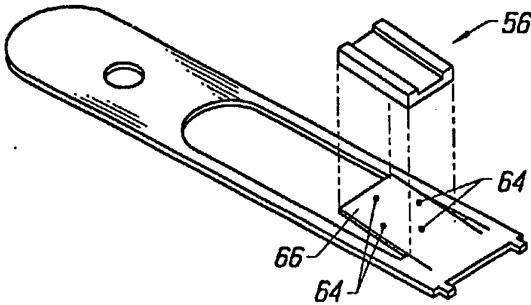




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(21) International Application Number: PCT/US94/12674 (22) International Filing Date: 7 November 1994 (07.11.94) (30) Priority Data: 152,328 12 November 1993 (12.11.93) US (71) Applicant: CONNER PERIPHERALS, INC. [US/US]; 3081 Zanker Road, San Jose, CA 95134 (US). (72) Inventors: LEE, Jia-Kuen, Jerry; 1398 Sajak Avenue, San Jose, CA 95131 (US). CHAO, Audrey, Mong-Ping; 722 Boar Circle, Fremont, CA 94539 (US). (74) Agent: FLIESLER, Martin, C.; Fliesler, Dubb, Meyer and Lovejoy, Suite 400, Four Embarcadero Center, San Francisco, CA 94111-4156 (US).		(81) Designated States: CA, CN, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(54) Title: HIGH TEMPERATURE HEAD SLIDER GEOMETRY CONTROL FOR CONTACT OR NEAR CONTACT RECORDING		
		
(57) Abstract A disk drive is provided for flying at low flying heights, for example $2\frac{1}{2}\mu''$. The disk drive includes an adhesive-bonded slider and head suspension design which does not lose its crown or camber with a change in temperature. In a preferred embodiment, the adhesive is applied at discrete points. It was found that applying the adhesive in this manner was sufficient to securely bond the slider to the flexure tongue and resulted in relatively little change in the crown or camber geometry over a wide range of temperatures.		

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HIGH TEMPERATURE HEAD SLIDER GEOMETRY
CONTROL FOR CONTACT OR NEAR CONTACT RECORDING

5

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a data storage device, and more particularly, to a disk drive
10 operating at low flying heights including a novel mounting of the head slider to the flexure.

Description of the Related Art

Conventional disk drives for use in work stations, personal computers, and portable computers are required
15 to provide a large amount of data storage within a minimum physical space. In general, disk drives operate by positioning a read/write transducing head over respective tracks on a magnetic recording disk. Positioning of the head over the tracks is accomplished
20 by an actuator coupled to control electronics, which control the positioning of the actuator and the read/write functions of the heads.

Greater demands are being placed on disk drives by
25 (1) the use of multi-user and/or multi-tasking operating systems, (2) work stations which provide an operating environment requiring the transfer of large amounts of data to and from a hard disk and/or large numbers of disk accesses to support large application programs or multiple users, (3) the present popularity
30 of notebook and laptop computers, and (4) the continuing trend toward higher performance

microprocessors. All such systems require a hard drive having high-capacity storage capability, while occupying a minimum of space within the host computer. In order to accommodate these demands, there is a need to produce a smaller hard disk drive which at the same time has an increased storage capacity. For such applications, single drive capacities on the order of hundreds of megabytes are common.

An important determinant in the storage capacity of a disk drive is the flying height of the transducing heads above the rotating disk. In conventional Winchester-type hard drives, once the storage disk achieves a certain angular velocity after start-up of the drive, a cushion of circulating air above the surface of the disk forces the head up off the surface of the disk to thereby achieve a flying height. Having very low flying heights offers several advantages, primary among them is that flying the head very close to the disk surface allows for a high data bit density (i.e., the number of data bits per inch on a data track). The greatest data bit density would be obtained where the transducing head rides in contact with the storage disk. However, the contact of the head and head slider with the disk surface would result in damage to the head and/or disk in an unreasonably short period of time. Thus, there has been an industry wide push to decrease the height at which read/write heads are maintained over the disk surface without actually riding in contact with the disk surface. In the 1960's flying heights were commonly about 100 microinches (μ "). At present, technological advances in read/write heads and disk drive design have allowed the reduction of flying heights to around 4 μ " in commercially viable disk drives.

When a head flies over a disk, the flying height does not remain constant, but rather tends to fluctuate slightly above and below the normal flying height. At lower flying heights, a variation in the fly height may cause the head to randomly contact the disk surface. This situation is referred to as intermittent contact. Presently, flying heights have been reduced to the point where intermittent contact with the disk surface has become an important consideration in the tribology of the head/disk interface. Repeated intermittent contact between the head and a particular location on the disk surface can cause damage to the head and/or disk, and may cause drive failure in an unreasonably short period of time.

Figs. 1A and 1B show a conventional actuator assembly 10 for supporting a read/write head 12 with respect to a disk 14. In particular, head 12 is supported on a flexure 16, which is in turn mounted on a load beam 18. The load beam 18 is attached to an actuator arm 20, which is attached to a voice coil motor (not shown) for pivoting the actuator assembly to position the head 12 over the desired data track on the disk 14. The load beam 18 is provided to exert a force or load to bias the head 12 toward the surface of disk 14. During operation of the drive, the force of the load beam 18 opposes and counteracts the force of the cushion of air under the slider so that the head reaches an equilibrium state at the desired flying height.

It is an important function of flexure 16 to provide a gimbaling action which allows the head 12 to fly flat, i.e., to orient the surface of the head 12 facing the disk 14 so that it is parallel to the surface of the disk while the disk is rotating. Toward this end, as shown in Fig. 2, flexure 16 includes a

tongue 22 provided at an angle with respect to the main body of flexure 16. The angle is provided to compensate for the angle that the load beam 18 forms with respect to the disk surface. When head 12 is mounted to tongue 22, the head 12 is generally parallel to the surface of the disk 14. The head is mounted on the surface of tongue 22 by an epoxy, such as for example ABLESTIK manufactured by Ablebound Corp. In conventional head assemblies, the epoxy is spread over substantially all or all of the tongue 22 in order to securely mount the head thereon.

The read/write head 12 is generally comprised of a transducer (not shown) for transferring the data to and from the disk, and a slider 24 for supporting the transducer at the desired flying height. Slider 24 generally includes rails 26a and 26b on the underside of the slider (shown inverted on Fig. 2), which rails are supported on the pressurized cushion of air during operation of the disk drive to provide the head flying height.

In a preferred conventional design, the slider is formed with a slight bow across both its length and its width, as shown in Figs. 3A and 3B, respectively. The bow has been exaggerated in the Figures for clarity. The distance d_1 in Fig. 3A is commonly referred as the "crown", and represents the amount the slider has bowed across the length of the slider. The distance d_2 in Fig. 3B is commonly referred as the "camber", and represents the distance the slider has bowed across the width of the slider.

The formation of a positive crown and camber have advantageous effects on the take-off and flying height properties of the slider. A positive crown or camber is a crown or camber wherein the middle of the slider is closer to the disk surface than the edges of the

slider. The slider shown in Figs. 3A and 3B has a positive crown and positive camber. It has been found that a positive crown enhances the formation of the air bearing under the slider, and thus allows the head to
5 take-off from the disk in a shorter period of time upon start-up of the disk drive. As such, there is less time that the head is dragging in contact with the rotating disk prior to take-off. Similarly, when the head is provided at higher skew angles, a positive
10 camber in the slider facilitates a better air bearing for the air contacting the slider from the side of the slider.

The crown and camber on a slider are formed two ways. First, the slider is provided with a positive
15 crown and camber during the slider fabrication process. Second, the positive crown and camber are enhanced during the curing process used to secure the slider to the tongue of the flexure. In the curing process after the epoxy has been applied between the slider and the
20 tongue, the slider and flexure are heated to evaporate the liquid in the epoxy to thereby solidify the epoxy. The flexure is formed from steel or aluminum, and when it is heated, it expands. The slider is conventionally formed of a ceramic material which expands only
25 slightly upon heating. After the epoxy solidifies and the bond is secure, the slider and flexure are cooled. Upon cooling, the flexure tongue shrinks back to its original size, which causes the slider bonded thereto to bow further, thereby increasing the positive crown
30 and camber. Conventionally, a positive crown may be advantageously formed anywhere from 0.3μ " to 3μ " and a positive camber may be advantageously formed anywhere from 0.05μ " to 0.25μ ".

A significant problem has emerged at low flying
35 heights as result of use of a disk drive at higher

temperatures. Due primarily to a difference between the thermal expansion coefficients of the flexure and slider, as mentioned above, at higher temperatures the flexure tongue expands, causing the slider to lose its crown and camber. If the temperature is high enough, and the flexure expands significantly, the slider crown and camber may even go negative. A loss of the crown and camber, in addition to increasing the take off time, results in a decrease in flying height after take-off. At higher flying heights, the change in flying height with an increase in temperature was relatively inconsequential because the percentage change of the flying height relative to the flying height itself was very small. However, flying heights have been reduced to the point where changes in the flying height as result of a loss of the positive crown and/or camber have become a significant consideration in the head/disk tribology. At low flying heights, for example 1 to 4 μ ", it is extremely important to be able to control the flying height to be as uniform as possible. A variation in the flying height, as by a change in the temperature for example, could cause repeated intermittent contact of the head with the disk, and drive failure in an unreasonably short period of time.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a disk drive with a read/write head flying at very low flying heights.

It is a further object of the present invention to provide a head suspension assembly which allows the head to fly at a relatively constant flying height over a wide range of temperatures.

It is a still further object of the present invention to provide a head suspension assembly which maintains a uniform crown and/or camber over a wide range of temperatures.

5 These and other objects are accomplished by the present invention which relates to a disk drive for flying at low flying heights, for example $2\frac{1}{2} \mu$ ". The disk drive includes an adhesive-bonded slider and head suspension design which will not lose its positive
10 crown or camber with a change in temperature. In a preferred embodiment, the adhesive is applied at discrete points. Application of the epoxy in discrete points between the slider and the flexure prevents the thermal expansion of the flexure upon an increase in
15 temperature from effecting the geometry of the slider. Even though there are relatively high stresses in the discrete epoxy points as compared to conventional epoxy application, it was found that the discrete epoxy points are able securely bond the slider to the
20 flexure.

A change in the crown and/or camber results in a change in the flying height of the head over the disk. Therefore, by substantially preventing a change in the crown or camber with a change in temperature, the head
25 flying height remains relatively constant over a wide range of temperatures.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained with reference to the Figures in which:

30 FIGURE 1A is a side view of a conventional actuator assembly;

FIGURE 1B is a top view of a conventional actuator assembly;

FIGURE 2 is an exploded perspective view of a flexure and a slider;

FIGURE 3A is a side view of a slider showing the crown;

5 FIGURE 3B is a front view of a slider showing the camber;

FIGURE 4 is a top view a disk drive according to the present invention;

10 FIGURE 5 is an exploded perspective view of a flexure, slider and epoxy points according to the present invention;

FIGURE 6 is an enlarged top view of a tongue and an epoxy application pattern according to the present invention; and

15 FIGURE 7 is a graph of the change in the slider crown with a change in temperature.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

20 The invention will now be described with reference to Figs. 4 through 7, which generally relate to a disk drive with a novel method for securely bonding a read/write head to a flexure. It is understood that the present invention may be utilized with disk drives of various sizes and designs, and used with various data storage technologies.

25 Referring now to Fig. 4 there is shown a disk drive 50 including a storage disk 52 and a read/write head 54. Read/write head 54 includes a transducer 55 mounted to a slider 56. The slider 56 is in turn supported on an actuator assembly 58. Transducer 55
30 may be a conventional inductive transducing element, or in an alternative embodiment, may be a magneto-resistive (MR) transducing element. The actuator assembly 58 is pivotally mounted so as to pivot around pin 60 in response to a force exerted on the actuator

assembly by voice coil motor 62. As is known in the art, during operation of the drive 50, disk 52 is rotated by a spin motor (not shown) and actuator assembly 58 pivots read/write head 54 across the surface of the disk so that data is transferred between the read/write head 54 and the disk 52 in a plurality of concentric data tracks. Slider 56 includes a pair of rails (not shown on Fig. 4) along the length of the slider, which are provided to support the transducer on an air bearing a very small distance above the surface of disk 52 as disk 52 rotates. In a preferred embodiment, the head may have a flying height between 1-4 μ ", and optimally about 2.5 μ ".

The actuator assembly 58 includes a conventional flexure 59 having a tongue 66 (Fig. 5), which flexure may preferably be formed of steel or aluminum. The flexure is provided to support the slider 56 in parallel relation to the disk surface. Slider 56 may preferably be formed of conventional ceramic materials, such as calcium titanate or a titanium carbide/aluminum oxide composition. As is appreciated in the art, the coefficient of thermal expansion of the flexure, whether steel or aluminum, is greater than that of the ceramic slider. As stated in the Background of the Invention section, a head slider is conventionally bonded to the tongue of the flexure by applying an epoxy over substantially the entire surface between the slider and the tongue. With such a bonding method, the slider tends to lose the positive crown and camber at higher temperatures as result of the thermal expansion of the flexure tongue being greater than the thermal expansion of the slider.

Therefore, according to the present invention as shown in Figs. 5 and 6, the epoxy is applied in discrete points 64 over the contact area between the

slider 56 and the flexure tongue 66. As shown in Fig. 5, and Fig. 6 which is an enlarged top view of the tongue 66 and the discrete epoxy points 64 shown in Fig. 5, there are preferably four such epoxy points. However, it is understood that in alternative embodiments, varying numbers of discrete epoxy points may be used at varying locations over the contact area. The discrete epoxy points 64 are preferably evenly spaced around the contact area between the slider 56 and the tongue 66 so as to create a relatively uniform bond area between the slider and tongue. A conventional epoxy for use in the present invention is ABLESTIK 868-7 manufactured by Ablebound Corp. Other epoxies or adhesives may be used in alternative embodiments.

It was found that applying the epoxy in discrete epoxy points greatly reduced the change in the crown and camber with a change in temperature. At higher temperatures, the tongue 66 still expands, and exerts a stress on the slider through the discrete epoxy points. However, the total area of the epoxy points relative to the area of the slider is small enough that the epoxy points are unable to bend or significantly effect the geometry of the slider 56. Thus, the geometry of the slider remains relatively constant. This being the case, the epoxy is unable to aid in the formation of the initial positive crown and camber during the curing process. Therefore, the slider may preferably be formed with a slightly greater crown and camber during the slider fabrication process as compared to conventional head and flexure assemblies.

In an alternative embodiment of the present invention, the slider 56 may be secured to the tongue 66 in an ultra violet ("UV") bonding process, as opposed to a conventional curing process. In this

embodiment, holes are provided through the tongue 66, one hole for each epoxy point 64. The epoxy is then provided in the holes, the slider is mounted on the tongue, and a UV light is applied to the back side of the tongue. The UV light causes the epoxy in the holes to solidify, thereby bonding the slider to the tongue. UV light is unable to penetrate the slider. Thus, in order to solidify the epoxy, the epoxy must be provided in the holes in the tongue. Accordingly, this process is not feasible with conventional epoxy applications, where the epoxy is applied over all or substantially all of the interface between the tongue and slider.

The shear stress created in the discrete epoxy points is much higher than the shear stress created in conventional epoxy applications. However, it has been determined through testing that the discrete epoxy points according to the present invention are able to withstand a shear stress of at least 900 grams. This stress is higher than any stress which may be created in the epoxy points as result of the thermal expansion mismatch between the flexure 59 and the slider 56. It is understood that the epoxy application according to the present invention may be used with any head suspension design at the contact area where the head slider is mounted to the head suspension.

A change in the crown over temperature has a slightly greater effect on the flying height than does a change in the camber. As shown in the graph of Fig. 7, it has been determined through testing that the crown (d_1 in Fig. 3A) can change at least 0.5μ " over a 30°C change in temperature in drives using conventionally bonded head/flexure assemblies. However, by applying discrete epoxy points according to the present invention, it was determined through testing that the change in the crown over a similar

30°C change in temperature was only about 0.1 μ ". It has further been determined by testing that, at least over a limited range of crown dimensions, there is a substantially linear relationship between a change in crown with temperature and a change in the flying height. Namely, in a seventy percent slider, for every 1.0 μ " loss of the crown, there is an accompanying 0.4 μ " loss in flying height. Therefore, for a 30°C change in temperature in a disk drive using a conventional epoxy bonding process, the change in flying height is as follows:

$$\Delta \text{ fly ht.} = 0.5 \mu" \Delta \text{ crown} \times \frac{0.4 \mu" \Delta \text{ fly ht.}}{1.0 \mu" \Delta \text{ crown}}$$

$$\Delta \text{ fly ht.} = 0.2 \mu".$$

For a normal flying height of 2.5 μ ", this represents an 8% change in the flying height. However, for a similar 30°C change in temperature in a disk drive according to the present invention, the change in flying height is as follows:

$$\Delta \text{ fly ht.} = 0.1 \mu" \Delta \text{ crown} \times \frac{0.4 \mu" \Delta \text{ fly ht.}}{1.0 \mu" \Delta \text{ crown}}$$

$$\Delta \text{ fly ht.} = 0.04 \mu".$$

For a normal flying height of 2.5 μ ", this represents an 1.6% change in the flying height. Accordingly, by applying discrete epoxy points, the change in flying height which normally occurs in conventional drives at higher temperatures is drastically reduced. As such, a disk drive according to the present invention may operate at a substantially constant flying height, independent of temperature, and repeated intermittent contact which may otherwise occur at higher temperatures is avoided.

Although the invention has been described in detail herein, it should be understood that the invention is not limited to the embodiments herein disclosed. Various changes, substitutions and
5 modifications may be made thereto by those skilled in the art without departing from the spirit or scope of the invention as described and defined by the appended claims.

WE CLAIM:

1. A disk drive for preventing significant loss in flying height with an increase in temperature, comprising:
 - 5 a storage media for storing data;
transducing means for transferring said data to and from said storage media;
a slider on which said transducing means is mounted;
 - 10 an actuator assembly for positioning said slider and said transducing means over respective data tracks on said storage media, said actuator assembly including a head suspension on which said slider is mounted;
 - 15 an adhesive applied to a contact area between said slider and said head suspension for securing said slider to said head suspension, said adhesive being applied at a plurality of discrete points in said contact area; and
 - 20 control electronics for controlling said transfer of data to and from said storage media and for controlling said positioning of said slider and said transducing means.
2. A disk drive as recited in claim 1, wherein said
25 head suspension includes a flexure, said slider being mounted to said flexure.
3. A disk drive as recited in claim 1, wherein said plurality of discrete points comprises four (4) discrete points.
- 30 4. A disk drive as recited in claim 1, wherein said plurality of discrete points can hold said slider

secure to said head suspension under a shear stress of at least 900 grams.

5 5. A disk drive as recited in claim 1, wherein said slider is provided to fly between approximately one microinch (1μ ") and approximately four microinches (4μ ") above said storage media.

6. A disk drive as recited in claim 5, wherein said slider is provided to fly approximately two and one-half microinches ($2\frac{1}{2} \mu$ ") above said storage media.

10 7. A disk drive as recited in claim 1, wherein said adhesive is an epoxy.

8. A disk drive as recited in claim 7, wherein said epoxy is ABLESTIK.

15 9. A disk drive as recited in claim 1, wherein said transducing means comprises an inductive read/write transducer.

10. A disk drive as recited in claim 1, wherein said transducing means comprises a magneto-resistive read/write transducer.

20 11. A head and flexure assembly for preventing significant loss in flying height of a read/write head in a disk drive with an increase in temperature, comprising:

 a slider mounted on the flexure; and
25 an epoxy for securing said slider to the flexure, said epoxy applied to a contact area between flexure and said slider in a plurality of discrete points.

12. A disk drive as recited in claim 11, wherein said plurality of discrete points comprises four (4) discrete points.
13. A disk drive as recited in claim 11, wherein said
5 epoxy is ABLESTIK.
14. A disk drive as recited in claim 11, wherein said plurality of discrete points can hold said slider secure to the flexure under a shear stress of at least 900 grams.
- 10 15. A disk drive as recited in claim 11, wherein the flexure is comprised of steel.
16. A disk drive as recited in claim 11, wherein the flexure is comprised of aluminum.
- 15 17. A disk drive as recited in claim 11, wherein said slider is comprised of a ceramic material.
18. A disk drive as recited in claim 17, wherein said ceramic comprises calcium titanate.
19. A disk drive as recited in claim 17, wherein said ceramic comprises a titanium carbide/aluminum oxide
20 composition.
20. A method of preventing significant loss in flying height of a read/write head in a disk drive with an increase in temperature, comprising the step of applying an epoxy in discrete points to a contact area
25 between a slider and a flexure to secure said slider to said flexure.

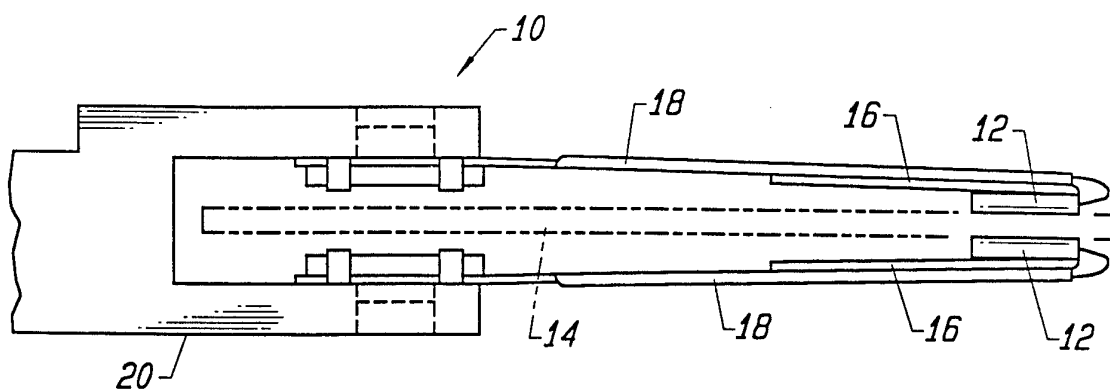


FIG. 1A
(PRIOR ART)

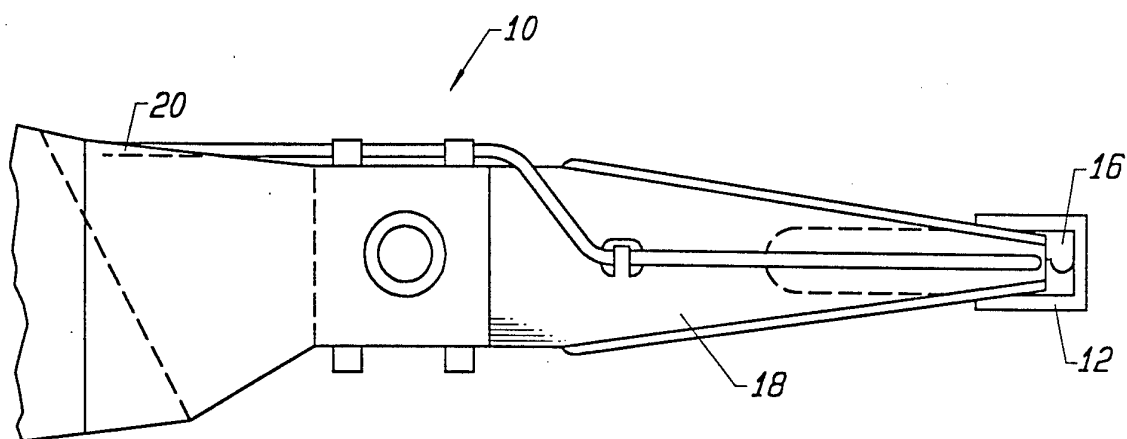


FIG. 1B
(PRIOR ART)

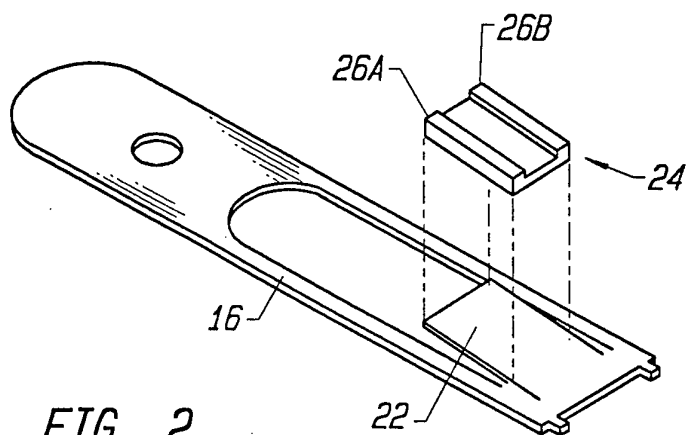


FIG. 2
(PRIOR ART)

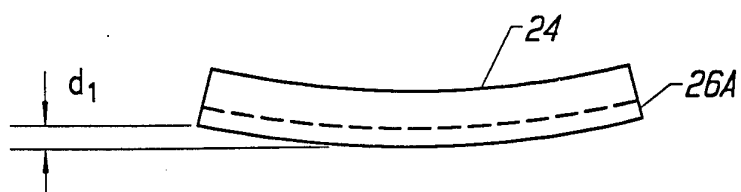


FIG. 3A

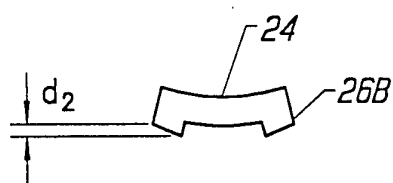


FIG. 3B

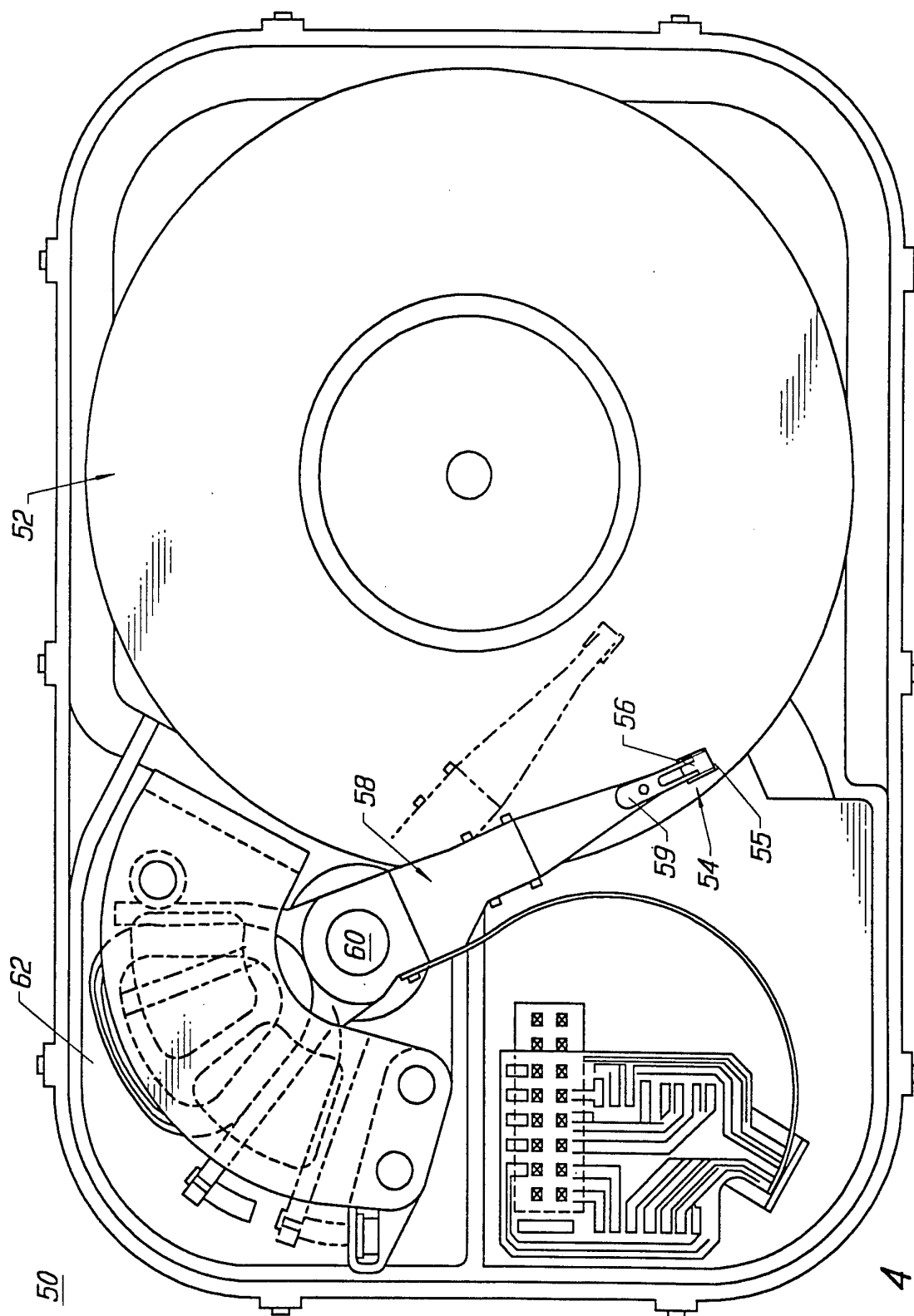


FIG. 4

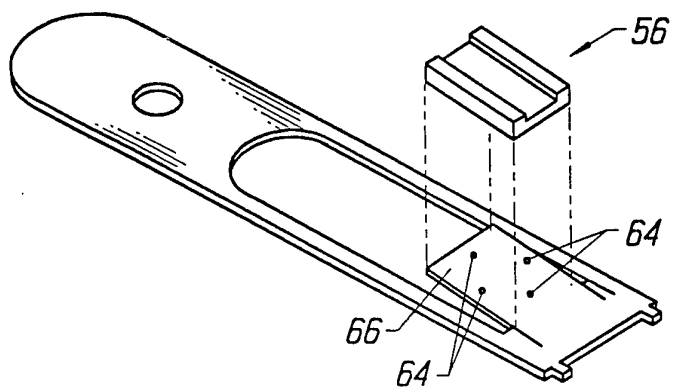


FIG. 5

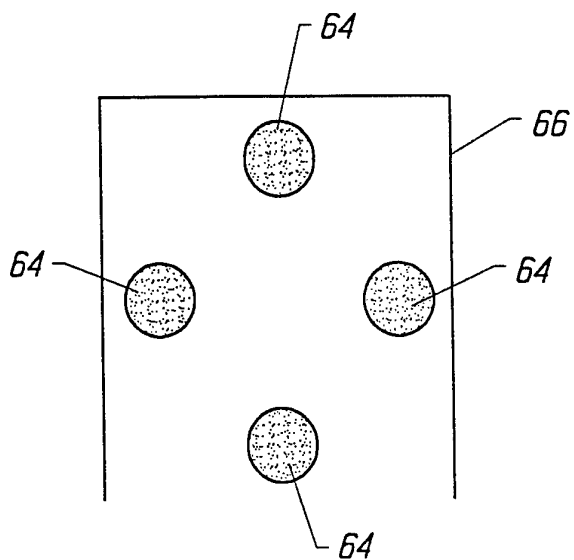
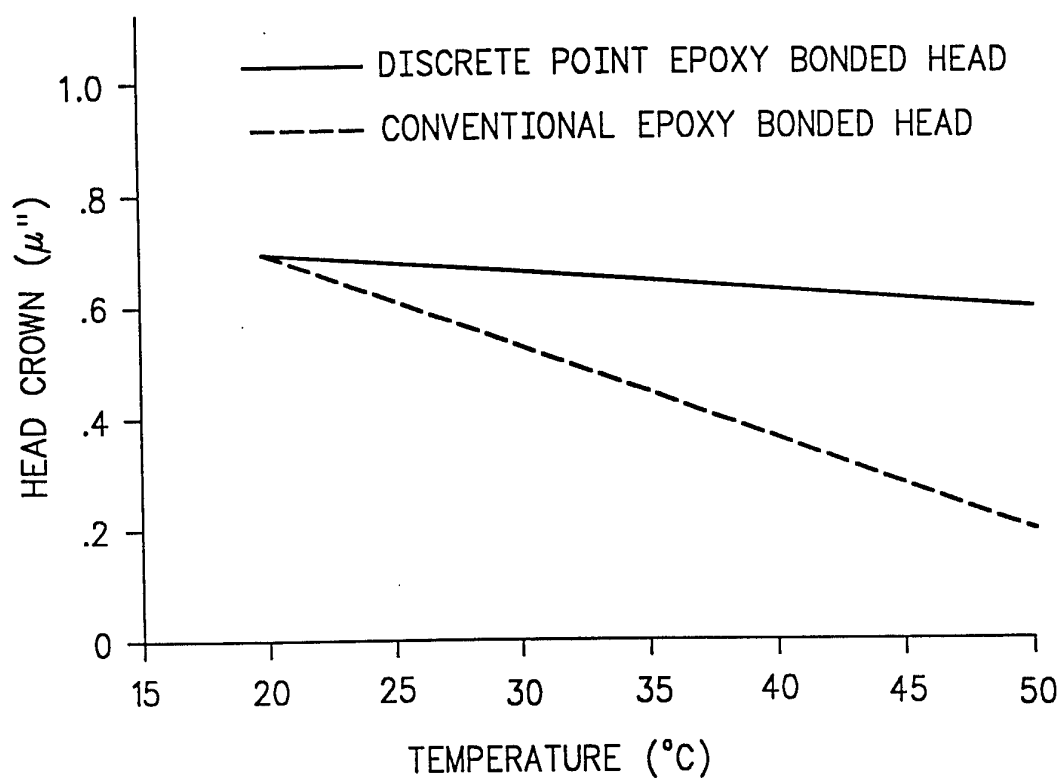


FIG. 6

*FIG. 7*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 94/12674

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G11B5/60 G11B21/21

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 265 720 (IBM CORP.) 4 May 1988 see figure 3 ---	1-20
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol.36, no.2, February 1993, NEW YORK US pages 11 - 12 'LOW SHEAR FORCE FLEXURE' see the whole document ---	1-20
A	PATENT ABSTRACTS OF JAPAN vol. 15, no. 492 (P-1287) 12 December 1991 & JP,A,03 212 809 (TDK CORP.) 18 September 1991 see abstract -----	1-20

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

2 March 1995

Date of mailing of the international search report

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Moyle, J

Information on patent family members

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0265720	04-05-88	US-A- 4761699	02-08-88
		DE-A- 3778290	21-05-92
		JP-A- 63113917	18-05-88
