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METHOD OF FABRICATING AN INVERTED MAGNETORESISTIVE HEAD

The present invention relates to a method of fabricating a magnetoresistive head for high frequency; high data rate, and high track density applications, and in particular to a method of fabricating an inverted magnetoresistive head having the reader portion of the magnetoresistive head fabricated on top of the writer portion of the magnetoresistive head.

Standard magnetoresistive (MR) heads are fabricated with the writer portion fabricated on top of the reader portion. MR heads are used in magnetic storage systems to detect magnetically encoded information from a magnetic storage medium or disc and to write magnetically encoded information to the storage medium. In a read mode, a time dependent magnetic field associated with a transition from a magnetic storage medium directly modulates the resistivity of an MR element. In operation, the change in resistance of the MR element can be detected by passing a sense current through the MR element and measuring the voltage across the MR element. The resulting signal can be used to recover information or data from the magnetic storage medium.

Practical MR elements are typically formed using ferromagnetic metal alloys because of their high magnetic permeability, an example of which is nickel iron (NiFe). A ferromagnetic material is deposited in a thin film upon the surface of an electrically insulated substrate or wafer. Changing magnetic fields originating from the magnetic storage medium produce a change in the magnetisation direction of the MR element and thereby change the resistance of the sensor. This phenomenon is called the MR effect.

The element itself comprises a strip of MR material deposited on a magnetic shield layer to form an MR element. A series of depositions and etching processes form an active region from a portion of the MR element. The active region is the area of the MR element that senses changing magnetic fields from the magnetic storage medium.

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- ☒ Description : paged¹ to paged¹³
- ☒ Claim(s) : paged¹⁴ to paged¹⁸
- ☒ Drawing(s) : paged¹ to paged⁹
- ☒ Abstract : paged¹⁹ to paged¹

Changing magnetic fields produce a change in the resistivity of the MR element. Typical resistivity changes are in the order of 0.5 percent to 2.0 percent change. An upper magnetic shield acts as a barrier between the MR element and the surface of the magnetic storage medium to prevent changing magnetic fields associated with transitions passing by the head from linking back to the element. The magnetic shield also serves to protect the element from receiving stray magnetic fields associated with transitions from surrounding magnetic storage media.

Giant MR (GMR) sensors formed from GMR materials are the new line in the family of MR sensors. GMR sensors are formed from GMR elements, which are multi-layered structures. These devices include layers of magnetic and non-magnetic material, which may be films of ferro-magnetic and non-ferro magnetic material or a similar set of films. Permalloy may or may not be part of the layered pattern. In GMR sensors, the change in resistivity can be in excess of 65 percent.

One problem which affects performance of MR heads is the degree to which surfaces in the head can be fabricated flat or "planarized." In particular, in prior art heads, the top shield of an MR sensor has a dip just above the active region of the MR element. This degrades off track performance. Lack of planarization can also cause an electrical short between various layers of the head, such as between the contacts to the MR element and the top shield or between the top shield and subsequent fabricated layers. In addition, the bottom shield is usually fabricated from sendust or other high permeability magnetic materials, which is relatively rough for a thin film. This relatively rough surface can also cause shorting problems between the bottom shield and the contact film. Attempts at planarizing MR readers have focused on smoothing the bottom shield, planarizing the insulator above the MR sensor, or smoothing the top shield. These steps take additional process time and can limit design flexibility.

Another problem which affects performance of MR heads is that GMR heads are susceptible to inter-diffusion among the extremely thin layers of a GMR head during a polymer cure, even when a low temperature polymer cure is utilized. This

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inter-diffusion can destroy the effectiveness of the GMR head.

In a first aspect, this invention provides a method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole in a recessed portion of a basecoat distal from an air bearing surface of the head;

positioning a polymer insulator and conductive coils above the bottom pole; and characterised by further comprising:

fabricating a write gap on top of the bottom pole at a level below the level of the top surface of the polymer insulator;

forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface;

fabricating a bottom shield having a planarized top surface on top of the pole tip and the write gap;

fabricating a first reader gap on top of the bottom shield;

forming a magnetoresistive element on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield on top of the second reader gap.

In a second aspect, this invention provides a method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole in a recessed portion of a basecoat distal from an air bearing surface of the head;

positioning a polymer insulator and conductive coils above the bottom pole; and characterised by further comprising:



fabricating a write gap on top of the polymer insulator distal to the air bearing surface and positioned on top of the bottom pole proximal to the air bearing surface;

forming a top pole on top of the write gap;

fabricating an oxide layer on top of the top pole proximal to the air bearing surface;

planarizing a top surface of the oxide layer and a top surface of a portion of the top pole distal to the air bearing surface;

fabricating a bottom shield on top of the oxide layer and the top pole;

fabricating a first reader gap on top of the bottom shield;

forming a magnetoresistive element on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield on top of the second reader gap.

The present invention is a method of manufacturing an inverted magnetoresistive head for reading magnetically stored information from a magnetic storage medium. The method includes fabricating a bottom pole in a recessed portion of a basecoat, which is distal from an air bearing surface of the magnetoresistive head. A polymer insulator and connective coils are positioned above the bottom pole. A write gap is fabricated on top of the bottom pole, below the top surface of the polymer. A pole tip of magnetic high moment material is formed in the write gap proximal to the air bearing surface. A top pole is fabricated on top of the pole tip and the write gap. The top pole is planarized. A bottom shield is fabricated on top of the top pole. The bottom shield may be planarized if desired. Alternatively, the bottom shield may be planarized and the top pole not be planarized. A first reader gap is fabricated on top of

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the bottom shield. A magnetoresistive element is formed on top of a portion of the first reader gap proximal to the air bearing surface. Electrical contacts are fabricated on top of a top portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the magnetoresistive head. A second read gap layer is fabricated on top of the electrical contacts and the magnetoresistive element. A top shield is fabricated on top of the second reader gap. Finally, an overcoat of oxide is fabricated on top of the top shield.

Alternatively, the top pole and bottom shield may be formed as a single element and the top surface of this combined top pole/bottom shield be planarized.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic figures, in which;

Figure 1A is a layer diagram view of the layer structure of a prior art magnetoresistive head.

Figure 1B is a layer diagram view showing the layer structure of the air bearing surface of a prior art magnetoresistive head.

Figure 2 is a layer diagram view of the layer structure of a bottom pole of a writer of a magnetoresistive head prior to planarization.

Figure 3 is a layer diagram view of the layer structure of a bottom pole of a writer of a magnetoresistive head after planarization.

Figure 4 is a layer diagram view of the layer structure of a bottom portion of a writer showing a recessed channel in the write gap.

Figure 5 is a layer diagram view of the layer structure of a writer of a magnetoresistive head.

Figure 6 is a layer diagram view of the layer structure of an embodiment of a bottom portion of a writer employing the invention showing a recess channel in the writer gap.

Figure 7 is a layer diagram view of the layer structure of the embodiment of Figure 6.

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Figures 8A-8C are layer diagrams of the layer structure of the air bearing surface of a writer of a magnetoresistive head showing an alternate method of fabricating a pole tip.

Figures 9A-9D are layer diagrams of the layer structure of the air bearing surface of a writer of a magnetoresistive head showing an alternate method of fabricating a pole tip.

Figure 10 is a cross-sectional view of the layer of the air bearing surface of a writer of a magnetoresistive head.

Figure 11 is a cross-sectional view of the layer structure of a complete magnetoresistive head.

Figure 12 is a cross-sectional view showing the layer structure of the air bearing surface of a complete magnetoresistive head.

Figure 1A is a cross-sectional view of the layer structure of prior art magnetoresistive (MR) head 10. MR head 10 of Figure 1 illustrates a standard MR head having the writer portion of the head positioned on top of the reader portion of the head. MR head 10 includes basecoat oxide 12, bottom shield 14, first reader gap oxide layer 16, electrical contacts 18, MR element 20, second reader gap oxide layer 22, top shield/bottom pole 24, write gap oxide layer 26, polymer insulator layers 28a, 28b, and 28c, conductive coil layers 30a and 30b, and top pole 32.

Bottom shield 14 is deposited upon basecoat oxide 12. First read gap oxide layer 16 is then deposited upon bottom shield 14. Next, MR element 20 is deposited in a magnetic field and patterned. MR element 20 is the portion of MR head 10 which senses a magnetic field associated with a transition from a magnetic storage medium during a read operation. Electrical contacts 18 are then deposited on MR element 20 and first read gap oxide layer 16. Second read gap oxide layer 22 is then deposited. The two oxide layers, 16 and 22, comprise the read gaps, inside which MR element 20 is fabricated. Next, top shield/bottom pole 24 is laid down. Top shield/bottom pole 24 is normally utilized to provide the top shield of the reader portion of MR head 10 as



well as the bottom pole of the writer portion of MR head 10.

Write gap oxide layer 26 is deposited, followed by polymer insulator layer 28a, conductive coil layer 30a, polymer insulator layer 28b, conductive coil layer 30b, and polymer insulator layer 28c. Finally, top pole 32 is deposited to complete the fabrication of MR head 10. Top shield/bottom pole 24 and top pole 32 provide the writing capability of MR head 10 during a write operation. The number of conductive coils 30 and polymer insulator layers 28 are determined by design and affect the inductance capabilities of the writer portion of MR head 10. Each polymer insulator layer, however, must be cured at temperatures between 200°C and 400°C for varying lengths of time depending upon the specific polymer. Only the lower half of this temperature range for the curing process will avoid possible degradation of the magnetics of the reader portion of MR head 10. In addition, any cure temperature above 200°C will degrade the magnetics of a GMR device. This limits the choice of polymers available as insulators for MR head readers.

As shown in Figure 1B, MR head 10 is fabricated such that a top surface of second read gap oxide layer 22 is not flat or planarized. The non-planar surface of second read gap oxide layer 22 dictates that subsequent deposited layers of MR head 10 are also not flat or planarized. In particular, top pole 32, which is covered by overcoat oxide layer 33, can be offset from the center of MR head 10, which can degrade the quality of tracks written from MR head 10. In addition, it is desired that each deposited layer of MR head 10 is flat or planarized to prevent shorting of later deposited layers, thereby rendering MR head 10 inoperable.

Figure 2 is a cross-sectional view showing a layer structure near air bearing surface 52 of bottom pole 56. Inverted MR head 50 includes base coat 54, bottom pole 56, polymer insulator 58 having top surface 60 and dip 62, and conductive coils 64. Leading edge 51 is identified relative to air bearing surface 52.

In one embodiment, in order to fabricate inverted MR head 50, bottom pole 56, formed from plated permalloy, is initially deposited into a recessed portion of base coat



54. The recess in basecoat 54 is formed through a combination of chemical etching and ion milling. Polymer insulator 58 and conductive coils 64 fill the portion above bottom pole 56. Conductive coils 64, which are typically made of copper, can be positioned in polymer insulator 58 in one row, or as seen in Figure 2, conductive coils 64 can be positioned in a plurality of rows. The number of conductive coils 64 and polymer insulator layers 58 affects the inductance capabilities of the writer portion of inverted MR head 50.

As shown in Figure 2, top surface 60 of polymer insulator 58 can be somewhat irregular. Dip 62 can arise due to loss of polymer volume during the curing process. In the present invention, it is critical that top surface 60 of polymer insulator 58 be flat or planarized so that the remaining layers of inverted MR head 50 which are deposited on top of top surface 60 are deposited on a flat surface. Thus, any rough, jagged portions of top surface 60, including dip 62, must be eliminated.

As shown in Figure 3, all jagged and rough portions of top surface 60, including dip 62, have been eliminated. This elimination is normally done in one of two ways. First, the polymer material forming polymer insulator 58 can be deposited such that top surface 60 is higher than bottom pole 56. Top surface 60 can then undergo both a blanket reactive ion etch-back process and/or a chemical-mechanical polish until top surface 60 of polymer insulator 58 is both smooth and level with bottom pole 56. Second, the polymer material forming polymer insulator 58 can be deposited having rough top surface 60 and dip 62 (shown in Figure 2). A layer of silica can be deposited such that the top surface of the silica layer is slightly above bottom pole 56. Then, photoresist is deposited on top of the silica layer. When the photoresist hardens, it will be perfectly level due to surface tension. The photoresist and silica layer can then undergo a blanket reactive ion etch-back process that removes the silica and photoresist at the same rate, until top surface 60 of polymer insulator 58 is both smooth and entirely flat.

As shown in Figure 4, inverted MR head 50 further includes write gap oxide

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layer 66 having top surface 68 and channel 70. Write gap oxide layer 66 is deposited on top of top surface 60 of polymer insulator 58. Write gap oxide layer 66 can be formed from a variety of insulating materials, such as silica, alumina, or diamond-like carbon. Channel 70, located near air-bearing surface 52, is then ion-milled into write gap oxide layer 66 to define actual write gap 66a beneath channel 70. This allows extremely accurate definition of the pole tip 72 (shown in Figures 5 and 10). The reason is that the photoresist is deposited upon a flat surface, allowing more precise development of the features in the photoresist mask. Write gap oxide layer 66a at air bearing surface 52 beneath channel 70 has a height in the range of approximately 0.1 to 1.0 microns, and preferably in the range of approximately 0.2 to 0.8 microns.

As shown in Figure 5, pole tip 72 is positioned at trailing edge 73 of air bearing surface 52 of inverted MR head 50. Pole tip 72 is an insert formed from a high moment magnetic material such as iron nitride or cobalt iron. A high moment magnetic material is capable of supporting a larger density flux than the permalloy used in standard MR heads. The high moment insert forming pole tip 72 concentrates the magnetic flux and allows writing of a narrow track.

The high moment magnetic material forming pole tip 72 is either plated or sputtered into channel 70 until it is significantly higher than top surface 68 of write gap oxide layer 66. The thickness of the high moment insert depends upon the magnetic materials in the writer design. Typical values for the thickness of the insert range from 0.5 to 2.0 microns, and typical values for the track width of the pole tip range from 2.0 to 5.0 microns. In one preferred embodiment used for plated inserts such as cobalt iron ($\text{Co}_{90}\text{Fe}_{10}$), a non-magnetic seed layer such as nickel vanadium ($\text{Ni}_{80}\text{V}_{20}$) can be used, which then becomes part of the write gap. The protruding section of high moment material is then masked and permalloy is plated around it to obtain an approximately level surface. The masking above the insert is then removed and the entire shield is plated as a unit to the desired thickness. The top surface of the top pole/bottom shield 74 combination will very likely contain irregularities, which are



then removed by chemical mechanical polishing.

Figures 6 and 7 are layered diagrams of the layer structure of a first embodiment of the present invention. Figures 6 and 7 are similar to Figures 4 and 5. Therefore, similar layers and elements have been labelled with identical numbers. As shown in Figures 6 and 7, polymer insulator 58 is larger than that shown in Figures 4 and 5. Therefore, write gap oxide layer 66, deposited on top of polymer insulator 58, does not have a level top surface 68. In this embodiment of the invention, gap oxide layer 66 is much thinner distal to air bearing surface 52 than in the previous embodiment. Top pole 67 is fabricated on top of gap oxide layer 66. Top pole 67 may be a high moment material. Next, oxide 75 is deposited and planarized by methods previously discussed. Oxide 75 may be, for example, silica. Bottom shield 74 is then deposited on top of top pole 67 and oxide 75. Bottom shield 74 may then be planarized. This may not be necessary because the oxide 75 has been planarized.

In the embodiment shown in figures 6 and 7, top pole 67 is deposited and planarized before the shield 74 is deposited. It would of course be possible to deposit the bottom shield 74 on top of the top pole 67 without first planarizing the top pole 67 and then planarize the bottom shield 74. It would also be possible to replace the top pole 67 and bottom shield 74 with a single combined top pole/bottom shield element and omit the oxide 75. The top surface of the combined top pole/bottom shield would be planarized.

The embodiment shown in Figures 6 and 7 provides a good definition zero throat. Good definition zero throat is necessary for proper performance.

Figures 8A-8C are layered diagrams of the layer structure of a second alternate method of fabricating pole tip 72. In Figures 8A-8C, pole tip 72 is plated or sputtered into channel 70. The pole material forming pole tip 72 is then ion milled to provide the proper width of pole tip 72. Bottom shield 74 is then fabricated on top of pole tip 72 and top surface 68 of write gap oxide layer 66. Bottom shield 74 is then planarized.

Figures 9A-9D are layered diagrams showing a third alternate method of

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forming pole tip 72. As shown in Figures 9A-9D, a layer of high moment material is plated or sputtered on top of write gap oxide layer 66. The sides of pole tip 72 are then ion milled to provide the proper width of pole tip 72. Lift-off photoresist layer 71 can be put on top of pole tip 72 and additional oxide layer can be fabricated. Bottom shield 74 can then be fabricated. Bottom shield 74 can then planarized.

Although the methods of forming pole tip 72 described above with reference to figure 5 and figures 8A to 8C and 9A to 9C are all described as forming an MR head of the type illustrated in one of figures 2 to 5 and 10, all of these methods described with reference to any one of figures 5 and 8A to 8C and 9A to 9C can be used in an MR head employing the present invention as described with reference to either one of figures 6 and 7.

Figure 10 is a layer diagram showing air bearing surface 52 of a writer of inverted MR head 50. As shown in Figure 10, pole tip 72 is aligned above bottom pole 56; with the critical portion of write gap oxide layer 66A located between bottom pole 56 and pole tip 72. The distance between bottom pole 56 and pole tip 72, which is the critical distance of write gap oxide layer 66 is in the range of approximately 1,000 to 10,000 angstroms, and preferably in the range of approximately 2,000 to 8,000 angstroms. In one preferred embodiment, bottom pole 56 has a height in the range of approximately 2.0 to 4.0 micrometers, write gap oxide layer 66 formed between top surface 60 of polymer insulator 58 and top surface 68 has a height in the range of approximately 2,000 to 8,000 angstroms, pole tip 72 has a height in the range of approximately 5,000 to 20,000 angstroms, and bottom shield 74 between top surface 68 of write gap oxide layer 66 and top surface 76 of bottom shield 74 has a height in the range of approximately 1.5 to 4.0 micrometers.

Figure 11 is a layer diagram showing the entire fabricated inverted MR head 50, including both the writer and the reader portions of inverted MR head 50. Once bottom shield 74 has been deposited and planarized, the remaining layers of the reader can be deposited on the flat surface of bottom shield 74. Deposition on a series of flat

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surfaces alleviates shorting, which is a critical issue in standard MR heads.

Once the writer portion of inverted MR head 50 has been fabricated, first reader gap oxide layer 78 is deposited on top of bottom shield 74. In one preferred embodiment, first reader gap oxide layer 78 has a height of less than 4000 angstroms. MR element 80 is fabricated on first reader gap oxide layer 78 near trailing edge 73 of inverted MR head 50. MR element 80 may be a single film or composite film structure. The specific embodiment of MR element 80 does not affect the usefulness of the present invention. Electrical contacts 82 are then deposited, followed by second reader gap oxide layer 84, top shield 86, and overcoat oxide layer 88. In one preferred embodiment, second reader gap oxide layer 84 has a height of less than 4000 angstroms. In addition, a boundary control stabilization layer, a permanent magnet stabilization layer, and/or an additional layer of contacts for inductive cancellation or low circuit resistance can be incorporated into the MR reader if necessary for a particular application.

Figure 12 is a layer diagram of inverted MR head 50 showing both the reader and the writer. As shown in Figure 12, bottom pole 56, pole tip 72, and MR element 80 are aligned with one another. This invention improves the accuracy of the alignment of the MR sensor to the pole tip and the top pole, since there are only one or two intervening mask layers to complicate mask alignment, as compared to ten or more intervening mask layers in prior art non-inverted MR heads. The alignment of bottom pole 56, pole tip 72, and MR element 80 is critical in forming an MR head which can both precisely read information from a magnetic storage medium and write information to the magnetic storage medium.

The inverted MR head 50 shown in figures 11 and 12 has a writer portion of the type shown in figures 2 to 5 and 10. The inverted MR head structure shown in figures 11 and 12 could also be used with a writer portion employing the present invention as described with reference to either one of figures 6 and 7.

There are several advantages of inverted MR head 50 of the present invention.

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First, precise definition of the top pole is achieved. Second, the distance between MR element 80 and top pole 72 is substantially reduced over the prior art. This allows inverted MR head 50 to write higher linear densities on the disc. Third, planarity of the top pole allows the reader and the writer to be offset without the top pole having a dip in it, such as the dip of the prior art shown in Figure 1B. Fourth, use of sendust or other rough films for the top shield will not cause shorting due to roughness, since the only film above the top shield surface is the overcoat. Fifth, building the writer prior to building the reader allows use of high temperature curing polymers such as polyimide and benzene cyclo-butene (BCB) without degrading the MR sensor magnetics or other properties. Sixth, building the writer prior to building the reader allows use of spin valves or giant MR sensors since high temperature polymer cures could cause inter-diffusion among the extremely thin layers of giant MR sensors or spin valves, thus destroying their effectiveness. By having all high temperature cures completed before the reader portion is built, few restrictions are placed on the use of giant MR and/or spin valves sensors. In particular, the materials for the reader and writer can be optimized independently of each other to a much greater extent than the prior art.

In the above description, the pole tip is described as being formed of a high moment magnetic material, the pole tip could instead be formed of a non-magnetic high moment material in any and all cases.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

The foregoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the present invention.

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CLAIMS

1. A method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole (56) in a recessed portion of a basecoat (54) distal from an air bearing surface (52) of the head;

positioning a polymer insulator (58) and conductive coils (64) above the bottom pole; and characterised by further comprising:

fabricating a write gap on top of the bottom pole at a level below the level of the top surface of the polymer insulator;

forming a pole tip (72) of high moment magnetic material in the write gap proximal to the air bearing surface;

fabricating a bottom shield (74) having a planarized top surface on top of the pole tip and the write gap;

fabricating a first reader gap (78) on top of the bottom shield;

forming a magnetoresistive element (80) on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts (82) on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap (84) on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield (86) on top of the second reader gap.

2. The method of claim 1 wherein the step of fabricating a bottom shield having a planarized top surface further comprises:

fabricating a top pole (67) on top of the pole tip and the write gap;





planarizing a top surface of the top pole; and
fabricating the bottom shield on top of the top pole.

3. The method of claim 2 wherein the step of planarizing the top surface of the top pole further comprises:

depositing an oxide layer (75) on top of the top surface of the top pole;
depositing a photoresistive layer on top of the oxide layer; and
reactive ion etching the oxide layer and the photoresistive layer until the top surface of the top pole is substantially smooth.

4. The method of any one of claims 1 to 3 and further comprising planarizing a top surface of the bottom shield.

5. The method of any preceding claim wherein the step of fabricating a bottom pole further comprises:

plating polymer into the basecoat.

6. The method of any preceding claim wherein the bottom pole is made of a plated permalloy.

7. The method of any preceding claim wherein the write gap is formed from silica, diamond-like carbon or alumina.

8. The method of any preceding claim and further comprising:
ion milling a channel (70) into the write gap; and
filling the channel with the high moment magnetic material.

9. The method of any preceding claim wherein the step of forming a pole tip of



high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

ion-milling a channel (70) into the write gap proximal to the air bearing surface;
plating the pole tip of high moment magnetic material into the channel such that a top surface of the pole tip is above a top surface (68) of the write gap; and
ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip.

10. The method of any one of claims 1 to 8 wherein the step of forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

ion-milling a channel (70) into the write gap proximal to the air bearing surface;
sputtering the pole tip of high moment magnetic material into the channel such that a top surface of the pole tip is above a top surface (68) of the write gap; and
ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip.

11. The method of any one of claims 1 to 8 wherein the step of forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

fabricating a first write gap layer on top of the top surface of the polymer;
plating the pole tip on the top surface of the first write gap layer proximal to the air bearing surface such that a top surface of the pole tip lies in a first plane;
ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip;
fabricating a lift-off photoresist layer (71) on top of the pole tip;
fabricating a second write gap layer on top of the first write gap layer so that a top surface of the second write gap layer lies in the first plane;

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removing the lift-off photoresist layer.

12. The method of any one of claims 1 to 8 wherein the step of forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

fabricating a first write gap layer on top of the top surface of the polymer;

sputtering the pole tip on the top surface of the first write gap layer proximal to the air bearing surface such that a top surface of the pole tip lies in a first plane;

ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip;

fabricating a lift-off photoresist layer (71) on top of the pole tip;

fabricating a second write gap layer on top of the first write gap layer so that a top surface of the second write gap layer lies in the first plane;

removing the lift-off photoresist layer.

13. The method of claim 11 and claim 12, and further comprising;

fabricating a third write gap layer on top of the second write gap layer and the pole tip.

14. A method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole (56) in a recessed portion of a basecoat (54) distal from an air bearing surface (52) of the head;

positioning a polymer insulator (58) and conductive coils (64) above the bottom pole; and characterised by further comprising:

fabricating a write gap (66A) on top of the polymer insulator distal to the air bearing surface and positioned on top of the bottom pole proximal to the air bearing surface;



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forming a top pole (67) on top of the write gap;

fabricating an oxide layer (75) on top of the top pole proximal to the air bearing surface;

planarizing a top surface of the oxide layer and a top surface of a portion of the top pole distal to the air bearing surface;

fabricating a bottom shield (74) on top of the oxide layer and the top pole;

fabricating a first reader gap (78) on top of the bottom shield;

forming a magnetoresistive element (80) on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts (82) on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap (84) on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield (86) on top of the second reader gap.

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* C L M S *

ABSTRACT

METHOD OF FABRICATING AN INVERTED MAGNETORESISTIVE READ

A method of fabricating an inverted magnetoresistive head is disclosed. The method includes fabricating a writer. The writer includes a bottom pole (56) positioned within a recessed substrate (54). The bottom pole is filled with copper coils (64) and polymer (58). A write gap (66A), a pole tip (72), and a top pole (67) are fabricated on a portion of the polymer. A top surface of the top pole is planarized and a bottom shield (74) is fabricated on the top pole to provide a substantially smooth surface upon which a reader can be placed. The reader is fabricated on top of the writer and includes a first reader gap (78), a magnetoresistive element (80), a second reader gap (84), and a shield (86).

Fig. 7

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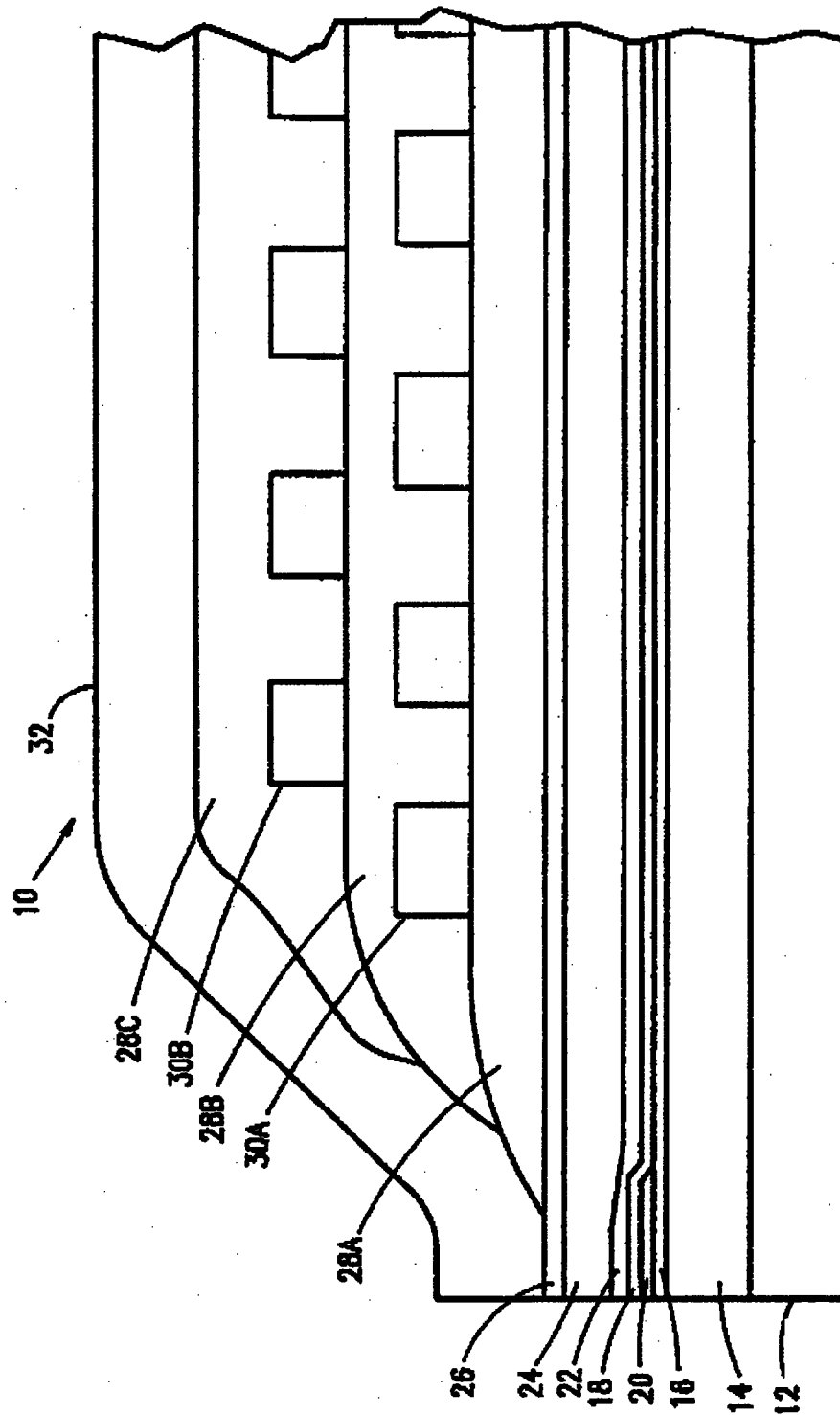


FIG. 1A
PRIOR ART

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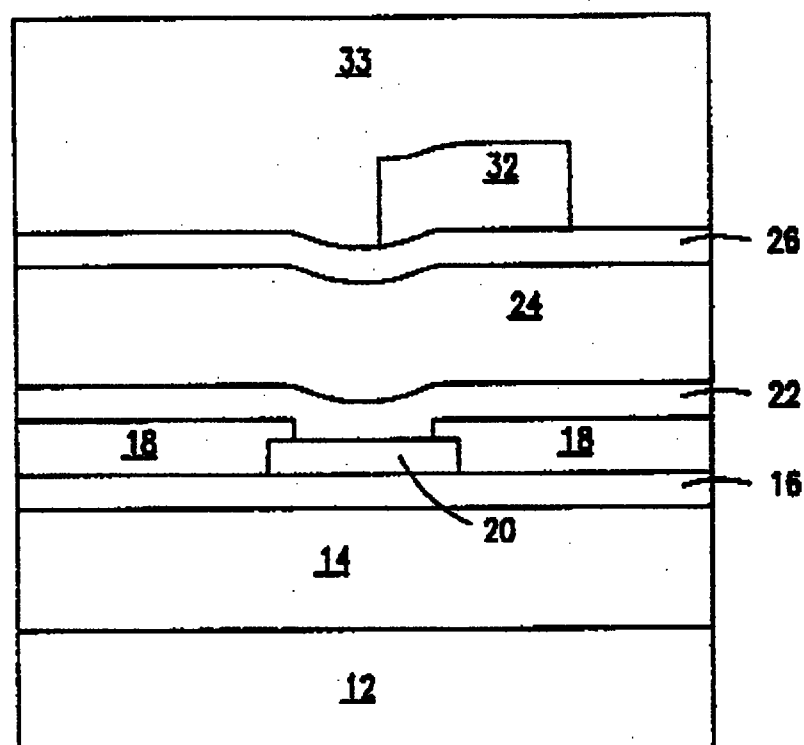
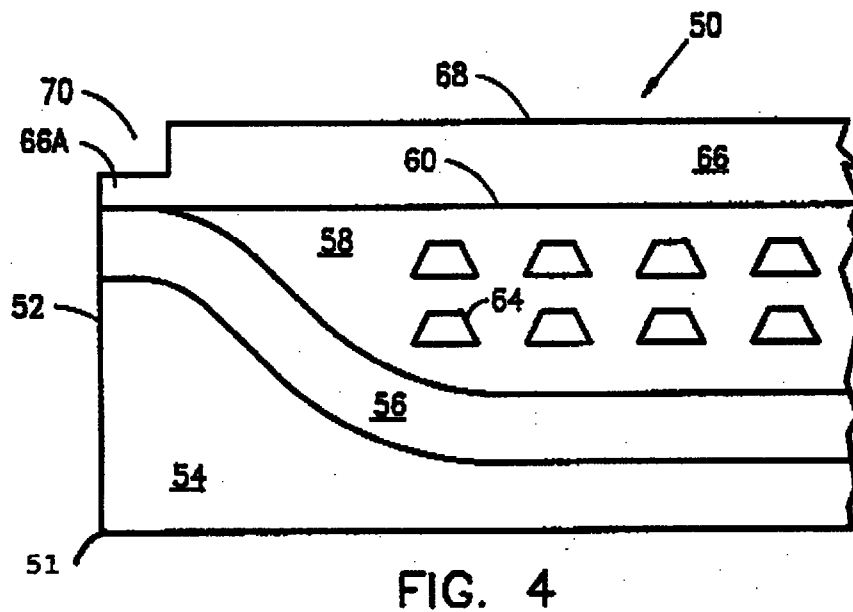
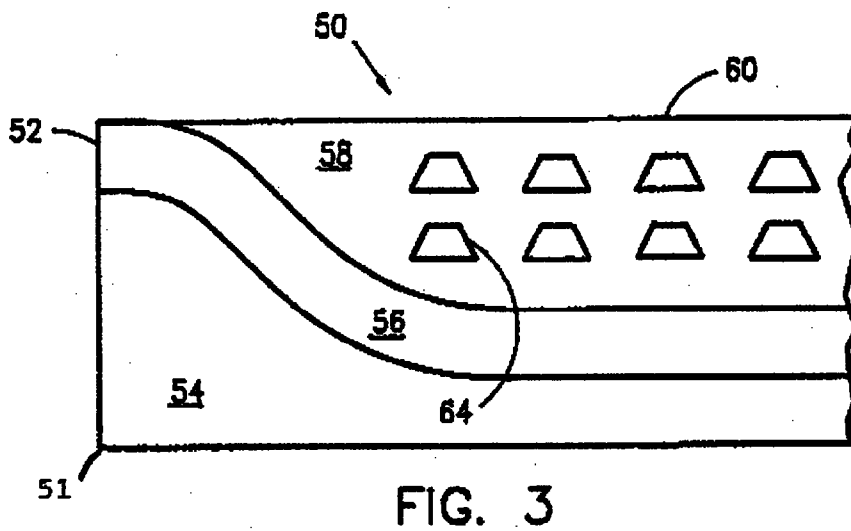
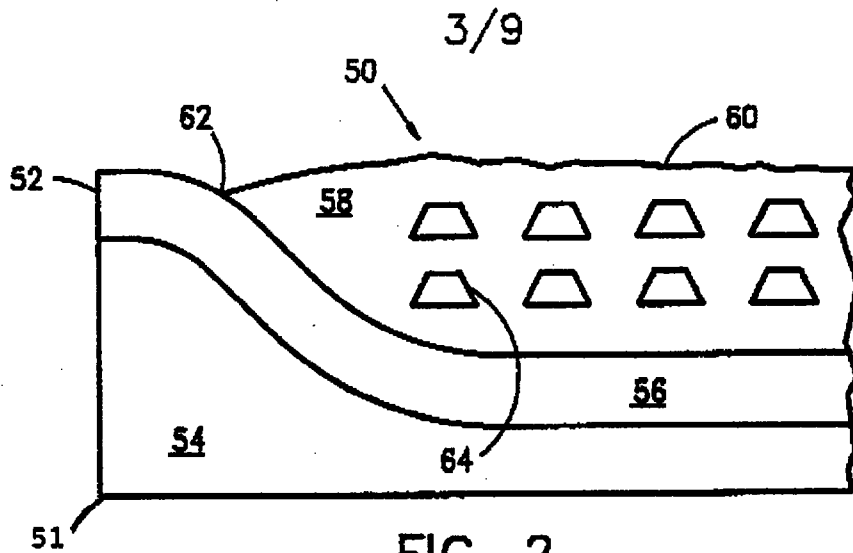


FIG. 1B

PRIOR ART

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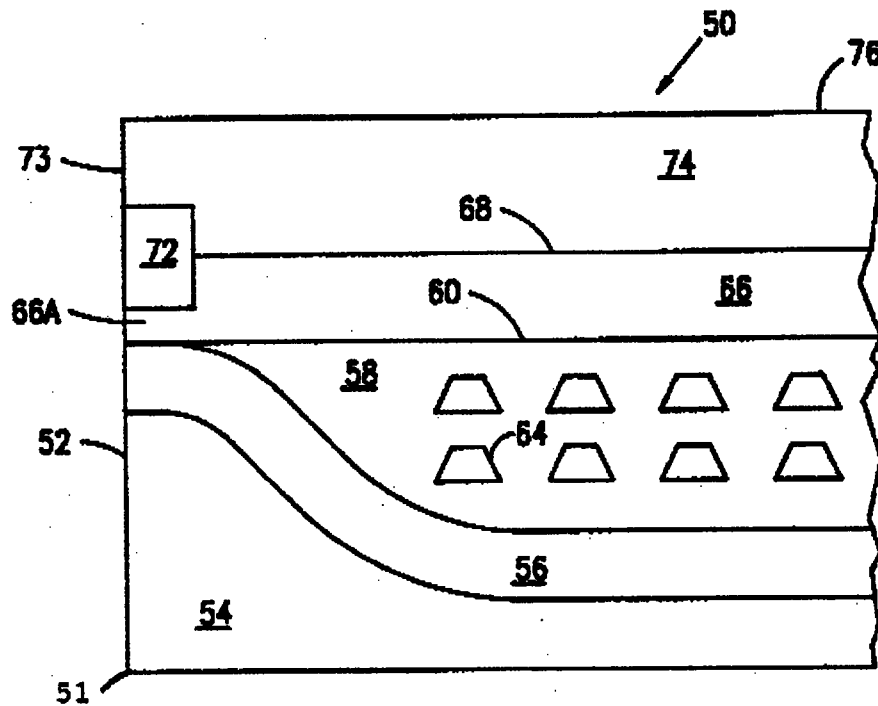


FIG. 5

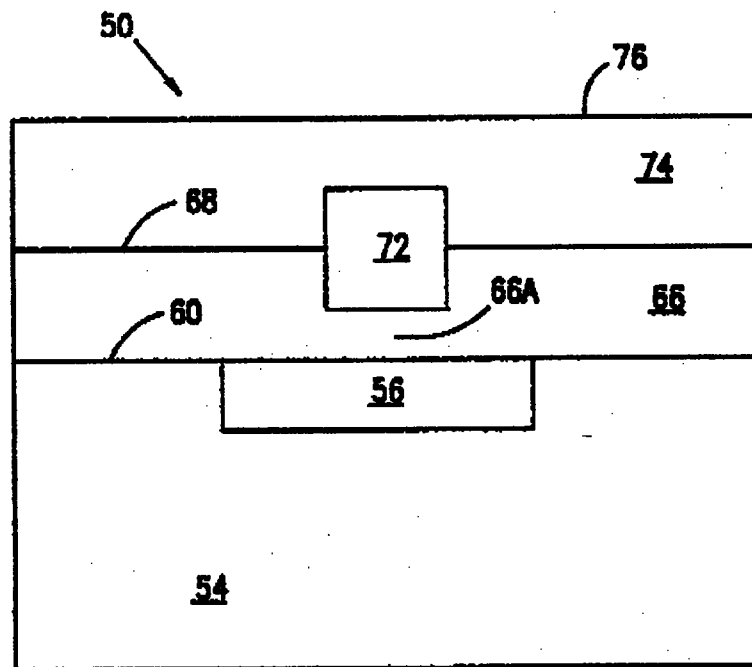


FIG. 10

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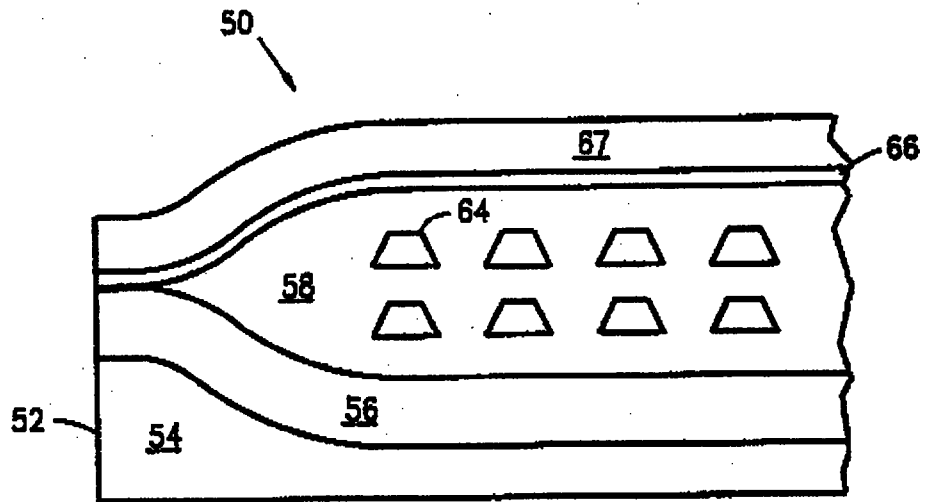


FIG. 6

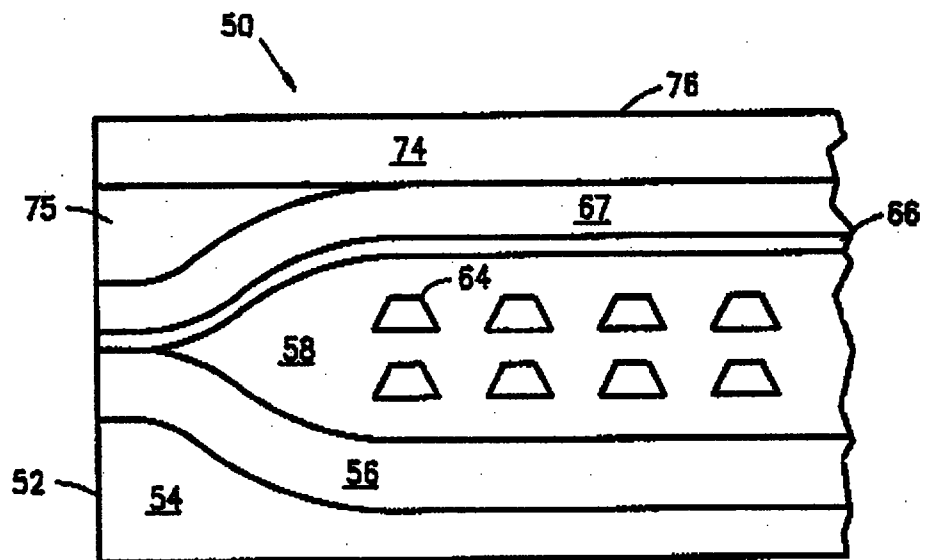


FIG. 7

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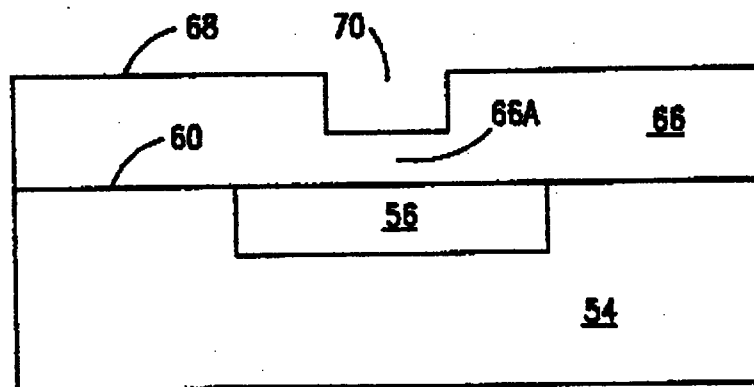


FIG. 8A

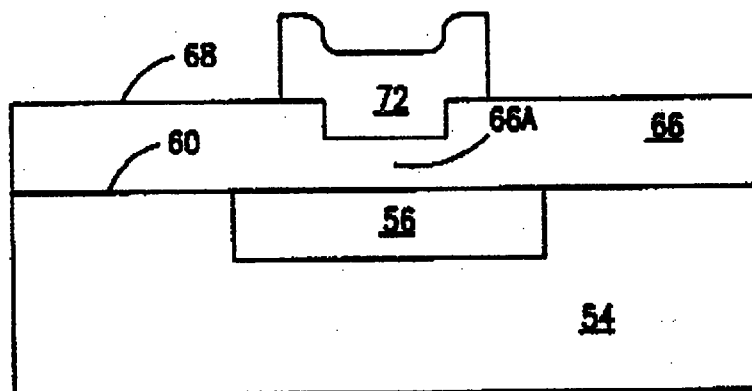


FIG. 8B

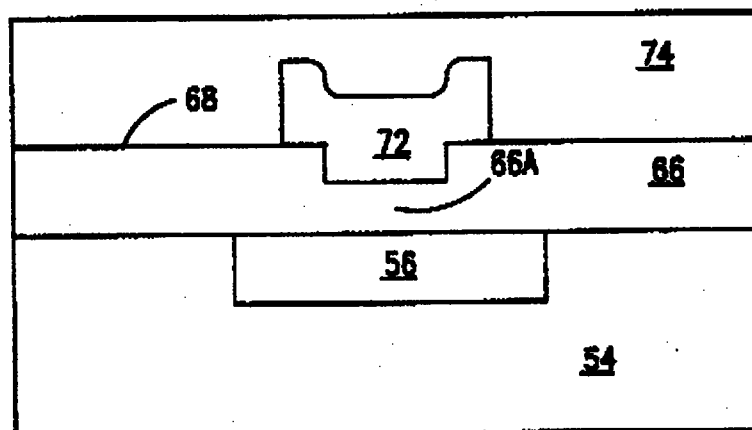


FIG. 8C

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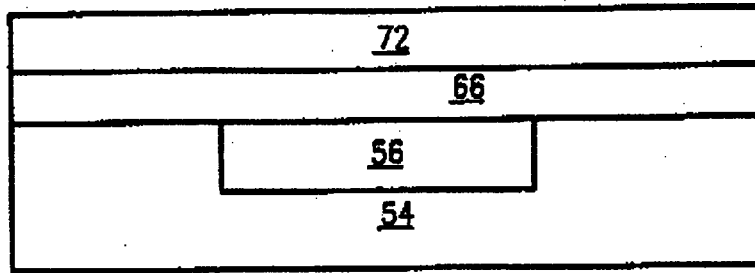


FIG. 9A

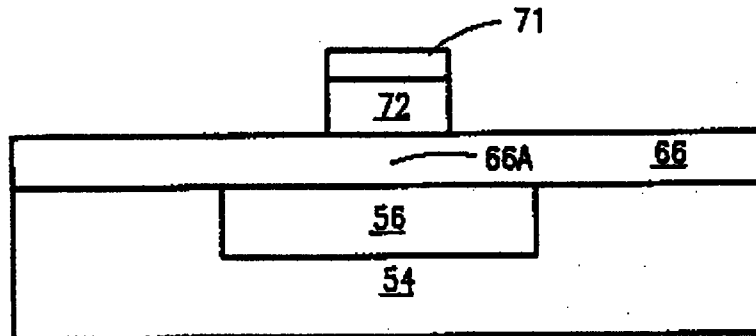


FIG. 9B

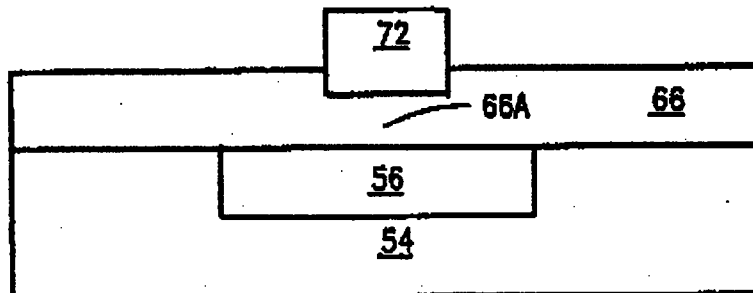


FIG. 9C

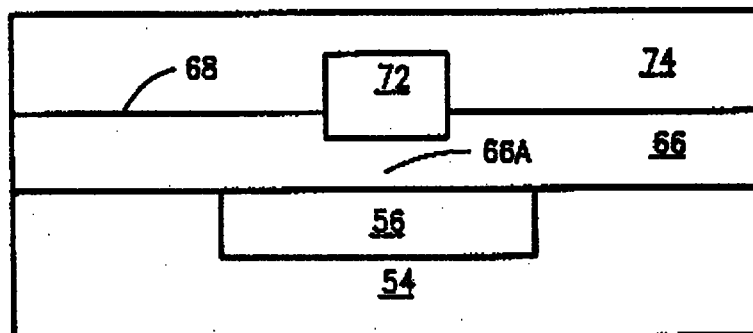


FIG. 9D

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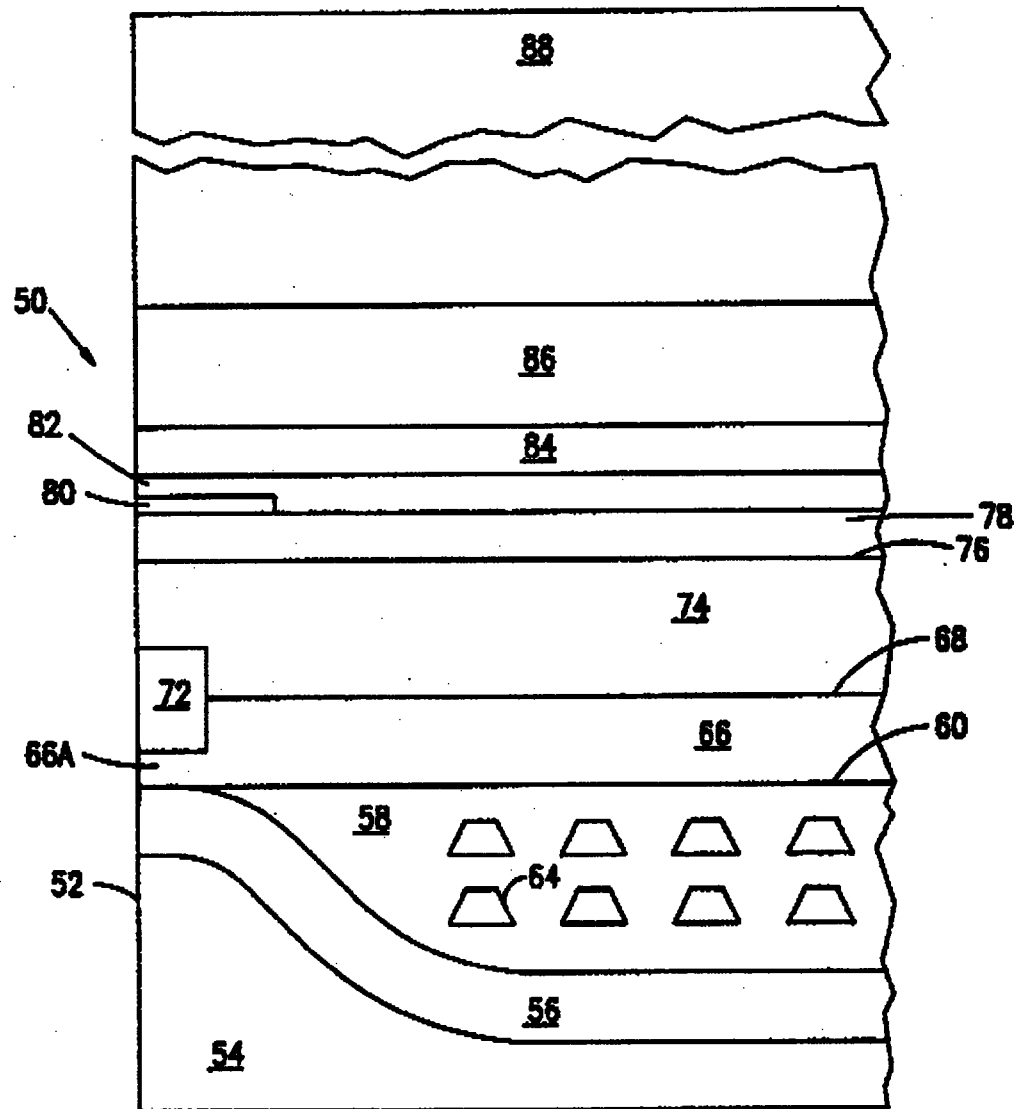


FIG. 11

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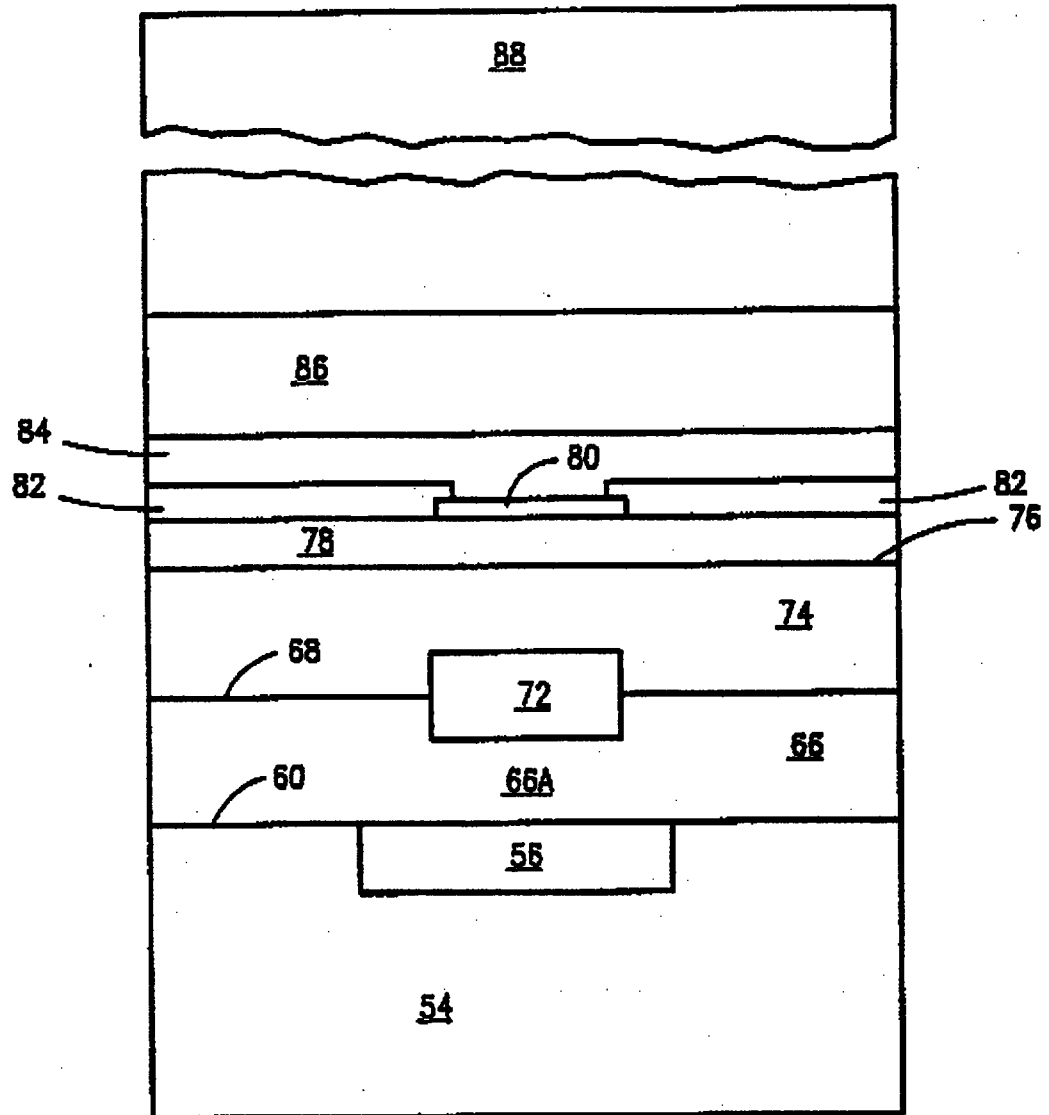


FIG. 12

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REPLACEMENT SHEETS		SG
☒ Description	: paged .../ to paged .../	13
☒ Claim(s)	: paged .../ to paged .../	14
☒ Drawing(s)	: paged .../ to paged .../	15
☒ Abstract	: paged .../ to paged .../	16
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REPLACEMENT SHEET

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METHOD OF FABRICATING AN INVERTED MAGNETORESISTIVE HEAD

The present invention relates to a method of fabricating a magnetoresistive head for high frequency; high data rate, and high track density applications, and in particular to a method of fabricating an inverted magnetoresistive head having the reader portion of the magnetoresistive head fabricated on top of the writer portion of the magnetoresistive head.

Standard magnetoresistive (MR) heads are fabricated with the writer portion fabricated on top of the reader portion. MR heads are used in magnetic storage systems to detect magnetically encoded information from a magnetic storage medium or disc and to write magnetically encoded information to the storage medium. In a read mode, a time dependent magnetic field associated with a transition from a magnetic storage medium directly modulates the resistivity of an MR element. In operation, the change in resistance of the MR element can be detected by passing a sense current through the MR element and measuring the voltage across the MR element. The resulting signal can be used to recover information or data from the magnetic storage medium.

Practical MR elements are typically formed using ferromagnetic metal alloys because of their high magnetic permeability, an example of which is nickel iron (NiFe). A ferromagnetic material is deposited in a thin film upon the surface of an electrically insulated substrate or wafer. Changing magnetic fields originating from the magnetic storage medium produce a change in the magnetisation direction of the MR element and thereby change the resistance of the sensor. This phenomenon is called the MR effect.

The element itself comprises a strip of MR material deposited on a magnetic shield layer to form an MR element. A series of depositions and etching processes form an active region from a portion of the MR element. The active region is the area of the MR element that senses changing magnetic fields from the magnetic storage medium.

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Changing magnetic fields produce a change in the resistivity of the MR element. Typical resistivity changes are in the order of 0.5 percent to 2.0 percent change. An upper magnetic shield acts as a barrier between the MR element and the surface of the magnetic storage medium to prevent changing magnetic fields associated with transitions passing by the head from linking back to the element. The magnetic shield also serves to protect the element from receiving stray magnetic fields associated with transitions from surrounding magnetic storage media.

Giant MR (GMR) sensors formed from GMR materials are the new line in the family of MR sensors. GMR sensors are formed from GMR elements, which are multi-layered structures. These devices include layers of magnetic and non-magnetic material, which may be films of ferro-magnetic and non-ferro magnetic material or a similar set of films. Permalloy may or may not be part of the layered pattern. In GMR sensors, the change in resistivity can be in excess of 65 percent.

One problem which affects performance of MR heads is the degree to which surfaces in the head can be fabricated flat or "planarized." In particular, in prior art heads, the top shield of an MR sensor has a dip just above the active region of the MR element. This degrades off track performance. Lack of planarization can also cause an electrical short between various layers of the head, such as between the contacts to the MR element and the top shield or between the top shield and subsequent fabricated layers. In addition, the bottom shield is usually fabricated from sendust or other high permeability magnetic materials, which is relatively rough for a thin film. This relatively rough surface can also cause shorting problems between the bottom shield and the contact film. Attempts at planarizing MR readers have focused on smoothing the bottom shield, planarizing the insulator above the MR sensor, or smoothing the top shield. These steps take additional process time and can limit design flexibility.

Another problem which affects performance of MR heads is that GMR heads are susceptible to inter-diffusion among the extremely thin layers of a GMR head during a polymer cure, even when a low temperature polymer cure is utilized. This

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inter-diffusion can destroy the effectiveness of the GMR head.

In a first aspect, this invention provides a method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole in a recessed portion of a basecoat distal from an air bearing surface of the head;

positioning a polymer insulator and conductive coils above the bottom pole; and characterised by further comprising:

fabricating a write gap on top of the bottom pole at a level below the level of the top surface of the polymer insulator;

forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface;

fabricating a bottom shield having a planarized top surface on top of the pole tip and the write gap;

fabricating a first reader gap on top of the bottom shield;

forming a magnetoresistive element on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield on top of the second reader gap.

In a second aspect, this invention provides a method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole in a recessed portion of a basecoat distal from an air bearing surface of the head;

positioning a polymer insulator and conductive coils above the bottom pole; and characterised by further comprising:

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fabricating a write gap on top of the polymer insulator distal to the air bearing surface and positioned on top of the bottom pole proximal to the air bearing surface;

forming a top pole on top of the write gap;

fabricating an oxide layer on top of the top pole proximal to the air bearing surface;

planarizing a top surface of the oxide layer and a top surface of a portion of the top pole distal to the air bearing surface;

fabricating a bottom shield on top of the oxide layer and the top pole;

fabricating a first reader gap on top of the bottom shield;

forming a magnetoresistive element on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield on top of the second reader gap.

The present invention is a method of manufacturing an inverted magnetoresistive head for reading magnetically stored information from a magnetic storage medium. The method includes fabricating a bottom pole in a recessed portion of a basecoat, which is distal from an air bearing surface of the magnetoresistive head. A polymer insulator and connective coils are positioned above the bottom pole. A write gap is fabricated on top of the bottom pole, below the top surface of the polymer. A pole tip of magnetic high moment material is formed in the write gap proximal to the air bearing surface. A top pole is fabricated on top of the pole tip and the write gap. The top pole is planarized. A bottom shield is fabricated on top of the top pole. The bottom shield may be planarized if desired. Alternatively, the bottom shield may be planarized and the top pole not be planarized. A first reader gap is fabricated on top of

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the bottom shield. A magnetoresistive element is formed on top of a portion of the first reader gap proximal to the air bearing surface. Electrical contacts are fabricated on top of a top portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the magnetoresistive head. A second read gap layer is fabricated on top of the electrical contacts and the magnetoresistive element. A top shield is fabricated on top of the second reader gap. Finally, an overcoat of oxide is fabricated on top of the top shield.

Alternatively, the top pole and bottom shield may be formed as a single element and the top surface of this combined top pole/bottom shield be planarized.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic figures, in which;

Figure 1A is a layer diagram view of the layer structure of a prior art magnetoresistive head.

Figure 1B is a layer diagram view showing the layer structure of the air bearing surface of a prior art magnetoresistive head.

Figure 2 is a layer diagram view of the layer structure of a bottom pole of a writer of a magnetoresistive head prior to planarization.

Figure 3 is a layer diagram view of the layer structure of a bottom pole of a writer of a magnetoresistive head after planarization.

Figure 4 is a layer diagram view of the layer structure of a bottom portion of a writer showing a recessed channel in the write gap.

Figure 5 is a layer diagram view of the layer structure of a writer of a magnetoresistive head.

Figure 6 is a layer diagram view of the layer structure of an embodiment of a bottom portion of a writer employing the invention showing a recess channel in the writer gap.

Figure 7 is a layer diagram view of the layer structure of the embodiment of Figure 6.

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Figures 8A-8C are layer diagrams of the layer structure of the air bearing surface of a writer of a magnetoresistive head showing an alternate method of fabricating a pole tip.

Figures 9A-9D are layer diagrams of the layer structure of the air bearing surface of a writer of a magnetoresistive head showing an alternate method of fabricating a pole tip.

Figure 10 is a cross-sectional view of the layer of the air bearing surface of a writer of a magnetoresistive head.

Figure 11 is a cross-sectional view of the layer structure of a complete magnetoresistive head.

Figure 12 is a cross-sectional view showing the layer structure of the air bearing surface of a complete magnetoresistive head.

Figure 1A is a cross-sectional view of the layer structure of prior art magnetoresistive (MR) head 10. MR head 10 of Figure 1 illustrates a standard MR head having the writer portion of the head positioned on top of the reader portion of the head. MR head 10 includes basecoat oxide 12, bottom shield 14, first reader gap oxide layer 16, electrical contacts 18, MR element 20, second reader gap oxide layer 22, top shield/bottom pole 24, write gap oxide layer 26, polymer insulator layers 28a, 28b, and 28c, conductive coil layers 30a and 30b, and top pole 32.

Bottom shield 14 is deposited upon basecoat oxide 12. First read gap oxide layer 16 is then deposited upon bottom shield 14. Next, MR element 20 is deposited in a magnetic field and patterned. MR element 20 is the portion of MR head 10 which senses a magnetic field associated with a transition from a magnetic storage medium during a read operation. Electrical contacts 18 are then deposited on MR element 20 and first read gap oxide layer 16. Second read gap oxide layer 22 is then deposited. The two oxide layers, 16 and 22, comprise the read gaps, inside which MR element 20 is fabricated. Next, top shield/bottom pole 24 is laid down. Top shield/bottom pole 24 is normally utilized to provide the top shield of the reader portion of MR head 10 as

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well as the bottom pole of the writer portion of MR head 10.

Write gap oxide layer 26 is deposited, followed by polymer insulator layer 28a, conductive coil layer 30a, polymer insulator layer 28b, conductive coil layer 30b, and polymer insulator layer 28c. Finally, top pole 32 is deposited to complete the fabrication of MR head 10. Top shield/bottom pole 24 and top pole 32 provide the writing capability of MR head 10 during a write operation. The number of conductive coils 30 and polymer insulator layers 28 are determined by design and affect the inductance capabilities of the writer portion of MR head 10. Each polymer insulator layer, however, must be cured at temperatures between 200°C and 400°C for varying lengths of time depending upon the specific polymer. Only the lower half of this temperature range for the curing process will avoid possible degradation of the magnetics of the reader portion of MR head 10. In addition, any cure temperature above 200°C will degrade the magnetics of a GMR device. This limits the choice of polymers available as insulators for MR head readers.

As shown in Figure 1B, MR head 10 is fabricated such that a top surface of second read gap oxide layer 22 is not flat or planarized. The non-planar surface of second read gap oxide layer 22 dictates that subsequent deposited layers of MR head 10 are also not flat or planarized. In particular, top pole 32, which is covered by overcoat oxide layer 33, can be offset from the center of MR head 10, which can degrade the quality of tracks written from MR head 10. In addition, it is desired that each deposited layer of MR head 10 is flat or planarized to prevent shorting of later deposited layers, thereby rendering MR head 10 inoperable.

Figure 2 is a cross-sectional view showing a layer structure near air bearing surface 52 of bottom pole 56. Inverted MR head 50 includes base coat 54, bottom pole 56, polymer insulator 58 having top surface 60 and dip 62, and conductive coils 64. Leading edge 51 is identified relative to air bearing surface 52.

In one embodiment, in order to fabricate inverted MR head 50, bottom pole 56, formed from plated permalloy, is initially deposited into a recessed portion of base coat

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54. The recess in basecoat 54 is formed through a combination of chemical etching and ion milling. Polymer insulator 58 and conductive coils 64 fill the portion above bottom pole 56. Conductive coils 64, which are typically made of copper, can be positioned in polymer insulator 58 in one row, or as seen in Figure 2, conductive coils 64 can be positioned in a plurality of rows. The number of conductive coils 64 and polymer insulator layers 58 affects the inductance capabilities of the writer portion of inverted MR head 50.

As shown in Figure 2, top surface 60 of polymer insulator 58 can be somewhat irregular. Dip 62 can arise due to loss of polymer volume during the curing process. In the present invention, it is critical that top surface 60 of polymer insulator 58 be flat or planarized so that the remaining layers of inverted MR head 50 which are deposited on top of top surface 60 are deposited on a flat surface. Thus, any rough, jagged portions of top surface 60, including dip 62, must be eliminated.

As shown in Figure 3, all jagged and rough portions of top surface 60, including dip 62, have been eliminated. This elimination is normally done in one of two ways. First, the polymer material forming polymer insulator 58 can be deposited such that top surface 60 is higher than bottom pole 56. Top surface 60 can then undergo both a blanket reactive ion etch-back process and/or a chemical-mechanical polish until top surface 60 of polymer insulator 58 is both smooth and level with bottom pole 56. Second, the polymer material forming polymer insulator 58 can be deposited having rough top surface 60 and dip 62 (shown in Figure 2). A layer of silica can be deposited such that the top surface of the silica layer is slightly above bottom pole 56. Then, photoresist is deposited on top of the silica layer. When the photoresist hardens, it will be perfectly level due to surface tension. The photoresist and silica layer can then undergo a blanket reactive ion etch-back process that removes the silica and photoresist at the same rate, until top surface 60 of polymer insulator 58 is both smooth and entirely flat.

As shown in Figure 4, inverted MR head 50 further includes write gap oxide

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layer 66 having top surface 68 and channel 70. Write gap oxide layer 66 is deposited on top of top surface 60 of polymer insulator 58. Write gap oxide layer 66 can be formed from a variety of insulating materials, such as silica, alumina, or diamond-like carbon. Channel 70, located near air-bearing surface 52, is then ion-milled into write gap oxide layer 66 to define actual write gap 66a beneath channel 70. This allows extremely accurate definition of the pole tip 72 (shown in Figures 5 and 10). The reason is that the photoresist is deposited upon a flat surface, allowing more precise development of the features in the photoresist mask. Write gap oxide layer 66a at air bearing surface 52 beneath channel 70 has a height in the range of approximately 0.1 to 1.0 microns, and preferably in the range of approximately 0.2 to 0.8 microns.

As shown in Figure 5, pole tip 72 is positioned at trailing edge 73 of air bearing surface 52 of inverted MR head 50. Pole tip 72 is an insert formed from a high moment magnetic material such as iron nitride or cobalt iron. A high moment magnetic material is capable of supporting a larger density flux than the permalloy used in standard MR heads. The high moment insert forming pole tip 72 concentrates the magnetic flux and allows writing of a narrow track.

The high moment magnetic material forming pole tip 72 is either plated or sputtered into channel 70 until it is significantly higher than top surface 68 of write gap oxide layer 66. The thickness of the high moment insert depends upon the magnetic materials in the writer design. Typical values for the thickness of the insert range from 0.5 to 2.0 microns, and typical values for the track width of the pole tip range from 2.0 to 5.0 microns. In one preferred embodiment used for plated inserts such as cobalt iron ($\text{Co}_{90}\text{Fe}_{10}$), a non-magnetic seed layer such as nickel vanadium ($\text{Ni}_{80}\text{V}_{20}$) can be used, which then becomes part of the write gap. The protruding section of high moment material is then masked and permalloy is plated around it to obtain an approximately level surface. The masking above the insert is then removed and the entire shield is plated as a unit to the desired thickness. The top surface of the top pole/bottom shield 74 combination will very likely contain irregularities, which are

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then removed by chemical mechanical polishing.

Figures 6 and 7 are layered diagrams of the layer structure of a first embodiment of the present invention. Figures 6 and 7 are similar to Figures 4 and 5. Therefore, similar layers and elements have been labelled with identical numbers. As shown in Figures 6 and 7, polymer insulator 58 is larger than that shown in Figures 4 and 5. Therefore, write gap oxide layer 66, deposited on top of polymer insulator 58, does not have a level top surface 68. In this embodiment of the invention, gap oxide layer 66 is much thinner distal to air bearing surface 52 than in the previous embodiment. Top pole 67 is fabricated on top of gap oxide layer 66. Top pole 67 may be a high moment material. Next, oxide 75 is deposited and planarized by methods previously discussed. Oxide 75 may be, for example, silica. Bottom shield 74 is then deposited on top of top pole 67 and oxide 75. Bottom shield 74 may then be planarized. This may not be necessary because the oxide 75 has been planarized.

In the embodiment shown in figures 6 and 7, top pole 67 is deposited and planarized before the shield 74 is deposited. It would of course be possible to deposit the bottom shield 74 on top of the top pole 67 without first planarizing the top pole 67 and then planarize the bottom shield 74. It would also be possible to replace the top pole 67 and bottom shield 74 with a single combined top pole/bottom shield element and omit the oxide 75. The top surface of the combined top pole/bottom shield would be planarized.

The embodiment shown in Figures 6 and 7 provides a good definition zero throat. Good definition zero throat is necessary for proper performance.

Figures 8A-8C are layered diagrams of the layer structure of a second alternate method of fabricating pole tip 72. In Figures 8A-8C, pole tip 72 is plated or sputtered into channel 70. The pole material forming pole tip 72 is then ion milled to provide the proper width of pole tip 72. Bottom shield 74 is then fabricated on top of pole tip 72 and top surface 68 of write gap oxide layer 66. Bottom shield 74 is then planarized.

Figures 9A-9D are layered diagrams showing a third alternate method of

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forming pole tip 72. As shown in Figures 9A-9D, a layer of high moment material is plated or sputtered on top of write gap oxide layer 66. The sides of pole tip 72 are then ion milled to provide the proper width of pole tip 72. Lift-off photoresist layer 71 can be put on top of pole tip 72 and additional oxide layer can be fabricated. Bottom shield 74 can then be fabricated. Bottom shield 74 can then be planarized.

Although the methods of forming pole tip 72 described above with reference to figure 5 and figures 8A to 8C and 9A to 9C are all described as forming an MR head of the type illustrated in one of figures 2 to 5 and 10, all of these methods described with reference to any one of figures 5 and 8A to 8C and 9A to 9C can be used in an MR head employing the present invention as described with reference to either one of figures 6 and 7.

Figure 10 is a layer diagram showing air bearing surface 52 of a writer of inverted MR head 50. As shown in Figure 10, pole tip 72 is aligned above bottom pole 56; with the critical portion of write gap oxide layer 66A located between bottom pole 56 and pole tip 72. The distance between bottom pole 56 and pole tip 72, which is the critical distance of write gap oxide layer 66 is in the range of approximately 1,000 to 10,000 angstroms, and preferably in the range of approximately 2,000 to 8,000 angstroms. In one preferred embodiment, bottom pole 56 has a height in the range of approximately 2.0 to 4.0 micrometers, write gap oxide layer 66 formed between top surface 60 of polymer insulator 58 and top surface 68 has a height in the range of approximately 2,000 to 8,000 angstroms, pole tip 72 has a height in the range of approximately 5,000 to 20,000 angstroms, and bottom shield 74 between top surface 68 of write gap oxide layer 66 and top surface 76 of bottom shield 74 has a height in the range of approximately 1.5 to 4.0 micrometers.

Figure 11 is a layer diagram showing the entire fabricated inverted MR head 50, including both the writer and the reader portions of inverted MR head 50. Once bottom shield 74 has been deposited and planarized, the remaining layers of the reader can be deposited on the flat surface of bottom shield 74. Deposition on a series of flat

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surfaces alleviates shorting, which is a critical issue in standard MR heads.

Once the writer portion of inverted MR head 50 has been fabricated, first reader gap oxide layer 78 is deposited on top of bottom shield 74. In one preferred embodiment, first reader gap oxide layer 78 has a height of less than 4000 angstroms. MR element 80 is fabricated on first reader gap oxide layer 78 near trailing edge 73 of inverted MR head 50. MR element 80 may be a single film or composite film structure. The specific embodiment of MR element 80 does not affect the usefulness of the present invention. Electrical contacts 82 are then deposited, followed by second reader gap oxide layer 84, top shield 86, and overcoat oxide layer 88. In one preferred embodiment, second reader gap oxide layer 84 has a height of less than 4000 angstroms. In addition, a boundary control stabilization layer, a permanent magnet stabilization layer, and/or an additional layer of contacts for inductive cancellation or low circuit resistance can be incorporated into the MR reader if necessary for a particular application.

Figure 12 is a layer diagram of inverted MR head 50 showing both the reader and the writer. As shown in Figure 12, bottom pole 56, pole tip 72, and MR element 80 are aligned with one another. This invention improves the accuracy of the alignment of the MR sensor to the pole tip and the top pole, since there are only one or two intervening mask layers to complicate mask alignment, as compared to ten or more intervening mask layers in prior art non-inverted MR heads. The alignment of bottom pole 56, pole tip 72, and MR element 80 is critical in forming an MR head which can both precisely read information from a magnetic storage medium and write information to the magnetic storage medium.

The inverted MR head 50 shown in figures 11 and 12 has a writer portion of the type shown in figures 2 to 5 and 10. The inverted MR head structure shown in figures 11 and 12 could also be used with a writer portion employing the present invention as described with reference to either one of figures 6 and 7.

There are several advantages of inverted MR head 50 of the present invention.

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First, precise definition of the top pole is achieved. Second, the distance between MR element 80 and top pole 72 is substantially reduced over the prior art. This allows inverted MR head 50 to write higher linear densities on the disc. Third, planarity of the top pole allows the reader and the writer to be offset without the top pole having a dip in it, such as the dip of the prior art shown in Figure 1B. Fourth, use of sendust or other rough films for the top shield will not cause shorting due to roughness, since the only film above the top shield surface is the overcoat. Fifth, building the writer prior to building the reader allows use of high temperature curing polymers such as polyimide and benzene cyclo-butene (BCB) without degrading the MR sensor magnetics or other properties. Sixth, building the writer prior to building the reader allows use of spin valves or giant MR sensors since high temperature polymer cures could cause inter-diffusion among the extremely thin layers of giant MR sensors or spin valves, thus destroying their effectiveness. By having all high temperature cures completed before the reader portion is built, few restrictions are placed on the use of giant MR and/or spin valves sensors. In particular, the materials for the reader and writer can be optimized independently of each other to a much greater extent than the prior art.

In the above description, the pole tip is described as being formed of a high moment magnetic material, the pole tip could instead be formed of a non-magnetic high moment material in any and all cases.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

The foregoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the present invention.

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CLAIMS

1. A method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole (56) in a recessed portion of a basecoat (54) distal from an air bearing surface (52) of the head;

positioning a polymer insulator (58) and conductive coils (64) above the bottom pole; and characterised by further comprising:

fabricating a write gap on top of the bottom pole at a level below the level of the top surface of the polymer insulator;

forming a pole tip (72) of high moment magnetic material in the write gap proximal to the air bearing surface;

fabricating a bottom shield (74) having a planarized top surface on top of the pole tip and the write gap;

fabricating a first reader gap (78) on top of the bottom shield;

forming a magnetoresistive element (80) on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts (82) on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap (84) on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield (86) on top of the second reader gap.

2. The method of claim 1 wherein the step of fabricating a bottom shield having a planarized top surface further comprises:

fabricating a top pole (67) on top of the pole tip and the write gap;



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planarizing a top surface of the top pole; and
fabricating the bottom shield on top of the top pole.

3. The method of claim 2 wherein the step of planarizing the top surface of the top pole further comprises:
depositing an oxide layer (75) on top of the top surface of the top pole;
depositing a photoresistive layer on top of the oxide layer; and
reactive ion etching the oxide layer and the photoresistive layer until the top surface of the top pole is substantially smooth.
4. The method of any one of claims 1 to 3 and further comprising planarizing a top surface of the bottom shield.
5. The method of any preceding claim wherein the step of fabricating a bottom pole further comprises:
plating polymer into the basecoat.
6. The method of any preceding claim wherein the bottom pole is made of a plated permalloy.
7. The method of any preceding claim wherein the write gap is formed from silica, diamond-like carbon or alumina.
8. The method of any preceding claim and further comprising:
ion milling a channel (70) into the write gap; and
filling the channel with the high moment magnetic material.
9. The method of any preceding claim wherein the step of forming a pole tip of



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high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

ion-milling a channel (70) into the write gap proximal to the air bearing surface;
plating the pole tip of high moment magnetic material into the channel such that a top surface of the pole tip is above a top surface (68) of the write gap; and
ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip.

10. The method of any one of claims 1 to 8 wherein the step of forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

ion-milling a channel (70) into the write gap proximal to the air bearing surface;
sputtering the pole tip of high moment magnetic material into the channel such that a top surface of the pole tip is above a top surface (68) of the write gap; and
ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip.

11. The method of any one of claims 1 to 8 wherein the step of forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

fabricating a first write gap layer on top of the top surface of the polymer;
plating the pole tip on the top surface of the first write gap layer proximal to the air bearing surface such that a top surface of the pole tip lies in a first plane;
ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip;
fabricating a lift-off photoresist layer (71) on top of the pole tip;
fabricating a second write gap layer on top of the first write gap layer so that a top surface of the second write gap layer lies in the first plane;



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removing the lift-off photoresist layer.

12. The method of any one of claims 1 to 8 wherein the step of forming a pole tip of high moment magnetic material in the write gap proximal to the air bearing surface further comprises:

fabricating a first write gap layer on top of the top surface of the polymer;

sputtering the pole tip on the top surface of the first write gap layer proximal to the air bearing surface such that a top surface of the pole tip lies in a first plane;

ion-milling a first and a second side of the pole tip to provide a proper width of the pole tip;

fabricating a lift-off photoresist layer (71) on top of the pole tip;

fabricating a second write gap layer on top of the first write gap layer so that a top surface of the second write gap layer lies in the first plane;

removing the lift-off photoresist layer.

13. The method of claim 11 and claim 12, and further comprising;

fabricating a third write gap layer on top of the second write gap layer and the pole tip.

14. A method of manufacturing an inverted magnetoresistive head, the method comprising:

fabricating a bottom pole (56) in a recessed portion of a basecoat (54) distal from an air bearing surface (52) of the head;

positioning a polymer insulator (58) and conductive coils (64) above the bottom pole; and characterised by further comprising:

fabricating a write gap (66A) on top of the polymer insulator distal to the air bearing surface and positioned on top of the bottom pole proximal to the air bearing surface;



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forming a top pole (67) on top of the write gap;

fabricating an oxide layer (75) on top of the top pole proximal to the air bearing surface;

planarizing a top surface of the oxide layer and a top surface of a portion of the top pole distal to the air bearing surface;

fabricating a bottom shield (74) on top of the oxide layer and the top pole;

fabricating a first reader gap (78) on top of the bottom shield;

forming a magnetoresistive element (80) on top of a portion of the first reader gap proximal to the air bearing surface;

fabricating electrical contacts (82) on top of a portion of the first reader gap, the electrical contacts electrically connecting the magnetoresistive element to a region outside of the inverted magnetoresistive head;

fabricating a second reader gap (84) on top of the electrical contacts and the magnetoresistive element; and

fabricating a top shield (86) on top of the second reader gap.



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ABSTRACT**METHOD OF FABRICATING AN INVERTED
MAGNETORESISTIVE READ**

A method of fabricating an inverted magnetoresistive head is disclosed. The method includes fabricating a writer. The writer includes a bottom pole (56) positioned within a recessed substrate (54). The bottom pole is filled with copper coils (64) and polymer (58). A write gap (66A), a pole tip (72), and a top pole (67) are fabricated on a portion of the polymer. A top surface of the top pole is planarized and a bottom shield (74) is fabricated on the top pole to provide a substantially smooth surface upon which a reader can be placed. The reader is fabricated on top of the writer and includes a first reader gap (78), a magnetoresistive element (80), a second reader gap (84), and a shield (86).

Fig. 7

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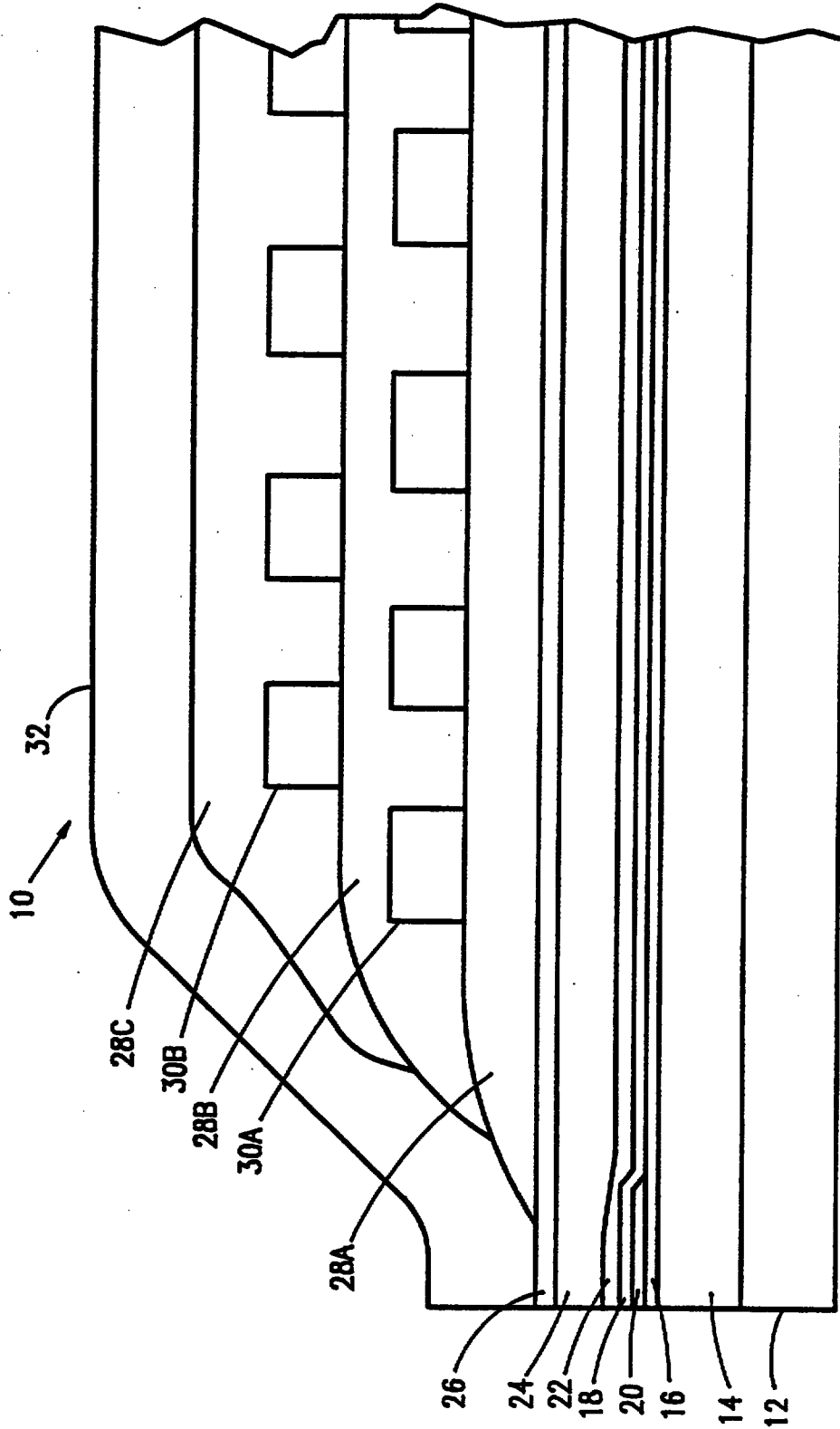


FIG. 1A

PRIOR ART

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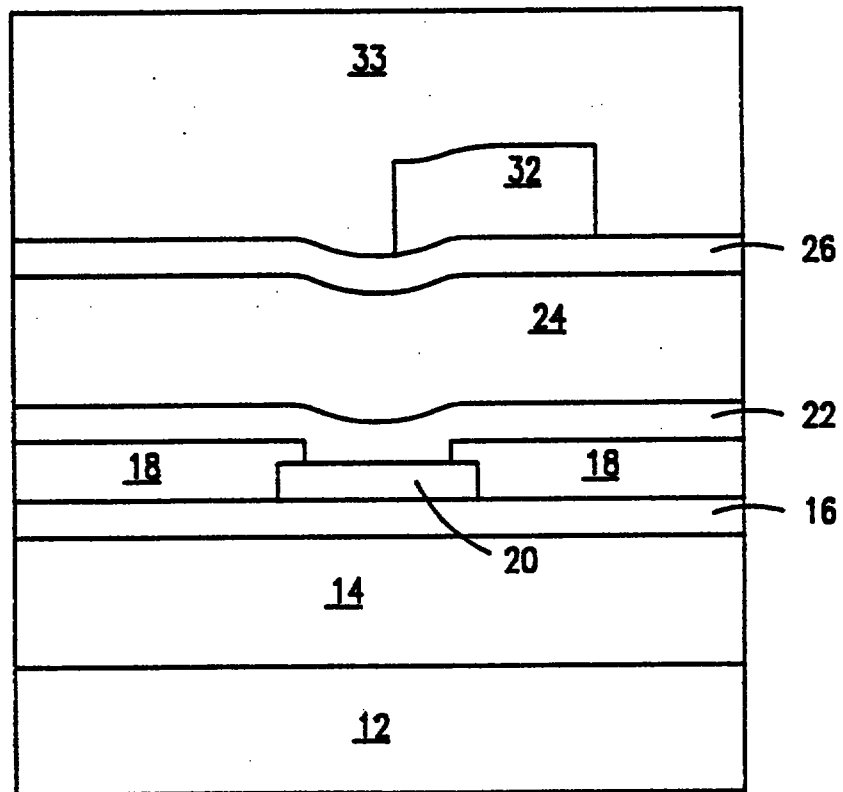


FIG. 1B

PRIOR ART

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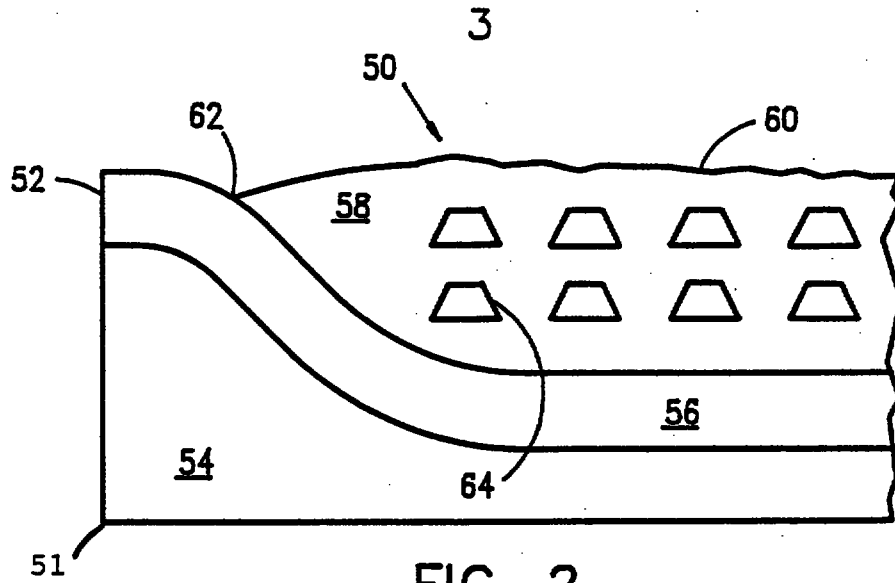


FIG. 2

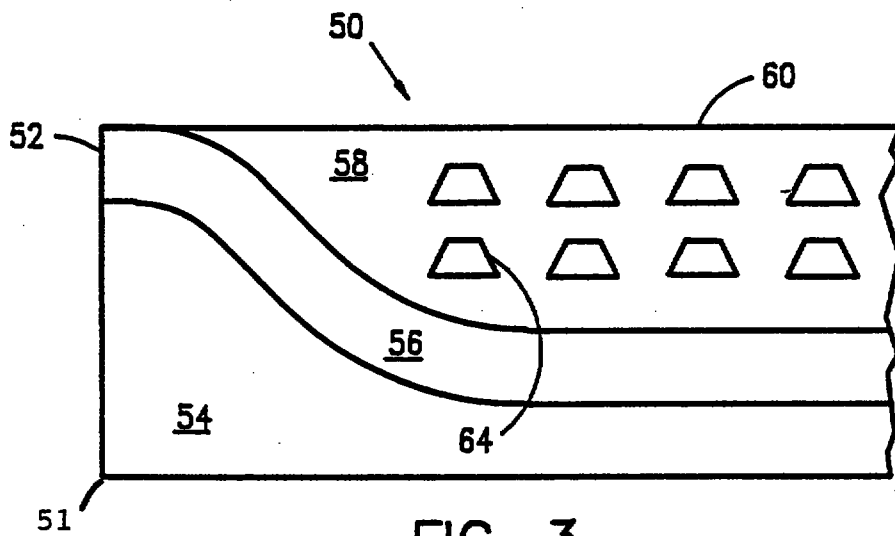


FIG. 3

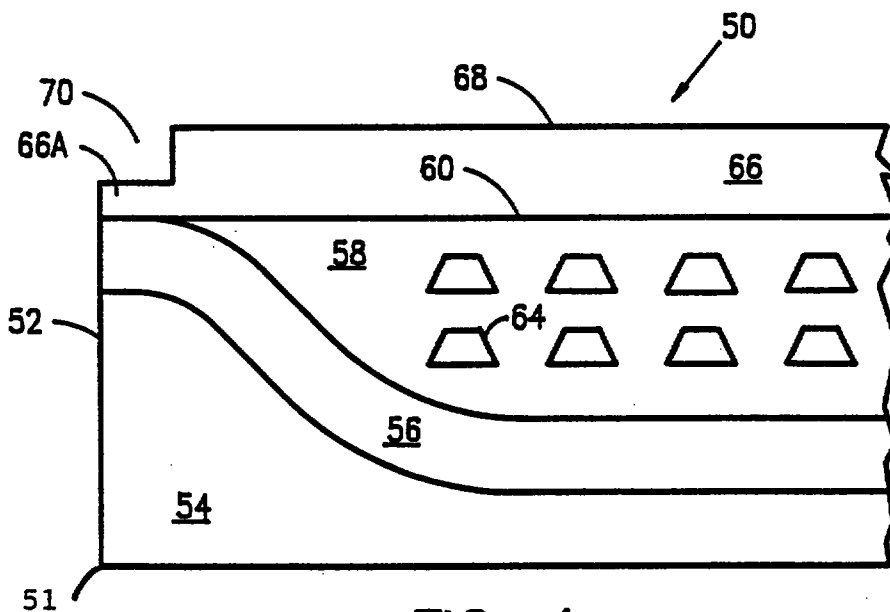


FIG. 4

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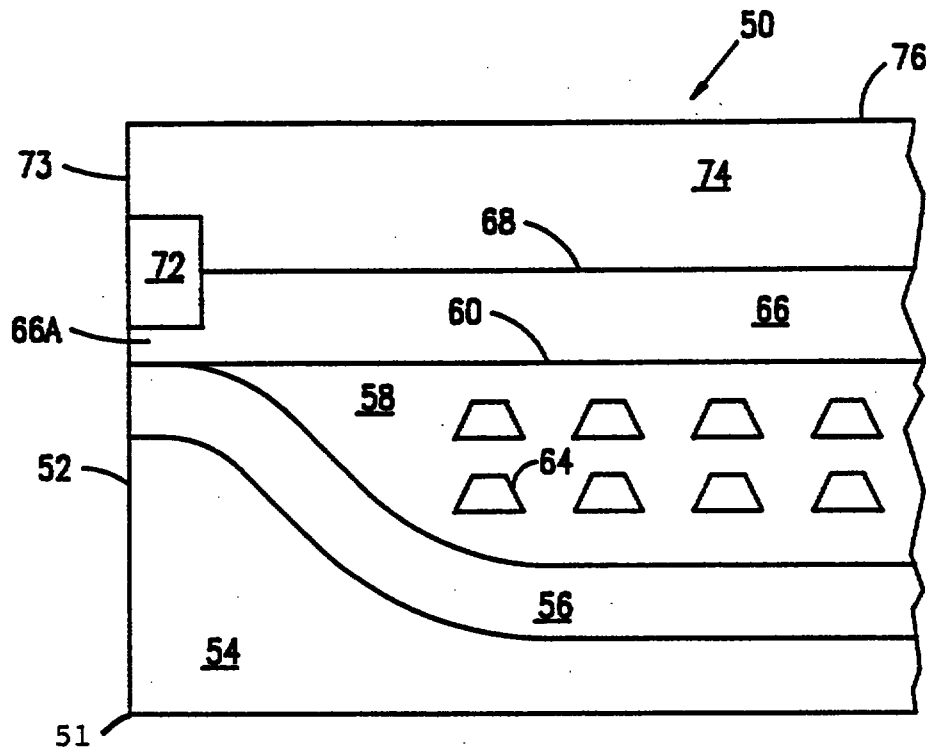


FIG. 5

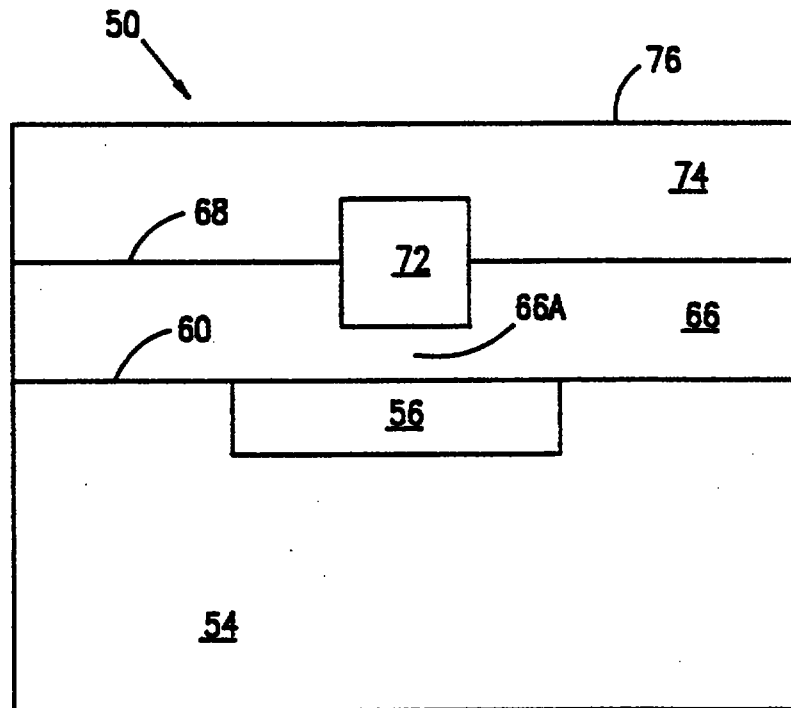


FIG. 10

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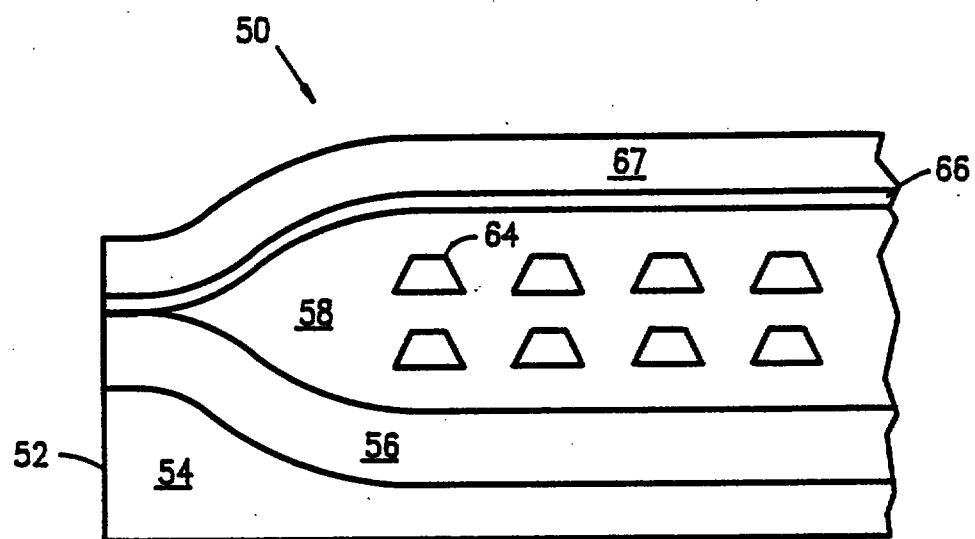


FIG. 6

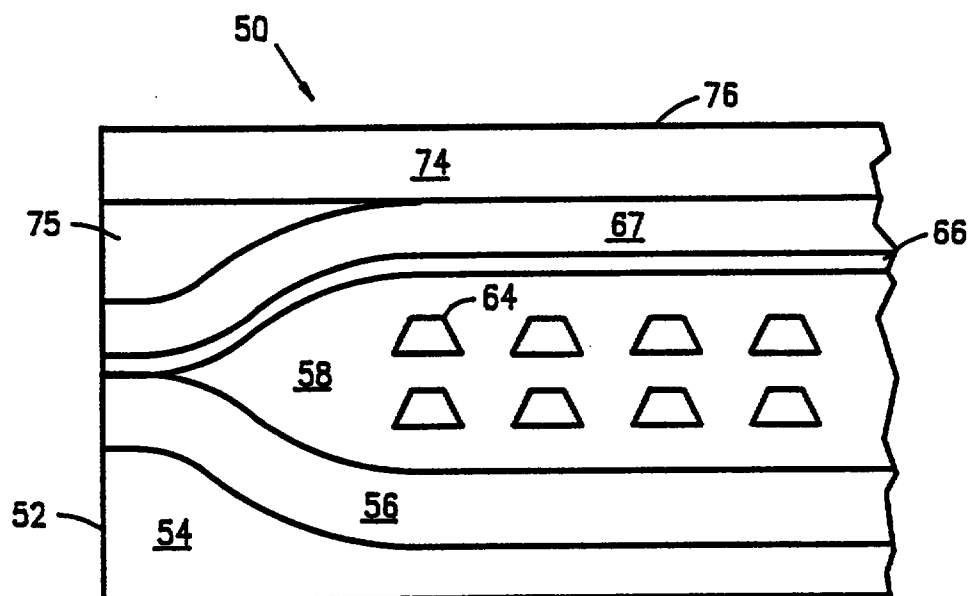


FIG. 7

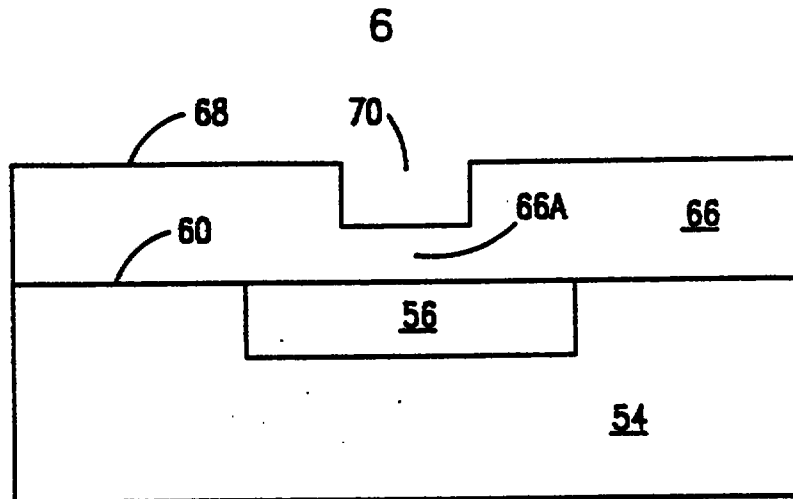


FIG. 8A

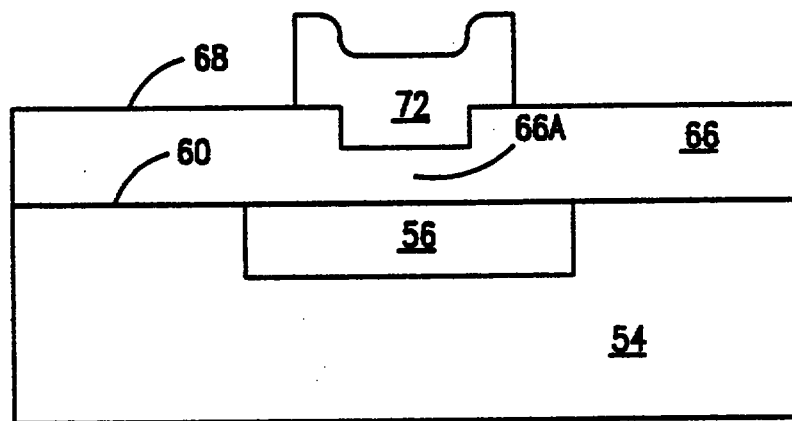


FIG. 8B

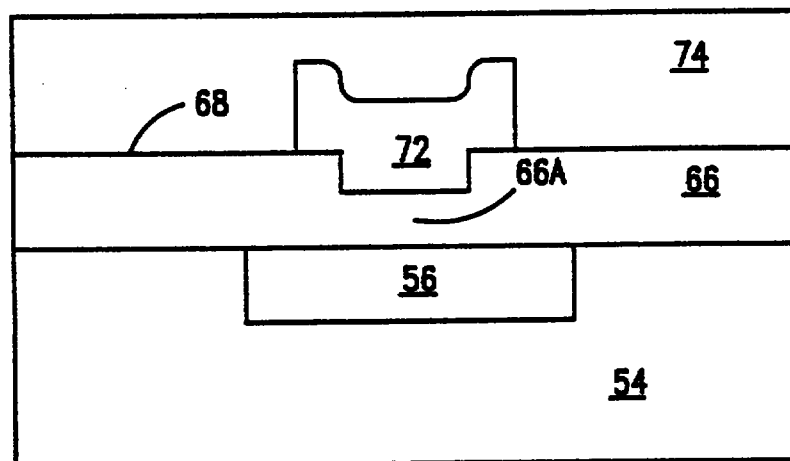


FIG. 8C

7

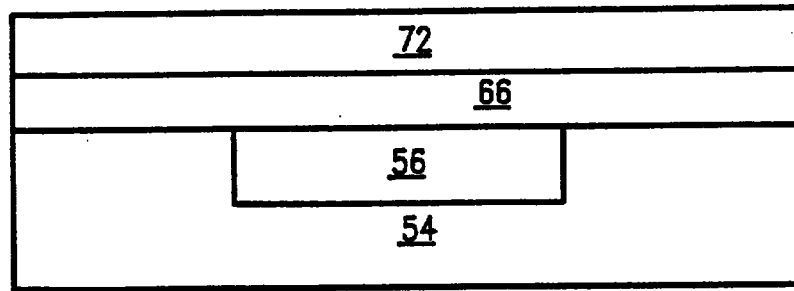


FIG. 9A

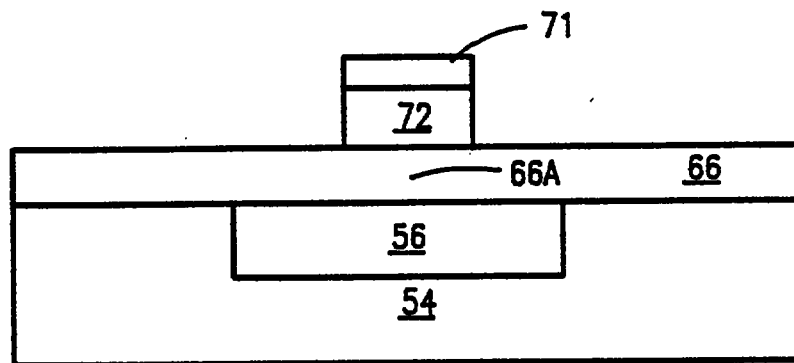


FIG. 9B

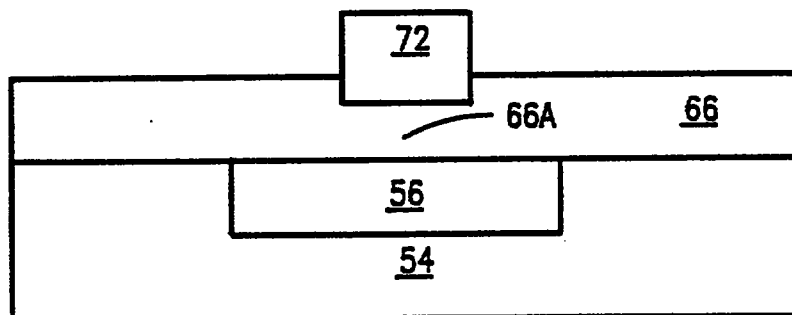


FIG. 9C

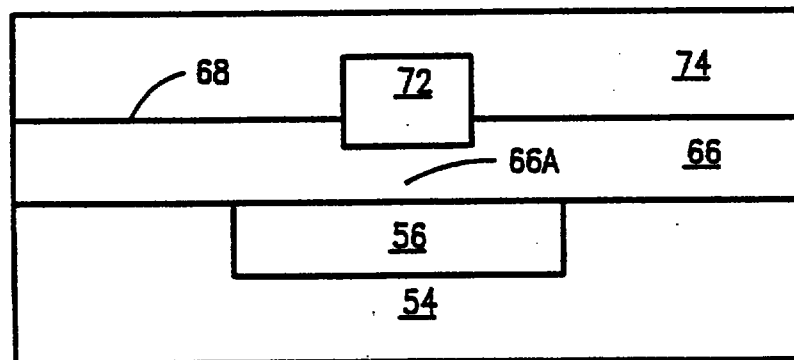


FIG. 9D

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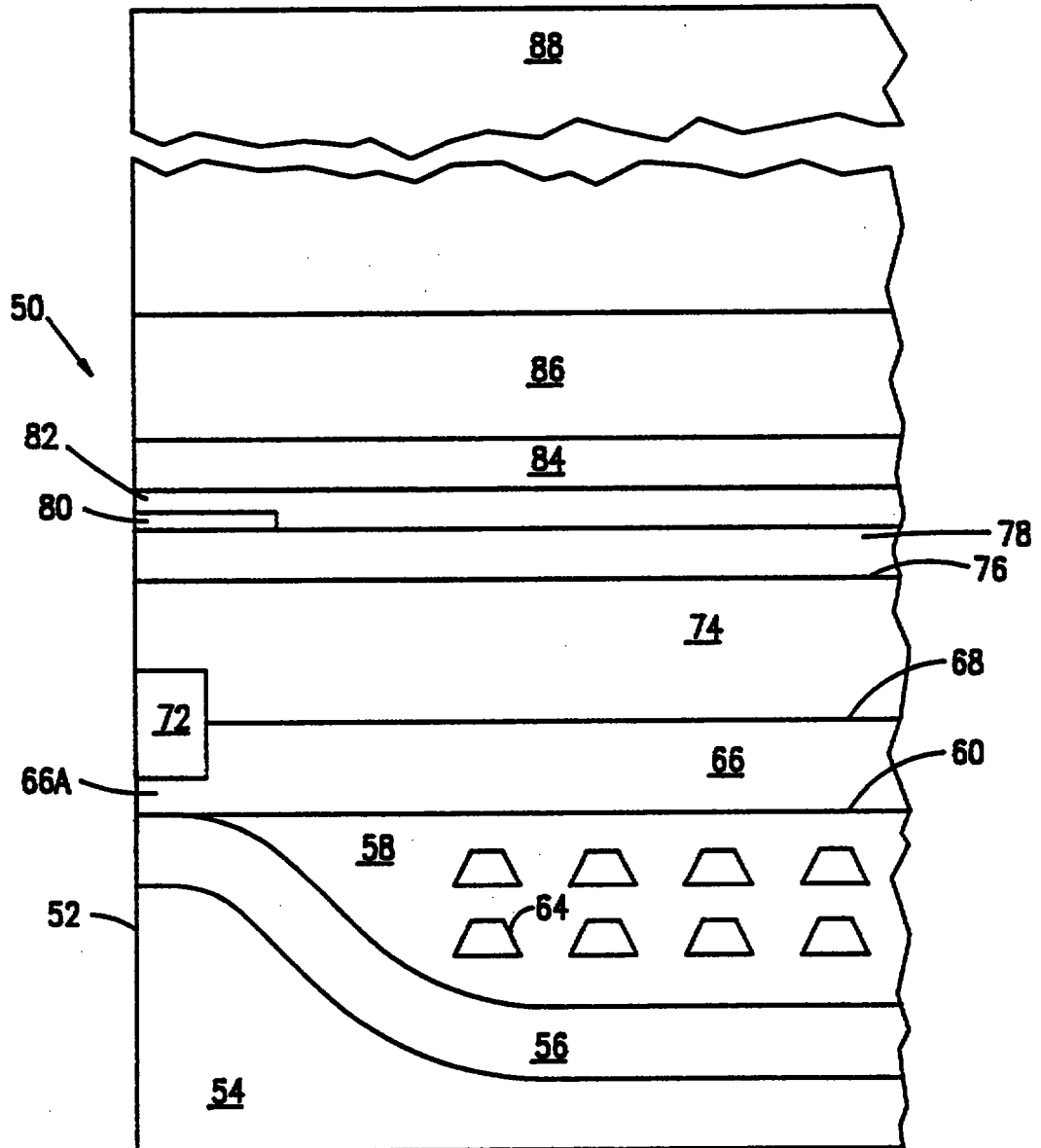


FIG. 11

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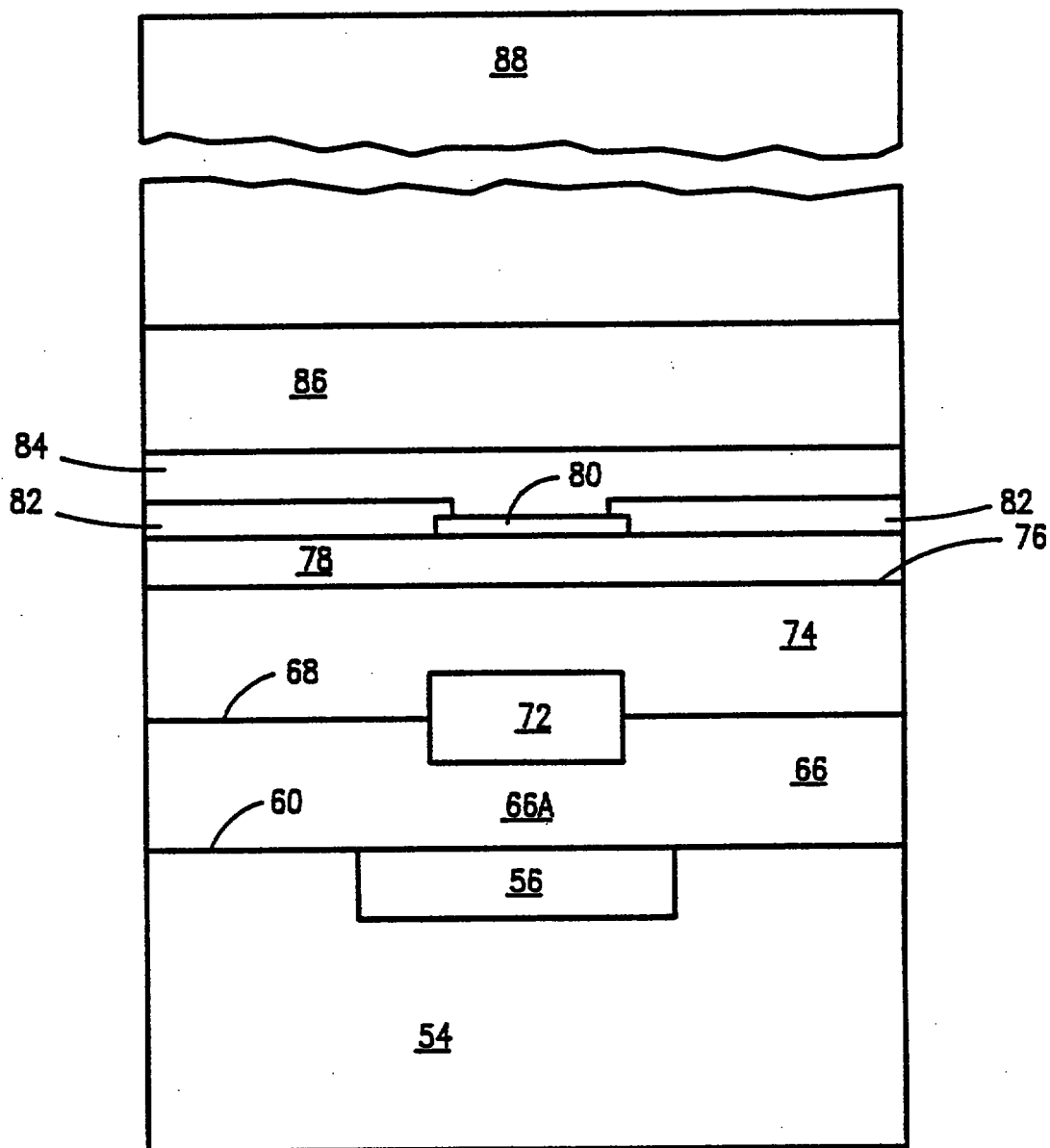


FIG. 12

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