

UNITARY MAGNETIC TRANSDUCER AND SUSPENSION STRUCTURE
FOR LONGITUDINAL OPERATION

DESCRIPTION

The present invention relates to a unitary magnetic transducer and suspension structure and the production and use thereof for longitudinal operation.

Moving magnetic storage devices, especially disk drives, are fast becoming the memory device of choice. This is due to their expanded nonvolatile memory storage capability together with a relatively low cost. Accurate retrieval of the stored information from these devices is essential and requires a transducer to be positioned as close to a storage media as possible. In some instances it is desirable that the transducer should touch the media.

Disk files are information storage devices which use at least one rotatable disk with concentric data tracks containing data information. A unitary transducer-slider-suspension assembly includes a transducer for reading the data from or writing the data to the various tracks, a slider for holding the transducer adjacent to the track generally in a flying mode above the media, and a suspension for resiliently holding the slider and the transducer over the tracks. A positioning actuator connects to the unitary structure to move the transducer to the desired track and maintains the transducer over the track centre line during a read or a write operation. The transducer is attached to the air bearing slider which supports the transducer close to the track by a cushion of air that is generated by the rotating disk. However, the transducer may be placed in contact with the disk. The suspension provides a high spring stiffness and dimensional stability between the slider and the actuator arm. The suspension is required to maintain the transducer and the slider next to the data surface of the disk with as low a loading force as possible. The actuator is controlled for positioning the transducer over the correct track according to the data desired on a read operation or to the correct track for placement of the data during a write operation.

In conventional disk drives, the transducer and its slider are formed separately from the suspension and then attached through an

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operator controlled precision operation. The parts are small and the positioning of each element relative to the other must be exact. The transducer must be exactly positioned over the track which in turn means that the suspension must be exactly positioned onto the slider. The
5 suspension must provide flexibility and pitch and roll motion for the slider in the direction of rotation of the disk and yet provide resistance to yaw motion. Any error in the placement of the suspension on the slider is detrimental to performance and durability of a storage device using such a structure. Even if the suspension and the slider are
10 correctly positioned, the conductor leads to the transducer must then be connected to the transducer. The conductor leads are generally directed along the suspension and connected to an amplifier placed on the suspension or the actuator. The conductor leads must not add to the spring stiffness of the slider while providing good electrical
15 interconnection.

Generally, the conductor leads are bonded by soldering, for instance, to both the transducer output and the amplifier by an operator. Again, errors can cause destruction of the entire unitary structure.

Contact or touching the media by the transducer/slider structure or
20 head presents unique problems in wear and the possibility of creating a "crash" of the media. To reduce the wear problem and "crash" potential, it has been recognized that the mass of the suspension system must be reduced. The lower mass reduces the physical contact the head has upon the media and thereby reduces the possibility of damage and of wear.

25 To this end there have been disclosed a variety of mechanisms which use a "reed" approach to producing a transducer in conjunction with a suspension. Structured to work in a perpendicular recording environment, the reed device allows the head and suspension to be easily manufactured having: (i) precise throat height control, (ii) precise contact
30 recording transducer placement or the formation of air bearings to achieve specified flying heights, (iii) bonding of sliders to suspensions, and, (iv) easy routing of conductor leads. Some structures, as disclosed in U.S. Patent No. 5,041,932 to Hamilton, for example, have included a horizontal transducer with a horizontal first pole piece and a
35 horizontal second pole piece which includes a vertical component that forms a magnetic gap in spaced relationship with the first pole piece.

As noted above, contact recording permits higher signals and greater resolution unregulated by variations in flying height. Unfortunately, the wear associated with contact recording, generally estimated to be 400 microinches over the file life, is usually not acceptable. A further disadvantage of contact recording is that the "reed" type of head is suitable only for perpendicular recording and is not suitable for longitudinal media. All of this has made the perpendicular recording head of the above design unsuitable for high density recording.

10 An object of the present invention is to provide a unitary magnetic transducer and suspension structure.

Another object of the present invention is to provide a magnetic moving storage device having a head structure that includes a unitary magnetic transducer and suspension structure.

15 Yet another object of the present invention to create a unitary magnetic transducer and suspension structure which is suitable for longitudinal recording.

It is another object of the present invention to make such a longitudinal head resistant to wear and to variations in contact pad contours.

Accordingly, the present invention provides a unitary magnetic transducer and suspension structure comprising a first pole piece having a poletip; a second pole piece having first and second components, said first component being disposed substantially parallel and adjacent to said first pole piece, said second component having a poletip disposed substantially perpendicular and adjacent to the poletip of the first pole piece and forming a magnetic gap therebetween; the first and second pole pieces being magnetically connected at a back gap region and magnetically isolated at the poletips by said magnetic gap; a coil electrically isolated from but magnetically coupled to the first and second pole pieces and encircling the first component of the second pole piece; and a suspension section of resilient material adjacent to the first component of the second pole piece and electrically and magnetically isolated from said second pole piece and coil, the resilient material extending beyond the back gap region.



According to another aspect, the present invention provides a disk drive assembly, including a unitary magnetic transducer and suspension structure, said drive assembly further comprising a housing; a rigid platter mounted in said housing having means for storing data in tracks
5 provided thereon; means for rotating said rigid platter in said housing; an actuator arm positioned in said housing and operable to place a free end in proximity to one track of said rigid platter; means for positioning said actuator arm adjacent to a particular track on said rigid platter; the unitary magnetic transducer and suspension structure
10 being mounted to the free end of said positioning means.

According to a further aspect, the present invention provides a method for making a unitary magnetic transducer and suspension structure comprising the steps of forming a contact region on a substrate;
15 forming a release layer on said substrate; forming a first pole piece of a magnetic material on said formed release layer and said contact region; forming a backgap member on said formed first pole piece; forming a wear resistant layer on said formed first pole piece and along a distance for a suspension section; forming a magnetic and electrical isolation layer
20 on said formed wear resistant layer covering at least said first pole piece layer and extending the distance for the suspension section as a first suspension layer; forming a first one-half of a coil of an electrically conductive material on said formed isolation layer; forming a first electrical insulating layer covering at least said formed one-
25 half of the coil; forming a first of a second pole piece layer of a magnetic material on said formed insulating layer; forming a second electrical insulating layer covering at least said second pole piece layer; forming a second one-half of the coil of an electrically conductive material on said formed second electrical insulating layer,
30 the second one-half of the coil being electrically connected to said first one-half to form a complete coil; forming a magnetic and electrical isolation layer on said formed second one-half of the thin film coil and extending the distance for the suspension section as a second suspension layer; forming a second section of the second pole piece layer of a
35 magnetic material contacting a free end of said first second of said second pole piece layer thereby forming a magnetic gap between said second section of the second pole piece layer and the first pole piece;

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forming a protective layer over said formed pole piece; and, releasing the substrate from said formed contact pad layer and said formed first pole piece layer by dissolving the release layer.

An embodiment of the present invention provides a unitary magnetic
5 transducer and suspension structure for longitudinal recording which can be used for contact recording or for flying above the media. The transducer includes a horizontal first pole piece and a horizontal and vertical sectioned second pole piece. A magnetic gap is formed between the first pole piece and the vertical section of the second pole piece.
10 The pole pieces are shaped to avoid magnetic saturation and to provide narrow poletips. The suspension is formed mainly from two layers. The first layer is an insulation layer that separates the first horizontal pole piece and the horizontal section of the second pole piece. The second layer is an insulation layer that covers and protects the
15 transducer layers.

Hinkel et al, USP 4,624,048 discloses a process for making magnetic head substrates suitable for use with the present invention.

In the method of producing the unitary magnetic transducer and suspension struction, a plurality of contact pads of patterned
20 photoresist is formed on the substrate in a row and column configuration. A release layer is then deposited on the substrate. A first pole piece is pattern formed in partial contact on each contact pad. A thick backgap layer of magnetic material is deposited on each first pole piece. A wear-resistant layer followed by a thick layer of electrical and
25 magnetic insulative material is deposited. This layer forms part of the suspension portion of the unitary structure. This suspension film is lapped flat and an initial coil layer is formed on the suspension film for each pole piece. A second pole piece of magnetic layer is deposited for each first pole piece on an insulation layer at least partially
30 covering the initial coil layer. An insulation layer covers the second pole piece layers, but permits contact to the initial coil layer. The coil circuit is then completed on this insulation layer along with conductor leads connected to the coil circuit. The conductor leads and subsequently deposited conducting studs provide the connection to the
35 drive circuitry (not shown) for each transducer. A second thick layer of electrical and magnetic insulative material is then deposited to form the second and last part of the suspension portion of the unitary structure.



A top portion of this film is lapped away to allow electrical contact to the studs previously formed. Since the unitary structures are deposited on a wafer in rows and columns, each is then divided into a plurality of rows of unitary structures.

- 5 The end of the partial row structure is polished and a magnetic gap layer is deposited. A contact via is then formed in the magnetic gap layer to expose the second pole piece layer. A third pole piece of magnetic material is pattern deposited over each row to form the vertical section of the second pole piece. A protective overcoat may then be
10 deposited over the completed row of unitary magnetic transducer and suspension structures. Then the row is divided into a plurality of individual unitary structures. The substrate is next removed by dissolving or etching the release layer to leave a partially completed unitary structure. The unitary structure is completed by removing the
15 portions of the gap, third pole piece and final protective layer which extend below the original contact pad. Preferably, the suspension is created using layers of deposited alumina (Al_2O_3). The desired structure of the suspension is formed by cutting the alumina layers and then separating the shaped suspension from the substrate surface.
20 Removal of the substrate is preferably accomplished using a release layer.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

- Fig. 1 is a plan view of a magnetic recording mechanism having a
25 unitary magnetic transducer and suspension structure attached for positioning to a rotary actuator in transducing relationship to a disk surface of a disk;

- Fig. 2 is a perspective view of a unitary magnetic transducer and suspension structure produced according to the present invention for use
30 with the disk drive as illustrated in Fig. 1;

Fig. 3 is a perspective view of a substrate with a plurality of structures formed thereon in rows and columns for use in the process to build the unitary structure as shown in Fig. 2;

Fig. 4 shows a cross sectional view taken along lines 4-4 of Fig. 3;

Fig. 5 is a perspective view of a row of structures taken from the substrate of Fig. 3 and mounted for further processing;

5 Figs. 6A and 6B are cross sectioned views of embodiments of a transducer according to the present invention; and

Fig. 7 is a perspective view of a transducer of the present invention without the insulation and conductor layers.

The preferred embodiments of the present invention are used in
10 large multiple disk drives but should also find use in the single disk drives used generally for personal computers, or any other type of media drives such as tape drives.

Referring to figure 1 there is shown a data recording disk file including a housing 8 in which is mounted a rotary actuator 10, an associated
15 magnetic storage disk 12 and a drive means 13 for rotating the disk 12. The rotary actuator 10 moves a unitary structure according to the present invention in an arcuate path over the disk 12. The rotary actuator 10 includes a voice coil motor, which comprises a coil 14 movable within the magnetic field of a fixed permanent magnet assembly having a core 16. An
20 actuator arm 20 is attached to the movable coil 14. The other end of the actuator arm 20 is attached to a unitary magnetic transducer and suspension structure 22 according to the present invention and produced according to the method set forth herein. The unitary structure 22 includes a transducer-slider segment 24 and a suspension section 26. The
25 suspension section 26 can support the transducer-slider segment 24 above the surface of the disk 12 on a bearing or cushion of air generated by the rotation of the disk 12. Preferably, the suspension section 26 supports the transducer-slider segment 24 in contact with the surface of disk 12. The air bearing or air bearing surface refers to the surface of
30 the transducer parallel and adjacent to the disk surface. It includes both configurations where the transducer is designed to fly above the disk, and where the transducer is designed to contact the recording media, the disk 12, during operation. The actuator arm 20 can include a plurality of arms with each arm supporting its own unitary structure 22,
35 each unitary structure 22 being associated with a surface of the disks

located in the data recording disk drive assembly. Therefore, for instance, the disk 12 can also have a unitary structure 22 mounted to the actuator arm 20 for association with the media surface on the underside of the disk 12. Further, other unitary structures are associated with the top and bottom sides of other disks which may be included in the disk drive assembly, the transducer access of which is also controlled by the actuator 10.

The suspension section 26 of the unitary magnetic transducer and suspension structure 22 provides a load to the transducer-slider segment 24 which is generally perpendicular to the surface of the disk 12. This perpendicular load maintains the transducer-slider segment 24 on or above the data surface of the disk 12. During rotation of the disk 12 by the drive means 13, the unitary structure 22 remains in contact with the disk 12 for reading or recording data. Alternatively, the unitary structure 22 can be designed to fly above the disk 12 using the lift or upwards force generated between the transducer-slider segment 24 and the disk 12 to oppose the perpendicular load applied to the transducer-slider segment 24 by the suspension section 26. Contact recording is the preferred embodiment of the present invention.

During operation, the transducer-slider segment 24 is moved to the desired track of the concentric data tracks on the data surface of the disk 12 by means of the coil 14, which moves within the magnetic field of the magnet assembly. Rapid movement of the transducer-slider segment 24 from one track to another track is required. In order to increase data access times, it is necessary that the transducer of the segment 24 be properly positioned over the desired track as quickly as possible. Cuzner, et al, USP 3,849,800, discloses a rotary actuator suitable for use in a drive using the present invention. It should be noted that while the actuator 10 illustrated in Fig. 1 is a rotary actuator, other types of conventional disk files use linear actuators which can be used with the present invention.

The suspension section 26 of the unitary structure 22 must provide radial stiffness, and have substantial flexibility in the pitch and roll directions as it holds the transducer of the segment 24 above the data surface of the disk 12. If desired, an integrated circuit amplifier 28 may also be produced on the suspension section 26 of the unitary

structure 22. An enlarged schematic configuration of the unitary structure 22 of Fig. 1 is shown in Fig. 2.

Referring to Fig. 2, the unitary structure 22 is shown positioned over the disk 12. The direction of rotation of the disk 12 is indicated by arrow 36. A transducer 38 of the transducer-slider segment 24 (vertical pole section shown) is positioned adjacent the disk 12 for reading and writing magnetic transitions onto the disk 12. The horizontal transducer-suspension of the present invention refers to the location of the transducer-suspension parallel to the disk 12 and is for ease of presentation of the invention since most disk drives have their disk mounted horizontally. It will be appreciated by one skilled in the art that the present invention is equally applicable to vertically mounted disks and that the operation of the transducer is still parallel to the disk surface notwithstanding the orientation of the disk mounting.

The suspension section 26 suspends the transducer 38 over the disk 12. The suspension section 26 in this embodiment includes a first insulation layer 40 and a second insulation layer 42. A conductive circuitry layer (not shown) is encapsulated between these layers. The bulk of the support provided by the suspension section is maintained by the first and second insulation layers 40 and 42. The transducer 38 is electrically connected to the conductive circuitry layer. Electrical connection conductor pads 48 are provided to interconnect with an amplifier which can be located adjacent thereto. An integrated circuit amplifier (not shown) could be provided in place of the conductor pads. The deposited integrated circuit amplifier 28 of Fig. 1 is an example of a potential placement of an amplifier.

The insulation layers 40 and 42 provide electrical insulation between the conductor layer and the possibly conductive magnetic portions of the transducer 38. The two insulation layers 40 and 42 provide the suspension support which holds the transducer 38 in position over a track of the disk 12.

Figure 3 illustrates the steps in the method of forming the unitary structure 22 according to the configuration as shown in Fig. 2. The batch fabrication of the unitary structure 22 is accomplished by preparing a non-magnetic wafer substrate 50. The substrate 50 has a thickness, T , which must be sufficient to support the structures during

the processing. A plurality of the unitary structures 22 are deposited onto the substrate 50 in a row and column configuration. Each row 52, five shown, and each column 54, four shown, delineate the formation of the unitary structures 22 into a plurality of rows which can then be
5 further separated into the individual structures. More or less than the number of rows 52 and columns 54 shown in Fig. 3 can be produced on a single wafer substrate 50. The number is dependent on the size of the wafer and on the size of the individual unitary structures.

Still referring to Fig. 3, one row 52A is separated from the wafer
10 50 by saw cuts 56, for instance. The row 52A has its transducer segments 38 at an end surface 59. The row 52A undergoes further processing as shown in Figs. 5 and 6 and then is separated into the individual structures by saw cuts 58 or otherwise dicing, as shown in Fig. 3. Fig. 4 shows the cross sectioned view of the layers deposited on the wafer 50
15 to provide the first part of the unitary structures 22.

Referring now to Fig. 4, the unitary structure 22 includes a plurality of layers that form the transducer-slider segment 24 and the suspension section 26. In the cross sectional view, the horizontal transducer contemplated in the present invention forms the whole or at
20 least a part of the transducer-slider segment 24 of Figs. 1 and 2. The transducer includes a first pole piece 62 placed horizontal, that is, parallel, to the contact surface of a magnetic disk (not shown). The first pole piece 62 is formed with a sloping contact region 63 that could be produced by molding the original substrate 50 surface as shown in Fig.
25 4. The surface of the wafer substrate 50 is coated with a release layer 60 before the deposition of the material that produces the pole piece 62. The wafer substrate 50 and the pole piece 62 are separated later in the process by dissolving the release layer 62. A magnetic member 64 is deposited in contact with the pole piece 62. After magnetic member 64 is
30 formed, the entire release layer 60 surface of the wafer substrate 50 is coated with a layer of a wear-resistant material 65 and an insulating layer 66. The wear-resistant layer 65 covers most of the contact area between the transducer section 24 and the disk 12 (see Fig. 2). The wear-resistant layer 65 and the insulation layer 66 are lapped flat after
35 deposition to provide a smooth surface for the subsequent layers and to expose the top surface of the member 64. A first set of conductor stripes 68 for the transducer coil is then formed on the insulation layer 66 and coated with a coil insulation layer 70 of an electrically

insulating material. A horizontal portion 72 of a second pole piece is then formed on the insulating layer 70. The second pole piece horizontal portion 72 contacts the member 64 to complete a back gap for the transducer. An additional layer of a coil insulation layer 74 is
5 deposited over the entire surface of the wafer. A second set of coil conductor stripes 76 is deposited on the coil insulation layer 74. The second set of coil conductor stripes 76 interconnects with the first set of conductor stripes to provide the activating conductor coil around the horizontal portion 72 of the second pole piece of the transducer section
10 24. The coil formed by the conductor stripes 68 and 76 are electrically connected to a conductor layer 78 deposited on the conductor coil insulating layer 74. This coil, together with the magnetic members of the transducer, permits the transducer to read and write magnetic transitions on the disk 12. The signals sensed by the coils are directed
15 by the conductor layers to circuitry (not shown) via a conductor stud 80 formed at the free end of the conductor layer 78. A second electrical insulation layer 82 is deposited over the conductor coil stripes 76 and the conductor layer 78. This second insulation layer 82 and the first insulation layer 66 are the support structure of the suspension section
20 26. The conductor pads 48 (see Fig. 2) are then formed on the second insulation layer 82 in contact with the conductor studs 80. The conductor pads 48 interconnect with the circuitry of its associated disk drive, possibly through integrated circuit 28 as shown in Fig. 1.

After completion of the deposition process as shown in Fig. 4, the
25 wafer 50 is cut into rows, see Fig. 3. In Fig. 3, the row 52A is separated from the wafer substrate 50 by the saw cuts 56. The row 52A is then fastened by an adhesive, for instance, to a transfer tool 90, see Fig. 5, with the end surface 59 of the row 52A exposed. The end surface 59 of the row 52A is then lapped flat. The further processing of the
30 transducer is shown in Fig. 6A for one embodiment of the present invention.

Referring now to Fig. 6A, the end surface 59 of the row 52A is lapped flat and a magnetic gap layer 92 is formed. The end of the horizontal part 72 of the second pole piece is exposed and a vertical
35 part 94 is deposited. The second pole piece 96 includes its horizontal part 72 and its vertical part 94. The transducer section 24 then includes the second pole piece 96 together with the magnetic gap 92 and, see Fig. 4, the first pole piece layer 62 and the magnetic member 64.

After completion of the vertical part 94, a protective layer 98 is deposited. This now completes the formation of the row 52A and the row is ready to be divided into individual unitary structures 22, see Fig. 2, for use with the disk 12. As shown in Fig. 3, the saw cuts 58 separate the row 52A containing a plurality of completed transducers into the individual unitary structures. A second type of vertical part for the second pole piece 96 is shown in Fig. 6B.

Referring now to Fig. 6B, the magnetic gap layer 92 is again first deposited on the end surface 59 of the row 52A. The magnetic gap layer 92 is then lapped at an angle X from the vertical to expose the end of the horizontal part 72 of the second pole piece. A layer of magnetic material is deposited to form a vertical part 99. The second pole piece 96 includes the horizontal part 72 and the vertical part 99. The transducer section 24 thus includes the second pole piece 96 together with the magnetic gap 92, the first pole piece layer 62, and the magnetic member 64. After completion of the vertical part 99, the protective layer 98 is deposited as previously stated. Similarly as discussed with Fig. 6A and Fig. 3, the formation of the row 52A is now completed and the row is ready to be divided into individual unitary structures 22.

Referring again to Fig. 4, the completed unitary structure 22 including the transducer section 24 and the suspension section 26 is separated from a substrate 50 by dissolving the release layer 60. The release layer 60 can be a plated copper. Another possible release layer material is tungsten. Removal of the copper release layer is readily accomplished using ammonia persulfate, for instance, which does not attack the alumina generally used in the process for providing the transducers. Once the unitary structure has been so manufactured, its incorporation into a rigid disk system is easily accomplished and is obvious to those of ordinary skill in the art.

The wafer substrate 50 can be any suitable material known to those in the art. Jacobs, USP 4,251,841, discloses a wafer-substrate material suitable for use with the present invention. There is no requirement that the wafer be alumina-titanium-carbide or silicon. The release layer 60 can, for instance, be an electrically conductive material and thereby serve as a seed or plating base layer for the subsequently deposited layers such as the first pole piece layer 62 of the transducer. The electrically conductive material is preferably plated copper but could be

gold or other suitable conductor. The conductor leads 78 are routed along the suspension portion 26 to the conductor stud 80. The conductor leads are configured into a stripline arrangement of two flat thin leads since the suspension portion 26 is thin and the stress symmetry required is compatible with a stripline design. The suspension section 26 is preferably produced by depositing alumina for the first and second insulating layers 66 and 82. Standard stud and pad technology is used to produce the conductor stud 80 and pad 48 to complete the thin film unitary magnetic transducer and suspension structure as known in the art.

10 A thick deposition of alumina can be used to encapsulate the transducer with the protective layer 98. A thin layer of alumina, for instance, can form the magnetic gap 92. Permalloy, for instance, can be the magnetic material that forms the pole piece portions of the transducer. The shape of the transducer pole pieces are shown in Fig. 7. The coils and

15 conductors are not shown to provide a view of the preferred shape of the magnetic portions of the transducer of this invention.

Referring now to Fig. 7, the preferred embodiment of the present invention includes a transducer that incorporates the advantages of the transducer shown in the Jones, Jr. et al, USP 4,190,872, issued on

20 February 26, 1980. The transducer includes the first pole piece layer 62 magnetically connected to the horizontal portion 72 of the second pole piece at a back gap 100 through the magnetic member 64. The vertical portion 94 of the second pole piece is magnetically connected to its horizontal portion 72 and is separated from the first pole piece 62 by

25 the magnetic gap 92. The first pole piece has a wider width at the back gap 100 than at its pole tip 102. Similarly the horizontal portion of the second pole piece has a wider width at the back gap 100 than its end 104 that connects the vertical portion 94. The vertical portion 94 also has a wider width at the end that connects to the pole piece 72 at the

30 end 104 than its pole tip 106. The preferred shape of the transducer as shown in Fig. 7 provides a narrow pole tip structure while avoiding saturation of the magnetic force along the pole pieces.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by

35 those skilled in the art that various changes in form and detail are possible. For instance, the transducer may be produced onto the wafer in the form as disclosed in U.S. Patent 4,190,872 for the preferred embodiment, but other configurations could be used without departing from

the present invention. The wafer may be made of material such as is the subject matter of the Jacobs U.S. Patent 4,251,841, entitled "Magnetic Head Slider Assembly". The suspension section according to the preferred embodiments could be a dual layer of a polyimide material and a metal
5 layer deposited thereon to provide sufficient resiliency and stiffness as required by a suspension structure. It should be noted that the suspension structure could be produced in a single layer if the correct thickness and stiffness were obtainable in the single layer. It is also well understood that many electrically conductive materials are available
10 to form the conductive circuitry and the transducer leads. Copper or gold is the preferred material but many others are available as is well known in the art. While air bearing suspensions are discussed herein, the present invention also includes contact recording in which the suspension places the transducer in contact with the media during
15 operation.

The present invention may advantageously provide a narrow gap between two magnetic poles on the contact pad surface, longitudinal recording is possible. This greatly enhances the applicability of the invention to applications which were previously beyond the scope of the
20 prior art. Additionally, the mostly planar deposition arrangement for the present invention permits major processing of the structure directly on a wafer surface. This greatly enhances the utility of the invention and allows batch production of the unitary structure.

Still another advantage of the present invention is the use of wear
25 resistance material on the head structure. This protects the poletip regions of the head.

CLAIMS

1. A unitary magnetic transducer and suspension structure comprising

a first pole piece having a poletip;

a second pole piece having first and second components, said first
5 component being disposed substantially parallel and adjacent to said
first pole piece, said second component having a poletip disposed
substantially perpendicular and adjacent to the poletip of the first pole
piece and forming a magnetic gap therebetween;

the first and second pole pieces being magnetically connected at a back
10 gap region and magnetically isolated at the poletips by said magnetic
gap;

a coil electrically isolated from but magnetically coupled to the first
and second pole pieces and encircling the first component of the second
pole piece; and

15 a suspension section of resilient material adjacent to the first
component of the second pole piece and electrically and magnetically
isolated from said second pole piece and coil, the resilient material
extending beyond the back gap region.
- 20 2. A unitary magnetic transducer and suspension structure as claimed in
claim 1 wherein the first and second pole pieces are configured with a
wider surface at the backgap region and a narrower surface at their
poletips.





3. A unitary magnetic transducer and suspension structure as claimed in any preceding claim further including an electrical conductor connected to said coil, said electrical conductor contained within said suspension layer.
- 5 4. A unitary magnetic transducer and suspension structure as claimed in any preceding claim further including a wear layer covering an exterior portion of said suspension layer and said first pole piece adjacent to its poletip.
- 10 5. A unitary magnetic transducer and suspension structure as claimed in any preceding claim wherein the portion of the second component of said second pole piece which is adjacent said magnetic gap and substantially perpendicular to the first pole piece and the remaining portion of the second component of the second pole piece is angled to contact the first component of said second pole piece.
- 15 6. A disk drive assembly, including a unitary magnetic transducer and suspension structure as claimed in any preceding claim, said drive assembly further comprising:
- a housing;
 - a rigid platter mounted in said housing having means for storing
 - 20 data in tracks provided thereon;
 - means for rotating said rigid platter in said housing;
 - an actuator arm positioned in said housing and operable to place a free end in proximity to one track of said rigid platter;
 - means for positioning said actuator arm adjacent to a particular
 - 25 track on said rigid platter;
 - the unitary magnetic transducer and suspension structure being mounted to the free end of said positioning means.
7. A method for making a unitary magnetic transducer and suspension structure comprising the steps of:
- 30 forming a contact region on a substrate;
 - forming a release layer on said substrate;
 - forming a first pole piece of a magnetic material on said formed release layer and said contact region;
 - forming a backgap member on said formed first pole piece;





forming a wear resistant layer on said formed first pole piece and along a distance for a suspension section;

forming a magnetic and electrical isolation layer on said formed wear resistant layer covering at least said first pole piece layer
5 and extending the distance for the suspension section as a first suspension layer;

forming a first one-half of a coil of an electrically conductive material on said formed isolation layer;

forming a first electrical insulating layer covering at least
10 said formed one-half of the coil;

forming a first component of a second pole piece layer of a magnetic material on said formed insulating layer;

forming a second electrical insulating layer covering at least said second pole piece layer;

15 forming a second one-half of the coil of an electrically conductive material on said formed second electrical insulating layer, the second one-half of the coil being electrically connected to said first one-half to form a complete coil;

forming a magnetic and electrical isolation layer on said
20 formed second one-half of the thin film coil and extending the distance for the suspension section as a second suspension layer;

forming a second component of the second pole piece layer of a magnetic material contacting a free end of said first second of said second pole piece layer thereby forming a magnetic gap between said
25 second section of the second pole piece layer and the first pole piece;

forming a protective layer over said formed second component of said second pole piece; and

releasing the substrate from said formed contact pad layer and said formed first pole piece layer by dissolving the release layer.

30 8. A method for making a unitary magnetic transducer and suspension structure as claimed in Claim 7 further including the steps of:

forming a first conductor layer of an electrically conductive material on said formed isolation layer along the distance for the suspension section and connected to said formed first one-half of the
35 coil;

forming a second conductor layer of an electrically conductive material on said formed second electrical insulating layer along the distance for the suspension section and connected to said formed second half of the coil; and,





forming conductor pads for said formed first and second conductor layers adjacent to an end of the suspension section opposite to the formed first and second pole pieces.

9. A method for making a unitary magnetic transducer and suspension
5 structure as claimed in either of Claims 7 or 8 wherein the steps of
forming a first pole piece of a magnetic material, forming a first
component of a second pole piece layer of a magnetic material, and
forming a second component of the second pole piece layer of a magnetic
material configure said first and second pole pieces with a wider surface
10 at their backgap region and narrower surfaces at their poletips.

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UNITARY MAGNETIC TRANSDUCER AND SUSPENSION STRUCTURE
FOR LONGITUDINAL OPERATION

ABSTRACT

A unitary magnetic transducer and suspension structure for
5 longitudinal recording which can be used for contact recording and flying
above the media. The transducer includes a horizontal first pole piece
and a horizontal and vertical sectioned second pole piece. The magnetic
gap is formed between the first pole piece and the vertical section of
the second pole piece. The suspension layers are formed mainly from the
10 insulation layer that separate the first horizontal pole piece and the
horizontal section of the second pole piece, and an insulation layer that
covers and protects the transducer layers. The layers of the unitary
structure head are deposited on a wafer in a row and column
configuration. A release layer is deposited on the substrate first and
15 then the individual thin film layers of the transducer are deposited. A
horizontal first pole piece is formed. A horizontal section of a second
pole piece is formed and activated by a conductor coil wound around the
horizontal section. The backgap is displaced horizontally from the
poletips. The wafer is then divided into rows. The vertical section of
20 the second pole piece is formed on the end of the row in contact with its
horizontal section. The substrate is removed by attacking the release
layers.



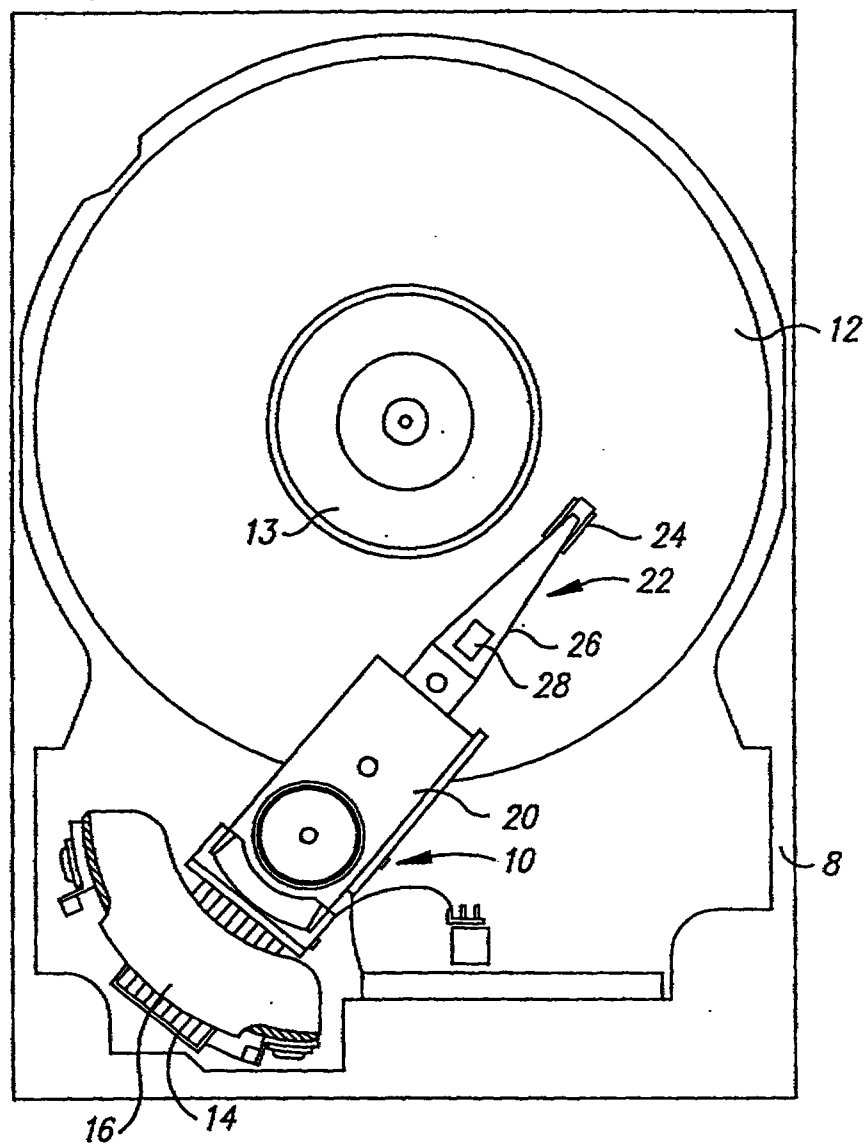
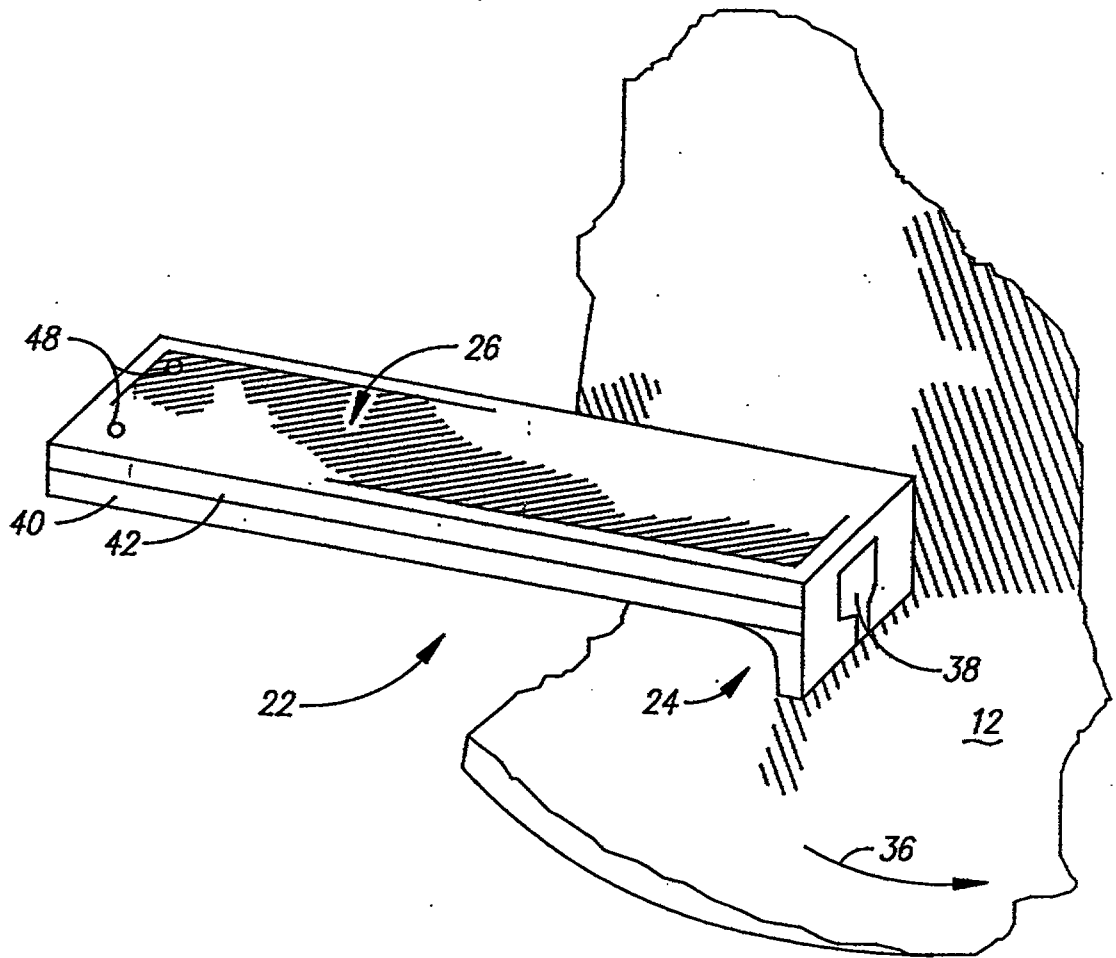
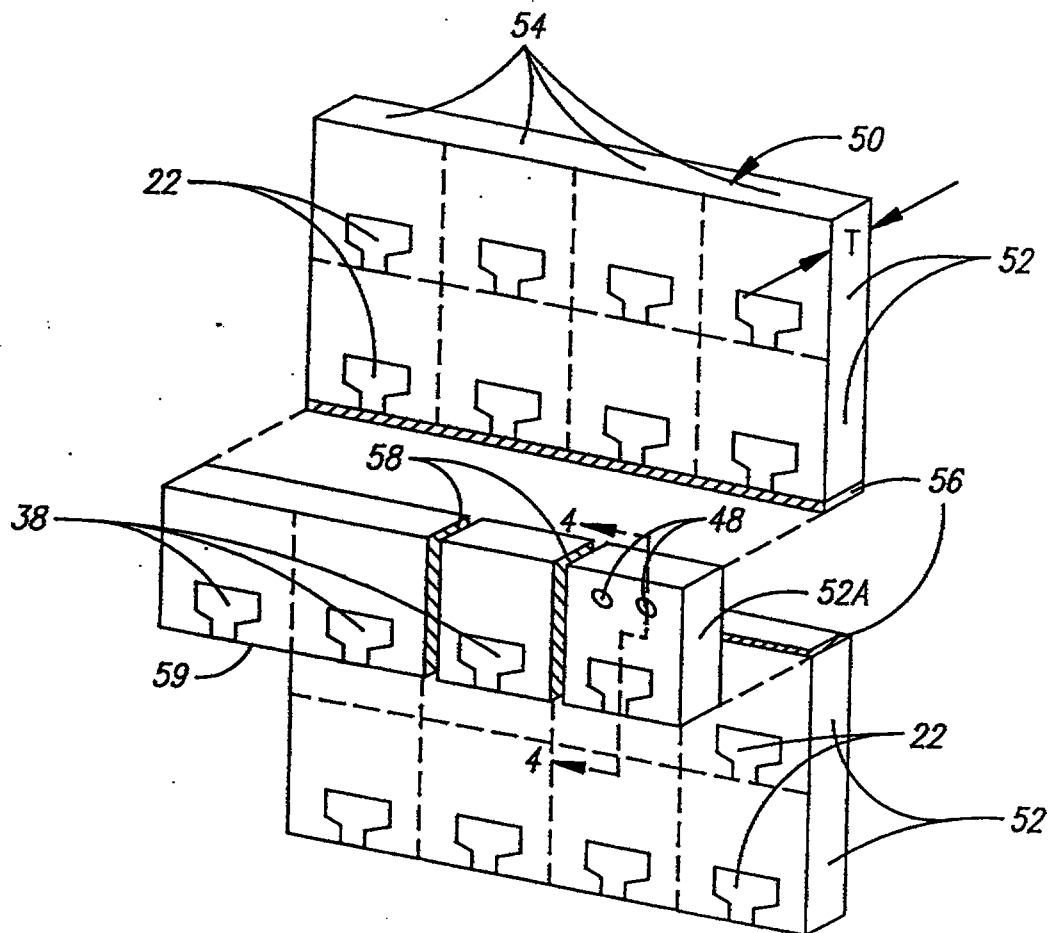


FIG. 1

*FIG. 2*

*FIG. 3*

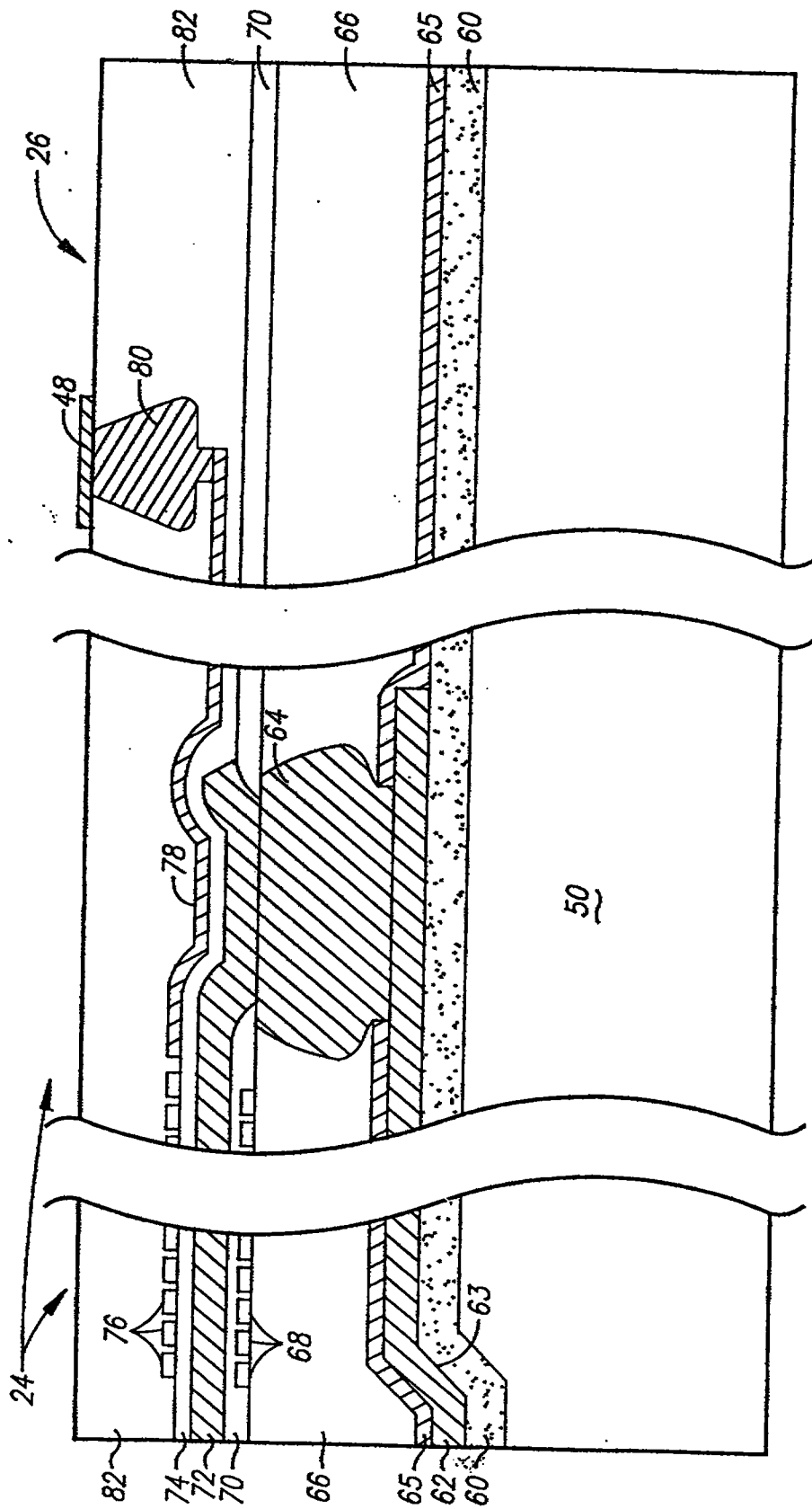
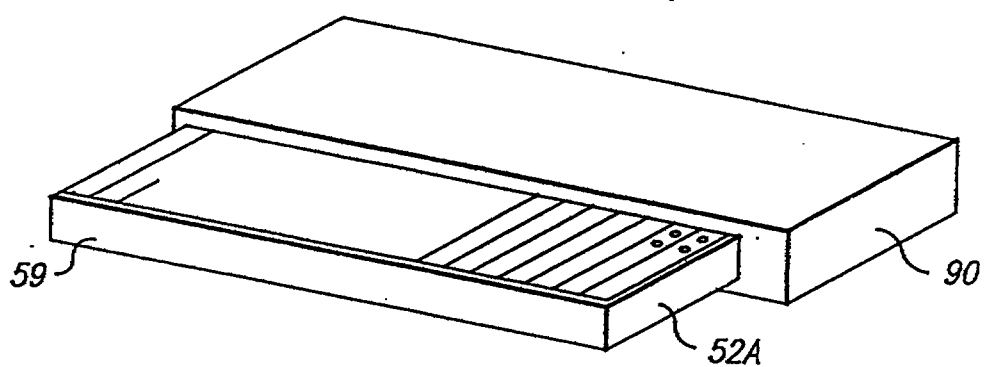
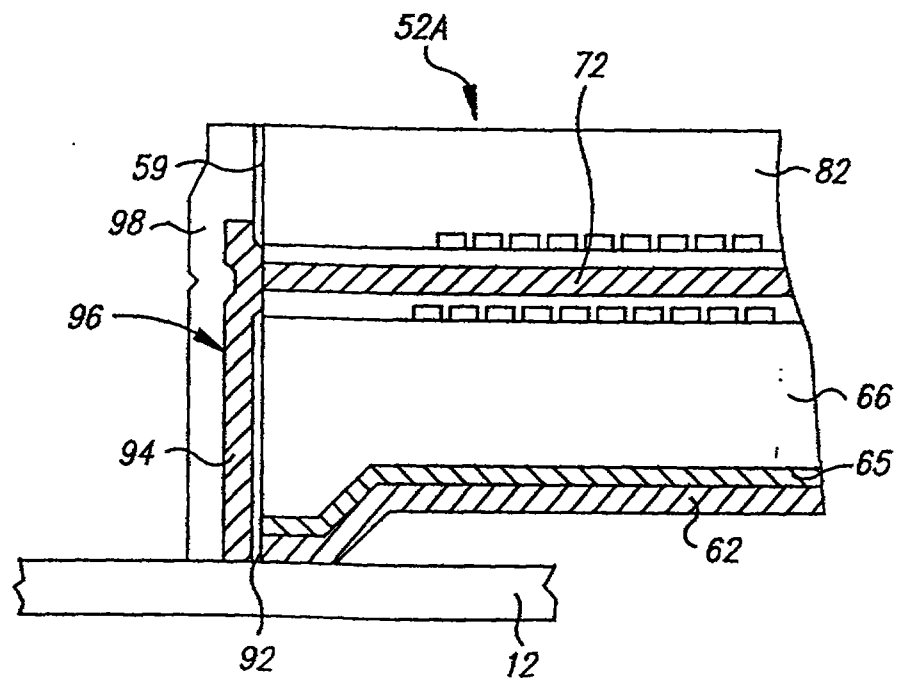


FIG. 4

*FIG. 5*

*FIG. 6A*

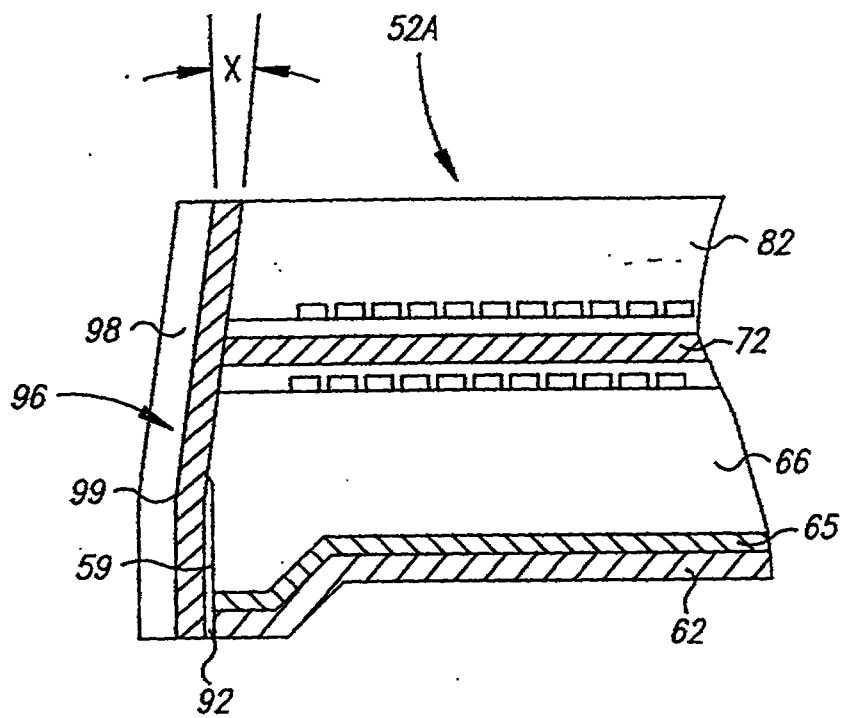
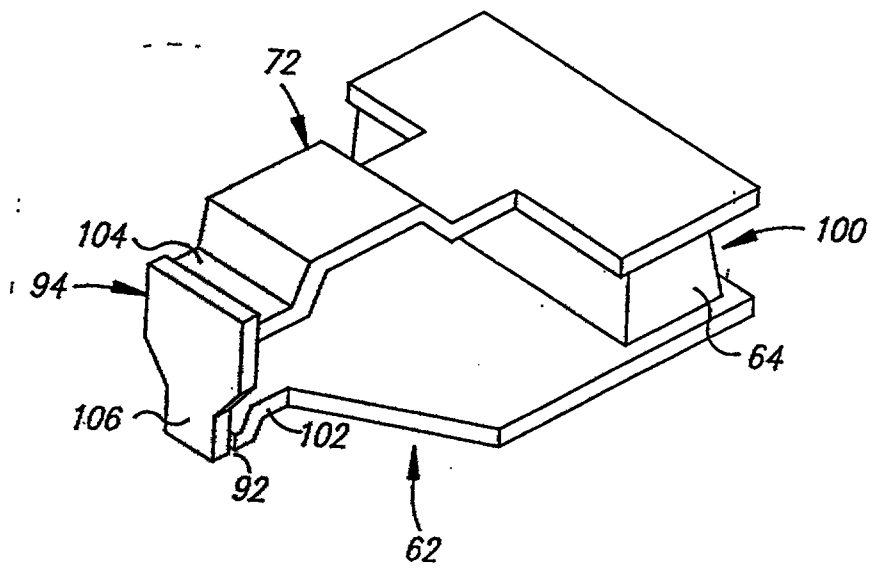


FIG. 6B

*FIG. 7*

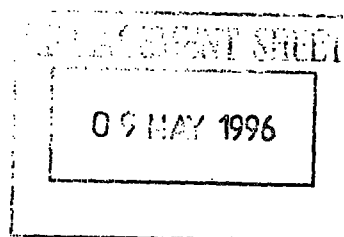
UNITARY MAGNETIC TRANSDUCER AND SUSPENSION STRUCTURE FOR LONGITUDINAL OPERATION

ABSTRACT

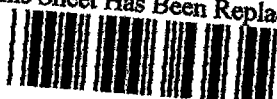
A unitary magnetic transducer and suspension structure for longitudinal recording which can be used for contact recording and flying above the media. The transducer includes a horizontal first pole piece (62) and a horizontal and vertical sectioned second pole piece. The magnetic gap is formed between the first pole piece (62) and the vertical section of the second pole piece. The suspension layers are formed mainly from the insulation layer (66) that separate the first horizontal pole piece (62) and the horizontal section (72) of the second pole piece, and an insulation layer (74) that covers and protects the transducer layers. The layers of the unitary structure head are deposited on a wafer in a row and column configuration. A release layer (60) is deposited on the substrate (50) first and then the individual thin film layers of the transducer (38) are deposited.

Fig. 4

THIS SHEET HAS BEEN
REPLACED



This Sheet Has Been Replaced



REPLACEMENT SHEET

3-55a15b, 15c, 15d

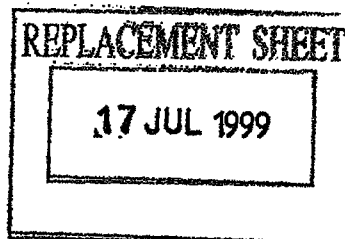
✓ Description : page 1 to page 1

✓ Claim(s) : page 15 to page 21

□ Drawing(s) : page 1 to page 1

□ Abstract : page 20 to page 1

DATE OF RECEIPT *7/17/99*



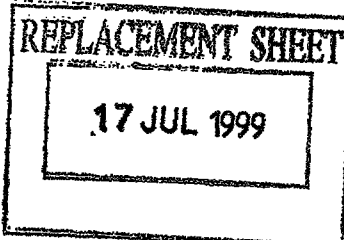
3

As noted above, contact recording permits higher signals and greater resolution unregulated by variations in flying height. Unfortunately, the wear associated with contact recording, generally estimated to be 400 microinches over the file life, is usually not acceptable. A further disadvantage of contact recording is that the "reed" type of head is suitable only for perpendicular recording and is not suitable for longitudinal media. All of this has made the perpendicular recording head of the above design unsuitable for high density recording.

An object of the present invention is to provide a unitary magnetic transducer, suspension structure and associated methods which at least ameliorate one or more of the above disadvantages.

Accordingly, in accordance with a first aspect, the present invention discloses a combination thin film magnetic head transducer and suspension system for longitudinal recording comprising:

- a horizontal thin film first pole piece having a pole tip;
- a substantially vertical thin film magnetic gap layer having oppositely facing first and second substantially vertical thin film surfaces;
- the first and second vertical thin film surfaces being made by a process of thin film deposition without lapping;
- the first thin film surface of the thin film magnetic gap layer directly contacting the pole tip of the horizontal thin film first pole piece;
- a thin film second pole piece having a vertical component which has a pole tip directly contacting the second vertical thin film surface of the thin film magnetic gap layer and a horizontal component magnetically isolated from, but adjacent and parallel to, said first pole piece, said first and second pole pieces magnetically connected at a back gap region and magnetically isolated at their pole tips by said magnetic gap;
- a thin film coil electrically isolated from but magnetically activating said first and second pole pieces and encircling the horizontal component of said second pole piece;
- said first and second pole pieces being configured with a wider surface at their back gap region and narrower surfaces at their pole tips;
- a suspension layer of a thin film layer of a resilient material at least covering said second pole piece horizontal component and being electrically and magnetically isolated



from said second pole piece and said coil, said resilient material extending beyond the back gap region;

the pole tip of the first pole piece being horizontal and substantially perpendicular to the vertical component of the second pole piece;

the first pole piece having a downwardly sloping portion which is adjacent to the pole tip of the first pole piece;

the first pole piece narrowing in width from said sloping portion to the pole tip; and

the vertical component of said second pole piece having an essentially vertical portion on an end adjacent to said magnetic gap layer and having a portion on a second end which is angled away from the essentially vertical portion to contact the horizontal component of said second pole piece.

In accordance with a second aspect of the present invention there is disclosed a disk drive assembly comprising:

a housing;

a rigid platter mounted in said housing having means for storing data in tracks provided thereon;

means for rotating said rigid platter in said housing;

an actuator arm positioned in said housing and operable to place a free end in proximity to one track of said rigid platter;

means for positioning said actuator arm adjacent to a particular track on said rigid platter;

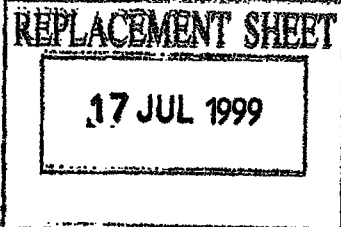
a combination thin film magnetic head transducer and suspension system for longitudinal recording mounted to the free end of said actuator arm and including:

a horizontal thin film first pole piece having a pole tip;

a substantially vertical thin film magnetic gap layer having oppositely facing first and second substantially vertical thin film surfaces;

the first and second vertical thin film surfaces being made by a process of thin film deposition without lapping;

the first thin film surface of the thin film magnetic gap layer directly contacting the pole tip of the horizontal thin film first pole piece;



a thin film second pole piece having a vertical component with a pole tip directly contacting the second vertical thin film surface of the thin film magnetic gap and a horizontal component magnetically isolated from, but adjacent and parallel to, said first pole piece, said first and second pole pieces being magnetically connected at a back gap region and magnetically isolated at their pole tips by said magnetic gap;

said first and second pole pieces being configured with a wider surface at their back gap region and narrower surfaces at their pole tips;

a thin film coil electrically isolated from, but magnetically activating, said first and second pole pieces and encircling the horizontal component of said second pole piece; and

a suspension layer of a thin film layer of a resilient material at least covering said second pole piece horizontal component and being electrically and magnetically isolated from said second pole piece and said coil, said resilient material extending beyond the back gap region;

the pole tip of the first pole piece being horizontal and substantially perpendicular to the vertical component of the second pole piece;

the first pole piece having a downwardly sloping portion which is adjacent to the pole tip of the first pole piece; and

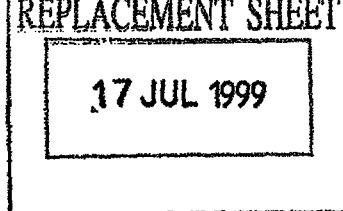
the vertical component of said second pole piece having an essentially vertical portion on an end adjacent to said magnetic gap and having a portion on a second end which is angled away from the essentially vertical portion to contact the horizontal component of said second pole piece.

In accordance with a third aspect of the present invention there is disclosed a thin film magnetic head for longitudinal recording comprising:

a horizontal thin film first pole piece having a pole tip;

a thin film second pole piece having a horizontal component and a substantially vertical component, the vertical component having a pole tip opposite the pole tip of the first pole piece;

a substantially vertical thin film magnetic gap layer having top and bottom portions;



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the bottom portion of the vertical thin film magnetic gap layer being sandwiched between the pole tip of the first pole piece and the pole tip of the vertical component of the second pole piece;

the bottom portion of the vertical thin film magnetic gap layer having first and second thin film surfaces the first and second thin film surfaces being made by a process of thin film deposition without lapping;

the first thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the first pole piece and the second thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the vertical component of the second pole piece;

the second pole piece having an angled portion which is integral with the vertical component of the second pole piece, the angled portion angling from the vertical component and making direct engagement with an exposed end of the horizontal component of the second pole piece; and

the exposed end of the horizontal component of the second pole piece having been exposed by a process of lapping the top portion of the vertical thin film magnetic gap layer.

In accordance with a fourth aspect of the present invention there is disclosed a method of making a magnetic head assembly comprising the steps of:

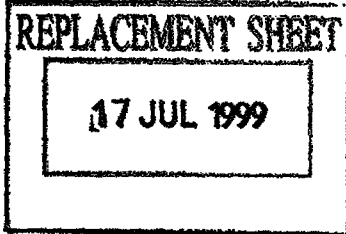
forming a substantially horizontal first pole piece, the horizontal first pole piece having a front edge;

forming in unordered steps an insulation stack, a coil assembly and a horizontal component of a second pole piece on said horizontal first pole piece wherein the insulation stack includes a plurality of insulation layers, the coil assembly includes at least one coil layer sandwiched between the insulation layers and the horizontal component of the second pole piece has a front edge;

forming a vertical gap layer on the front edge of the first pole piece and on the front edge of the horizontal component of the second pole piece;

removing a portion of the gap layer adjacent the front edge of the horizontal component of the second pole piece so that the front edge of the horizontal component of the second pole piece is exposed; and

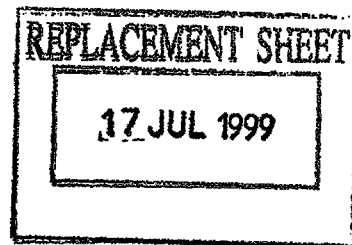
forming a vertical component of the second pole piece on the gap layer and on the exposed front edge of the horizontal component of the second pole piece.



5b

In accordance with a fifth aspect of the present invention there is disclosed a method for making a combination thin film magnetic head transducer and suspension system comprising the steps of:

- obtaining a wafer substrate;
- forming a sloping contact region on said obtained substrate;
- forming a release layer on said obtained substrate;
- forming a first pole piece of a magnetic material on said formed release layer and said contact region;
- forming a patterned back gap member on said formed first pole piece;
- forming a wear resistant layer on said formed first pole piece extending along a distance for a suspension section;
- forming a magnetic and electrical isolation layer on said formed wear resistant layer covering at least said first pole piece layer and extending along the distance for the suspension section as a first suspension layer;
- forming a first one-half of a thin film coil of an electrically conductive material on said formed isolation layer;
- forming a first electrical insulating layer covering at least said formed one-half of the thin film coil;
- forming a horizontal section of a patterned second pole piece layer of a magnetic material on said formed insulating layer;
- forming a second electrical insulating layer covering at least said patterned second pole piece layer;
- forming a second one-half of the thin film coil of an electrically conductive material on said formed second electrical insulating layer and electrically connected to said first one-half to form a complete coil;
- forming a magnetic and electrical isolation layer on said formed second one-half of the thin film coil and extending the distance for the suspension section as a second suspension layer;
- forming a magnetic gap layer of a magnetically insulating material on a free end of the assembly produced by the forming steps and covering the end of said formed first pole piece layer opposite to said formed back gap layer;



5c

forming a vertical section of the patterned second pole piece layer of a magnetic material on said formed magnetic gap layer;

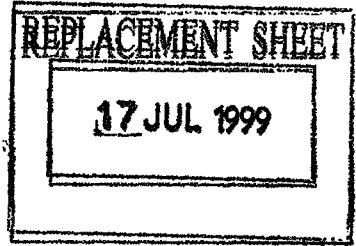
forming a covering protective layer over said formed pole piece vertical section; and

releasing the substrate from said formed contact pad layer and said formed first pole piece layer by dissolving the release layer.

An embodiment of the present invention provides a unitary magnetic transducer and suspension structure for longitudinal recording which can be used for contact recording or for flying above the media. The transducer includes a horizontal first pole piece and a horizontal and vertical sectioned second pole piece. A magnetic gap is formed between the first pole piece and the vertical section of the second pole piece. The pole pieces are shaped to avoid magnetic saturation and to provide narrow poletips. The suspension is formed mainly from two layers. The first layer is an insulation layer that separates the first horizontal pole piece and the horizontal section of the second pole piece. The second layer is an insulation layer that covers and protects the transducer layers.

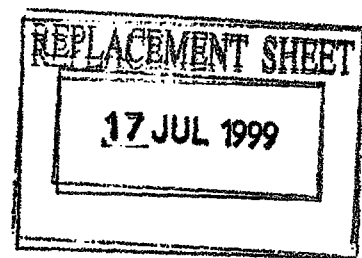
Hinkel et al, USP 4,624,048 discloses a process for making magnetic head substrates suitable for use with the present invention.

In an embodiment of the method of producing the unitary magnetic transducer and suspension struction, a plurality of contact pads of patterned photoresist is formed on the substrate in a row and column configuration. A release layer is then deposited on the substrate. A first pole piece is pattern formed in partial contact on each contact pad. A thick back gap layer of magnetic material is deposited on each first pole piece. A wear-resistant layer followed by a thick layer of electrical and magnetic insulative material is deposited. This layer forms part of the suspension portion of the unitary structure. This suspension film is lapped flat and an initial coil layer is formed on the suspension film for each pole piece. A second pole piece of magnetic layer is deposited for each first pole piece on an insulation layer at least partially covering the initial coil layer. An insulation layer covers the second pole piece layers, but permits contact to the initial coil layer. The coil circuit is then completed on this insulation layer along with conductor leads connected to the coil circuit. The conductor leads and subsequently deposited conductor studs provide the connection to the drive circuitry (not shown) for each transducer. A second



5d

thick layer of electrical and magnetic insulative material is then deposited to form the second and last part of the suspension portion of the unitary structure.



Claims

1. A combination thin film magnetic head transducer and suspension system for longitudinal recording comprising:

a horizontal thin film first pole piece having a pole tip;

a substantially vertical thin film magnetic gap layer having oppositely facing first and second substantially vertical thin film surfaces;

the first and second vertical thin film surfaces being made by a process of thin film deposition without lapping;

the first thin film surface of the thin film magnetic gap layer directly contacting the pole tip of the horizontal thin film first pole piece;

a thin film second pole piece having a vertical component which has a pole tip directly contacting the second vertical thin film surface of the thin film magnetic gap layer and a horizontal component magnetically isolated from, but adjacent and parallel to, said first pole piece, said first and second pole pieces magnetically connected at a back gap region and magnetically isolated at their pole tips by said magnetic gap;

a thin film coil electrically isolated from but magnetically activating said first and second pole pieces and encircling the horizontal component of said second pole piece;

said first and second pole pieces being configured with a wider surface at their back gap region and narrower surfaces at their pole tips;

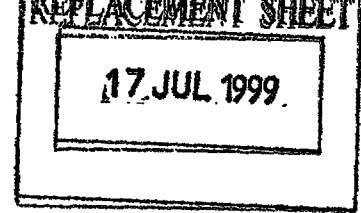
a suspension layer of a thin film layer of a resilient material at least covering said second pole piece horizontal component and being electrically and magnetically isolated from said second pole piece and said coil, said resilient material extending beyond the back gap region;

the pole tip of the first pole piece being horizontal and substantially perpendicular to the vertical component of the second pole piece;

the first pole piece having a downwardly sloping portion which is adjacent to the pole tip of the first pole piece;

the first pole piece narrowing in width from said sloping portion to the pole tip; and

the vertical component of said second pole piece having an essentially vertical portion on an end adjacent to said magnetic gap layer and having a portion on a second end



which is angled away from the essentially vertical portion to contact the horizontal component of said second pole piece.

2. A disk drive assembly comprising:

a housing;

a rigid platter mounted in said housing having means for storing data in tracks provided thereon;

means for rotating said rigid platter in said housing;

an actuator arm positioned in said housing and operable to place a free end in proximity to one track of said rigid platter;

means for positioning said actuator arm adjacent to a particular track on said rigid platter;

a combination thin film magnetic head transducer and suspension system for longitudinal recording mounted to the free end of said actuator arm and including:

a horizontal thin film first pole piece having a pole tip;

a substantially vertical thin film magnetic gap layer having oppositely facing first and second substantially vertical thin film surfaces;

the first and second vertical thin film surfaces being made by a process of thin film deposition without lapping;

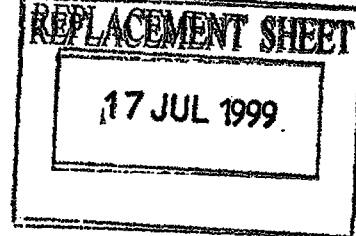
the first thin film surface of the thin film magnetic gap layer directly contacting the pole tip of the horizontal thin film first pole piece;

a thin film second pole piece having a vertical component with a pole tip directly contacting the second vertical thin film surface of the thin film magnetic gap and a horizontal component magnetically isolated from, but adjacent and parallel to, said first pole piece, said first and second pole pieces being magnetically connected at a back gap region and magnetically isolated at their pole tips by said magnetic gap;

said first and second pole pieces being configured with a wider surface at their back gap region and narrower surfaces at their pole tips;

a thin film coil electrically isolated from, but magnetically activating, said first and second pole pieces and encircling the horizontal component of said second pole piece; and

a suspension layer of a thin film layer of a resilient material at least covering



said second pole piece horizontal component and being electrically and magnetically isolated from said second pole piece and said coil, said resilient material extending beyond the back gap region;

the pole tip of the first pole piece being horizontal and substantially perpendicular to the vertical component of the second pole piece;

the first pole piece having a downwardly sloping portion which is adjacent to the pole tip of the first pole piece; and

the vertical component of said second pole piece having an essentially vertical portion on an end adjacent to said magnetic gap and having a portion on a second end which is angled away from the essentially vertical portion to contact the horizontal component of said second pole piece.

3. A thin film magnetic head for longitudinal recording comprising:

a horizontal thin film first pole piece having a pole tip;

a thin film second pole piece having a horizontal component and a substantially vertical component, the vertical component having a pole tip opposite the pole tip of the first pole piece;

a substantially vertical thin film magnetic gap layer having top and bottom portions;

the bottom portion of the vertical thin film magnetic gap layer being sandwiched between the pole tip of the first pole piece and the pole tip of the vertical component of the second pole piece;

the bottom portion of the vertical thin film magnetic gap layer having first and second thin film surfaces the first and second thin film surfaces being made by a process of thin film deposition without lapping;

the first thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the first pole piece and the second thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the vertical component of the second pole piece;

the second pole piece having an angled portion which is integral with the vertical component of the second pole piece, the angled portion angling from the vertical component and making direct engagement with an exposed end of the horizontal component of the second pole piece; and



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the exposed end of the horizontal component of the second pole piece having been exposed by a process of lapping the top portion of the vertical thin film magnetic gap layer.

4. A thin film magnetic head for longitudinal recording comprising:

a horizontal thin film first pole piece having a pole tip;

a thin film second pole piece having a horizontal component and a substantially vertical component, the vertical component having a pole tip opposite the pole tip of the first pole piece;

a substantially vertical thin film magnetic gap layer having top and bottom portions;

the bottom portion of the vertical thin film magnetic gap layer being sandwiched between the pole tip of the first pole piece and the pole tip of the vertical component of the second pole piece;

the bottom portion of the vertical thin film magnetic gap layer having first and second thin film surfaces, the first and second thin film surfaces being made by a process of thin film deposition without lapping;

the first thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the first pole piece and the second thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the vertical component of the second pole piece;

the top portion of the thin film magnetic gap layer having an aperture opposite an end of the horizontal component of the second pole piece; and

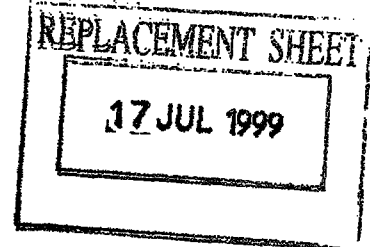
the vertical component of the second pole piece being connected to the end of the horizontal component of the second pole piece through said aperture.

5. A thin film magnetic head for longitudinal recording comprising:

a horizontal thin film first pole piece having a pole tip;

a thin film second pole piece having a horizontal component and a substantially vertical component the vertical component having a pole tip opposite the pole tip of the first pole piece;

a substantially vertical thin film magnetic gap layer having top and bottom portions;



the bottom portion of the vertical thin film magnetic gap layer being sandwiched between the pole tip of the first pole piece and the pole tip of the vertical component of the second pole piece;

the bottom portion of the vertical thin film magnetic gap layer having first and second thin film surfaces, the first and second thin film surfaces being made by a process of thin film deposition without lapping;

the first thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the first pole piece and the second thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the vertical component of the second pole piece;

the first pole piece and the horizontal component of the second pole piece being magnetically connected at a back gap;

a thin film suspension of resilient material covering the first pole piece and the horizontal component of the second pole piece between the vertical thin film magnetic gap layer and the back gap and continuing a distance past the back gap away from the first pole piece and the horizontal component of the second pole piece;

the thin film magnetic gap layer having an aperture opposite an end of the horizontal component of the second pole piece; and

the vertical component of the second pole piece being connected to the end of the horizontal component of the second pole piece through said aperture.

6. A disk drive including the thin film magnetic head for longitudinal recording of claim 5, the disk drive including:

a housing;

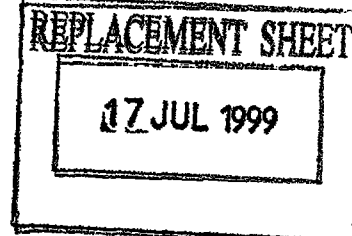
means mounted in the housing for rotating a magnetic disk;

an actuator mounted in the housing; and

the thin film suspension being mounted on the actuator so that the pole tips of the first and second pole pieces can be placed in a transducing relationship with respect to the magnetic disk.

7. A thin film magnetic head for longitudinal recording comprising:

a horizontal thin film first pole piece having a pole tip;



a thin film second pole piece having a horizontal component and a substantially vertical component the vertical component having a pole tip opposite the pole tip of the first pole piece;

a substantially vertical thin film magnetic gap layer having top and bottom portions;

the bottom portion of the vertical thin film magnetic gap layer being sandwiched between the pole tip of the first pole piece and the pole tip of the vertical component of the second pole piece;

the bottom portion of the vertical thin film magnetic gap layer having first and second thin film surfaces, the first and second thin film surfaces being made by a process of thin film deposition without lapping;

the first thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the first pole piece and the second thin film surface of the bottom portion of the vertical thin film magnetic gap layer directly engaging the pole tip of the vertical component of the second pole piece;

the first pole piece and the horizontal component of the second pole piece being magnetically connected at a back gap;

a thin film suspension of resilient material covering the first pole piece and the horizontal component of the second pole piece between the vertical thin film magnetic gap layer and the back gap and continuing a distance past the back gap away from the first pole piece and the horizontal component of the second pole piece;

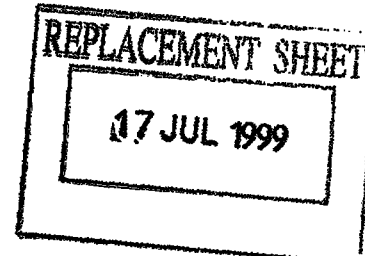
the second pole piece having an angled portion which is integral with the vertical component of the second pole piece, the angled portion angling from the vertical component and making direct engagement with an exposed end of the horizontal component of the second pole piece; and

the exposed end of the horizontal component of the second pole piece having been exposed by a process of lapping the top portion of the vertical thin film magnetic gap layer.

8. A thin film magnetic head for longitudinal recording as claimed in claim 7 including:

the pole tip of the first pole piece being horizontal and substantially perpendicular to the vertical component of the second pole piece; and

the first pole piece having a downwardly sloping portion which is adjacent to



the pole tip of the first pole piece.

9. A disk drive including the thin film magnetic head for longitudinal recording of claim 8, the disk drive including:

a housing;

means mounted in the housing for rotating a magnetic disk;

an actuator mounted in the housing; and

the thin film suspension being mounted on the actuator so that the pole tips of the first and second pole pieces can be placed in a transducing relationship with respect to the magnetic disk.

10. A method of making a magnetic head assembly comprising the steps of:

forming a substantially horizontal first pole piece, the horizontal first pole piece having a front edge;

forming in unordered steps an insulation stack, a coil assembly and a horizontal component of a second pole piece on said horizontal first pole piece wherein the insulation stack includes a plurality of insulation layers, the coil assembly includes at least one coil layer sandwiched between the insulation layers and the horizontal component of the second pole piece has a front edge;

forming a vertical gap layer on the front edge of the first pole piece and on the front edge of the horizontal component of the second pole piece;

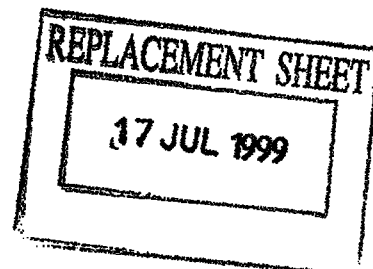
removing a portion of the gap layer adjacent the front edge of the horizontal component of the second pole piece so that the front edge of the horizontal component of the second pole piece is exposed; and

forming a vertical component of the second pole piece on the gap layer and on the exposed front edge of the horizontal component of the second pole piece.

11. A method as claimed in claim 10 wherein the step of removing comprises forming a via in said gap layer to expose the front edge of the horizontal component of the second pole piece.

12. A method as claimed in claim 10 wherein the step of removing comprises lapping the gap layer at an angle toward the front edge of the horizontal component of the second pole piece to expose the front edge of the horizontal component of the second pole piece.

13. A method as claimed in claim 10 further comprising the step of forming the vertical component of the second pole piece with a narrow portion adjacent the front edge



of the first pole piece and with a wide portion adjacent the front edge of the horizontal component of the second pole piece.

14. A method as claimed in claim 13 wherein before the step of forming the vertical component, the step of removing comprises forming a via in said gap layer to expose the front edge of the horizontal component of the second pole piece.

15. A method as claimed in claim 13 wherein before the step of forming the vertical component, the step of removing comprises lapping the gap layer at an angle toward the front edge of the horizontal component of the second pole piece to expose the front edge of the horizontal component of the second pole piece.

16. A method as claimed in claim 10 further comprising the step of forming a suspension layer or layers on the first pole piece and/or the horizontal component of the second pole piece which extends from the gap layer to a location back of the first pole piece and the horizontal component of the second pole piece.

17. A method as claimed in claim 10 further comprising the step of forming the first pole piece with first and second horizontal portions which are interconnected by an interconnecting portion which slopes downwardly from said first horizontal portion to said second horizontal portion, the second horizontal portion terminating in said front edge of the first pole piece.

18. A method as claimed in claim 17 further comprising the steps of:

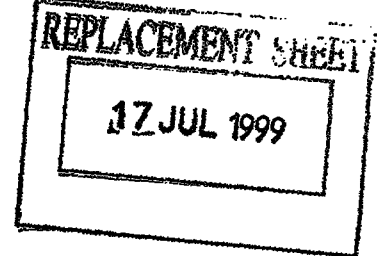
forming said second horizontal portion, the gap layer and the vertical component of the second pole piece with bottom surfaces which are contiguous with respect to one another; and

forming a cover layer over the vertical component of the second pole piece with a bottom surface which is contiguous with the bottom surfaces of the vertical component of the second pole piece, the gap layer and the second horizontal portion so that the bottom surfaces form an air bearing surface.

19. A method as claimed in claim 18 further comprising the step of before forming the first pole piece, forming a substrate with a downwardly sloping portion to form said interconnecting portion of the first pole piece.

20. A method as claimed in claim 19 further comprising the steps of:

before forming the first pole piece forming a conductive release layer on the substrate; and



employing the conductive release layer as a seedlayer for forming the first pole piece.

21. A method as claimed in claim 10 further comprising the steps of:

forming a back gap connection between the first horizontal portion of the first pole piece and the horizontal component of the second pole piece; and

forming a wear layer back of the back gap connection.

22. A method as claimed in claim 10 further comprising the steps of:

forming a back gap connection between the first horizontal portion of the first pole piece and the horizontal component of the second pole piece; and

after forming the first pole piece forming a first one of said insulation layers on top of the first pole piece so that after forming said horizontal component of the second pole piece the first insulation layer is located between the first pole piece and the horizontal component of the second pole piece and extends back from said back gap connection;

forming a pair of leads on top of the first insulation layer from said at least one coil layer to a location back of said back gap connection;

depositing a second one of said insulation layers on top of said at least one coil layer and the leads; and

forming a pair of contact pads in the second insulation layer in connection with the pair of leads.

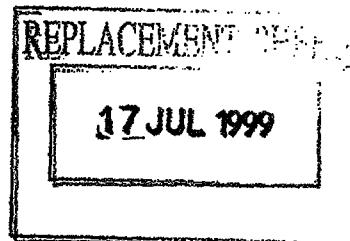
23. A method as claimed in claim 22 further comprising the steps of:

forming each of the first and second insulation layers with a front edge which is contiguous with the front edges of the first pole piece and the horizontal component of the second pole piece; and

the step of forming the gap layer comprises forming the gap layer on the front edge of the first pole piece, the front edge of the horizontal component of the second pole piece and the front edges of the first and second insulation layers.

24. A method as claimed in claim 23 further comprising the steps of:

before forming the gap layer, forming a multiple of said first and second pole pieces insulation layers, coil layer, leads and contact pads in rows and columns on a substrate;



dicing the substrate into discrete substrate rows so that respective front edges are exposed adjacent a substrate row edge of each substrate row;

the step of forming the gap layer comprises forming the gap layer on one of the substrate row edges;

the step of forming the vertical component of the second pole piece comprising forming the vertical component of the second pole piece on the gap layer on the substrate row edge;

the step of forming the cover layer comprising forming the cover layer on the vertical component of the second pole piece on the substrate row edge;

dicing the substrate row into discrete substrates which support discrete reed magnetic heads; and

releasing said discrete reed magnetic heads from said discrete substrates.

25. A method as claimed in claim 23 further comprising the step of forming the vertical component of the second pole piece with a narrow portion adjacent the front edge of the first pole piece and with a wide portion adjacent the front edge of the horizontal component of the second pole piece.

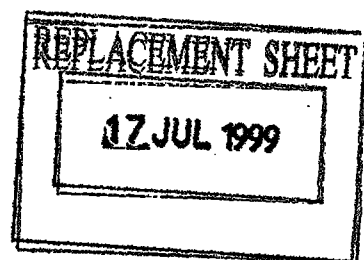
26. A method as claimed in claim 25 further comprising the step of forming the first pole piece with first and second horizontal portions which are interconnected by an interconnecting portion which slopes downwardly from said first horizontal portion to said second horizontal portion, the second horizontal portion terminating in said front edge of the first pole piece.

27. A method as claimed in claim 26 further comprising the steps of:

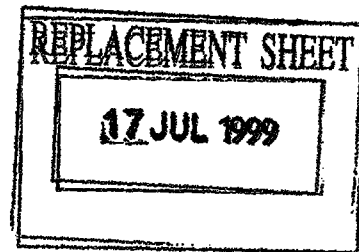
forming said second horizontal portion, the gap layer and the vertical component of the second pole piece with bottom surfaces which are contiguous with respect to one another; and

forming a cover layer over the vertical component of the second pole piece with a bottom surface which is contiguous with the bottom surfaces of the vertical component of the second pole piece, the gap layer and the second horizontal portion so that the bottom surfaces form an air bearing surface.

28. A method as claimed in claim 27 wherein the step of removing comprises forming a via in said gap layer to expose the front edge of the horizontal component of the second pole piece.



29. A method as claimed in claim 27 wherein the step of removing comprises lapping the gap layer at an angle toward the front edge of the horizontal component of the second pole piece to expose the front edge of the horizontal component of the second pole piece.
30. A method as claimed in claim 29 further comprising the step of before forming the first pole piece, forming a substrate with a downwardly sloping portion to form said interconnecting portion of the first pole piece.
31. A method as claimed in claim 30 further comprising the steps of:
before forming the first pole piece forming a conductive release layer on the substrate; and
employing the conductive release layer as a seedlayer for forming the first pole piece.
32. A method as claimed in claim 31 further comprising the step of forming a suspension layer or layers on the first pole piece and/or the horizontal component of the second pole piece which extends from the gap layer to a location back of the first pole piece and the horizontal component of the second pole piece.
33. A method as claimed in claim 32 further comprising the steps of:
forming a back gap connection between the first horizontal portion of the first pole piece and the horizontal component of the second pole piece; and
forming a wear layer back of the back gap connection.
34. A method as claimed in claim 33 wherein the step of removing comprises forming a via in said gap layer to expose the front edge of the horizontal component of the second pole piece.
35. A method as claimed in claim 33 wherein the step of removing comprises lapping the gap layer at an angle toward the front edge of the horizontal component of the second pole piece to expose the front edge of the horizontal component of the second pole piece.
36. A method for making a combination thin film magnetic head transducer and suspension system comprising the steps of:
obtaining a wafer substrate;
forming a sloping contact region on said obtained substrate;
forming a release layer on said obtained substrate;
forming a first pole piece of a magnetic material on said formed release layer and said contact region;



forming a patterned back gap member on said formed first pole piece;

forming a wear resistant layer on said formed first pole piece extending along a distance for a suspension section;

forming a magnetic and electrical isolation layer on said formed wear resistant layer covering at least said first pole piece layer and extending along the distance for the suspension section as a first suspension layer;

forming a first one-half of a thin film coil of an electrically conductive material on said formed isolation layer;

forming a first electrical insulating layer covering at least said formed one-half of the thin film coil;

forming a horizontal section of a patterned second pole piece layer of a magnetic material on said formed insulating layer;

forming a second electrical insulating layer covering at least said patterned second pole piece layer;

forming a second one-half of the thin film coil of an electrically conductive material on said formed second electrical insulating layer and electrically connected to said first one-half to form a complete coil;

forming a magnetic and electrical isolation layer on said formed second one-half of the thin film coil and extending the distance for the suspension section as a second suspension layer;

forming a magnetic gap layer of a magnetically insulating material on a free end of the assembly produced by the forming steps and covering the end of said formed first pole piece layer opposite to said formed back gap layer;

forming a vertical section of the patterned second pole piece layer of a magnetic material on said formed magnetic gap layer;

forming a covering protective layer over said formed pole piece vertical section;
and

releasing the substrate from said formed contact pad layer and said formed first pole piece layer by dissolving the release layer.

37. A method for making a combination thin film magnetic head transducer and suspension system as defined in claim 36 further including the steps of:



forming a first conductor layer of an electrically conductive material on said formed isolation layer along the distance for the suspension section and connected to said formed first one-half of the coil;

forming a second conductor layer of an electrically conductive material on said formed second electrical insulating layer along the distance for the suspension section and connected to said formed second half of the coil; and

forming conductor pads for said formed first and second conductor layers adjacent to an end of the suspension section opposite to the formed first and second pole pieces.

38. A method for making a combination thin film magnetic head transducer and suspension system as defined in claim 36 wherein the steps of forming a first pole piece of a magnetic material, forming a horizontal section of a patterned second pole piece layer of a magnetic material, and forming a vertical section of the patterned second pole piece layer of a magnetic material configure said first and second pole pieces with a wider surface at their back gap region and narrower surfaces at their pole tips.

39. A method for making a combination thin film magnetic head transducer and suspension system suitable for longitudinal recording, said method comprising the steps of:

a) obtaining a substrate wafer;

b) creating multiple rows and columns of combination systems on said obtained substrate wafer by;

1) forming a sloping contact region on said obtained wafer along each of the created multiples rows at one edge thereof;

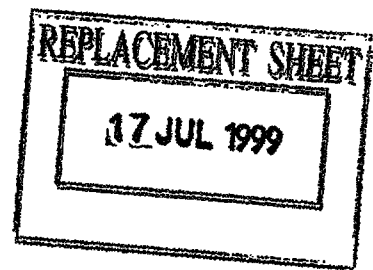
2) forming a release layer on said obtained wafer and over each of said formed sloping contact regions;

3) forming a first pole piece of a magnetic material on said formed release layer and each patterned contact pad;

4) forming a patterned back gap member on each formed first pole pieces:

5) forming a wear resistant layer on said formed first pole pieces extending along a distance for a suspension section for each formed first pole piece;

6) forming a magnetic and electrical isolation layer on said formed wear resistant layers covering at least said first pole piece layers and extending along the



distance for the suspension section as a first suspension layer for each formed first pole piece;

7) forming a first one-half of a thin film coil of an electrically conductive material for each formed first pole piece on said formed isolation layer;

8) forming a first electrical insulating layer covering at least each of said formed one-half of the thin film coils;

9) forming a horizontal section of a patterned second pole piece layer of a magnetic material on said formed insulating layer for each of said formed first pole pieces;

10) forming a second electrical insulating layer covering at least each of said patterned second pole piece layers;

11) forming a second one-half of the thin film coil of an electrically conductive material on said formed second electrical insulating layer for each of said formed first one-half of the thin film coils;

12) forming a magnetic and electrical isolation layer on each formed second one-half of the thin film coil and extending the distance for each suspension section as a second suspension layer;

c) detaching a row from said created multiple rows and columns on said obtained substrate wafer and containing said combination systems;

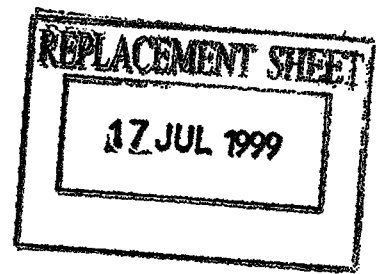
d) lapping a preselected design on each detached row on the edge having the sloping contact region;

e) forming a magnetic gap layer of insulator material on each lapped row edge of each detached row;

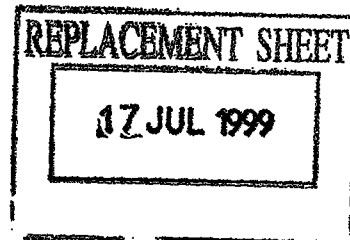
f) forming a layer of a magnetic material to provide a vertical section of said formed horizontal section of the second pole piece on said formed gap layer ends of each detached row; and,

g) forming a covering protective layer over said formed vertical section of said second pole piece of each detached row.

40. A method for making a combination thin film magnetic head transducer and suspension system suitable for longitudinal recording as defined in claim 39 further including the steps of:



- a) detaching individual combination systems from each detached row; and
- b) releasing said substrate from each detached individual combination system by dissolving the release layer.



UNITARY MAGNETIC TRANSDUCER AND SUSPENSION STRUCTURE FOR LONGITUDINAL OPERATION

ABSTRACT

A unitary magnetic transducer and suspension structure for longitudinal recording which can be used for contact recording and flying above the media. The transducer includes a horizontal first pole piece (62) and a horizontal and vertical sectioned second pole piece. The magnetic gap is formed between the first pole piece (62) and the vertical section of the second pole piece. The suspension layers are formed mainly from the insulation layer (66) that separate the first horizontal pole piece (62) and the horizontal section (72) of the second pole piece, and an insulation layer (74) that covers and protects the transducer layers. The layers of the unitary structure head are deposited on a wafer in a row and column configuration. A release layer (60) is deposited on the substrate (50) first and then the individual thin film layers of the transducer (38) are deposited.

Fig. 4