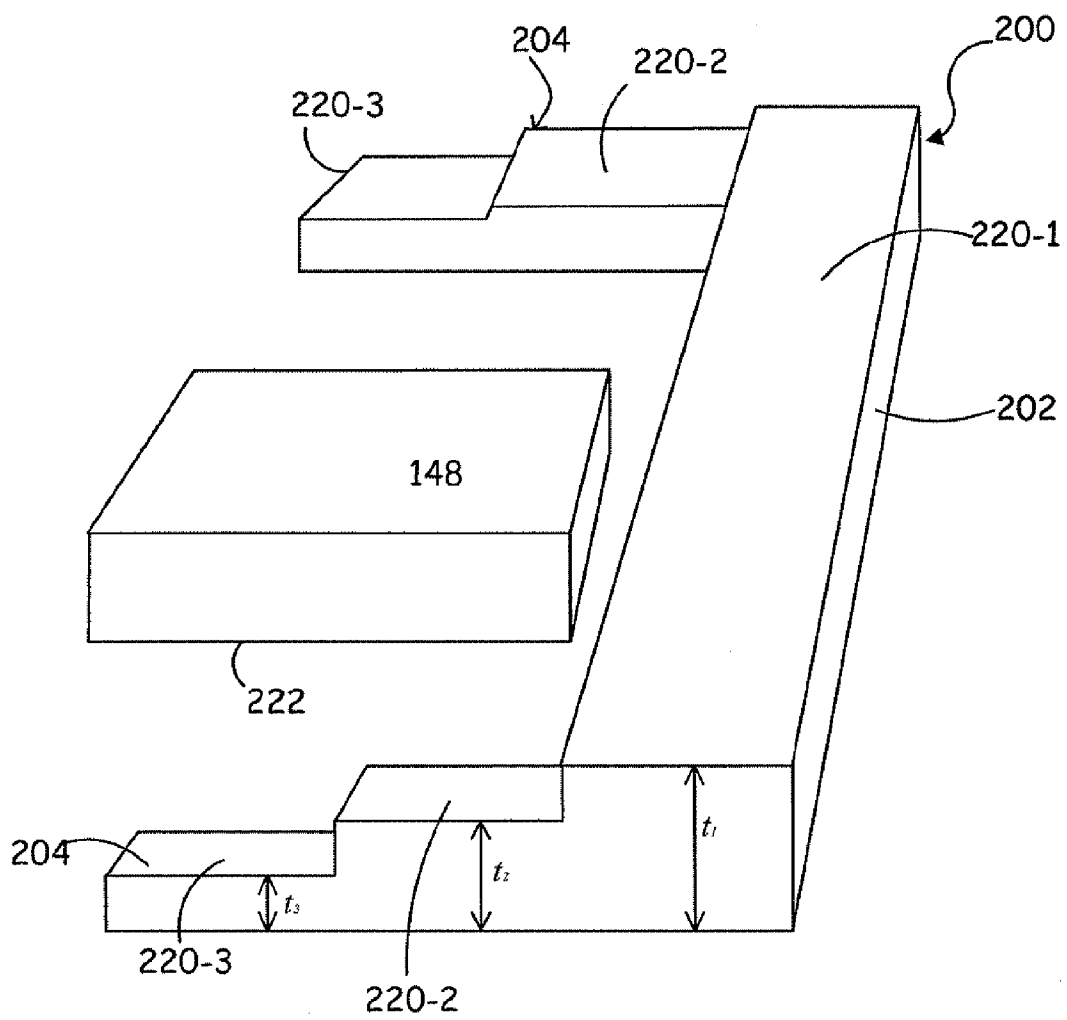


FIG. 8A

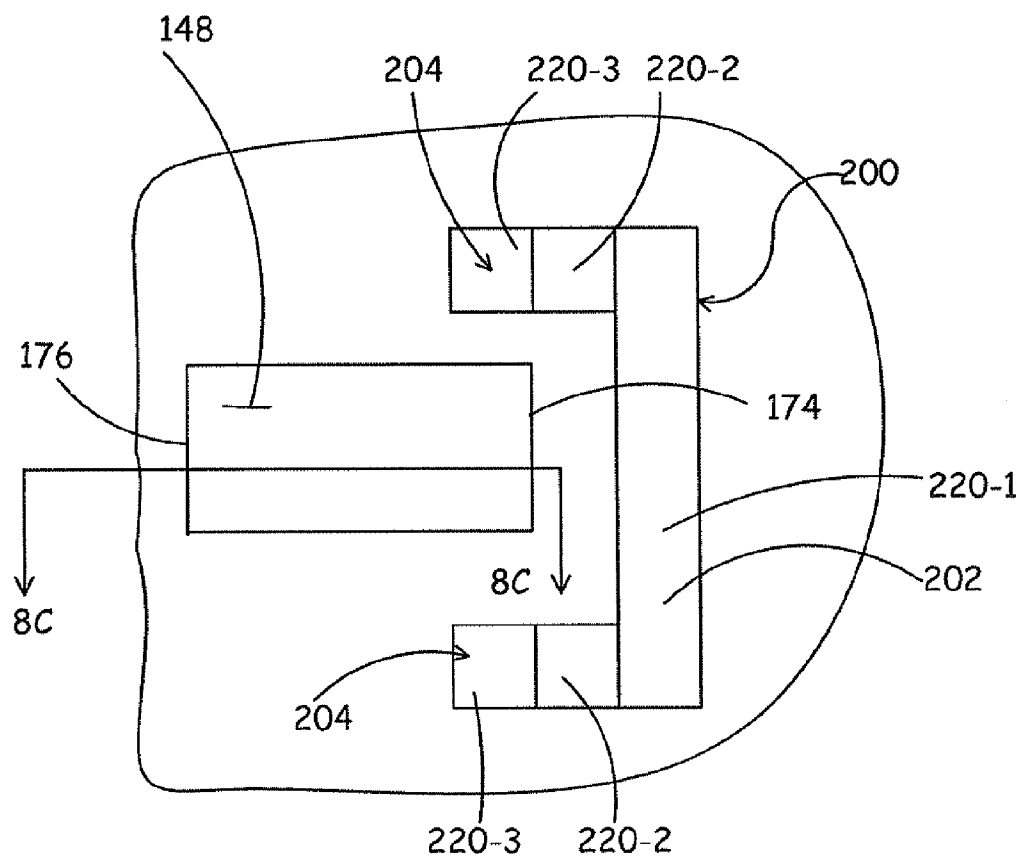


FIG. 8B

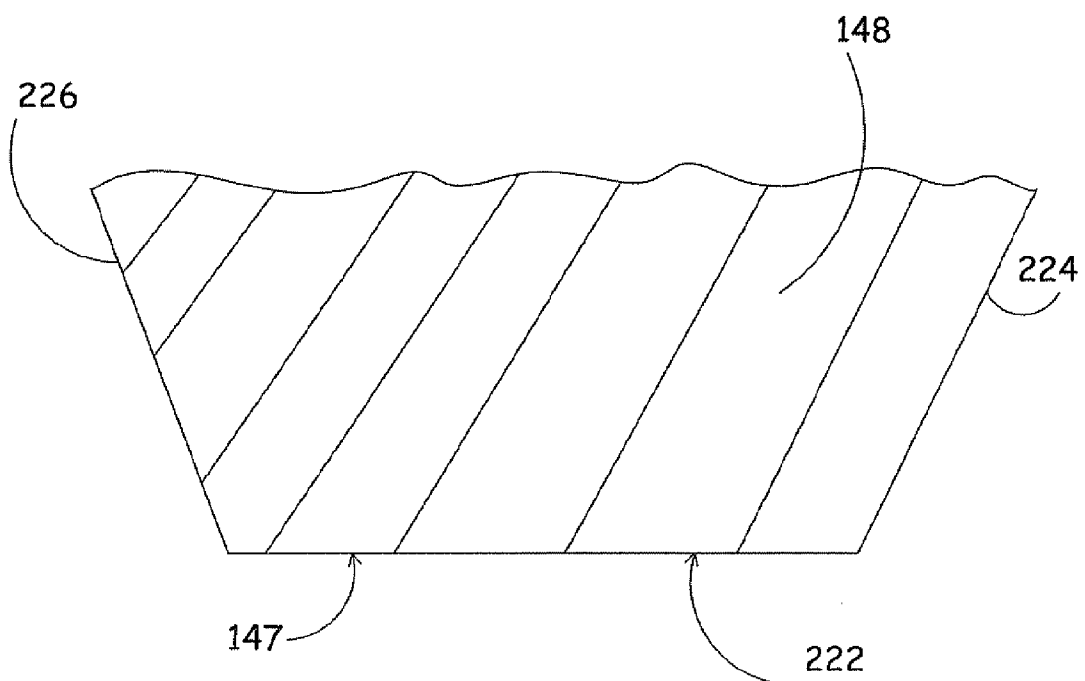
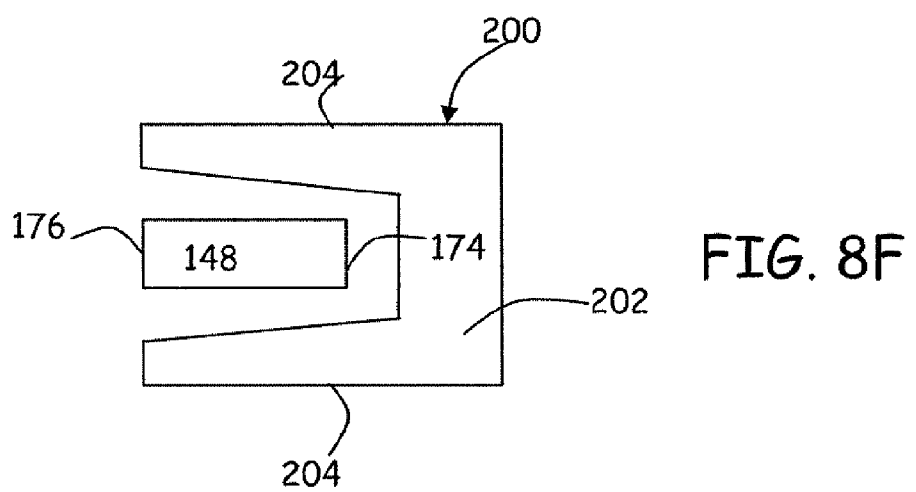
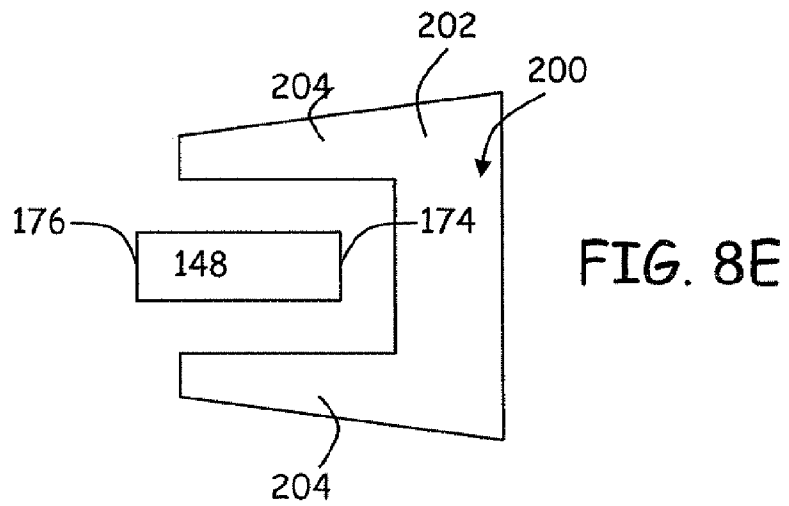
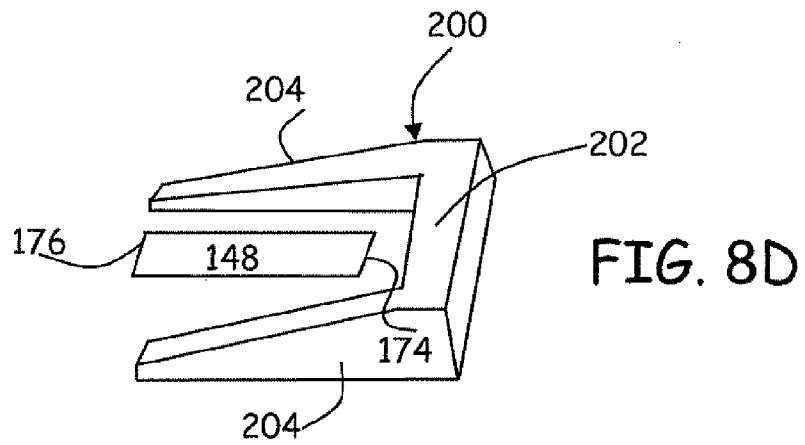


FIG. 8C



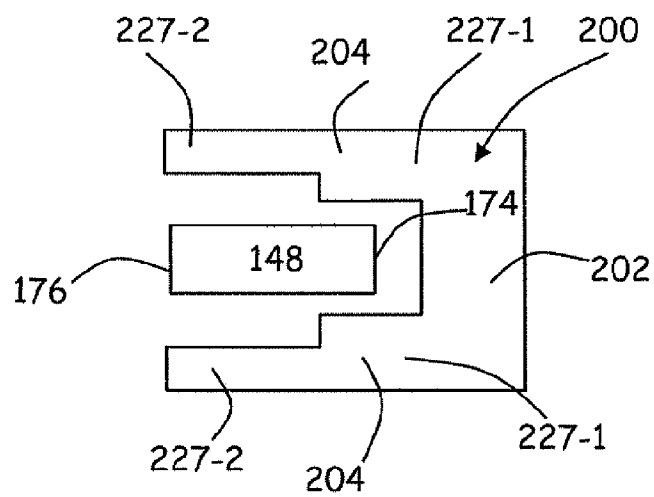


FIG. 8G

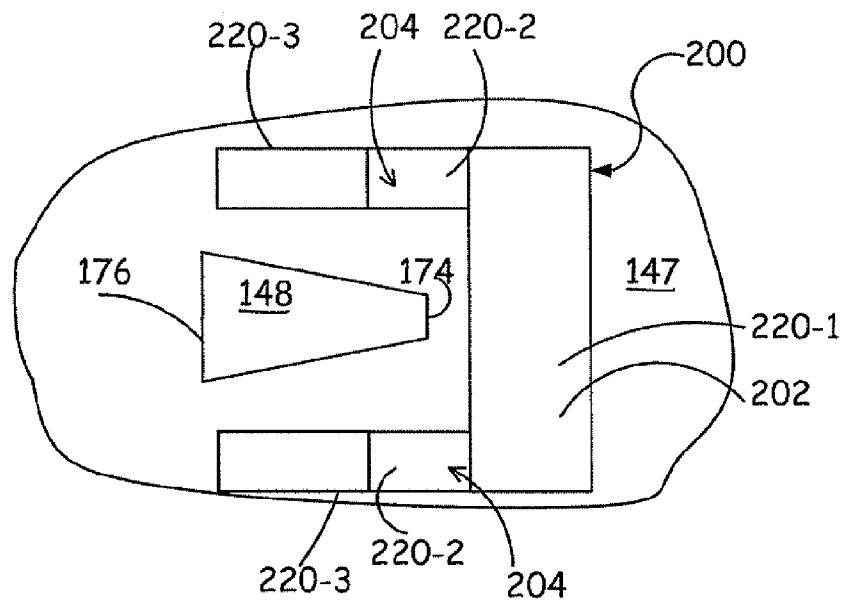


FIG. 9A

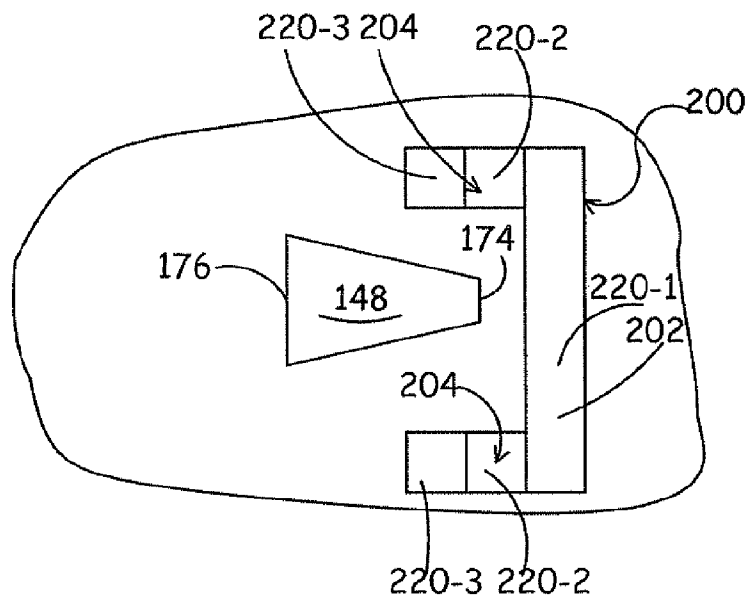


FIG. 9B

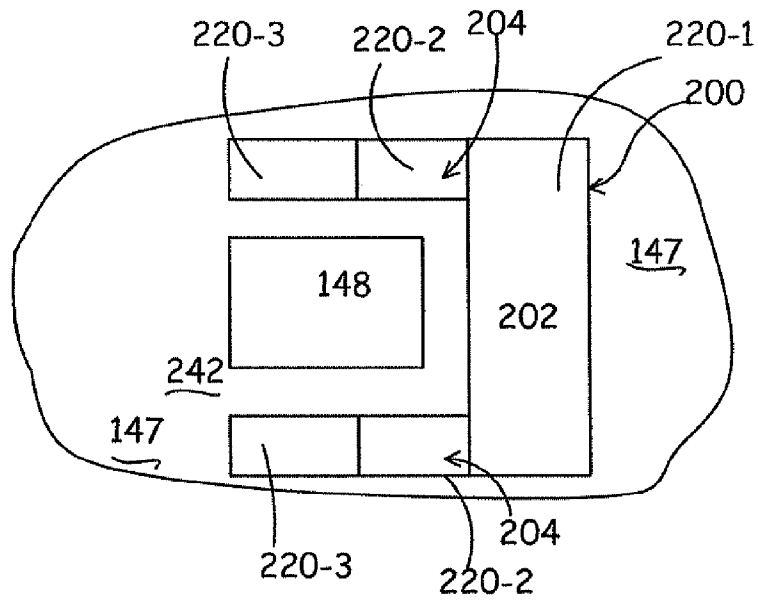


FIG. 10A

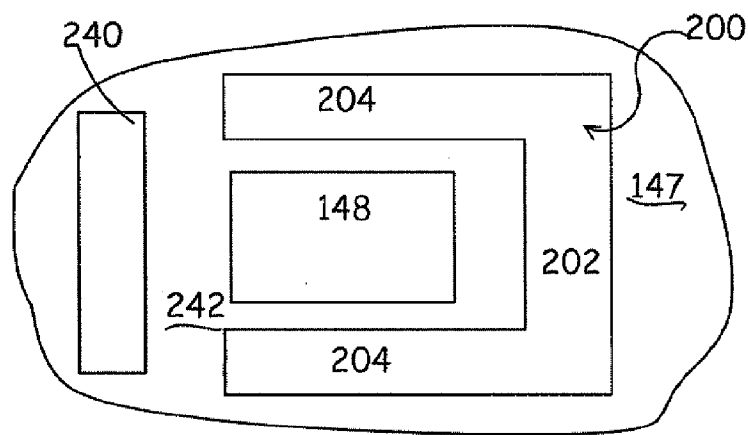


FIG. 10B

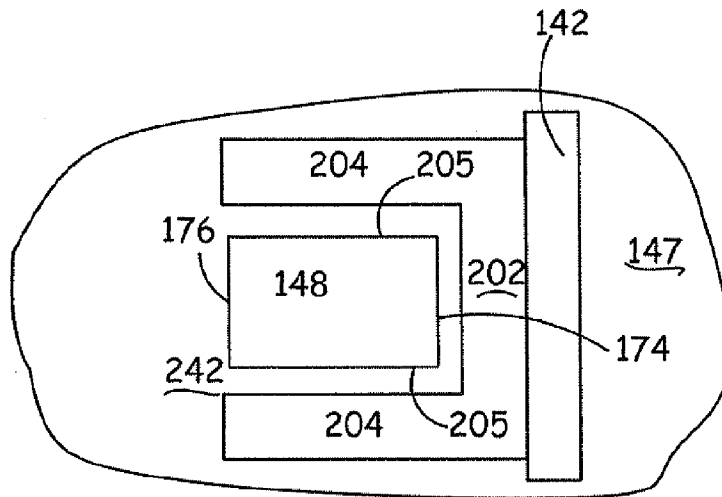


FIG. 11A

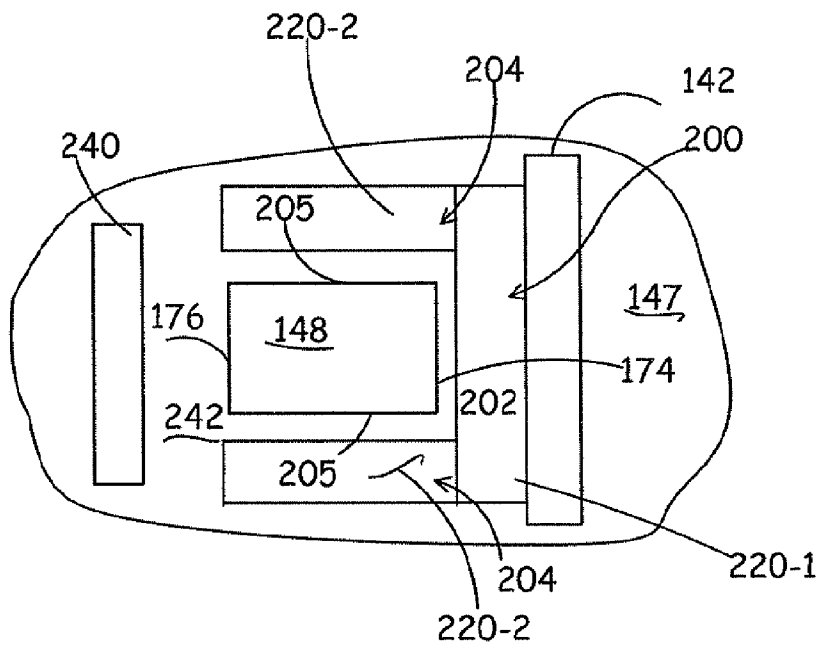


FIG. 11B

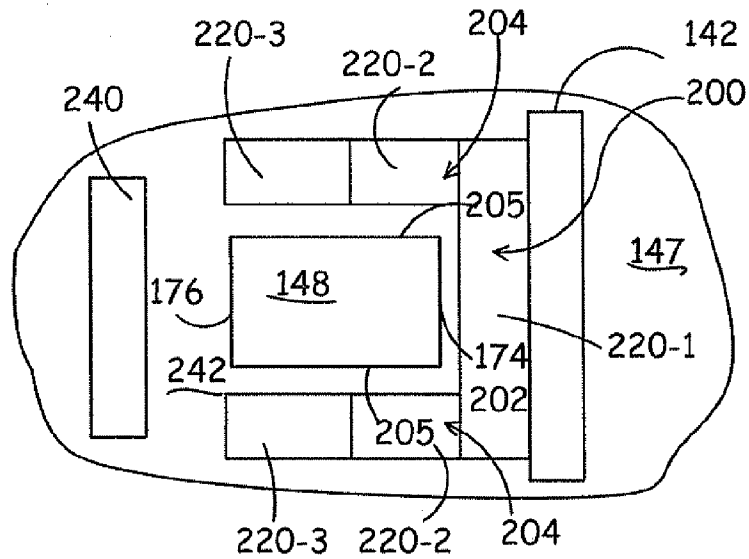


FIG. 11C

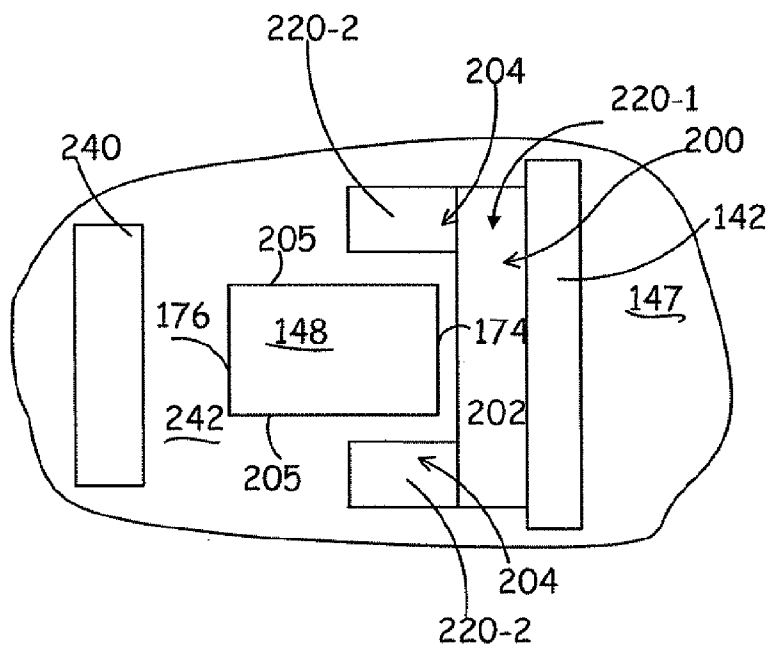


FIG. 11D

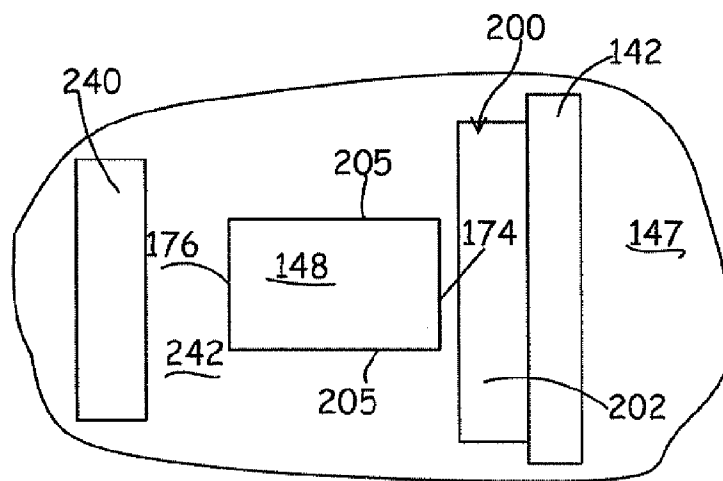


FIG. 11E

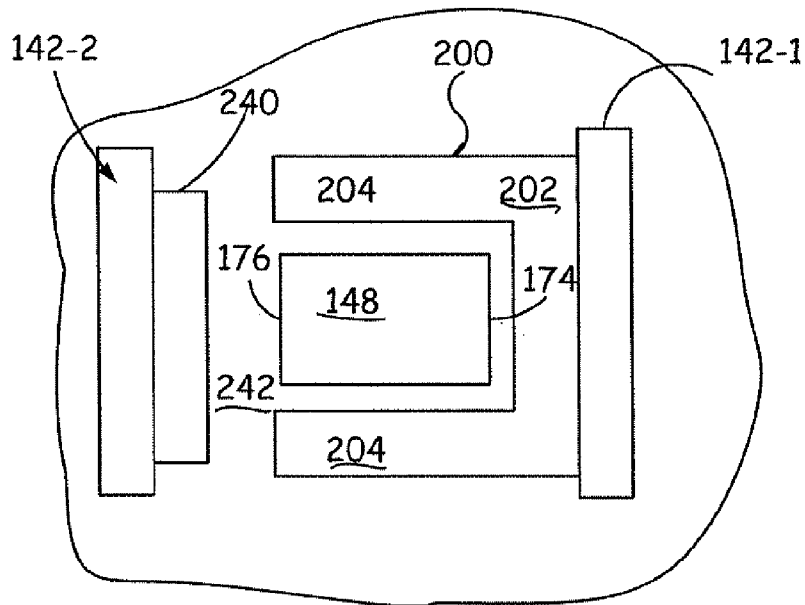


FIG. 12A

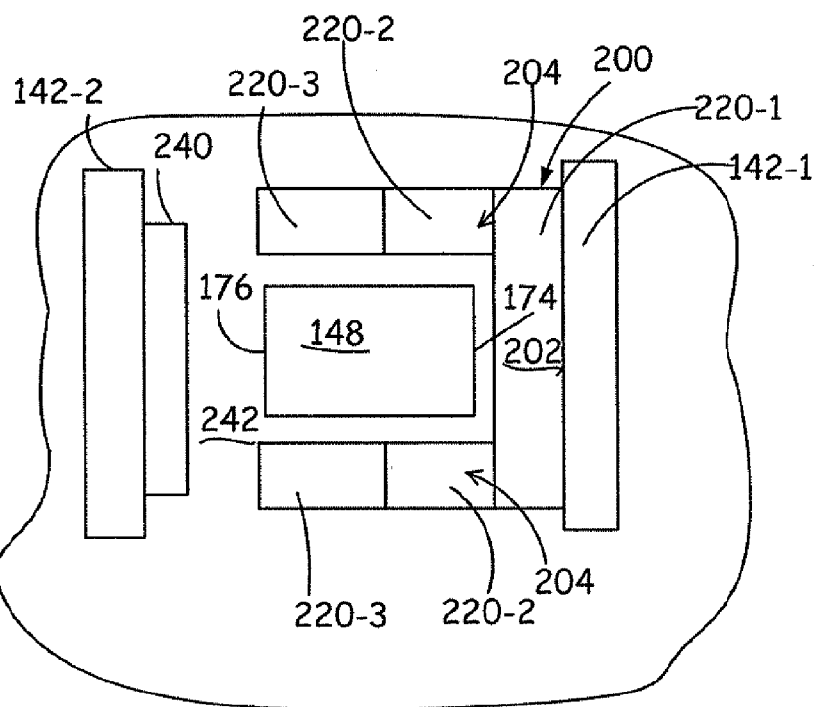


FIG. 12B