A MAGNETIC TRANSDUCING HEAD

The following statement is a full description of this invention, including the best method of performing it known to us.

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The invention relates to a magnetic transducing head.

According to the invention there is provided a magnetic transducing head comprising a magnetically permeable leg split into a lower member and an upper member, a non-magnetic gap between said members, and a magnetoresistive element disposed adjacent said gap and electrically insulated from said members.

The invention will now be described by way of example with reference to the accompanying drawings, in which:-

FIGURE 1 is a cross-section of a magnetic transducing head according to the invention;

FIGURE 2 is a cross-section of the transducing head illustrating thin film layers that comprise such head;

FIGURE 3 shows how the width of the magnetoresistive element and its distance from a moving tape are related to the resolution of a transducing head;

FIGURE 4 illustrates a read-write circuit usable with the transducing head; and

FIGURE 5 illustrates resistance-magnetic field plot of a magnetoresistive element.

The transducing head 2 shown in Figure 1 comprises a yoke 4 having legs 6 and 8 and a split central leg composed of upper portion 10 and lower portion 12 connected together by a non-magnetic spacer 14 and a magnetoresistive element 16 disposed adjacent the spacer 14. For magnetic purposes, the three legs, namely, leg 6, leg 8, and split leg (10 and 12) are made of magnetically permeable material, such as permalloy or ferrite.
magnetic purposes, the spacer layers, namely layer 14, layer 18, and layer 20 are made of non-magnetic materials, such as copper or glass. For electrical purposes, the magnetoresistive element 16 must not contact any other electrically conductive layer in the cross-section of Figure 1. Thus, if electrically conductive materials are chosen for magnetic elements 10 and 12, or for spacer elements 14 or 18, then additional thin insulating layers, not shown, must be used to isolate the magnetoresistive element 16. When the head is to be used for writing onto a magnetic medium, one of the spacer layers, such as layer 20, which does not contact the magnetoresistive element 16, can be electrically conductive. A thin ferromagnetic film 46, having low anisotropy and a high magnetoresistance coefficient, such as permalloy, serves as the magnetoresistive sensing element of the head 2. Surrounding the magnetoresistive element 16 and the central leg on both sides are fillers 18 and 20. Such fillers not only give body to the head but, as will be described hereinafter, can serve as electrical conductors when the head 2 is used for writing or for applying a biasing magnetic field to the magnetoresistive element 16.

Figure 2 illustrates one manner in which the head 2 of Figure 1 is fabricated as a multilayer thin film using conventional vapour deposition and electroplating techniques. On a suitable substrate 22 of glass, SiO₂ or the like, is vapour deposited a first layer 24 of permalloy, over which is deposited an insulating layer 26,
SiO₂ being an acceptable material to serve as such insulating layer, though other equivalent insulators can be used. Magnetoresistive element 28 is laid down on such insulating layer 26, followed by the deposition of a second insulating layer 30 to envelop magnetoresistive element 28. A second layer of permalloy 32 is deposited onto the first permalloy layer 24 and over the second insulating layer 30, save for a window 34 which is blocked off during the deposition of the second layer 32 of permalloy so that no permalloy is immediately over a portion of magnetoresistive element 28, leaving effectively an upper leg 10' and a lower leg 12'.

After this window 34 is filled with insulating material, similar to that of layers 26 and 30, a conducting strip 36 is deposited that is substantially coextensive with the insulating layers 26 and 30 and is made of any conducting, non-magnetic material, i.e., copper. A final layer 38 of permalloy overlies conducting strip 36 as shown, making contact also with second layer 32 of permalloy as well as with the first permalloy layer 24. After the last layer of permalloy has been deposited, the entire assembly is cut and polished so that everything to the left of line A-A and to the right of the dotted line B-B of Figure 2 is removed, and the head 2 is complete save for the electrical contacts and leads that are to be attached to them.

It should be noted that spacer 34 need not be distinct from spacer 36. They can be deposited as a single layer, with a resulting ripple in the surface contour between spacer layer 36 and layer 38. This
An alternative technique can be readily relied upon when the thickness of layer 32 is less than the thickness of layer 36, assuring that the depth of window 34 will be filled.

Figure 1 depicts the reading head more likely to be used as a bulk type head wherein, for symmetry, two fillers 18 and 20 are used. But in the thin film version of the novel head of Figure 2, only one strip 36 of electrically conducting material is used. The thicknesses of the deposited films or layers of an operative head 2 made by thin film technology are as follows:

- Permalloy layer 24 ~ 30,000Å
- Insulating SiO₂ layer 26 ~ 5,000Å
- Magnetoresistive layer 28 ~ 200Å
- Insulating SiO₂ layer 30 ~ 800Å
- Permalloy layer 32 ~ 2,000Å
- Copper layer 34 ~ 5,000Å
- Permalloy layer 36 ~ 30,000Å

As seen in Figure 3, when a recording medium M, which could be tape, or disc file, wire or the like, passes underneath the head, it is desirable that the head 2 have high linear resolution. If one were to plot the output voltage signal of a read head as a function of the number of magnetic bits per inch, the value of the density of the data bits (how many bits per inch) at the half-amplitude (half-way between zero voltage output and maximum voltage output) value of this plot is a measure of the linear resolution of the head. For the vertical head of the type
described in United States Patent 3,493,694, the density of half-amplitude \( \frac{1}{w+2s} \), where \( w \) is the width of the magnetoresistive element and \( s \) is the shortest distance from that element to medium \( m \). In this invention the dimension \( w \) is limited by the minimum attainable linewidths and \( s \) is limited by the combined polishing, wear, and flying height tolerances. Modern technology does not allow a resolution greater than a few thousand bits per inch. For the head of Figure 3, however, the linear resolution is determined primarily by the thicknesses of spacer layers 26, 30, and 36 and of magnetic layer 12'. For a properly proportional head, the resolution will be approximately that of a conventional inductive head with a gap width of half the sum of the thicknesses of layers 26, 30, 12', and 36. Since these layers are very thin, this resolution is high (~30,000 bits/inch). That the above considerations are valid may be seen from Figure 3. The permalloy legs 24 and 38 reduce the effective magnetic field of view of the magnetoresistive element 28. Thus magnetic bits \( m_1, m_2 \) or \( m_3 \) are shielded from magnetic sensing by element 28 until they are individually under that element 28. As recording medium \( m \) moves past the immediate range of magnetoresistive element 28, the permalloy leg 24 prevents magnetic information now to the left of element 24 from being sensed by element 28.

An advantage of the head of Figure 3 is that the properties of linear resolution and wear tolerance can be optimized separately. Thus, the tolerance for wear is determined by the distance \( s' \), which can be
worn away before the element begins to suffer damage. The linear resolution is mostly determined by thicknesses of layers 26, 30, 12' and 36, as noted above. The resolution of the head is only weakly dependent on the thicknesses of the outer magnetic legs 24 and 38, so that they could be massive blocks which replace the substrate 22 or are otherwise part of the mechanical package of the head.

The manner in which the reading head 2 is employed for reading and writing is better seen in conjunction with Figures 4 and 5. In Figure 4, the magnetoresistive element 28 is shown illustratively as a resistor 28. The magnetoresistive element 28 is connected to a battery 40 at one end and at the other end to a resistive element 48, which together constitute a source of bias current $I_b$ through element 28, so that the changes of resistance of element 28 will appear as a signal voltage \((\frac{I_b}{R}) \Delta R\) at the amplifier 42. The resistance change of element 28 is shown as a function of magnetic field in Figure 5. In order that a small magnetic signal from the medium \(m\) will produce the largest and most linear resistance change, the element 28 should be exposed to a constant magnetic bias field $H_b$. This can be produced by a current $I_w$ flowing in the spacing layer 36, shown as a resistor 36 in Figure 4.

Thus the head requires two types of bias, the current bias $I_b$, and the magnetic bias $H_b$ (which can be produced by a current $I_w$). In some cases, one can connect elements 28 and 36 in series to accomplish
both types of bias with a single current.

In some types of digital magnetic recording, linearity is not required, and a magnetic bias point other than the maximum slope $\frac{dR}{dH}$ will be chosen.

When the head 2 of Figure 3 is to be used to write, a generator 46 applies write current $I_w$ through strip 36, such current $I_w$ being much greater than $I_b$ so as to apply a large $H$ to the moving recording member $m$.

In the present case, the width of the written track on the medium $m$ is greater than the width of the information being read. Reading width is dependent on the length of magnetoresistive element 16 or 28 whereas writing width depends on the lengths of copper conductor 18, 20 or 36 and magnetic layers 24 and 38.

In the instant case, looking perpendicularly to the plane of the drawing of Figures 1 and 3, the length of magnetoresistive element 16 is less than the lengths of 14 as 6 and 8 or fillers 18 and 20; or the length of element 28 is less than the length of permalloy layers 24, 32, 38 and copper filler 36. Consequently, the novel recording head 2 forming the present invention has the capability of writing widely and reading narrowly, and such capability eases the mechanical tolerances in a recording system.

In summary, a three-legged recording head, capable of being built either as a unitary bulk unit or by thin film technology, has been provided that lends itself to both reading and writing, where the width of the magnetic information recorded on a recording member is greater than the width of magnetic information...
read by that same head. The head, using a magneto-
resistive element, has a large wear tolerance and high
resolution. Since the heads 2 can be made 10 mils
wide or less, they lend themselves for use wherever
high density magnetic recording is used.
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A magnetic transducing head comprising a magnetically permeable leg split into a lower member and an upper member, a non-magnetic gap between said members, and a magnetoresistive element disposed adjacent said gap and electrically insulated from said members.

2. A head according to Claim 1, in which the non-magnetic gap is formed of copper.

3. A head according to Claim 1 or 2, including two spaced apart magnetically permeable legs, said members and said element being disposed between said two legs.

4. A head according to Claim 3, in which a non-magnetic electrically conductive material is embedded between said element and one of said two legs, the element being insulated from the embedded material.

5. A head according to Claim 4 in which the embedded material is copper.

6. A magnetic transducing head comprising a first layer of permalloy, a first layer of insulation thereon, a layer of magnetoresistive material over a portion of said insulation, a second layer of insulation covering said magnetoresistive material, a second layer of permalloy overlying said second layer of insulation and having an
opening therein facing said magnetoresistive element, a non-magnetic material filling said opening, a layer of non-magnetic, electrically conductive material overlying said second layer of permalloy, and a third layer of permalloy overlying said layer of electrically conductive material.

7. A head according to any one of claims 4 to 6 including means for applying electrical energy to bias said magnetoresistive element.

8. A head according to any one of claims 4 to 7 including means for applying writing current to said non-magnetic electrically conducting material.

9. A magnetic transducing head substantially as hereinbefore described with reference to Figures 1 and 4 or 2, 3 and 4 of the accompanying drawings.

Dated this 17th day of March, 1975.

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