A MULTI-PIECE INTEGRATED SUSPENSION ASSEMBLY FOR A MAGNETIC STORAGE SYSTEM

Field of the Invention

The present invention relates to a slider-suspension assembly for a magnetic storage system, and more particularly to a multi-piece integrated suspension assembly for use in a magnetic disk storage system.

Description of the Related Art

Magnetic disk drives are information storage devices which utilize at least one rotatable disk with concentric data tracks containing the information, a head (or "transducer") for reading data from or writing data to the various tracks, and a head positioning actuator connected to the head for moving it to the desired track and maintaining it over the track centerline during read or write operations. The transducer is attached to an air-bearing slider which is supported adjacent the data surface of the disk by a cushion of air generated by the rotating disk. The slider is mounted on a support arm of the head positioning actuator by means of a suspension.

The suspension provides dimensional stability between the slider and actuator arm, and controlled flexibility in slight vertical as well as pitch and roll motions (gimbaled motions) of the slider during its relative motion above the rotating magnetic disk surface. The suspension generally comprises a load beam, which is mounted to an actuator arm of the head positioning actuator, and a flexure element supported by the load beam which supports the slider. The load beam provides a resilient spring action which biases the slider toward the surface of the disk, while the flexure provides flexibility for the slider as the slider rides a cushion of air in close proximity against the rotating disk. In the past, various suspension structures have been proposed. For those suspensions having flexures with integrated conductor leads for making electrical connections to the sliders mounted thereon, they are sometimes referred to as trace suspension assemblies or integrated suspension assemblies.

With the push for higher recording densities, it becomes a challenge to format the disk surface with narrower data tracks and narrower inter-track spacings in order to pack more data tracks on the disk surface. To meet this challenge, the performance specification requirements for the flexure is more stringent, in addition to the requirements of the other structural and mechanical components of the disk drive system which are relatively easier to achieve and control. For example, it is important that the integrated suspension be constructed of

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a light weight structure that is dimensionally stable. The flexure of the integrated suspension must be durable in maintaining its flexibility and reliable in accurately and repeatedly positioning the slider with respect to the disk surface such that the densely packed data tracks can be accessed with tight tolerance in slider/track alignment. Further, it is desired to develop smaller integrated suspensions so as to meet the requirement of disk drive systems of smaller physical size. Due to the relatively small physical size and fragile structure of the suspension assembly, it becomes a challenge to develop integrated suspension structures that are designed for manufacturability while achieving the desired performance specifications and yield requirement.

U.S. Patent No. 4,996,623 discloses a laminated suspension having a flat flexible sheet of material bonded on both sides to patterned metal layers. This suspension includes an arm portion for attachment to the actuator support arm, a slider portion to which the slider is attached, and a link portion interconnecting the arm and slider portions such that the slider portion extends beyond the actuator support arm at its end. The structure of this design is relatively complex.

Fig.1 depicts a prior art integrated suspension 20. This integrated suspension 20 includes a load beam 22, a flexure 24 of reduced thickness integrally extending from the load beam 22, conductive leads 26, and a slider 30 mounted to the surface of the flexure 24. An intermediate layer of dielectric material 27 separates the leads 26 from the load beam 22 and the flexure material (see Fig. 2), and supports the leads 26 in a suspended manner along some of its sections (see Fig. 3). The leads 26 terminate on the slider 30 in electrical connection to the read and write sensors contained therein. It is noted that the terminations of the leads 26 are routed over the end of the flexure 24 to terminate on the end face 32 of the slider, which makes the leads 26 more prone to damage during manufacturing and subsequent handling of the integrated suspension 20. Also, it has been found that in a disk drive system which implements a stack of integrated suspensions 20 for multiple disks, more vertical height is needed in the actuator stack to accommodate interconnection of the leads and a flex cable from the control electronics of the disk drive system.

DISCLOSURE OF THE INVENTION

The present invention presents a simplified integrated suspension structure that is relatively easy to manufacture. The novel integrated suspension may be assembled from separate pieces, including a load beam, a flexure and a mounting plate. The load beam provides rigid structural support of the flexure. The flexure includes a flexible member and leads

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integrally formed thereon. A section of the flexible member is fixedly attached to the load member, and another section having the slider mounted thereon presses against a pivot projection in the load beam for gimbal motions. An interlocking structure is provided to limit the extent of gimbal motions of the flexible member, comprising a tab extending from the flexible member into an aperture in the load beam. Alternatively, a tang is formed in the flexible member which is used to form a clip which serves to limit gimbal motions as it interacts with the load beam.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of the slider region of a prior art integrated suspension assembly;

Fig. 2 is a sectional view taken along line 2-2 in Fig. 1;

Fig. 3 is a sectional view taken along line 3-3 in Fig. 1;

Fig. 4 is a schematic/block diagram of a magnetic disk storage system in which the integrated suspension of the present invention is implemented;

Fig. 5 is a perspective view of an integrated suspension assembly in accordance with one embodiment of the present invention;

Fig. 6 is an exploded perspective view of the integrated suspension assembly shown in Fig. 5;

Fig. 7 is a perspective view of the slider region of the integrated suspension assembly shown in Fig. 5;

Fig. 8(a) - (d) are top views of the load arm and the sequence of the different layers of the flexure of the integrated suspension assembly shown in Fig. 5;

Fig. 9 is a sectional view taken along line 9-9 in Fig. 7;

Fig. 10 is a sectional view taken along line 10-10 in Fig. 7;

Fig. 11 is a sectional view taken along line 11-11 in Fig. 7;

Fig. 12 is a sectional view taken along line 12-12 in Fig. 7;

Fig. 13 is a sectional view taken along line 13-13 in Fig. 7;

Fig. 14 is a bottom perspective view of the slider region of an integrated suspension assembly in accordance with another embodiment of the present invention;

Fig. 15 is a top perspective view of the slider region shown in Fig. 14;

Fig. 16(a) and (b) are top views of the load beam and flexure at the slider region shown in Fig. 15;

Fig. 17 is a sectional view taken along line 17-17 in Fig. 16(b);

Fig. 18 is a sectional view taken along line 18-18 in Fig. 16(b); and

Fig. 19 is a sectional view taken along line 19-19 in Fig. 14.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 4 illustrates a simplified schematic block diagram of a magnetic disk storage system 40 embodying the present invention. The magnetic disk storage system 40 comprises at least one rotatable magnetic disk 42 which is supported on a spindle 44 and rotated by a disk drive motor 46, and at least one slider 48 positioned in close proximity to the magnetic recording media at the disk surface 43. Data is stored in the magnetic recording media on each disk 42 in the form of an annular pattern of concentric data tracks (not shown). Each slider 48 contains one or more magnetoresistive MR sensors and write transducers (not shown). The slider 48 is mounted to an integrated suspension 50 which is connected to an actuator means 54 by way of an actuator arm 52. As the disk 42 rotates, the slider 48 is controlled to move across the disk surface 43 by the actuator means 54 so that the slider 48 may access different portions of the disk surface 43 where desired data is recorded or read. The integrated suspension 50 provides a slight spring force which biases the slider 48 against the disk surface 43 and controls flexibility in slight vertical as well as roll and pitch movements of the slider 48 relative to the rotating disk surface 43. The actuator means as shown in Fig. 4 may be a voice coil motor (VCM), for example. The various components of the magnetic disk storage system 40 are controlled in operation by control signals generated by control unit 56, such as control of the actuator means 54, drive motor 46 and reading/writing data.

Fig 5 is a perspective view of a multi-piece integrated suspension 50 in accordance with one embodiment of the present invention. Fig. 6 is an exploded perspective view of the major components making up the integrated suspension 50, and the actuator arm 52 to which the integrated suspension 50 is attached. The actuator arm 52 pivotally supports the integrated suspension 50 about the axis S of the spindle (not shown) of the actuator means 54 in the disk drive system 40. The primary pieces of this integrated suspension 50 include a load beam 58, a flexure 60 and a mount plate 62. One end of the load beam 58 is fixedly attached to the actuator arm 52 using the mount plate 62, and the other end supports on its surface the flexure 60. The flexure 60 has integrated conductor leads 64 or traces on its surface. The slider 48 is bonded to the tip end of the flexure 60. The slider 48 may be of the type which contains an integrated MR read sensor 65 and inductive write transducer 48. (The read sensor and write transducer are schematically depicted by dotted lines in the figures for illustrative purpose only. The actual sizes and locations of these components differ from what are shown, which do not affect the understanding of the present invention herein.) The mount plate 62 supports the ends of the leads 64. The leads terminate at one end at the slider 48 and at the other end in a multiconnector 63 on the mount plate

62 for electrically connecting to the electronics of the control unit 56 (shown in Fig. 4) via a flex cable (not shown).

Fig. 7 more clearly illustrates the slider region on the flexure 60. The leads 64 terminate on the contact pads 78 on the end face of the slider 48; one pair of the leads 64 being in electrical connection with the MR read sensor 65, and the other pair of leads 64 being in electrical connection with the write transducer 66. The lead terminations may be bonded to the slider pads 78 by conventional ultrasonic bonding processes or soldering. It is noted that the leads 64 are bent at their ends so that they can be positioned with a flat surface against the pads for bonding thereto. The leads 64 may be bent before or after the flexure 60 has been attached to the load beam 58. If the latter, the aperture 80 in the load beam 58 and apertures 82 in the flexure 60 provide access for forming the bent lead terminations. Also, these apertures 80 and 82 provide access to the slider so that it can be rigidly held during bonding (e.g., by ultrasonic bonding operation) of the leads to the slider pads. More detail descriptions of the structure of the various components and assembly thereof follow below.

Referring to Fig. 8(d), the load beam 58 is generally flat and rigid, made of stainless steel or a ceramic material, for example. In the illustrated embodiment, the load beam is stainless steel of about 0.04 to 0.05 mm thick. For faster slider positioning response in the disk drive system 40, it is desirable to maintain the weight and inertia of the load beam 58 as small as possible using thinner material without compromising its structural rigidity. To improve torsional rigidity of the thin load beam 58, it is stamped with surface features on its flat structure, such as the triangular depression or well 68. As will be apparent from below, this well 68 together with the flexure 60 attached thereon, form a box structure which is more rigid than an otherwise entirely flat load beam 58 (see Fig. 9). Further, the edges along the length of the load beam are curled to form flanges 70. These flanges 70 also facilitate handling of the integrated suspension 50 to avoid handling damage during the manufacturing process. In addition, a tongue 72 extends from the end of the load beam 58 which also facilitates handling of the integrated suspension 50 during its assembly in the disk drive system 40. The tongue 72 can also be used to load and unload the slider 48 on the disk 42.

The flexure 60 includes several layers of different materials in an integral structure (see Fig. 9). Referring to Figs. 8 (a) - (c), the various layers of the flexure 60 are indicated in a top down sequence in plan views. The structure layer of the flexure 60 is a sheet of flexible material (hereinafter referred to as the spring layer 74) which may be stainless steel, or other suitable spring material, and of a thickness

(about 18 to 20 microns in the illustrated embodiment) that can provide the desired elastic deflections. It may be shaped by etching or stamping processes. The layer of dielectric material 76 (polyimide, for example) is an intermediate layer separating the spring layer 74 and the layer of leads 64 (made of copper, for example). The dielectric and lead layers may be formed by using conventional photolithographic processes well know in the art. The mount plate 62 may be of the same material as the spring layer 74 and formed in the same process as the spring layer 74. It is noted that the sections 84 of the leads 64 are positioned beyond the edges of the spring layer 74. These sections 84 of the leads are maintained in a fixed spaced apart relationship by the dielectric material at several points 86 along these sections 84 (see also Figs. 10 and 11). This lead configuration is intended to eliminate their contact with the spring layer 74. As will be understood from the discussion below, the spring layer 74 needs to maintain flexibility for gimbal support of the slider about its roll and pitch axes.

The flexure 60 is structured and attached to the load beam 58 in a manner as to provide the desired gimbal motions. Specifically, the section 88 of the spring layer 74 is rigidly attached to the load beam 58 by means of welding, rivets or epoxy, for example. As mentioned before, the flexure spring layer 74 with the well 68 on the load beam 58 form a rigid box structure (Fig. 9). The section 90 of the flexure 60 with the slider 48 thereon is not fixedly attached to the load beam 58, but is biased by the spring layer 74 to rest against a gimbal pivot 92 on the load beam 58. The gimbal feature of the integrated suspension 50 is now explained more clearly in reference to Figs. 12 and 13. The gimbal pivot 92 is located on the load beam 58 in the slider region against which the spring layer 74 of the flexure 60 rests. The spring layer 74 with the slider 48 attached thereon is free to elastically pivot about pitch (X) and roll (Y) axes at this gimbal pivot 92, since the spring layer 74 at the section 90 is not fixedly attached to the load beam 58. Due to the flat laminated structure of the flexure 60, motion along the X axis is restricted. To limit the extent of pitch and roll motions so as to prevent damage to the flexure 60, tabs 94 are provided in the spring layer 74 of the flexure 60 which extend through the aperture 80 on the load beam 58 (see Fig. 13). One or both of the tabs 94 would interlock against the edge 96 of the aperture 80 before pitch and/or roll motions exceed their designed range, thereby limiting such motions.

A second embodiment of an integrated suspension 100 in accordance with the present invention is illustrated in reference to Figs. 14 to 19. For simplicity, only the slider end of the integrated suspension 100 is shown in the figures, as the other end of the suspension 100 may be similar to that of the previous embodiment. In this second embodiment,

the load beam 102 also has flanges 103 along its longitudinal edges. In addition, at the end of the load beam 102 in the slider region, bumpers 104 are provided which further facilitates handling of the integrated suspension. As in the previous embodiment, a tongue 106 extends from the end of the load beam. A gimbal pivot 108 is provided on the load beam 102 for pivoting gimbal motions of the slider 48. The flexure 110 has a spring layer 112 and integral leads 114 formed thereon with an intermediate integral dielectric layer 116. Some sections of the leads 114 are suspended without support of the flexure spring layer 112 along these sections (see Fig. 18). The slider 48 is bonded to the flexure spring layer 112 by adhesive, for example. Like in the previous embodiment, the lead terminations are bent for bonding to the slider pads 78. Apertures 118 and 120 in the load beam 102 and flexure 110 facilitates such bonding. The flexure 110 is fixedly attached to the load beam 102 at the end not shown in the figures in a manner similar to the previous embodiment. The slider end of the flexure 112 is biased by the spring layer to rest against the gimbal pivot 108 on the load beam 102.

It is noted that in this embodiment, a tang 122 is etched in the spring layer 112 which is looped to form an U-shaped clip 124. This clip 124 serves to limit excessive roll and pitch motions about the gimbal pivot 108 (see Fig. 19). The clip 124 may be pre-formed on the flexure 110 prior to its attachment to the load beam 102. The flexure can then be clipped onto the load beam 102 through the aperture 126.

As one can appreciate from the foregoing description of the present invention in reference to the illustrated embodiments, the structure of the novel integrated suspension assembly is less complex compared to those in the prior art, while providing the desired gimbal characteristics. The novel structure is relatively easy to manufacture, with separate pieces of the suspension assembly (namely, the flexure and load beam) formed separately and finally assembled.

Although the present invention is described in reference to a magnetic disk storage system and in particular one which implements a slider containing a magnetoresistive ("MR") sensor, it will be apparent that the invention may be implemented in other magnetic storage systems including recording systems such as a magnetic tape recording system or other applications which could take advantage of an integrated head suspension assembly.

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CLAIMS

1. A multi-piece integrated suspension assembly (50, 100) for supporting a slider (48) in a magnetic storage system (40), comprising:

a rigid load member (58, 102);

a flexure (60,110) including a flexible member (74, 112) and conductive leads (64) integrally formed thereon, said slider being mounted on the flexible member at one end thereof in electrically connection to the leads; and

pivoting means (108) between the flexible member and the load beam for pivoting gimbal motions of the flexible member;

wherein a section of the flexible member is fixedly attached to the load beam with another section of the flexible member free to pivot about the pivoting means for gimbal motions.

2. A multi-piece suspension assembly (50, 100) as in claim 1 wherein:

the load member (58, 102) is generally flat, said load member including first and second sections having first and second surfaces spanning across the first and second sections of the load member,

the flexible member (74, 112) is generally flat which includes first and second sections having first and second sides spanning across said first and second sections of the flexible section, said leads integrally formed on the first and second sections, said slider (48) being mounted on the first surface at the first section of the flexible member,

said second section of the flexible member being fixedly attached to the second section of the load member with the second surface of the flexible member towards the first surface of the load member; and

said pivoting means (108) locating between the first surface of the first section of the load member and the second surface of the first section of the flexible member,

whereby the first section of the flexible member can pivot about said pivoting means so as to gimbal the slider mounted thereon.

3. A multi-piece integrated suspension assembly (50) as claimed in claim 2 wherein the pivoting means (108) is a projection on the first surface at the first section of the load member which pivotally supports

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surface at the first section of the load member which pivotally supports the first section of the flexible member (74), said second surface of the first section of the flexible member pressing against the projection.

4. A multi-piece integrated suspension assembly (50) as claimed in claim 2 wherein the leads (64) are formed on the first surface of the first and second sections of flexible member (74).

5. A multi-piece integrated suspension assembly (50) as claimed in claim 4 wherein the flexure (60) further includes an integral intermediate layer of dielectric material (76) between the leads (64) and the flexible member (74).

6. A multi-piece integrated suspension assembly (50) as claimed in claim 5 wherein the leads (64) terminate at one end on the slider (48), the leads having its ends bent to have a flat side contacting the slider.

7. A multi-piece integrated suspension assembly (50) as claimed in claim 4 wherein the leads are integrally formed on the flexible member (74) by a photolithographic process.

8. A multi-piece integrated suspension assembly (50) as claimed in claim 4 wherein the leads (64) include a section which extends beyond the edge of the first section of the flexible member (74).

9. A multi-piece integrated suspension assembly (50) as claimed in claim 4 wherein the leads (64) terminate on the slider (48) at a far end of the slider (48) relative to the second section of the flexible member (74).

10. A multi-piece integrated suspension assembly (50) as claimed in claim 9 wherein the leads (64) are configured around the lateral sides of the slider (48) and along the first and second sections of the flexible member (74).

11. A multi-piece integrated suspension assembly (50) as claimed in claim 3 further comprising a mount plate (62) attached on the first surface of the second section of the load member (58), wherein part of the leads (64) are integrally formed on the mount plate.

12. A multi-piece integrated suspension assembly (50) as claimed in claim 3 wherein the load member (58) has a tongue (72) extending from a distal end of the first section of the load member.

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13. A multi-piece integrated suspension assembly (50) as claimed in claim 3 wherein the load member (58) has edges along its first and second sections bent to add structural rigidity to the load member.

14. A multi-piece integrated suspension assembly (50) as claimed in claim 4 wherein an aperture (82) is provided in the first section of the flexible member (74) in a position below the termination of the leads (64) on the slider (48) to facilitate bending of the leads integrally formed on the flexible member.

15. A multi-piece integrated suspension assembly (50) as claimed in claim 2 wherein the flexure further includes limiting means for limiting the gimbal motions of the first section of the flexible member (112).

16. A multi-piece integrated suspension assembly (50) as claimed in claim 15 wherein the limiting means include an aperture (126) provided on the load member (102) and an integral tang (122) extending from the first section of the flexible member (112) and through said aperture which interacts with the edge of the aperture to limit gimbal motions of the first section of the flexible member.

17. A multi-piece integrated suspension assembly (50) as claimed in claim 16 wherein the integral tang (122) forms a U-shaped clip which clips onto the load beam (102) through the aperture (126).

18. A magnetic storage system comprising:

a magnetic storage medium having a plurality of tracks for receiving data;

drive means for moving the storage medium;

a slider including a read sensor and a write transducer maintained in a closely spaced position relative to said magnetic storage medium during relative motion between said slider and said storage medium;

actuator means coupled to said slider for moving said slider relative to the magnetic storage medium to selected tracks on said magnetic storage medium, said actuator means including an integrated suspension assembly as claimed in any one of claims 1 to 17; and

control means for controlling the operations of drive means, actuator means and reading and writing of data with respect to the magnetic storage medium.

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19. A method of making an integrated suspension assembly (50, 100) for supporting a slider (48), comprising the steps of:

forming a rigid load member (58, 102);

forming an integral flexure (60, 110) including a flexible member (74, 112) and conductive leads (64) thereon, said slider being mounted on the flexible member at one end thereof in electrically connection to the leads;

forming a pivoting means (108) between the flexible member and the load beam for gimbal motions of the flexible member;

attaching a section of the flexible member to the load beam with another section of the flexible member free to pivot about the pivoting means for gimbal motions.

20. A method as claimed in claim 19 wherein:

the load member (58, 102) is formed to be generally flat, said load member including first and second sections having first and second surfaces spanning across the first and second sections of the load member,

the flexible member (74, 112) is formed to be generally flat which includes first and second sections having first and second sides spanning across said first and second sections of the flexible section, said leads integrally formed on the first and second sections, said slider (48) being mounted on the first surface at the first section of the flexible member,

said attaching of the flexible member to the load member includes fixedly attaching the second section of the flexible member to the second section of the load member with the second surface of the flexible member towards the first surface of the load member, and

the pivot means (108) is located between the second surface of the first section of the flexible member and the first surface of the first section of the load member, whereby the first section of the flexible member can pivot about said pivoting means so as to gimbal the slider mounted thereon.

21. A method as claimed in claim 20 wherein the pivoting means (108) is a projection on the first surface at the first section of the load member which pivotally supports the first section of the flexible member (74), said second surface of the first section of the flexible member pressing against the projection.

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22. A method as claimed in claim 20 wherein the leads (64) are formed on the first surface of the first and second sections of flexible member (74).

23. A method as claimed in claim 22 wherein the flexure is formed to include an integral intermediate layer (76) of dielectric material between the leads (64) and the flexible member (74).

24. A method as claimed in claim 22 wherein the leads (64) are integrally formed on the flexible member (74) by a photolithographic process.

25. A method as claimed in claim 20 wherein the flexure (110) is formed to include a limiting means for interacting with the load member (102) to limit the gimbal motions of the first section of the flexible member (112).

26. A method as claimed in claim 25 wherein the limiting means include an aperture (126) provided on the load member (102) and an integral tang (122) extending from the first section of the flexible member (112) and through said aperture which interacts with the edge of the aperture to limit gimbal motions of the first section of the flexible member.

27. A method as claimed in claim 26 wherein the integral tang (122) is formed into a U-shaped clip which clips onto the load beam (102) through the aperture (126).

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