

HEAD POSITIONING APPARATUS AND MANUFACTURING METHOD

FIELD OF THE INVENTION

5 The present invention relates to a head positioning apparatus and its manufacturing method. In particular, it relates to an integrated electrostatic microactuator and a slider for positioning read/write heads in a data storage system.

10 BACKGROUND OF THE INVENTION

 In a data storage system such as a hard disc drive, magnetic heads are used to read and write data in the form of digital signals to and from the data storage discs. Because data storage discs are constantly being researched and developed to achieve higher density and thus higher storage capacity within a particular disc, it is always a challenge to achieve fast and precise positioning of a read/write heads on the discs.

 Typically, a two-stage actuator is used to position the read/write head. The actuator uses a first stage to coarsely adjust the position of the head and a second stage to finely adjust the position of the head over the disc. A Voice Coil Motor (VCM) may be used to move a slider to achieve coarse positioning in the first stage, microactuators such as electromagnetic, piezoelectric or electrostatic types may be used to precisely position read/write heads mounted on a slider over the disc.

 US Patent 5,959,808 to Fan et al discloses a shielded electrostatic microactuator for magnetic head positioning such devices, in which a slider is connected to a gimbal structure of a suspension through an electrostatic rotary microactuator. Because the slider moves together with the read/write head when it is used, the slider becomes an additional load that must be driven by the microactuator. The additional load therefore increases the risk of data read/write

errors. In addition, the distant location of the actuator from the read/write head limits the servo bandwidth of the structure and/or reduced positioning accuracy.

5 Deep Reactive Ion Etching (DRIE) and Chemical Vapour Deposition (CVD) are the conventional methods for manufacturing an electrostatic microactuator of the above type. In these methods, the gaps between the electrically conductive plates of the electrostatic microactuator are formed by the photoresist process. It is desirable to reduce the width of the gap to increase the driving force. In the meantime, it is also desirable to increase the height of the gap to obtain high
10 resonance frequency. As such, a high aspect ratio (height of gap/width of gap) is desired to meet the above requirements.

By using the conventional methods such as Ultra Violet (UV) exposing or Ultraviolet Lithografie Galvanofirmung Abformung (UV LIGA), the maximum
15 aspect ratio is about 25 (i.e. 100:4) and therefore, the corresponding track density is about 40 thousand to 50 thousand track per inch (kTPI). An aspect ratio higher than this limit may be achieved for example, by X-ray exposing process. However, the cost of this X-ray exposing process or the like is high, therefore it is not appropriate for mass production of the microactuators.

20 SUMMARY OF THE INVENTION

The present invention seeks to provide a method for manufacturing a head positioning apparatus for a data storage system and a head positioning apparatus,
25 which removes the slider from being a movable part in the second stage of the head positioning operation. By integrately forming an electrostatic microactuator between the slider and the read/write heads, an aspect ratio higher than 100:4 is achieved without using the high cost process such as the X-ray exposing process. In addition, the weight of the second stage movable parts are reduced therefore
30 the servo control bandwidth may be increased and a track density higher than 100 kTPI can be achieved.

In accordance with one aspect of the present invention, there is provided a method for forming a head positioning apparatus for a data storage system. The method comprises forming a first group of electrically conductive plates onto a slider, coating the first group of electrically conductive plates with a sacrificial layer and forming a second group of electrically conductive plates each at one side of the respective one of the first group of electrically conductive plates and on the sacrificial layer. A supporting member is formed on the slider. A head plate is formed to connect the second group of electrically conductive plates and the supporting member. The sacrificial layer is then removed to leave a gap between each pair of the respective first and second group of the electrically conductive plates. A read/write head can be formed onto the head plate. The second group of electrically conductive plates is therefore movable relative to the first group of electrically conductive plates, which carries the read/write head movable relative to the slider to achieve precise positioning of the read/write.

Preferably, the head plate has openings and the sacrificial layer is removed by applying etchant thereon through the openings.

Preferably, the method further comprises forming a head film with corresponding openings onto the head plate.

Preferably, the method further comprises forming a protective layer with corresponding openings onto the head film to protect the head film during removal of the sacrificial layer.

Preferably, the sacrificial layer is formed on the first group of electrically conductive plates by electroplating.

In accordance with another aspect of the present invention, there is provided a head positioning apparatus for a data storage system, the head positioning apparatus comprises a slider which is movable together with a Voice Coil Motor for coarsely positioning a read/write head above a data storage

medium, an electrostatic microactuator integrately formed on the slider and a read/write head integrately formed on the electrostatic microactuator. The read/write head is movable relative to the slider through the electrostatic microactuator to achieve precise positioning.

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Preferably, the electrostatic microactuator further comprises a first group of electrically conductive plates coupled to the slider; a second group of electrically conductive plates formed interdigitally with the first group of electrically conductive plates and a support member connecting the first group and second group of electrically conductive plates, wherein the read/write head is coupled to the second group of electrically conductive plates. . .

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Preferably, the electrostatic microactuator further comprises a first electrode formed onto the slider and electrically connected to the first group of electrically conductive plates, and a second electrode fixed onto the slider and electrically connected to the second group of electrically conductive plates; wherein when a first voltage is applied between the first electrode and the second electrode, the second group of electrically conductive plates moves in a first direction relative to the first group of electrically conductive plates by biasing against the support member.

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In one embodiment, the electrostatic microactuator further comprises a third group of electrically conductive plates formed on the slider and fixed onto, but electrically isolated from the first group of electrically conductive plates; and a fourth group of electrically conductive plates formed interdigitally with the third group of electrically conductive plates and the fourth group of electrically conductive plates is fixed together with the second group of electrically conductive plates.

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Preferably, the electrostatic microactuator further comprises a third electrode fixed onto the slider and electrically connected to the third group of electrically conductive plates; wherein when a second voltage is added between

the first electrode and the third electrode, the second group and forth group of electrically conductive plates move in a second direction relative to the third group of electrically conductive plates by biasing against the support member, and wherein the second direction is opposite to the first direction.

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10 In accordance with a further aspect of the present invention, there is provided a head positioning apparatus for a data storage system, the head positioning apparatus comprises a slider which is movable together with a Voice Coil Motor for coarsely positioning a read/write head above a data storage medium, a head assembly and a support member. The slider has formed thereon a first group of electrically conductive comb members defining a plurality of recesses therebetween. The head assembly has a second group of electrically conductive comb members and a read/write head formed thereon; the second group of electrically conductive comb members extend into the respective plurality of recesses, and the support member connects the slider and the head assembly. The first and the second group of comb members are electrically isolated from each other. The second group of comb members is movable relative to the first group of comb members in a direction substantially perpendicular to the first group and second group of comb members.

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25 Preferably, each of the second group of electrically conductive comb members is located adjacent to one side of the respective first group of electrically conductive comb members, and when a voltage is applied over the first and second groups of electrically conductive comb members, the second group of comb members moves relative to the first group of electrically conductive comb members in a direction substantially perpendicular to the first and second groups of electrically conductive comb members.

30 Preferably, one of the first group and second group of comb members further comprises two sub-groups of comb members, one sub-group of comb members is located adjacent to one side of the respective other group of comb

members, and the other sub-group of comb fingers is located adjacent to the opposite side of the respective other group of comb fingers.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a partial perspective view showing a head positioning apparatus according to one embodiment of the present invention;

Fig. 2 is a partial perspective view of Fig. 1 showing details of the relevant parts when disassembled;

Fig. 3 is a partial cross sectional view of Fig. 1 along A-A line;

Fig. 4 is a partial cross sectional view of Fig. 1 along B-B line;

Figs. 5A – 5H are partial cross sectional views showing the method of forming a head positioning apparatus according to the present invention;

Fig. 6 is a flow chart showing the method of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to one embodiment of the present invention as shown in Figs. 1 and 2, a head positioning apparatus comprises a slider 10, an electrostatic microactuator 20, a dust cover 25 and a head assembly 30. The electrostatic microactuator 20 comprises a first part formed onto one end of the slider 10, and a second part, which is movable relative to the first part. The head assembly 30 comprises a head plate 32 and a read/write head 34 formed integrately thereon. The head plate 32 is connected to the second part of the electrostatic microactuator 20. The head plate 32 has a plurality of openings 132 for removing excess materials formed during the manufacturing process of the head positioning apparatus. The openings 132 also reduce the weight of the head plate 32, which

also contributes to the increase of the servo bandwidth and the positioning accuracy of the head positioning apparatus.

As shown in Figs. 3 and 4, the first part of electrostatic microactuator 20 comprises a first main group of parallel, electrically conductive plates or comb members 122 (only one plate is numbered for purposes of illustration) formed onto the slider 10. The second part comprises a second main group of parallel, electrically conductive plates or comb members 124 formed interdigitally with the first group of plates 122. The term "interdigitally" denotes a positioning relationship between the first main group and the second main group of plates 122 and 124 in such a way that each plate is extended into the respective space between the other group of the respective plates, as shown in Fig. 3. A pair of supporting members 56 is formed to mechanically connect the slider and the second main group of plates 124. The first main group and the second main group of plates 122 and 124 are electrically isolated.

In one embodiment as shown in Figs. 3 and 4, the first main group of plates 122 is further divided into a first sub-group 122a and a second sub-group 122b. The first sub-group of plates 122a is located adjacent to the left sides 124a of the second main group of plates 124, and the plates in the second sub-group 122b are positioned adjacent to the right sides 124b of the second main group of plates 124. A first electrode 302a is electrically connected to the first sub-group of plates 122a, a second electrode 302b is electrically connected to the second sub-group of plates 122b, and a third electrode 304 is electrically connected to the second main group of plates 124.

Driven by the electrostatic force between the respective plates when a first voltage V1 is applied over the first electrode 302a and the third electrode 304, the second main group of plates 124 moves left towards the third electrode 304 along a direction 402 substantially perpendicular to the lateral direction 404 of the plates or comb members 124. When a second voltage V2 is applied over the second electrode 302b and the third electrode 304, the second main group of plates 124

moves right towards the second electrode 302b. It will be appreciated that above motions may be controlled by varying the voltage to achieve precise positioning of the read/write heads formed onto the second group of plates over the data storage discs.

5 Figs. 5A – 5H illustrate the process of forming a head positioning apparatus according to one embodiment of the present invention. As shown in Figs. 5A and 5B, a seed layer 51 made of Chromium (Cr), for example, is firstly formed on to a substrate, such as a slider 50. A first sacrificial layer 52, made of copper (Cu), for
10 example, with a predetermined pattern is then formed onto the seed layer 51 by an appropriate method, such as lithography.

Thereafter, a photoresist layer 53 is formed onto the first sacrificial layer 52 with the same pattern as the first sacrificial layer 52, while reserving a plurality of
15 first group of recesses 54 into which a first group of parallel plates 55 is filled thereafter. The first group of parallel plates 55 is preferably a type of electrically conductive material, such as nickel. The photoresist layer 53 is removed after the formation of the first group of parallel plates 55 onto the slider 50, as shown in Fig. 5B. At left and right sides of the slider 50, support members 56 are formed in
20 conjunction with the first group of parallel plates 55. Details of the support members 56 will be described below.

A second sacrificial layer 57 is electroplated onto the first group of plates 55 and support members 56, as shown in Fig. 5C. The thickness of the second
25 sacrificial layer may be controlled in the electroplating process to preferably be about 4 micrometer (μm). In a subsequent photoresist process, the trenches between the first group of plates 55 are partially filled with a sacrificial material 157, and a second group of recesses 59 adjacent to the respective first group of plates 57 are formed, as shown in Fig. 5D. A second group of parallel plates 155
30 is formed by filling a conductive material, such as nickel, into the second group of trenches 59, as shown in Fig. 5E.

A head plate 32 with the a pattern corresponding to that of the sacrificial layer 52 is electroplated to connect the support members 56, the second group of plates 155, the sacrificial layer 57 and the sacrificial material 157. The head plate 32 patterned with a plurality of openings 132 is also filled with sacrificial material, overlapping part of the sacrificial layer 57 and the sacrificial material 157. The solid areas 232 of the head plate 32 cover the second group of plates 155. A head film 130 is formed onto the head plate 132, and a protective layer 40 is formed onto the head film 130. Both the head film 130 and the protective layer 40 have the same patterns as the head plate 32 therefore forming a plurality of vias at the openings 132, as shown in Fig. 5F. The protective layer 40 is formed mainly for the purpose of protecting the head film 130 during the subsequent etching process, which is illustrated below.

An etchant is applied onto the sacrificial layer 57 and the sacrificial material 157 through the plurality of vias, which etches-off the sacrificial layer 57 and the sacrificial material 157 from the head plate 32 and the trenches between the first group of plates 55, and form gaps 190 between the respective first group and second group of parallel plates 56 and 156, as shown in Fig. 5G. It is appreciated that the width of the gaps 190 is substantially the same as the thickness of the second sacrificial layer 57, i.e. about 4 μm . Upon completion of the removal of the sacrificial layer 57 and the sacrificial material 157, the protective layer 40 is removed to expose the head film 130, as illustrated in Fig. 5H. A read/write head may be formed onto the head film 130 in a conventional manner.

A method 60 of forming a head positioning apparatus according to the present invention may be illustrated in Fig. 6. In a first block 61, a first group of electrically conductive plates are formed onto a slider. In the next block 62, a sacrificial layer is coated on the first group of electrically conductive plates. A second group of electrically conductive plates are thereafter formed on the sacrificial layer at block 63. Each of the second group of electrically conductive plates is adjacent to one side of the respective first group of individual electrically conductive plate. Further at block 64, a support member is formed on the slider.

At block 65, a head plate is formed to connect the second group of plates and the support member. Once the second group of electrically conductive plates is formed, the sacrificial layer is removed at block 66. Gaps between the respective pairs of first and second groups of the electrically conductive plates are formed by the removal of the sacrificial layer.

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention. Furthermore, certain terminology has been used for the purposes of descriptive clarity, and not to limit the present invention. The embodiments and preferred features described above should be considered exemplary, with the invention being defined by the appended claims.

CLAIMS

1. A method for making a head positioning apparatus comprising:
 - forming a first group of electrically conductive plates onto a slider;
 - coating a sacrificial layer on the first group of electrically conductive plates;
 - forming a second group of electrically conductive plates on the sacrificial layer, wherein each of the second group of electrically conductive plates is adjacent to one side of the respective one of the first group of individual electrically conductive plate;
 - forming a support member on the slider;
 - forming a head plate to connect the second group of plates and the support member; and
 - removing the sacrificial layer by applying an etchant through a plurality of openings provided on the head plate to leave a gap between each of the first and second groups of electrically conductive plates.
2. The method as recited in claim 1, further comprising forming a head film with a set of openings onto the head plate.
3. The method as recited in claim 2, further comprising forming a protective layer with a set of openings onto the head film.
4. The method as recited in claim 3, further comprising removing the protective layer after the sacrificial layer is removed.
5. The method as recited in claim 1, further comprising connecting the first group of electrically conductive plates to a first electrode and electrically connecting the second group of conductive plates to a second electrode.
6. The method as recited in claim 1, wherein the sacrificial layer is coated onto the first group of electrically conductive plates by electroplating.

7. A head positioning apparatus for a data storage system, the head positioning apparatus comprising:
 - a slider;
 - an electrostatic microactuator coupled to the slider
 - a head plate having a plurality of openings, wherein the head plate is coupled to the electrostatic microactuator; and
 - a read/write head coupled to the head plate,wherein the electrostatic microactuator is to move the read/write head relative to the slider.
8. The head positioning apparatus as recited in claim 7, wherein the electrostatic microactuator further comprises:
 - a first group of electrically conductive plates coupled to the slider;
 - a second group of electrically conductive plates formed interdigitally with the first group of electrically conductive plates; and
 - a support member to connect the first group and second group of electrically conductive plates,wherein the read/write head is coupled to the second group of electrically conductive plates.
9. The head positioning apparatus as recited in claim 8, further comprising:
 - a first electrode electrically connected to the first group of electrically conductive plates;
 - a second electrode electrically connected to the second group of electrically conductive plates; andwherein when a first voltage is applied between the first electrode and the second electrode, the second group of electrically conductive plates moves in a first direction.

10. The head positioning apparatus as recited in claim 9, further comprising:
 - a third group of electrically conductive plates formed on the slider, wherein the third group of electrically conductive plates is electrically isolated from the first group of electrically conductive plates; and
 - a fourth group of electrically conductive plates formed interdigitally with the third group of electrically conductive plates.
11. The head positioning apparatus as recited in claim 10, further comprising:
 - a third electrode coupled to the slider and electrically connected to the third group of electrically conductive plates;
 - wherein when a second voltage is applied between the first electrode and the third electrode, the second group and fourth group of electrically conductive plates move in a second direction.
12. The head positioning apparatus as recited in claim 7, further comprising a cover on the electrostatic microactuator.
13. A head positioning apparatus for a data storage system comprising:
 - a slider having a first group of electrically conductive comb members defining a plurality of recesses between the comb members;
 - a head assembly coupled to a read/write head, wherein the head assembly comprises a head plate having a plurality of openings formed thereon, and a second group of electrically conductive comb members formed on the head plate; the second group of electrically conductive comb members define a plurality of recesses, wherein the second group of electrically conductive comb members are electrically isolated from the first group of electrically conductive comb members, and
 - a support member to connect the slider and the head assembly, wherein the second group of electrically conductive comb members is movable to position the read/write head above the data storage medium.

14. The head positioning apparatus of claim 13, wherein each of the second group of electrically conductive comb members is located adjacent to one side of each of the first group of electrically conductive comb members, and when a voltage is applied between the first and second groups of electrically conductive comb members, the second group of comb members moves relative to the first group of electrically conductive comb members in a direction substantially perpendicular to the first and second groups of electrically conductive comb members.
15. The head positioning apparatus of claim 13, wherein the first group of comb members further comprises a first and second sub-groups of comb members, and wherein the first sub-group of comb members is located adjacent to one side of the second group of comb members, and the second sub-group of comb fingers is located adjacent to the opposite side of the second group of comb fingers.
16. The head positioning apparatus of claim 17, wherein the first group of comb members comprises the first and second sub-groups of comb members, and when a first voltage is applied over the first sub-group of comb members and the second group of comb members, the head assembly moves in a first direction, and when a second voltage is applied over the second sub-group of comb members and the second group of comb members, the head assembly moves in a second direction which is opposite to the first direction.