

[54] **MAGNETIC TRANSDUCER HAVING A COMPOSITE MAGNETIC CORE STRUCTURE**

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[56] **References Cited**

UNITED STATES PATENTS

3,194,894	7/1965	Smith.....	346/74 MC
3,480,736	11/1969	Johnson et al.	179/100.2 C
2,711,945	6/1955	Kornei.....	345/74 MC
3,057,967	10/1962	Clark	179/100.2 C
3,344,237	9/1967	Gregg.....	179/100.2 C
3,365,709	1/1968	Gooch	346/74 MC

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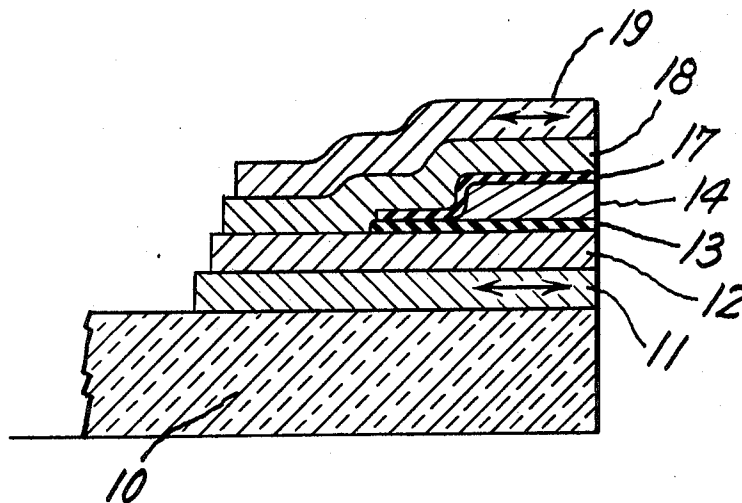
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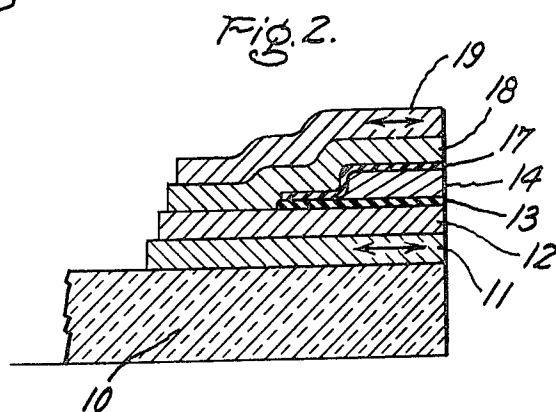
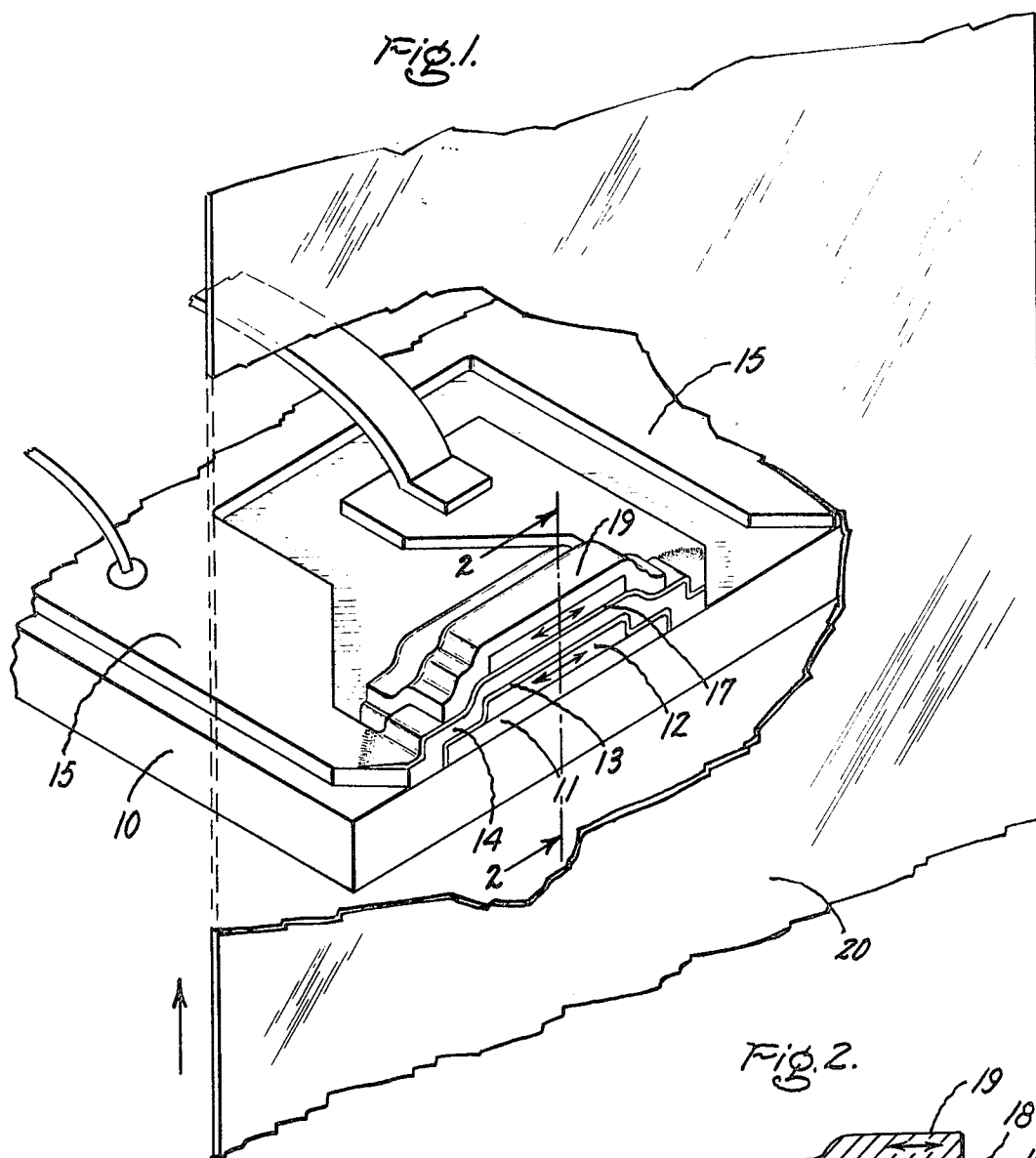
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[57] **ABSTRACT**

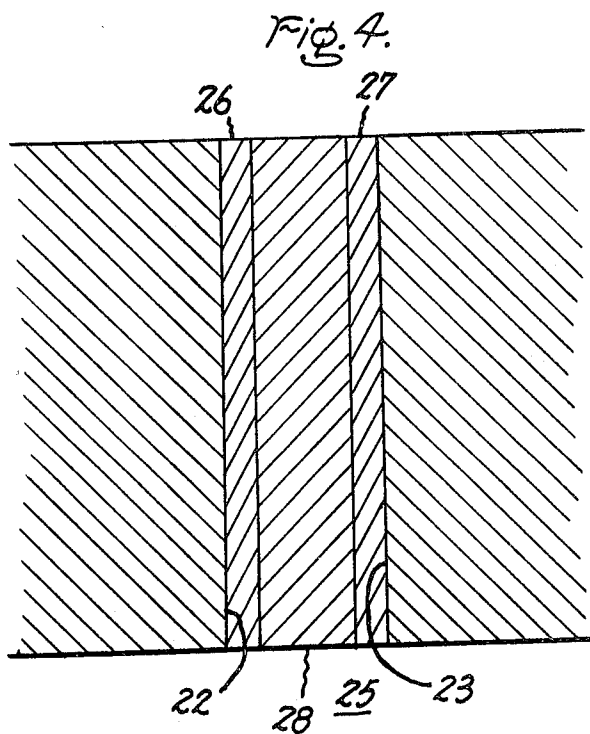
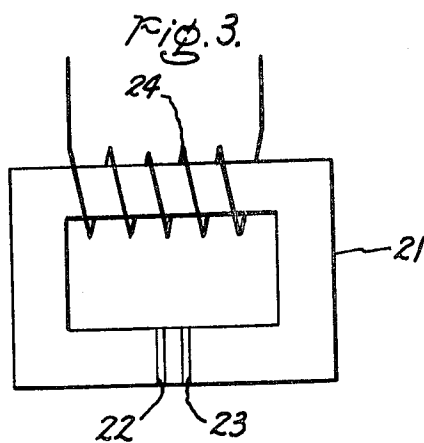
A magnetic transducer for read-write applications is disclosed in which a composite core having two closely spaced legs is provided with each leg having one layer of magnetic material of higher permeability and lower saturation flux density than the second layer of that leg. The read-write conductor means is positioned between the two legs and is thereby inductively coupled to the core. The higher permeability layer is narrow in a direction perpendicular to both the length of the leg and the thickness of the layer, is adjacent the conductor means and is saturated at flux densities encountered in writing so that the wider lower permeability outer layers of the two legs are effective during writing and the higher permeability narrower layers are effective or dominant during reading. In a modification, a composite shim is employed in the gap of a more conventional stacked lamination head to obtain some of the advantages of the present invention.

7 Claims, 4 Drawing Figures





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MAGNETIC TRANSDUCER HAVING A COMPOSITE MAGNETIC CORE STRUCTURE

The present invention relates to an improved transducer and particularly to an improved magnetic read-write head having improved operating characteristics for the read-write functions.

The requirements for high quality operation of a magnetic head for the writing function are substantially different from those required during the reading function. Accordingly, it has been difficult to provide a single structure with entirely satisfactory characteristics for both functions. Some attempts have been made to improve the compromise in the characteristics of read-write heads and in some cases separate heads have been employed for the two functions even though this has resulted in more expensive and more complex systems.

Accordingly, it is an important object of the present invention to provide an improved magnetic transducer for both reading and writing functions which provides for deep penetration of the recording medium by the magnetic field in writing as well as good resolution and high sensitivity in reading.

While not limited thereto, the invention is particularly applicable to deposited film-type transducers and makes use of at least two layers of magnetic material in each leg of the magnetic circuit of the transducer with the materials having different characteristics and, in the preferred embodiment, having different compositions. The present invention also provides for a head whose read-write gap is effectively wider for the writing function than it is for the reading function in a direction perpendicular to the direction of relative movement between the head and recording medium and the length of the magnetic circuit and whose read-write gap is effectively wider in the direction parallel to the relative movement between the recording medium and the magnetic head for the writing function as compared to the effective gap width for the reading function. These characteristics result from the magnetic properties of the material employed in the different layers and the orientation of their magnetic anisotropy with respect to the read-write gap and the conductive means associated with them. These properties and orientations are chosen so that the different magnetic states that exist during writing and reading automatically produces the changes in effective length and width of the read-write gap.

Further objects and advantages of my invention will become apparent as the following description proceeds, reference being had to the accompanying drawing and its scope will be pointed out in the appended claims.

IN THE DRAWING

FIG. 1 is an isometric view of a deposited film-type of read-write head embodying the present invention;

FIG. 2 is a sectional view along the line 2—2 of FIG. 1;

FIG. 3 illustrates a modification of the invention as applied to a more conventional stacked lamination-type of read-write head; and

FIG. 4 is an enlarged sectional view of the read-write gap of the head of FIG. 3.

In FIGS. 1 and 2 of the drawing, the present invention is shown embodied in a deposited film-type of transducer in which the multiple layer structure providing the magnetic circuit and associated inductively coupled conductor means is produced by the deposition of successive layers on a substrate 10 of suitable material, such as silicon, which provides a support for the head assembly as well as a heat sink for absorbing heat generated in the device. Certain ceramics such as beryllia and alumina may also be employed as the substrate material. As is well understood, the deposited film technique is particularly suited to the production of an array of small and closely spaced transducer assemblies and the structure described in connection with FIG. 1 may be one of a series of such structures positioned in side-by-side relation on the substrate 10.

As illustrated in the drawing, the structure is made up of successive layers of material deposited on the substrate 10 and upon one another. The first layer 11 is magnetic material such as a cobalt-iron alloy. The second layer 12 is also of magnetic material and is narrower in width than layer 11 and is of a suitable alloy such as nickel-iron. This second layer has a higher initial permeability and lower saturation flux density than the first layer or lamination 11. Next is a layer 13 of insulating material such as silicon dioxide and then a conductor 14 such as copper or gold having one edge thereof connected with what may be considered a bus 15 which interconnects one terminal of the conductor of each of a plurality of magnetic heads which, as mentioned, may be located side-by-side on substrate 10. The other terminal of the conductor 14 is provided by the portion 16 which is individual to each device. The device is completed by successive layers in the reverse order including an insulating layer 17 of silicon dioxide, the layer 18 of relatively high permeability low-saturation flux density magnetic material such as nickel-iron and finally the outer layer of magnetic material 19 of lower permeability higher saturation flux density material. As will be readily understood by those skilled in the art, the head operates in very closely spaced relation with a disk or, as illustrated, a tape 20 providing the magnetic recording medium, and the relative movement between the medium and the head during reading or writing is in a vertical direction as viewed in FIGS. 1 and 2 and as indicated by the arrow in FIG. 1.

As indicated earlier, the head is preferably formed as a deposited film device and methods for making such deposited films are well developed in the art and include evaporation, electroplating and sputtering. Sputtering is the preferred method since the deposition of a sputtered layer of predetermined composition is much more easily obtained an controlled than it is in evaporation, for example.

As an example of specific materials and method of fabricating a device embodying the present invention, a substrate of silicon of suitable dimensions for an array of magnetic heads in side-by-side relation, perhaps 200 or so, is placed in a suitable vacuumtight enclosure or bell jar for carrying out the sputtering process and the layers are then applied and photoengraved to the required pattern in succession as will be readily understood. The first layer 11 of magnetic material may have a width on the order of 10 mils and a thickness of 1 microns and a composition of pure cobalt, pure iron, or alloys thereof with up to 20 percent of either the cobalt or the iron. A preferred composition for providing the lower permeability, high-saturation flux density characteristics desired for the two outer or write layers 11 and 19 is 95 percent cobalt, 5 percent iron. The next layer or lamination 12 is of iron-nickel and has a composition such that the permeability is much higher and the saturation flux density much lower than those same parameters of the cobalt-iron layer 11 and is physically narrower than layers 11 and 19, preferably about 80 percent of the width or 8-mils-wide. The desired characteristics are readily obtained with a composition of 85 percent nickel and 15 percent iron, for example. Next, a layer of silicon dioxide is sputtered over the laminations in an area near the free edge thereof to provide insulation between the laminations and the conductive layer 14. This layer is preferably as thin as possible consistent with providing adequate electrical insulation between the magnetic layer and the conducting layer and may be approximately 1,000 A. thick. The gold or copper conductor is then deposited over the insulating layer and over the two magnetic layers 11 and 12 near the edge of the substrate and extending over the substrate to provide the conductor and terminal areas 15 and 16. The desired configuration can be obtained by electroplating through holes in an insulating film which are of the desired shape, or since the previously deposited metal films are now covered by the insulating film, photoetching can also be used to define this member. The conductor may be rather thin and in the particular example being described is 3-to 5-microns-thick. Steps similar to these are then carried out to establish the second insulating layer of

silicon dioxide 17, the nickel-iron layer 18 and the cobalt-iron layer 19. If desired, a thin-sputtered layer of chromium may be provided over the substrate and/or both sides of the silicon dioxide layers to promote adherence of the films.

As will be readily understood, the construction just described provides a magnetic circuit terminating in pole pieces at the edge of the substrate which are spaced apart with each leg of the magnetic circuit provided with two layers of magnetic material with different characteristics, and in the example just described of different compositions. Also, the conductor is near the free ends of the spaced leg portions of the magnetic circuit and is inductively coupled to the magnetic structure to provide means for the writing input to the magnetic head or the reading output connection to the magnetic head by way of the common terminal 15 and individual terminal 16 and the associated read and write circuitry. It will be understood that the edge of assembly may be machined or ground to a smooth surface, which coincides with the aerodynamic surface of a flying head shoe, to provide a recording gap or a reading gap. The flux passing across the gap passes through the adjacent material of the recording medium to magnetize the recording medium during the write operation or to sense the magnetic state of the recording medium in the read operation.

It is an important feature of the present invention that the width of the head be greater for writing in a direction perpendicular both to the direction of relative movement between the magnetic head and the recording medium and to the length of the magnetic circuit of the head as compared with the effective width during the reading operation. This is accomplished in the embodiment illustrated by the magnetic properties and the relative widths of the two layers of each leg. At the relatively low flux density encountered during the read operation, the narrower laminations 12 and 18 of relatively high permeability are unsaturated and dominate in the magnetic circuit associated with the conductor 14. During the write operation, much higher flux densities are encountered and said inner layers are saturated. The characteristics of the head during writing are therefore determined by the lower permeability high-saturation flux density material of the outer or write laminations or layers of magnetic material 11 and 19. It will be noted that by having the read magnet circuit provided by the layers 12 and 18 adjacent the conductor that the gap is much shorter in the direction of relative movement between the head and the medium for read than it is for the write operation and by making the width of the inner layers less than the outer layers, which are effective during writing, that a narrower width of the recording material is sensed during reading than the width of the track in writing. By providing a narrower gap associated with the read circuit, sensitivity to short wavelength signals is improved and by providing a narrower track during reading, the edge or marginal portions of the recorded track are eliminated. Since the edge portion of the track is not recorded with good fidelity, and since spurious signals may be found in these regions, the fidelity of the read back is improved.

While particular materials have been described above, it is apparent that the advantages of the present invention may be obtained with any combination of materials in which the layer adjacent the conductor means has a relatively high permeability and low-saturation flux density compared to the material on the outer layer. It is possible to obtain much of the advantage of the present invention by providing the layer adjacent the conductor means with a much higher permeability than the outer layer, even though the saturation flux density may be the same. This may be accomplished in a simple manner by using the same composition for all of the magnetic layers and making use of the large difference in permeability produced by shifting the axis of easy magnetization by 90° in the inner layers as compared with the outer layers. As is well understood by those skilled in the art, this axis of easy magnetization is determined by the direction of the magnetic field applied during the deposition of the film layers and the axis of

easy magnetization is in the direction of such applied magnetic field. The axis of easy magnetization is shown by the arrows on the inner and outer layers of magnetic material in FIGS. 1 and 2 of the drawing. For such an embodiment utilizing a single material, nickel-iron alloy is particularly well-suited and the permeability may be changed by a factor of 100 in this manner for an alloy of 60 percent nickel, 40 percent iron. Satisfactory results are readily obtained with nickel ranging from 50 percent to 80 percent and iron ranging from 50 percent to 20 percent. It will be understood that the affect of the direction of the easy axis of the magnetization will be used in the embodiment of the invention utilizing different compositions in the inner and outer magnetic films to enhance the difference in the magnitudes of the permeabilities of the inner and outer layers.

In FIG. 3 I have shown a further modification embodying features of my invention in which by a suitable composite shim certain advantages of my invention are obtained with a more conventional type of laminated head structure. As shown in FIG. 3, the head may include a stack of laminations 21 of generally "C" shape terminating with opposed faces 22 and 23 across which the flux extends and couples with the recording medium. A read-write coil 24 is inductively coupled to the core.

A composite shim 25 which fills the entire gap or space between the pole pieces may be made up of two layers 26 and 27 adjacent the pole pieces 22 and 23 of high-permeability, low-saturation flux density magnetic material such as a nickel-iron alloy, described above, separated by a layer 28 of non-magnetic material, such as copper. Preferably, the high-permeability material is of a lesser dimension in a direction into the paper as shown in FIG. 3 than the other laminations at the pole faces 22 and 23 so that the width of the shim adjacent the magnetic material of the core is less than the width of the laminations, thus giving a narrower effective head during reading than the effective width of the head during writing. It will be apparent that with this construction, the high-permeability material is not saturated during the read operation and sensitivity as well as good resolution are provided because of the narrowed width for reading as well as the relatively narrow gap during reading. During write, the high-permeability material is saturated and the effective gap as well as width of the head for writing is greater, being determined by the laminations of the head.

Thus, it will be seen that by this relatively simple modification of what may be considered a somewhat conventional laminated construction of a read-write head that improved operating characteristics for the combined functions of reading and writing are obtained.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A read-write head comprising a magnetic core having a pair of legs in series magnetic relation, read-write conductor means inductively coupled to said legs and passing therebetween, each leg comprising two superimposed layers, each of a different magnetic material, the magnetic material of the layers closest to said conductor means have a substantially higher permeability and lower saturation flux density than the other layers.

2. The read-write head of claim 1 wherein said one layer is physically narrower in a direction perpendicular both to the thickness of the layer and to the length of the leg of which it is a part than the other layer.

3. The read-write head of claim 1 wherein said one layer saturates at flux densities therein during writing so that the other layer of each leg provides the dominant magnetic circuit during writing.

4. A read-write head comprising a magnetic core having a pair of legs in series magnetic relation, read-write conductor means inductively coupled to said core and passing between the legs thereof, each leg comprising two superimposed layers, each of magnetic material having different initial permeability, the layers having higher permeability being adjacent said

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read-write conductor means so that the last-mentioned layers dominate the magnetic characteristics of said head during the read operation.

5. The read-write head of claim 4 where the axis of easy magnetization of the layers adjacent said conductor being parallel to the width of said layers and the axis of easy magnetization of the other two layers being parallel to the length of said layers. core.

6. The read-write head of claim 4 wherein the width of the magnetic layers adjacent the read-write conductor means is narrower than the other of said layers.

7. A read-write head comprising a magnetic core having a

stack of laminations of magnetic material terminating in spaced opposed pole faces defining a gap and a composite shim including a layer of magnetic material adjacent each pole face having a substantially higher permeability and lower saturation flux density than the magnetic material of said core and a layer of nonmagnetic material interposed between said layers of magnetic material, said composite shim having a lesser width dimension than that of the stack of laminations of said core for providing a narrower effective head during reading than during writing and read-write conductor means inductively coupled to said core.

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