

A Micro-actuator for Moving a Data Read/Write Head

Field of the Invention

The present invention relates to an actuator and in particular one which is suitable for use for positioning the read/write head of a data storage device which reads data from and/or writes data to a data storage medium. Such an application requires that the actuator is of small size, and hence it is frequently referred to in this document as a "micro-actuator". The invention further relates to a data storage device incorporating the micro-actuator. The invention further relates to methods for fabricating the micro-actuator.

Background of the Invention

In many known data storage devices, the read/write head is positioned on a slider. The slider is supported by a suspension (e.g. by a gimbal suspension) which moves the slider over the surface of a recording medium (e.g. the magnetic material of a hard disk or a floppy disk), with high accessing speed and positioning accuracy. The head records data on, and reads data from, the recording medium.

With the need to increase the track density and storage capacity of discs, such as hard discs, there is a requirement for an extremely high precision actuator to control the read/write heads and to hold them over specific data tracks for information data exchange. A conventional actuator is a voice coil motor (VCM) which acts on the arm supporting the suspension. It is very difficult to satisfy these high requirements with such a system because of its large mass, low resonant frequency and the non-linear response of the shaft ball bearings. The use of a so-called secondary fine actuator provides an alternative solution for these problems since it is capable of providing rapid and accurate movement and position compensation of the read/write head. In such a dual stage system, a VCM is used as a coarse or track-seeking

actuator, and the fine actuator (a so-called "micro-actuator") is used for accurate track-following.

Two main types of secondary fine actuators have been proposed and are currently under development. They are:

- 5 1. electrostatic-based fine actuators; and
2. piezo-based fine actuators.

An electrostatic-based fine actuator is usually fabricated using Micro-Electro-Mechanical System (MEMS) technology and is sandwiched in between the gimbal and the slider of the apparatus. The actuation is required so as to
10 overcome the suspension and gimbal resonance which are at lower frequency. However, a disadvantage of this system is that it has a low actuation ability. In order to increase the output displacement, either a high driving voltage or a large number of capacitive parallel plates and a narrower electrode gap must be used. With a high voltage and a narrower electrode
15 gap there is a high risk of electrostatic discharging (ESD) and using a large number of capacitive parallel plates will increase the size and weight of the micro-actuator. With the piezoelectric micro-actuator on the other hand, the piezoelectric micro-actuator is formed as a bulk of piezo-electric material or a plurality of stacked beams of piezoelectric material. Such a micro-actuator
20 provides high actuation ability and output stiffness. This type of micro-actuator is generally placed into the arm-suspension assembly. A typical example of this is shown in US Patent No. 6,046,888.

Fine actuators will be able to overcome pivot non-linearity, FPC bias forces and various pivot and arm resonance modes. However, the increase of servo
25 band width is limited by the resonant frequency of the suspension. If a piezoelectric micro-actuator is sandwiched between the gimbal and the slider there is no requirement to change the configuration of a conventional slider

and the head disc interface (HDI) properties. Also it can generate a high resonance frequency with decreasing size and weight of the slider. This type of actuator is described in an article entitled "Piezoelectric Piggy-Back Micro-Actuator for Hard Disc Drives" by Yoshikazu Soeno et al (IEEE Transactions on Magnetism, vol 35, no. 2, 1999, pages 983-987). This is a piezo-stacked layer dual-beam micro-actuator which utilizes the expansion and contraction of piezoelectric materials to produce an in-plane bending. In order to increase output displacement with a low driving voltage, either the number of stacked active layers and the length of the beams are increased or the gap between the beams is reduced. However, as the length increases and gap decreases the structure is sensitive to any torsion and twist deformation. In addition, since the piezoelectric ceramic is brittle and its density is higher than other alternatives such as silicon, a micro-actuator made from piezoelectric bulk materials has a relatively low shock resistance and high weight.

15 Summary of the invention

It is an object of the present invention to provide an actuator (micro-actuator) which at least mitigates the disadvantages of the prior systems described above.

According to one aspect of the present invention, there is provided an actuator, the actuator comprising a substrate and deposited on the substrate a multilayer film comprising one or more electrically conductive layers and a layer of an actuation material which is deformed by application of voltage to the electrically conductive layer or layers, whereby deformation of the actuation material deforms the substrate.

25 In a first case, the actuation material may be a material which is sensitive to a magnetic field generated by current in the electrically conductive layer(s) by the voltage applied to them, i.e. the actuation material is magnetically deformable. For example, the actuation layer may be a permanently magnetic

or soft magnetic thin film. The electrically conductive layers may be arranged, e.g. patterned as a coil, to generate a strong magnetic field in relation to the generated current.

Alternatively, the actuation material may be a piezoelectric material which is
5 sensitive to a voltage differential across it created by applying a voltage to the electrically conductive layer(s), i.e. the deformable material is electrically deformable. For example, the piezoelectric material may be $\text{Pb}(\text{Ti,Zr})\text{O}_3$ (PZT).

Preferably, the multilayer film comprises two layers of electrically conductive
10 material sandwiching the actuation layer. For example, if the actuation material is a piezoelectric layer, deformation is caused by applying a voltage differential between the electrically conductive layers.

Note however that in certain circumstances the present invention can be operating using just one conductive layer. For example, in the case of an
15 actuation material which is deformed by a voltage differential, if the substrate is electrically conductive a single conductive layer may be provided on the side of the actuation material opposite the substrate, since in this case the deformation of the deformable layer may be controlled by applying a voltage differential between the first conductive layer and the substrate.

20 Conversely, however, if the substrate is electrically conductive it may be preferable to deposit an insulating layer directly on it, so as to insulate the substrate electrically from the electrode layer(s) and actuation material deposited on the insulating layer.

Suitably the substrate has two opposite faces and the multilayer film
25 (piezoelectric layer, one or two electric layers and optionally an insulating layer) is disposed on one of the faces.

Preferably, however, such a multilayer film is disposed on both faces of the substrate.

Note that the multilayer film need not be uniform over the face(s) of the substrate. In particular, the electrode layer(s) of the actuator may comprise a plurality of separate islands on the face of the piezoelectric layers. Furthermore, the multilayer film itself (the piezoelectric layer and its electrode(s) and the optional insulating layer) may be provided in a plurality of separate islands on the face(s) of the substrate.

Preferably, the substrate has an aperture, which for example may be H-shaped. Alternatively, the aperture may be of any other shape, such as rectangular. There may be a plurality of such (e.g. rectangular) apertures.

A further aspect of the invention is a method of fabricating an actuator comprising the steps of:

successively depositing on a substrate the layers of a multilayer film, comprising one or more electrically conductive layers and a layer of an actuation material which is deformed by application of voltage to the electrically conductive layer or layers; and

micro-machining the substrate to form the actuator.

Preferably, the first step in depositing of the layers is the formation of an insulating layer on the substrate, e.g. a SiO_2 oxide layer if the substrate is an Si substrate.

This is followed by the deposition of a conductive layer on the substrate (for example so that the substrate has the structure Pt/Ti/ SiO_2 /Si), and the deposition of a piezoelectric layer such as PZT via sputtering, chemical vapour deposition (CVD), a sol-gel method or screen printing.

The micro-machining, which may include surface and/or bulk micro-machining, may be followed by wafer bonding.

The actuator has various potential applications in micro-positioning and micro-manipulation environments, such as lithography, mask alignment, micro-machining, optical fibre switching, etc. However, here we will describe in detail
5 a specific application of the actuator which is positioning a data read/write head in relation to a data storage medium.

Thus, in a third aspect the invention provides a data storage device comprising: a head arranged for movement across a data storage medium,
10 and an actuator,

the actuator comprising a substrate and deposited on the substrate a multilayer film comprising one or more electrically conductive layers and a layer of an actuation material which is deformed by application of voltage to the electrically conductive layer or layers, whereby deformation of the
15 actuation material deforms the substrate,

the actuator being arranged to support the head whereby deformation of the substrate moves the head in relation to the data storage medium.

Preferably, the actuator (micro-actuator) is mounted between the head and an arm-suspension assembly such that the micro-actuator can move the head
20 with respect to the arm-suspension assembly to adjust the position of the head with respect to the data storage medium.

Preferably, the micro-actuator moves the head in a direction parallel to the surface of the data storage medium.

In one example of the invention, the data storage medium comprises a
25 magnetic disk, the head is installed in a slider of a magnetic disk drive and the micro-actuator is mounted between the slider and a arm-suspension

assembly of the disk drive which supports the slider. Typically, where the slider is coupled to the arm-suspension assembly by a gimbal, the micro-actuator is mounted between the slider and the gimbal.

- Note however that the invention is not limited in this respect, and the micro-actuator of the present invention may be used in a data storage device such as an optical disc drive or a magnetic-optical disc drive.

Brief description of the figures

Embodiments of the invention will now be described with reference to the accompanying drawings in which:

- 10 Figure 1 is a schematic view of a conventional Hard Disc Drive (HDD) assembly.

Figure 2 is a schematic cross-sectional view of a micro-actuator which is embodiment of the invention, and having a piezoelectric layer, electrode layers, an insulating layer and a substrate;

- 15 Figure 3 is a view of a PZT unimorph structure of the micro-actuator of Fig. 2;

Figure 4 shows how the micro-actuator of Figure 3 is deformed by an applied voltage;

Figure 5 is a schematic cross-sectional view of a micro-actuator which is a further embodiment of the invention;

- 20 Figure 6 shows how the micro-actuator of Figure 5 is deformed by an applied voltage;

Figure 7, which is composed of Figs. 7(a) and 7(b), is two views of a micro-actuator which is a further embodiment of the invention, having two separate top electrodes on each surface of the piezoelectric layer;

Figure 8 shows how the micro-actuator of Figure 7 is typically deformed by electrical control signals;

Figure 9 is a schematic cross-sectional view of a micro-actuator which is a further embodiment of the invention having piezoelectric islands on each
5 substrate surface;

Figure 10 is a schematic view of a micro-actuator which is a further embodiment of the invention;

Figure 11 is a schematic diagram of the steps in the fabrication of the micro-actuator of Figure 10;

10 Figure 12 is a schematic cross-sectional view of a micro-actuator which is a further embodiment of the invention;

Figure 13 is a schematic view of a micro-actuator according to the invention and similar to that shown in Fig. 7, sandwiched in use between the gimbal and the slider of a data storage apparatus according to the invention;

15 Figure 14 is a block diagram of a control system employing a micro-actuator according to the invention.

Detailed Description of the Embodiments

Figure 1 shows a conventional HDD assembly having a shaft 1 driven by a spindle motor. On the shaft 1 are stacked several discs 2, which each have a
20 thin film of magnetic material provided on at least one surface. Each film includes many data tracks. The top disk is marked as 3, and has thin film 4 on its upper surface. The assembly includes a plurality of arms pivoted at a pivot 5. The arm which moves over disk 3 is marked as 6. Each arm supports a suspension 7 having a gimbal (not shown) which in turn supports a slider
25 (not shown). Each slider incorporates a magnetic type read/write (or

reproduce/record) head (not shown) at a close distance to a surface of a corresponding disc 2. The head is driven by the arm and suspension to track across the disc 2 for track seeking and track following over the disc medium. In particular, a VCM assembly 8 actuates the arms and suspensions to cause
5 them to pivot and move the heads to a desired track on the discs 2 by a lateral direction movement (i.e. perpendicular to the tracks in the discs 2 but in the plane of the discs 2). The conventional HDD assembly further comprises a head actuator assembly 9, a base 10, a stop latch assembly 11, and an electronic board 12.

10 In this conventional HDD assembly the VCM assembly 8 provides both the track seeking function and the track following function capability. The track-seeking and track-following process will induce residual vibration of the slider (and therefore the head) in the lateral direction perpendicular to the tracks in the discs 2. This residual vibration eventually provides a limit to the speed at
15 which data can be accessed and also limits tracking accuracy. The use of the head micro-actuator of the present invention (micro-actuator) for dual-stage control provides an additional lateral micro-positioning of the slider and as a result the servo bandwidth and tracking accuracy are improved.

Referring to Figure 2 there is shown a cross-section of a micro-actuator
20 according to the invention, which micro-actuator comprises a rectangular silicon Si substrate 13, having an SiO₂ layer 14 on one side. On the top side of the SiO₂ layer 14 a bottom electrode layer 15 has been deposited. Deposited on top of the bottom electrode layer 15 is a thinner section piezoelectric layer 16. Deposited on top of the piezoelectric layer 16 is a top
25 electrode layer 17. The electrodes 15 and 17 are respectively connected to a source of electrical energy to activate the piezoelectric layer 16 to cause it to deform and thereby deform the silicon substrate 13. Controlled deformation of the silicon substrate 13 causes controlled movement of the slider to which

in use the micro-actuator is attached (as discussed below with reference to Fig. 13), and therefore movement of the head.

Silicon is adopted as the micro-actuator base material 13 of the micro-actuator since it has a higher shock resistance and lower density than piezoelectric ceramic bulk material. In addition, by adopting a silicon substrate 13 it becomes feasible to use silicon-based MEMS techniques to fabricate the micro-actuator.

The piezoelectric material of the layer 16 may be $\text{Pb}(\text{Ti,Zr})\text{O}_3$ (PZT). When the ceramic (PZT) is energised the silicon substrate 13 is deflected with a motion proportional to the applied voltage. Piezoelectric (PZT) layers can be patterned and integrated with the substrate using surface and bulk micro-machining techniques. The use of PZT can provide a fine and sensitive motion of the slider and therefore head movement in track following.

Figure 3 shows the composite structure of Fig. 2 in a vertical position. In Fig. 3, and all succeeding figures, the insulator layer 14 and the electrode layers 15, 17 have been omitted for clarity.

In Figure 4 the piezoelectric (PZT) layer 16 of Fig. 3 has been deformed by a voltage differential applied to the electrodes 15, 17 and as a result deforms the silicon layer 13 in a horizontal direction. As shown in this case the deformation is maximum at the top of the structure (as shown in Fig. 4) where in use the structure is engaged with the slider, and minimum at the bottom of the structure. Variation in the extent of deformation by controlled variation in the electrical signals enables accurate tracking of the disc medium to be obtained by movement of the slider (and thereby the head) by the micro-actuator.

Note that in one possible variant on the above embodiment within the scope of the invention, the silicon substrate 13 is conductive and the insulating layer

14 and the bottom electrode layer 15 are omitted. The voltage across the piezoelectric layer 16 is provided by applying different voltages to the top electrode layer 17 and the silicon substrate 13.

Figure 5 shows a micro-actuator which is a second embodiment of the invention. In this micro-actuator there are two PZT layers 16 located on either side of the silicon substrate 13. Each of the PZT layers is sandwiched by a respective pair of electrode layers (not shown), and the bottom electrode layer of each pair which is closer to the silicon substrate 13 is spaced from that substrate by a respective SiO₂ insulator layer. Figure 6 shows how the structure of Fig. 5 is deformed by a voltage applied across both PZT layers 16. The use of two PZT layers 16 improves the actuation ability of the micro-actuator.

Figs. 7(a) and (b) show a third embodiment of a micro-actuator 20 according to the invention. Fig. 7(b) shows an overall view of the micro-actuator 20, while Fig. 7(a) shows at greater resolution the section of Fig. 7(b) shown by the box 18. The micro-actuator 20 comprises a silicon substrate 21, having two opposite faces 22, 23 (facing towards respective sides of Fig. 7(a)). The micro-actuator 20 has a mirror plane of symmetry which is vertical in Fig. 7(a), and half way between the faces 22, 23 of the substrate. Deposited on each of faces 22, 23 are, in order, an SiO₂ layer 24, a bottom electrode layer 25, and a PZT layer 26. All these layers substantially cover the faces 22, 23. On the PZT layer 26 of each face 22, 23 is provided a respective pair of top electrode layers 27, 28 as islands on the PZT layers. The first top electrode layer 27 on each of the faces 22, 23 is located close to the upper part of the substrate 21 (as shown on Fig. 7(b)) while the second top electrode layer 28 on each of the faces 22, 23 is located a little way past the mid-section of the substrate 21 towards its bottom end (as shown on Fig. 7(b)). When the two PZT layers 26 on the respective faces 22, 23 are actuated, the substrate 21 is caused to flex horizontally at its top end 31. The substrate 29 has a central H-shaped

aperture 30 to provide maximum contact area with both the gimbal (not shown) and the slider (not shown), and the resulting composite structure induces in the silicon substrate 21 a highly controllable deformation of the substrate 21 in the horizontal direction and therefore a highly sensitive and
5 controllable movement of the slider and consequently the head. The structure described has a comparatively high resistance to flexing or bending except in the horizontal direction where flexibility is required. The structure therefore in effect only permits relative motion along one (horizontal) axis. For this reason it is considered to have only one degree of freedom. As the structure has a
10 comparatively light weight (due to the presence of the aperture) the micro-actuator described has a very high resonant frequency.

In Figure 8, a circuit 40 is shown for controlling the micro-actuator 20 described in Figure 7, the micro-actuator 20 being shown schematically in its deformed condition. A control signal 42 is provided and is split between two
15 amplifiers 43 and 44 having equal amplification factors K but opposite output polarities. The amplifier 43 is connected respectively to the first top electrode layer 27 on each face 22, 23 of the micro-actuator 20, and the amplifier 44 is connected to the second top electrode layer 28 on each face 22, 23 of the micro-actuator 20. The bottom electrode layer 25 on each face 22, 23 is
20 connected to ground by connections which are not shown on Fig. 8.

In Figure 9, a micro-actuator 50 which is a further embodiment of the invention comprises a substrate 51 having two faces 52, 53 facing to either side of Fig. 9. The face 52 is provided with a pair of PZT islands 54, 55, while the face 53 is provided with a second pair of PZT islands 56, 57. The silicon
25 substrate 51 further includes three rectangular apertures 58, 59, 60 consisting of a central aperture 58 and on either side of this central aperture 58 a respective lateral aperture 59, 60. The central aperture 58 is separated from the lateral apertures 59, 60 by strips 61, 62. The structure further includes two bottom electrode layers (not shown) provided on and substantially covering

respective faces 52, 53, and a respective top electrode layer (not shown) provided on each of the PZT islands 54, 55, 56, 57. This structure can be deformed electrically using a circuit similar to that described in Figure 8.

5 In Figure 10, a micro-actuator 63 which is further embodiment of the invention is shown. The micro-actuator 63 comprises a silicon substrate 68 which has two oppositely facing side surfaces 64 corresponding to the side faces 23, 24 of Fig. 7. As in Fig. 7, each side surface 64 is provided, in order on the silicon substrate 68, with a SiO₂ layer (not shown), a bottom electrode layer (not shown) substantially covering the side surface 64, a piezoelectric layer (not shown) and a pair of top electrode layer islands 65, 66. In fact, the micro-actuator 63 only differs from the one shown in Fig. 7 in that the substrate 68 has a rectangular central aperture 67 (rather than the H-shaped one of Fig. 7).

15 In Fig. 11, the fabrication process of the micro-actuator 63 is shown. The process begins with the provision of a Si wafer 68, shown in Fig. 11(a). As shown in Fig 11(b), a layer of SiO₂ 69 is deposited on the substrate 68 to insulate the wafer 68 electrically. As shown in Fig. 11(c), a layer of Pt/Ti 70 is deposited on the layer 69 to constitute the bottom electrode. As shown in Fig. 11(d) a layer of PZT 71 is deposited on the Pt/Ti/SiO₂/Si substrate by either sputtering, CVD, a sol-gel method or screen printing. As shown in Fig. 11(e), a Pt layer 72 is deposited over the whole of the PZT layer. As shown in Fig. 11(f), the Pt layer 72 is patterned and etched using ion milling to provide the two top electrode layer islands 65, 66. As shown in Fig. 11(g), the silicon wafer 68 is etched. Finally, as shown in Fig. 11(h), wafer bonding is used to attach and harden together two structures as shown in Fig. 11(g) to form the micro-actuator 63 of Fig. 10.

25 So far the use of a piezoelectric material such as PZT as the actuation source for deforming the substrate has been described. However other means may be used to deform the substrate.

In Figure 12 electromagnetic force is used to deform the silicon substrate. A micro-actuator 73 which is a further embodiment of the invention comprises a silicon substrate having a rectangular body portion 74 with a central aperture 75 and legs 76, 77 which are attached to a base 78. A pair of planar coils 79, 80 are attached to opposite faces of the legs 76, 77. A permanent magnetic component 81 such as a small magnet or a deposited soft magnetic thin-film is located within the aperture 75 and attached to the base 78. Alternatively a coil with a yoke may be wrapped around the substrate. When a current is passed through the coils 79, 80 an electromagnetic force is generated with respect to the permanent magnetic component 81 which causes a deflection of the legs 76, 77 in a manner similar to that previously described above in relation other embodiments.

Figure 13 illustrates the use of a micro-actuator according to the present invention in a record/reproduce or read/write assembly. The micro-actuator 90 is sandwiched between the gimbal 91 and the slider 92. The micro-actuator 90 is secured via an upper face 93 (as shown in Fig. 13) to the gimbal 91 and via a lower face 94 (as shown in Fig. 13) to the slider 92. When the micro-actuator 90 deforms it moves or drives the slider 92 and thereby the head (not shown) to implement the necessary micro/nano-scale motion of the head for accurate positioning during dual-stage control.

Certain embodiments of the present invention achieve the following objects when the embodiments are used in a data recording and/or reproducing device:

- (a) to increase positioning accuracy;
- (b) to increase servo-bandwidth and reduce off-track error;
- (c) to improve data storage capacity;
- (d) to provide higher shock resistance than prior art devices; and

(e) to make possible the use of known sliders such as nano-, pico-, femto and atto- sliders.

Figure 14 shows a control system in which a VCM 100 (Coarse actuator) is used in combination with a micro-actuator 101 (Fine actuator) according to the present invention to provide fine tuning of the alignment of a slider with a track in a HDD. The VCM 100 is operated by a Coarse Actuator Controller 102, to control the movement of the arm-suspension whilst the micro-actuator 101 is operated by a Fine Actuator Controller 104 to control the movement of the slider relative to the arm-suspension for fine tuning of the alignment of the slider with the track. Both the micro-actuator 101 and the VCM 100 provide movements which influence the position of the slider. The control system has an input 107 for receiving a voltage indicating a target position for the slider in the track. A subtraction unit 105 determines the difference between this voltage and a voltage indicating the actual position of the slider, to derive a position error signal (PES) as a voltage which is split between the Fine Actuator Controller 104 and the Coarse Actuator Controller 102. The respective controllers 102,103 use the PES to control the VCM 100 and the micro-actuator 101, to cause displacement of the slider (indicated schematically as addition unit 106). The position of the slider is then measured and/or estimated as the voltage which is fed back to the unit 105.



Claims

1. An actuator comprising a substrate and deposited on the substrate a multilayer film comprising one or more electrically conductive layers and a layer of an actuation material which is deformed by application of voltage to
5 the electrically conductive layer or layers, whereby deformation of the actuation material deforms the substrate.
2. An actuator according to claim 1 in which the at least one layer of actuation material is piezoelectric.
3. An actuator according to claim 2 in which the piezoelectric material is
10 PZT.
4. An actuator according to claim 2 or claim 3 in which the substrate has two opposite faces and the multilayer film is disposed on only one of the two faces.
5. An actuator according to claim 2 or claim 3 in which the substrate has
15 two opposite faces and the multilayer film is disposed on both of the two faces.
6. An actuator according to any preceding claim in which in each multilayer film the layer of actuation material is sandwiched by a bottom electrode layer in the direction of the substrate and a top electrode layer in the
20 direction away from the substrate.
7. An actuator according to claim 6 in which each multilayer film further comprises an insulating layer between the bottom electrode layer and the substrate



8. An actuator according to claim 6 or claim 7 in which in each multilayer film the top electrode layer comprises at least two separate portions on the layer of piezoelectric material.
9. An actuator according to claim 7 in which the bottom electrode layer
5 comprises at least two separate portions on the insulating layer.
10. An actuator according to claim 7 in which both the bottom electrode layer and the top electrode layer comprise at least two portions, which sandwich the piezoelectric layer.
11. An actuator according to claim 6 or claim 7 in which the multilayer film
10 comprises at least two separate islands on each face of the substrate, and each island includes the piezoelectric layer and the top and bottom electrode layers.
12. An actuator according to claim 1 in which the layer of actuation material is a magnetic material.
13. An actuator according to claim 12 in which the magnetic material is a
15 permanent magnet.
14. An actuator according to claim 12 in which the magnetic material is a soft magnetic thin film.
15. An actuator according to any of the preceding claims in which the
20 substrate is silicon.
16. An actuator according to any of the preceding claims in which the substrate has an aperture.
17. An actuator according to claim 16 in which the aperture is rectangular.
18. An actuator according to claim 16 in which the aperture is "H" shaped.



19. An actuator according to claim 16, claim 17 or claim 18 in which there are a plurality of apertures.
21. An actuator according to any preceding claim fabricated by film deposition, and/or surface and bulk micro-machining, and/or wafer bonding
5 techniques.
22. A data storage device comprising: a head arranged for movement across a data storage medium, and an actuator,
- the actuator comprising a substrate and deposited on the substrate a multilayer film comprising one or more electrically conductive layers and a
10 layer of an actuation material which is deformed by application of voltage to the electrically conductive layer or layers, whereby deformation of the actuation material deforms the substrate,
- the actuator being arranged to support the head whereby deformation of the substrate moves the head in relation to the data storage medium.
- 15 23. A data storage device according to claim 22 in which the actuator is mounted between the head and an arm-suspension assembly such that the actuator can move the head with respect to the arm-suspension assembly to adjust the position of the head with respect to the data storage medium.
24. A data storage device according to claim 23 in which the actuator is
20 arranged to move the head in a direction parallel to the surface of the data storage medium.
25. A method of fabricating an actuator comprising the steps of:
- successively depositing on a substrate the layers of a multilayer film comprising one or more electrically conductive layers and a layer of an



actuation material which is deformed by application of voltage to the electrically conductive layer or layers; and

micro-machining the substrate to form the actuator.