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SHEAR MODE PIEZOELECTRIC ACTUATOR ASSEMBLY

BACKGROUND OF THE INVENTION

5 The invention relates generally to electromechanical actuators for
- positioning a positioned element with respect to another component. More
particularly, the invention provides a shear mode piezoelectric actuator assembly
adapted to provide fine positioning of a slider over a data storage medium in a
hard disk drive or another data storage apparatus.

10 Figure 1 is a plan view showing a conventional hard disk drive 5. A data
disk 10 has a data surface 12 for storing data. The data in a magnetic storage
drive are binary data stored as tiny magnetically charged areas arrayed on the
data surface in concentric data tracks. The disk is driven around a central spindle
15 by a spindle motor (not shown).

20 A support arm 17 rotates about a pivot bearing 20. The support arm is
driven by a voice coil motor (not shown). A slider 21 (too small to be clearly
visible in this view) at the end of the support arm "flies" over the data disk 10 so
that data can be written to and read from the data surface 12. A flexible cable 23
attaches to a connector 25 to transmit electrical signals between the slider and a
computer or another device in which the disk drive 5 is installed.

25 Though the plan view of Fig. 1 depicts only a single data disk 10, those of
skill in this art will know that disk drives may include several data disks stacked on
a single spindle and spaced apart on the spindle to provide access to multiple
data surfaces, one on either side of each disk. In that type of drive, multiple arms
are provided, each carrying an individual slider over each data surface. This is to
provide greater data storage than would be possible in a single disk unit.

30 Figure 2 depicts one conventional suspension assembly 28 for suspending
a slider 21 over the data surface of the data disk. The suspension assembly

includes a suspension bar 29 with a base plate 30 and a swage boss 33 at one end. A spring beam 35 holds a load beam 37 at an end opposite the base plate, with flanges 40 increasing the stiffness of the load beam. A mounting beam 42 is secured to the load beam.

The mounting beam 42 includes a flexure member 45, upon which the slider 21 is mounted. The flexure element provides high compliance, *i.e.*, relative ease of movement, in the pitch, roll, and vertical directions, and high stiffness in the yaw and in-plane directions.

Referring once again to Fig. 1, the swage boss 33 of the suspension assembly 28 is swaged onto the pivot bearing 20 so that the slider can be moved laterally from track to track as the slider 21 flies over the data surface 12 of the data disk 10.

Hard disk drives of this general type have enjoyed much success and contributed greatly to the development of business and personal computer systems and related devices. The data storage capabilities of these devices have increased remarkably. Each year has seen new disk drives become available with capabilities that would have been unthinkable just a few years before.

This development has been made possible in large part through astounding increases in the density of data that can be stored in the data tracks on the data disk's data surfaces. As this document is being written, it is anticipated that track densities will soon be on the order of 100,000 tracks per inch, which means that individual track widths will decrease to less than one-fourth of a micrometer (0.25 μm). This means, of course, that new and better mechanisms will be needed to position and track the sliders precisely over these extremely narrow data tracks.

Difficulties arise, though, with the use of conventional mechanisms like that described above. Tracking errors and internal bearing friction limit the precision of even the best available voice coil motors. Resonances and vibrations, moreover,

are present in the arm and suspension, and these too limit the ability of the suspension arm to drive the slider precisely over the narrow data tracks.

5 Suggestions have been made to provide dual actuator systems that would
10 combine, e.g., a conventional voice coil motor for gross positioning of the slider
 over the data surface, along with a more high precision microactuator to provide
 fine positioning of the slider precisely over the individual data track. It has been
 suggested that such dual actuator systems might successfully overcome some of
 the limitations of conventional single actuator systems, and thereby allow further
15 increases in data storage density in hard disk drives, optical data storage drives,
 and other such devices in which extreme precision is required in the positioning of
 a read/write head over a data storage medium.

15 It would be highly desirable, therefore, to devise improved microactuator
 assemblies capable of positioning sliders with enhanced precision over data
 tracks on a data storage disk. The improved actuators should not add excess
 weight, interfere unduly with the flying characteristics of the slider over the data
 surface, or otherwise adversely affect the operation of slider or the motor-driven
20 arm. Such actuators should provide quick and precise operation, while
 consuming little power and not generating excess heat. These improved
 actuators should, moreover, be relatively simple, reliable, and easy to
 manufacture and assemble.

25 These and other advantages are provided by the improved actuator
 assemblies described herein, as will be understood more fully from the detailed
 description provided below.

SUMMARY OF THE INVENTION

30 The invention provides a piezoelectric actuator assembly operable to
 position a positioned element such as a data slider in a data disk drive.
 Embodiments of the invention include at least one shear mode piezoelectric

element, with corresponding structure through which force is applied to the positioned element to position it in response to a control signal supplied to the piezoelectric element.

5 In a preferred embodiment a shear mode piezoelectric element is mounted at the back side of a data slider. Arms mounted to each end of the piezoelectric element extend around the slider and hold the slider between a pair of hinge assemblies at the ends of the arms. When a voltage is applied to the piezoelectric element, two faces of the piezoelectric element shear with respect to one another and the ends of the piezoelectric element change their angular orientations. This moves the two arms, which in turn moves the slider to a degree that depends on the magnitude of the control signal applied to the piezoelectric element.

15 In another preferred embodiment, four piezoelectric elements are arranged in a rectangular configuration, two on each side of the data slider or other positioned element. A pair of these elements is arranged on one side of the slider to shear outward away from each other, and the pair on the other side of the slider to shear inwardly toward one another, when control signals are applied to the elements. Flexible members extend between the two elements of each pair on each side of the slider, and are configured to apply force to either side of the slider to move the slider to a degree that depends on the magnitudes of the control signals.

25 These embodiments and other alternative embodiments may be used in conjunction with conventional slider positioning apparatus to provide fine positioning of the slider over a data surface of a data disk in a data disk drive system.

BRIEF DESCRIPTION OF THE DRAWINGS

30 Figure 1 is a plan view of conventional hard disk drive in which a read/write head is driven by an actuator over the surface of a disk on which data are stored.

Figure 2 is a perspective view showing elements of a conventional swage-mounted head suspension assembly suitable for use in the hard disk drive of Fig. 1.

Figure 3 is a schematic illustration depicting the function of a piezoelectric shear element usable in piezoelectric actuators according to the invention.

Figure 4 is an exploded perspective view of one preferred embodiment of a piezoelectric actuator assembly that incorporates the present invention.

Figure 5 is a plan view of a part of the piezoelectric actuator assembly of Fig. 4.

Figure 6 is a plan view that illustrates, schematically, the operation of the actuator assembly of Figs. 4 and 5.

Figure 7 is a partially exploded view depicting an alternative piezoelectric actuator assembly that incorporates another embodiment of the invention.

Figure 8 is a plan view providing a schematic depiction of the operation of the actuator assembly of Fig. 7.

Figure 9 is a plan view of an alternative actuator assembly according to a further alternative embodiment of the invention.

Figure 10 is an enlarged view of a portion of the embodiment of Fig. 8, illustrating amplification of shear motion in the actuator assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention is embodied in an improved actuator assembly of the type used for positioning a slider precisely over a data surface of a data disk such as that found in a hard disk drive system.

Preferred embodiments of the invention use a shear mode piezoelectric actuator. Figure 3 illustrates schematically the function of a piezoelectric shear element 48 used in the piezoelectric actuator. Normally, the shear element has the configuration indicated by the solid lines in Fig. 3. When a voltage is applied to the piezoelectric element across terminals 50 and 53, the shear element shears or deforms to a configuration indicated by the dashed lines in Fig. 3. The front face 55 and rear face 58 of the element are displaced with respect to one another,

and the ends 60 of the element change their angular orientations with respect to the front and back faces. This behavior of piezoelectric shear elements is conventional and well known to those of skill in the art.

5 Figure 4 is an exploded perspective view of one preferred embodiment of the invention. In this embodiment, a secondary actuator assembly 47 is mounted to the flexure member 45 on the mounting beam 42 of the suspension assembly 28 (see Fig. 2). The secondary actuator assembly provides for relatively fine positioning of the slider 21 over the disk data surface, in comparison with the
10 voice coil motor, which provides relatively course positioning of the slider by driving the suspension assembly over the surface of the disk.

 In the embodiment shown in Fig. 4, a shear mode piezoelectric microactuator 63 is positioned at the back side of the slider. A pair of arms 65 are
15 fixed at each end of the microactuator and disposed around the left and right sides of the slider. The slider is held between the arms by pads 68 at the end of each arm. Each pad has a hinge 70 between the pad and its corresponding arm. The pad and hinge at each hinge mounting location form a hinge assembly at that location on each arm.

20 The hinges allow relative rotational movement between the slider and each of the two arms at the mounting positions where the hinges contact the slider. The first and second ends of the piezoelectric element and the first and second hinge mounting positions are together in a substantially rectangular configuration
25 when the assembly is in the condition illustrated in Fig. 4.

 A frame 73 comprises a tab 75 and a mounting surface 78. The tab is fixed to the side of microactuator 63 opposite the face closest to the back side of the slider 21. The frame's mounting surface is fixed to the flexure member 45 on the
30 mounting beam 42. The slider is thereby suspended by the flexure member between the arms 65 extending from either end of the microactuator, and the

slider is thus mounted to the support arm through the arms, the frame, and the flexure member on the mounting beam.

Figure 5 is a plan view illustrating the normal condition of the secondary actuator assembly 47. When a voltage is applied across the piezoelectric microactuator 63, the front and back faces of the microactuator shear with respect to one another and the ends of the microactuator change their angular orientation. This moves the arms 65 into a position illustrated by the dashed lines in Fig. 6, in which the first and second ends of the piezoelectric element and the first and second hinge mounting positions are arranged together generally in the form of a parallelogram. The assembly 47 is movable substantially continuously between the continuations of Figs. 5 and 6, depending upon the magnitude of the voltage applied across the piezoelectric element, and thus the amount of shear produced within that element.

As the arms 65 rotate about the ends of the microactuator 63, the slider 21 is carried into the position the dashed lines illustrate. This motion is allowed by the hinges 70, which allow relatively free rotation between the arms and the hinges while substantially constraining the slider's movement in other directions.

The arms 65 act as levers that magnify the lateral movement of the slider 21 in comparison with the relatively small movements at the ends of the microactuator 63. Although the slider 21 does move somewhat in the direction perpendicular to the shearing direction of the microactuator, the slider's motion is predominantly parallel to the microactuator's shear direction. When the slider is installed into the system, this predominant direction of motion is generally perpendicular to the long axis of the support arm 17 (see Fig. 1). The support arm is driven by its voice coil motor to apply relatively large movements of the slider over the data disks 10, while voltage signals applied to the microactuator provide for fine positioning of the slider precisely over one or more of the desired data tracks.

The assembly shown in Figs. 4-6 is advantageous in that the piezoelectric element 63 is positioned on the back side of the slider 21, with the pads 70 hinged to either side of the slider. This leaves the front side of the slider exposed and free of any externally-mounted apparatus so that the slider's flying characteristics are largely unaffected by the microactuator assembly.

Figures 7-9 illustrate details of two more preferred embodiments of the invention. Figure 7 is an perspective view of one of these embodiments. The frame 73 in this embodiment has a pair of tabs 75, one on either side of the frame. These tabs enclose an array comprising four piezoelectric microactuators 63, two on each side of the slider 21, in a generally rectangular configuration. The frame is mounted on the support arm 17 (see Fig. 1) of the suspension assembly so that the two tabs of this frame are disposed on either side of the long axis of the support arm.

A plan view of this same embodiment is depicted in Fig. 8. Each microactuator 63 has a leg 80 mounted on the surface of the microactuator closest to the slider 21. The two legs come together to form a flex beam 83, which is attached at the middle of the flex beam to the side of the slider.

The microactuators 63 in this embodiment are disposed to shear in opposite directions. The microactuators on a given side of the slider 21 are disposed, moreover, to shear in opposite directions in comparison with the microactuators on the other side of the slider. For example, the microactuators on the right side of the slider in Fig. 8 shear inward toward the space between them. This presses the legs 80 and thus the middle of the flex beam 83 against the right side of the slider, thereby pushing the slider to the left. At the same time, the microactuators on the left side of the slider shear outward away from the space between those microactuators. This pulls the legs and thus the middle of that flex beam in a direction away from the left side of the slider, thereby pulling the slider and contributing to its motion to the left as viewed in Fig. 8.

The embodiment shown in plan view in Fig. 9 is generally similar to the embodiment of Fig. 8, except that the configurations of the legs 80 and the flex beams 83 are somewhat different. Where the flex beams in the embodiment of Fig. 8 are mounted to outer ends of their respective legs, the flex beams in the embodiment of Fig. 9 are mounted to inner ends of their respective legs. In either embodiment, though, the microactuators 63 on one side of the slider 21 shear away from one another (pulling the slider toward them), while the microactuators on the other side of the slider shear toward one another (pushing the slider away from them in the same direction).

Both of the embodiments depicted in Figs. 8 and 9 have in common that the legs 80 of the flex beams 83 act as levers that magnify the shear motion of the microactuators 63. Figure 10 is an enlarged view of a portion of the embodiment of Fig. 8. Figure 10 illustrates the magnification of the shear motion of the microactuators, as that motion is amplified and converted into sideways motion of the slider 21. In Fig. 10, x is the distance between the slider and the base of either leg of the flex beam. Y is the distance between the center of that base and the middle of the flex beam, so that the distance between the centers of the bases of the flex beam's two legs is about $2Y$.

If each of the microactuators 83 generates a shear motion of ΔY , then the slider will move sideways a distance of ΔX . With the geometry as shown in the figure ΔX is approximately $Y/X \cdot \Delta Y$. In other words, the shear motion of the microactuators 63 is amplified by approximately the ratio of one-half the distance between the centers of the bases of the two legs 80 of the flex beam 83 to the distance between the mounting position of the slider on the flex beam and the center of the bases of the flex beam's legs (Y/X). The system can be configured if desired so that $Y \gg X$. Considerable amplification can thus be achieved between the shear motions of the microactuators and the sideways motion of the slider.

As in the embodiment illustrated in Figs. 4-6, the motor-driven support arm 17 (see Fig. 1) provides for gross movement of the slider 21 over the data surface

12 to position the slider generally over one or more data tracks, with the piezoelectric microactuator 63 of Figs. 7-10 providing fine positioning of the slider precisely over the center of a particular track of interest. The degree to which the four microactuators in these embodiments shear, and thus the degree of movement of the slider, depends upon the magnitude of the voltages applied across the microactuator elements. The control signals applied to the individual microactuators will have identical magnitudes in the preferred embodiment. In alternative embodiments, individual control signals having different magnitudes might be supplied to each of the microactuators, e.g., to control the angular orientation of the slider. In either case, first, second, third and fourth control signals will be applied to the corresponding microactuators, whether those control signals are identical, or different for each microactuator.

In the embodiments of Figs. 7-10, the flex beams 83 attach to the sides of the slider 21, leaving the front and back faces of the slider unconstrained and free of any externally-mounted apparatus. These configurations leave the flying characteristics of the slider mostly unchanged in comparison with conventional configurations.

Microactuator assemblies of the type described herein are simple in construction, and reasonably easy to manufacture and assemble. Microactuator assemblies of this type may be manufactured using conventional machining technologies. In such a case the piezoelectric elements, the related supporting structure, and the slider will be fabricated as individual parts and assembled together using conventional assembly technologies.

In the alternative, advanced microfabrication technologies can be used to produce these assemblies. In that case, the piezoelectric elements, the related supporting structures, and the slider itself can be fabricated together using art similar to that currently used to manufacture disk drive recording heads, with the individual parts formed together as an assembly on a common substrate. Such

methods promise significant economies through large scale manufacturing of multiple microactuator assemblies on a single wafer.

Although the description herein has largely assumed that the slider will
5 include a read/write head for reading and writing data onto a data surface in a hard-disk drive unit, other types of data head may be incorporated into the slider. For example, various data heads operable only to read data (and not to write it) may be used where the data medium is of a read-only type. Other uses might be found where the data head would operate only to write data, but not to read it.
10 Moreover, although the description above has contemplated mainly the reading and writing of magnetic data, other data types, such as for example optical data, may be read or written by a data head incorporated into the slider. In fact the invention does not concern itself primarily with the particular type of element that may be used in any particular assembly, but rather with apparatus for positioning
15 a wide variety of positioned elements as required in any particular application.

In any event, although the invention has been described above in connection with its presently preferred embodiments, improvements, modifications, and alternatives may no doubt be devised by those of skill in the art
20 without departing from the basic principles of the invention. The scope of the invention should thus not be assessed primarily by reference to the discussion above, but rather according to the following claims and the full scope of equivalents to which those claims are properly entitled.

CLAIMS

1. A piezoelectric actuator assembly operable to position a positioned element, the piezoelectric actuator assembly comprising:

5 a shear mode piezoelectric element having first and second ends, wherein the piezoelectric element is configured so that angular orientations of the first and second ends change when an electrical signal is applied to the piezoelectric element;

a first arm mounted to the first end of the piezoelectric element; and

10 a second arm mounted to the second end of the piezoelectric element;

wherein the positioned element is mounted to the first arm at a first mounting position some distance away from the first end of the piezoelectric element, and to the second arm at a second mounting position some distance away from the second end of the piezoelectric element.

15 2. The piezoelectric actuator assembly of claim 1, wherein the positioned element is a slider that includes the data head of a data storage device.

20 3. The piezoelectric actuator assembly of claim 2, wherein the first mounting position is on a first side of the slider, the second mounting position is on a second side of the slider opposite the first side, and the piezoelectric element is disposed at the back of the slider.

25 4. The piezoelectric actuator assembly of claim 1, wherein the first end of the piezoelectric element, the second end of the piezoelectric element, the first mounting position, and the second mounting position are in a generally rectangular arrangement when the actuator assembly is in a first configuration.

30 5. The piezoelectric actuator assembly of claim 4, wherein the actuator assembly is operable to move between the first configuration and a second configuration in which the first end of the piezoelectric element, the second end of

the piezoelectric element, the first mounting position, and the second mounting position are arranged generally in the form of a parallelogram.

5 6. The piezoelectric actuator assembly of claim 5, wherein the actuator
assembly is operable to move substantially continuously between intermediate
configurations between the first and second configurations in response to a
variable input signal applied to the piezoelectric element.

10 7. The piezoelectric actuator assembly of claim 1, and further
comprising:

 a first hinge assembly at the first mounting position; and
 a second hinge assembly at the second mounting position.

15 8. The piezoelectric actuator assembly of claim 7, wherein:
the first hinge assembly comprises a first mounting pad secured to the
positioned element and a first hinge between the first mounting pad and the first
arm; and

 the second hinge assembly comprises a second mounting pad secured to
the positioned element and a second hinge between the second mounting pad
20 and the second arm.

 9. A piezoelectric actuator assembly operable to position a positioned
element, the piezoelectric actuator assembly comprising:

25 a first shear mode piezoelectric element;
a second shear mode piezoelectric element;
a first flexible member mounted between the first and second piezoelectric
elements;

 a third shear mode piezoelectric element;
a fourth shear mode piezoelectric element; and
30 a second flexible member mounted between the third and fourth
piezoelectric elements;

wherein the first flexible member is mounted to a first side of the positioned element and wherein the second flexible member is mounted to a second side of the positioned element.

5 10. The piezoelectric actuator assembly of claim 9, wherein the positioned element is a slider that includes the data head of a data storage device.

10 11. The piezoelectric actuator assembly of claim 10, wherein the first flexible member is mounted to a first side of the slider, the second flexible member is mounted to a second side of the slider opposite the first side of the slider, and wherein the front of the slider is free of any externally-mounted apparatus.

15 12. The piezoelectric actuator assembly of claim 11, and wherein the back of the slider is free of any externally-mounted apparatus.

20 13. The piezoelectric actuator assembly of claim 9, wherein the first and second piezoelectric elements are mounted adjacent one another on one side of the positioned element, and the third and fourth piezoelectric elements are mounted adjacent one another across the positioned element from the first and second piezoelectric elements, respectfully, so that the first, second, third and fourth piezoelectric elements are arranged in a generally rectangular configuration.

25 14. The piezoelectric actuator assembly of claim 9, wherein the first and second shear mode piezoelectric elements are configured with surfaces mounted to the first flexible member that shear outward away from one another upon the application of an input signal to the first and second shear mode piezoelectric elements, and the third and fourth shear mode piezoelectric elements are configured with surfaces mounted to the second flexible member that shear
30 inward towards one another upon the application of an input signal to the third and fourth piezoelectric elements.

15. The piezoelectric actuator assembly of claim 14, wherein the shearing outward of the first and second shear mode piezoelectric elements pulls the first flexible member and the positioned element in a direction toward the first and second shear mode piezoelectric elements, and the shearing inward of the third and fourth shear mode piezoelectric elements pushes the second flexible member and the positioned element in a direction away from the third and fourth shear mode piezoelectric elements.

16. The piezoelectric actuator assembly of claim 9, wherein each of the first and second flexible members comprises a pair of legs mounted to its respective piezoelectric elements and a central flex beam between the two legs.

17. The piezoelectric actuator assembly of claim 16, wherein the central flex beams are mounted to outer ends of their respective legs.

18. The piezoelectric actuator assembly of claim 16, wherein the central flex beams are mounted to inner ends of their respective legs.

19. A data disk drive comprising:
a rotating data disk having a data surface;
a data slider operable to communicate data with the data surface of the data disk, the data slider having an air bearing surface opposed to the data surface, a front side surface, a back side surface on a side of the slider opposite the front side of the slider, and first and second side surfaces opposed to one another on opposite sides of the data slider; and
a shear mode piezoelectric element positioned proximate the back surface of the data slider and operable to apply force to the first side surface of the data slider to position the data slider over the data surface in response to a control signal applied to the piezoelectric element.

20. The data disk drive of claim 19, wherein the shear mode piezoelectric element is operable in response to the control signal to apply force to

the first side surface of the data slider in a first direction, and to apply force to the second side surface of the data slider in the first direction.

5 21. The data disk drive of claim 20, wherein the shear mode piezoelectric element is operable to apply force to the first side surface of the data slider in the first direction through a first arm, and to the second side surface of the data slider in the first direction through a second arm.

10 22. The data disk drive of claim 21, wherein the first arm is mounted to the shear mode piezoelectric element at a first end of the piezoelectric element and to the data slider at a first mounting position on the first side surface of the data slider, and wherein the second arm is mounted to the shear mode piezoelectric element at a second end of the piezoelectric element and to the data slider at a second mounting position on the second side surface of the data slider.

15 23. The data disk drive of claim 22, and further comprising:
a first hinge assembly at the first mounting position; and
a second hinge assembly at the second mounting position.

20 24. The data disk drive of claim 23, wherein the first hinge assembly comprises a first mounting pad secured to the data slider and a first hinge between the first mounting pad and the first arm, and wherein the second hinge assembly comprises a second mounting pad secured to the data slider and a second hinge between the second mounting pad and the second arm.

25 25. The data disk drive of claim 19, wherein the shear mode piezoelectric element is operable to apply force to the first side surface of the data slider through a first arm.

30 26. The data disk drive of claim 25, wherein the first arm is mounted to the shear mode piezoelectric element at a first end of the piezoelectric element

and to the data slider at a first mounting position on the first side surface of the data slider.

27. The data disk drive of claim 26, and further comprising a first hinge assembly at the first mounting position.

28. The data disk drive of claim 27, wherein the first hinge assembly comprises a first mounting pad secured to the data slider and a first hinge between the first mounting pad and the first arm.

29. A data disk drive comprising:

a rotating data disk having a data surface;

a data slider operable to communicate data with the data surface of the data disk, the data slider having an air bearing surface opposed to the data surface, a front surface, a back surface on the slider opposite the front of the slider, and first and second side surfaces opposed to one another on opposite sides of the data slider; and

a first shear mode piezoelectric element positioned proximate the first side surface of the data slider and operable to apply force to the first side surface of the data slider to position the data slider over the data surface in response to a first control signal applied to the piezoelectric element.

30. The data disk drive of claim 29, wherein the first shear mode piezoelectric element is operable to shear in a direction substantially parallel to the first side surface of the data slider and to apply force to the first side surface of the data slider in a direction toward the first piezoelectric element in response to the first control signal applied to the first piezoelectric element.

31. The data disk drive of claim 29, wherein the first shear mode piezoelectric element is operable to shear in a direction substantially parallel to the first side surface of the data slider and to apply force to the first side surface of

the data slider in a direction away from the first piezoelectric element in response to the first control signal applied to the first piezoelectric element.

5 32. The data disk drive of claim 29, and further comprising a second shear mode piezoelectric element positioned proximate the first side surface of the data slider and operable to apply force to the first side surface of the data slider in response to a second control signal applied to the second shear mode piezoelectric element.

10 33. The data disk drive of claim 32, wherein the first and second shear mode piezoelectric elements are operable to apply force to the first side surface of the data slider in a direction towards the first and second piezoelectric elements in response to the first and second control signals.

15 34. The data disk drive of claim 32, wherein the first and second shear mode piezoelectric elements are operable to apply force to the first side surface of the data slider in a direction away from the first and second piezoelectric elements in response to the first and second control signals.

20 35. The data disk drive of claim 32, and further comprising:
a third shear mode piezoelectric element positioned proximate the second side surface of the data slider and operable to apply a force to the second side surface of the data slider in response to a third control signal applied to the third shear mode piezoelectric element; and

25 a fourth shear mode piezoelectric element positioned proximate the second side surface of the data slider and operable to apply a force to the second side surface of the data slider in response to a fourth control signal applied to the fourth shear mode piezoelectric element.

30 36. The data disk drive of claim 35, wherein the first and second shear mode piezoelectric elements are operable to shear in a direction away from one another in response to the first and second control signals to apply a force to the

first side of the data slider in a direction toward the first and second shear mode piezoelectric elements, and wherein the third and fourth shear mode piezoelectric elements are operable to shear in a direction toward one another in response to the third and fourth control signals to apply a force to the second side of the data slider in a direction away from the third and fourth shear mode piezoelectric elements.

37. The data disk drive of claim 29, and further comprising a second shear mode piezoelectric element positioned proximate the second side surface of the data slider and operable to apply force to the second side surface of the data slider in response to a second control signal applied to the second shear mode piezoelectric element.

38. A data disk drive comprising:
a rotating disk having a data surface;
a first actuator;
a support arm configured to be driven over the data surface by the first actuator;
a second actuator held by the support arm over the data surface;
wherein the second actuator comprises:
a shear mode piezoelectric element having first and second ends, wherein the piezoelectric element is configured so that angular orientations of the first and second ends change when an electrical signal is applied to the piezoelectric element;
a first arm mounted to the first end of the piezoelectric element; and
a second arm mounted to the second end of the piezoelectric element; and
a data slider mounted between the first and second arms.

39. The data disk drive of claim 38, and further comprising a flexure member configured to be carried by the support arm over the data surface, wherein the second actuator is mounted to the flexure member.

5 40. The data disk drive of claim 39, and further comprising a frame comprising a tab and a mounting surface, wherein the second actuator is mounted to the flexure member through the frame.

10 41. The data disk drive of claim 40, wherein the shear mode piezoelectric element is mounted to the tab of the frame, and the mounting surface is mounted to the flexure member.

15 42. The data disk drive of claim 38, and further comprising a frame comprising a tab and a mounting surface, wherein the second actuator is mounted to the support arm through the frame.

20 43. The data disk drive of claim 42, wherein the shear mode piezoelectric element is mounted to the tab of the frame, and the mounting surface is mounted to the support arm.

25 44. A data disk drive comprising:
a rotating disk having a data surface;
a first actuator;
a support arm configured to be driven over the data surface by the first actuator;
a second actuator held by the support arm over the data surface;
wherein the second actuator comprises:
a first shear mode piezoelectric element;
a second shear mode piezoelectric element;
30 a first flexible member mounted between the first and second piezoelectric elements;
a third shear mode piezoelectric element

a fourth shear mode piezoelectric element; and
a second flexible member mounted between the third
and fourth piezoelectric elements; and
a data slider mounted between the first and second flexible members.

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45. The data disk drive of claim 44, and further comprising a flexure member configured to be carried by the support arm over the data surface, wherein the second actuator is mounted to the flexure member.

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46. The data disk drive of claim 45, and further comprising a frame comprising a first tab, a second tab, and a mounting surface, wherein the second actuator is mounted to the flexure member through the frame.

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47. The data disk drive of claim 46, wherein the first and second shear mode piezoelectric elements are mounted to the first tab of the frame, the third and fourth shear mode piezoelectric elements are mounted to the second tab of the frame, and the mounting surface is mounted to the flexure member.

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48. The data disk drive of claim 44, and further comprising a frame comprising a first tab, a second tab, and a mounting surface, wherein the second actuator is mounted to the support arm through the frame.

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49. The data disk drive of claim 48, wherein the first and second shear mode piezoelectric elements are mounted to the first tab of the frame, the third and fourth shear mode piezoelectric elements are mounted to the second tab of the frame, and the mounting surface is mounted to the support arm.