

METHOD FOR THE MAKING OF A MAGNETIC RECORDING/READING
HEAD, AND RECORDING/HEADING HEAD

BACKGROUND OF THE INVENTION

The invention relates to a method for making a
5 magnetic recording/reading head. It can be applied
especially to the making of multiple-track heads for
the reading of all types of media such as magnetic
disks, magnetic tapes and magnetic cards, in all fields
covering all types of equipment such as video
10 recorders, computer peripherals, data recorders for
space vehicles, etc.

The writing and/or reading of a large number of
tracks very close to one another, for example tracks
arranged in parallel on a magnetic tape at a pitch of
15 10 μm , requires a magnetic head having elementary heads
compatible with an information density of this type.

The French patent application No. 2 630 853
describes the organization of a matrix head adapted to
such an application. The French patent 2 648 940
20 describes various methods of making such a head.

However, there is a problem of the integration of
the coils of the magnetic heads and of the connection
of these coils to the control circuits.

The invention proposes the making of an integrated
25 head with its coils and also the integration of the
control circuits. This removes the drawbacks of the
prior art. The resulting component is potentially
inexpensive and provides for a greater density of gaps
in a matrix organization of magnetic heads.

30 According to the invention, the integrated head
takes the form of a component combining control logic,
power transistors, multiple-turn coils and magnetic
circuits.

SUMMARY OF THE INVENTION

The invention therefore relates to a method for the making of a magnetic recording/reading head comprising the following steps:

- 5 - the making of magnetic excitation wires on or in a first face of a substrate comprising this first face and a second face opposite the first face;
- the making, on the first or second face of the substrate, of at least two magnetic poles separated by
10 a gap;
- the drilling of holes through the substrate from the face opposite the one bearing the magnetic poles, each ending in such a way that there is magnetic coupling between the bottom of the hole and the pole;
- 15 - the deposition of a layer of material with high magnetic permeability in the holes and in the zones of the substrate located between the holes.

The invention also relates to a magnetic recording/reading head comprising a non-magnetic
20 substrate having, on one face, at least one magnetic excitation conductor and, on this face or on the opposite face, two magnetic poles separated by a gap as well as an element made of a material with high magnetic permeability having a U-shape, with the arms
25 of this U being substantially perpendicular to the face bearing the magnetic poles and with the ends of the arms being each magnetically coupled with a magnetic pole, said element and said poles forming a magnetic circuit that surrounds the conductor, wherein the
30 substrate is made of a semiconductor material in which the control circuits to which the conductor is connected are implanted.

BRIEF DESCRIPTION OF THE DRAWINGS

The different objects and features of the invention
35 shall appear more clearly from the following description, and from the appended figures, of which:

- Figure 1 shows a general exemplary embodiment according to the invention;

- Figure 2 shows a detailed example of a magnetic head according to the invention;

5 - Figures 3a to 3e show a method for the making of a magnetic head according to the invention;

- Figures 4a to 4e show a variant of the method of manufacture according to the invention;

10 - Figure 5 shows a magnetic head and a method of manufacture according to which magnetic poles are not directly on the substrate plate;

- Figure 6 shows a variant of the method of manufacture of Figure 5;

15 - Figure 7 shows an application of the invention to the making of matrix magnetic head;

- Figures 8 to 14 show different modes of coils of a matrix magnetic head.

MORE DETAILED DESCRIPTION

20 According to the invention, the control logic circuits, the supply transistors and the coils are made on a substrate of semiconductor material (silicon) by using a technology that is now tested and widely used on an industrial scale such as, for example, a technology using complementary MOS transistors and a
25 double level of metallization. Figure 1 gives a schematic view of such a circuit of the kind that can be obtained on wafers in the semiconductor industry. It will be noted that the connections are positioned on the top and bottom edges of the chip so as to free the
30 right-hand and left-hand edges for the running of the tape.

 The control transistors have a resistance well below that of the coils so that the currents are determined by the impedance of said coils. It follows
35 therefrom that the heat dissipation zone is that of the coils.

Figure 2 shows an example of a schematic sectional view in the zone of the coils. It shows a magnetic circuit with a gap imbricated in a coil.

It has a substrate 1 bearing, on one of its faces
5 10, magnetic excitation conductors 2 or coil wires. The substrate 1 is, for example, made of semiconductor material (silicon for example) and control circuits 7, 7' are implanted in the substrate. The circuits 7, 7' are therefore semiconductor circuits and contain power
10 transistor circuits that can be used to supply the connection wires with current. They are then connected by means known in the prior art to the excitation wires 2. The circuits 7, 7' may also contain logic control circuits receiving commands from the exterior and
15 controlling the power supply circuits of the excitation wires.

Above the coils there are positioned magnetic poles 3, 3' separated by a gap 30. A layer of insulator material 13 may be provided above the excitation wires
20 2. This layer, whose surface is plane and slightly curved, enables the poles 3, 3' to be received easily and to be insulated from the excitation wires 2. The poles 3, 3' are made advantageously according to the method for the manufacture of thin layers as described
25 in the French patent application No. 2 605 783.

Holes 12 and 12' go through the substrate 1 and the layer 13 and contain a material with high magnetic permeability 4 in such a way that this material is in contact or almost in contact with the poles 3, 3' so as
30 to be magnetically coupled with the poles 3, 3'. The layer 4 therefore magnetically couples the poles 3 and 3' to each other.

Finally, a supporting plate 6 which is preferably rigid is fixed to the plate 11 of the substrate 1 with,
35 for example, bonder 5. Advantageously, the plate 6 is made of a material that is a good conductor of heat,

for example silicon, to enable the cooling of the circuits.

According to the exemplary embodiment of Figure 2, the excitation wires 2 and the circuits 7, 7' are positioned on the face 10 of the substrate but in another embodiment they could be on the face 11.

Referring to Figures 3a to 3e, a description shall now be given of a method for making a magnetic head according to the invention.

10 In a first step (Figure 3a), control circuits 7, 7' and excitation wires 2 are made on the surface 10 of a substrate 1. In the case of an embodiment using semiconductors, the control circuits 7, 7' are implanted in the substrate and the excitation wires 2
15 are made on the surface of the substrate. The excitation wires 2 are electrically connected to the control circuits 7, 7'. The face 10 and the excitation wires are covered with an insulator layer 13. This layer is preferably flattened or slightly curved (in
20 the case of applications for the reading of magnetic tapes).

In a second step, the magnetic poles 3, 3' separated by a gap are made on the layer 13. According to a thin-layer manufacturing method, the magnetic pole
25 3 is made on the face 10 and then a layer of non-magnetic material 30 is made on this pole.

This non-magnetic layer 30 has a thickness smaller than that of the pole 3. A layer of magnetic material designed to form the pole 3 is then made on the unit.
30 Then, this magnetic layer and the non-magnetic layer 30 are machined above the pole 3 so as to bring out this pole 3. Thus the structure of Figure 3b is obtained.

According to the exemplary embodiment of Figure 3b, the layer of non-magnetic material 30 located between
35 the poles 3' and the face 10 has been kept but,

according to another embodiment, it could be eliminated.

During a third step (Figure 3c), holes 12, 12' are drilled in the substrate 1 from the face 11. The hole 12 preferably reaches the pole 3. The hole 12' reaches the layer 30 or the pole 3'. The holes 12 and 12' may also be holes that do not lead into the substrate 1 or the layer 13. It is enough then that there should be a magnetic coupling between the poles 3, 3' and the holes 12, 12' respectively.

In a fourth step (Figure 3d), a material with high magnetic permeability 4 is then deposited in the holes 12, 12' and on the zone of the substrate 1 located between the holes. This material 4 is aimed at obtaining the magnetic coupling of the poles 3 and 3' and forming the element that closes the magnetic circuit of the magnetic head.

In this state, the magnetic head according to the invention is made.

In a fifth step (Figure 3e) the face 11 of substrate may be fixed to a supporting plate 6 whose role is to make the unit rigid as well as possibly to act as a cooling unit.

For example, the thickness of the substrate 1 may be equal to about a hundred micrometers while that of the pole 3 may be equal to about ten micrometers while the non-magnetic layer 30 is some micrometers thick.

The materials used will be for example:

- substrate = silicon
- poles 3, 3' = sendust (alloy of iron, tin and aluminium)
- layer of magnetic material 4 = permalloy.

Figures 4a to 4e show an alternative to the method described here above.

In Figure 4a, during the first step, the excitation wires and circuits 7, 7' are made on the face 11 of the substrate.

In the second step (Figure 4b), the magnetic poles
5 3, 3' are made on the face 10.

The holes 12, 12' are made during the third step (Figure 4c) as here above. Then, the magnetic material 4 is deposited in the holes 12, 12' as above (Figure 4d). Finally, a supporting element 6 is attached to
10 the unit.

There is thus obtained a structure (Figure 4e) which differs from that of Figure 3e by the fact that the excitation wires and the control circuits 7, 7' are made on the face 11 instead of on the face 10.

15 The difficulty with this type of completely integrated technology is the compatibility of the operations for processing the magnetic head and the silicon circuits. There is a risk of destroying the logic transistors and the control transistors during
20 the operations for annealing the poles. This is why an alternative method of manufacture shall now be described.

This alternative method is illustrated in Figure 5.

A composite plate 9 made of non-magnetic material
25 90 and of magnetic material 91 is made separately. The non-magnetic material 90 is, for example, glass and the magnetic material 91 is ferrite. The magnetic poles 3, 3' are made on a face 92 above magnetic zones 91 so that each of them is magnetically coupled to the face
30 93 of the plate 9.

During the second step described here above, this face is then fixed by bonding, for example, to the face 10 of the substrate.

The substrate 1 is then thinned out on the face 11
35 side and then holes are drilled in the substrate 1 before the electrodeposition of permalloy as here

above. A supporting plate 6 of silicon or heat conductor may then be bonded to make the unit rigid.

Other variants may give the final result. In particular, the U-shaped permalloy structure may be
5 obtained on the active faces of the chips (after the making of blind holes by chemical corrosion) and then the heat conductor is bonded to this active face or thinned out by the rear face up to the permalloy and the unit is bonded to the glass-ferrite composite
10 material.

According to another variant shown in Figure 6, instead of using a plate 9 of composite material, a wafer 8 of homogeneous and non-magnetic material such as silicon is used. The magnetic poles 3, 3' are made
15 on this wafer. Then this wafer is thinned out. Then, as here above, this wafer 8 is attached to the substrate plate 1 bearing the excitation wires 2 and the control circuits. The plate 1 is thinned out. Then, the holes 12 and 12' are made through the
20 substrate 1 and through the wafer 8.

The magnetic material 4 deposited in the holes 12, 12' enables the constituting of the magnetic circuits coupling the two magnetic poles 3 and 3'.

Various alternative ways of making the magnetic
25 closing circuit are possible. The first silicon substrate may be drilled with its blind holes (leading to the poles) before the bonding of the second substrate. These same blind holes may be filled with permalloy before bonding. This brings us to the
30 variants explained in the above paragraph.

This embodiment is advantageous for two reasons:

- the two silicon substrates 1 and 8 may have the same dimensions;
- the density of the gaps may be greater than in
35 the previous approach because there is no longer any glass-ferrite composite material used.

The coils may be made in two levels of metallization with the possibility of connecting these two levels by cross-connections that go through the substrate 1 and even through the supporting plate 6.

5 The invention can be applied to the making of a set of matrix heads as shown in Figure 7 and described in the French patent application No. 2 630 853.

10 In a set of heads such as this, the heads are organized in rows and columns. A head such as T1 has two poles 3, 3' separated by a gap 30, each located on a magnetic pad PL1 connected to a layer or to a plate of magnetic material 1. Magnetic excitation conductors or row coils L1 enable the induction of a magnetic flux in the magnetic circuits of a row of magnetic heads.

15 Other magnetic excitation conductors or column coils C1 enable the induction of a magnetic flux in the magnetic circuits of a column of magnetic heads. A magnetic head located at the intersection of a row coil and a column coil is excited.

20 According to the invention, the coil conductors are not housed in grooves. They are on the surface of the substrate 1. The working of the magnetic heads is, however, the same. Their mode of coiling determines the pads PL1.

25 Figures 8 to 14 show different modes of coils made possible by the method of the invention.

Figure 8 shows a matrix head in which each magnetic head has its own two poles. Each row of magnetic heads has a row coil, D1 for example, that is individually

30 coiled around the poles D1 of a row. Each column of magnetic heads has a column coil S1 that is coiled around all the poles D1 to D5 of a column together. Such an arrangement enables the reduction of all cross-talk between magnetic heads owing to the fact that

35 there is no common pole between neighboring heads. A

mode of coiling such as this also enables the reduction of the inductance.

Figure 9 shows a matrix head in which a magnetic pole is common to two heads. A row coil D1 is coiled
5 around the poles of a row. For each column, there are two coils such as S3 and S4 coiled around the poles of a column alternately.

Figure 10 shows a mode of coiling in which it is the column coils that are each common to a column of
10 poles and in which there are two row coils coiled around the poles of a row alternately.

Figure 11 shows a mode of coiling similar to that of Figure 9, but the magnetic heads are positioned in a zigzag arrangement and connect the magnetic poles
15 diagonally.

Figure 12 shows a mode of coiling similar to that of Figure 11 but wherein the pads and poles are square-shaped. They are positioned at 45° with respect to the direction of the rows and columns.

20 Figure 13 shows a mode of coiling in which the pads and poles positioned at 45° (as in Figure 12) have row coils and column coils coiled around them individually.

Figure 14 shows a mode of coiling in which there are two coils per row D3, D4 for example, coiled around
25 the poles of a row alternately as well as two coils per column S1 and S2 for example, coiled around the poles of a column alternately.

WHAT IS CLAIMED IS:

1. A method for the making of a magnetic recording/reading head comprising the following steps:

5 - the making of magnetic excitation wires on or in a first face of a substrate having this first face and a second face opposite the first face;

- the making, on the first or second face of the substrate, of at least two magnetic poles separated by a gap;

10 - the drilling of holes through the substrate from the face opposite the one bearing the magnetic poles, each ending in such a way that there is magnetic coupling between the bottom of the hole and the pole;

15 - the deposition of a layer of material with high magnetic permeability in the holes and in the zones of the substrate located between the holes.

2. A method according to claim 1, comprising an additional step for the bonding of the face of the substrate opposite the face bearing the magnetic poles
20 to a supporting plate.

3. A method according to claim 1, wherein the making of the magnetic poles is done by:

- the making of a first magnetic pole on the face of the substrate;

25 - the making of a layer of non-magnetic material with a thickness smaller than that of the first magnetic pole on the first pole and on the face of the substrate bearing this first pole;

30 - the machining of the layer of the second pole and of the non-magnetic material located on the first pole.

4. A method according to claim 1, wherein the electronic control circuits are made on or in the first substrate face.

5. A method according to claim 4, wherein the
35 substrate is made of a semiconductor material and



wherein the electronic circuits are implanted in the substrate.

6. A method according to claim 1, wherein the material with high magnetic permeability is made of permalloy.

7. A method according to claim 1, wherein the making of the magnetic poles is done separately on a supporting plate, this supporting plate being then fixed by its face opposite the face bearing the poles to the first face or to the second face of the substrate.

8. A method according to claim 7, wherein the supporting plate is made of a non-magnetic material.

9. A method according to claim 7, wherein the supporting plate is made of a composite material of magnetic elements and non-magnetic elements perpendicular to its main faces, the magnetic elements magnetically coupling each pole to the face opposite the one that bears these poles.

10. A magnetic recording/reading head comprising a non-magnetic substrate having, on one face, at least one magnetic excitation conductor and, on this face or on the opposite face, two magnetic poles separated by a gap as well as an element made of a material of high magnetic permeability having a U-shape, the arms of this U being substantially perpendicular to the face bearing the magnetic poles and the ends of the arms being each magnetically coupled with a magnetic pole, said element and said poles forming a magnetic circuit that surrounds the conductor, wherein the substrate is made of a semiconductor material in which the control circuits to which the conductor is connected are implanted.

11. A magnetic head according to claim 10, comprising an element made of non-magnetic material between the magnetic poles and the substrate.



12. A magnetic head according to claim 10 comprising, between the magnetic poles and the substrate, a composite part made of elements of magnetic materials and elements of non-magnetic materials magnetic coupling each magnetic pole to one end of an arm of the U-shaped element.

13. A matrix of heads organized in rows and columns applying the magnetic head according to one of the foregoing claims wherein, for each row, there is provided a row coil coiled, in common, around one pole of the heads of a row and, for each column, there is provided a column coil coiled separately around one pole of the heads of a column.

14. A matrix of heads organized in rows and columns applying the magnetic head according to one of the foregoing claims wherein, for each row, there is provided a row coil coiled, in common, around one pole of the heads of a row and, for each column, at least two independent coils coiled separately around the poles of alternate magnetic heads.