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Device for contacting and/or modifying a surface having a cantilever and a method for production said cantilever



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TECHNICAL FIELD

The present invention relates to a device for contacting and/or modifying a surface having a cantilever connected to an almost plane carrier element staying apart from said surface, said cantilever has a tip at it's loose end being in close contact to said surface. The device is useable for thermomechanical writing and thermal readout of binary information in a storage media, like a thin polymer film, or suitable for lithographic and imaging techniques and as well for surface modification. As well the invention relates to a method for production of said cantilever with said tip.

BACKGROUND OF THE INVENTION

Devices for ultrahigh-density, high-speed data storage applications using thermomechanical writing and thermal readout in thin polymer film as storage media work on bases of atomic force microscopy (AFM) technique and are described in the following publications representing the state of the art:

- H.J. Mamin et al., 'Highdensity data storage using proximal probe techniques', IBM J. Res. Develop., Vol. 39, No. 6, pp. 681700, 1995,
- E. Grochowski and R.F. Hoyt, 'Future Trends in Hard Disk Drives', IEEE Trans. Magnetics Vol. 32, No. 3, pp. 18501854, 1996
- R.P. Ried et al., '6MHz 2N/m Piezoresistive AtomicForceMicroscope Cantilevers with Incisive Tips', J. Microelectromech. Syst., Vol. 6, No. 4, pp. 294302, 1997,
- US Patent 5835477 entitled 'MassStorage and
- P. Vettiger et al., 'Ultrahigh Density, High data rate Micromechanical Scanning Probe Storage System', Proc. Intl. Conf. on Micro and NanoEngineering 98, LeuvenBelgium, Sept. 1998, to be published in Microelectronic Engineering.

A basic arrangement for thermomechanical writing and readout is shown in Fig. 1 representing prior art. Very close to the surface of a storage media 1 consisting of a polymer film, a tip 2 is positioned directing towards the surface of the storage media 1. The tip 2 protrude from the loose end of a cantilever 3 which is fixed to a plane shaped carrier element 4 which is positioned in a defined distance from the surface of the storage media. For writing a binary information into the storage media 1 the polymer surface is locally softens/melts with the heated tip 2 by simultaneously applying a light pressure onto the tip 2 by the cantilever 3 resulting in nanometer-scale indentations in the surface of the storage media 1 representing the binary information in form of indents.

Heating of the tip 2 is provided by a resistive platform underneath the tip. For reading the binary information stored in the storage media 1 the heated platform and the heated tip are also used as a sensing element to detect topographical changes on the surface of the polymer film. While reading, a low constant electrical power is applied to heater platform, so that the temperature of the platform is modulated by the distance between the platform and the storage media. The temperature change is measured through the platform's resistivity and depend on the heat sinking capability of the heater platform environment.. By scanning bit indentations, like it is the case in Fig. 1b, the distance between the platform and the surface of the storage media is changing by some 10 nm, resulting in a platform temperature change due to cooling of the storage media. In case of Fig. 1b the tip of the cantilever dips into the indentation so that more cooling of the cantilever system is caused than in case of Fig. 1c where the cantilever has a greater distance towards the surface of storage media.

For designing the cantilever with a tip at its loose end some important aspects have to be considered: The mass of the cantilever has to be as small as possible to obtain soft, high-resonant frequency cantilevers. Soft levers are required for low loading force in order to eliminate or reduce tip and media wear, whereas a high resonant frequency allows high speed scanning. Also the tip height should be as short as possible as heater platform sensitivity depends strongly on the platform-media distance as it is described relating to Fig. 1. However this requirement contradicts the demand of a large gap between the

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surface of the carrier element and the storage media to guarantee that only the tips are making contact to the media and not the carrier element.

The object of the present invention is to realize a device especially for thermomechanical writing and thermal readout of binary information in a storage media taking the above mentioned demands into account. Especially the object of the invention is to provide a tip arrangement which allows an array arrangement of a multitude of single cantilevers and to guarantee as well, that each single tip of said cantilevers stays in close contact to the surface of the storage media without wearing the surface of the storage media. Of course devices comprising the same basic assembly - i.e. having a cantilever connected to an almost plane carrier element staying apart from a surface, said cantilever has a tip at its loose end being in close contact to said surface - but usable for different applications like lithography, surface modification and/or imaging, just to name a few, shall also be improved in the same way and with the same inventive steps like in case of the beforementioned device.

It is a further object of the invention to improve the tip geometry and the way of production the cantilever and tip at the loose end of the cantilever using methods which are easy to handle allowing a low cost fabrication and high yields. The tip volume shall be as small as possible so that the tip mass can be reduced for realizing a high-resonant frequency cantilever system and reduce the heating time constant.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided a device for contacting and/or modifying a surface, said device comprising a cantilever connected to an almost plane carrier element staying apart from said surface, said cantilever has a tip at the loose end thereof being closely contactable to said surface,

wherein said cantilever stands out of the plane of said carrier element, and

wherein said cantilever is at least partially attached with additional material, said additional material has a thermal expansion coefficient c_1 which is different to the thermal expansion coefficient c_2 of the material of which said cantilever is made.

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According to a second aspect of the invention there is provided a device for contacting and/or modifying a surface, said device comprising

a cantilever connected to an almost plane carrier element staying apart from said surface; and

a tip at the loose end of said cantilever, said tip being closely contactable to said surface,

wherein said cantilever stands out of the plane of said carrier element, and

wherein the cantilever is made of a material or a material composition providing an intrinsic stress such that the cantilever bends out of the plane of said carrier element

According to a third aspect of the invention there is provided a method for producing a cantilever connected to a plane carrier element staying apart from a surface, said cantilever having a tip at a loose end thereof and being closely contactable to said surface, the method comprising the step of:

bending said cantilever such that said cantilever stands out of the plane of said carrier element.

The inventive idea concerns to the shape of the cantilever which is normally straight and lying in the same plane as the carrier element. Instead of making the tip longer, as it is the normal and known way to become contact to the surface for sure beside of all combined disadvantages, it is proposed inventively to bent the cantilever out of the plane of the carrier element for example for a few micrometers.

The way of bending the cantilever can be manifold for example by bending the cantilever along its whole direction. Bending occurs by providing an intrinsic or inbuilt stress in the cantilever which is usually independent of the temperature environment of the cantilever. Intrinsic stress in the cantilever can be reached for example by a special heat treatment of the cantilever or by implantation of additional material like doping material into the cantilever or by stress building up during the cantilever material deposition .

An other method to bent the cantilever is to have a second material layer on top or under the cantilever which built a stress at the interface during the cantilever/stressing material stack fabrication which will perform the bending when the lever is released .

Bending of the cantilever can also be built up attaching additional material onto said cantilever by using an additional material having a thermo expansion coefficient c_1 which is different to the thermal expansion coefficient c_2 of the material of which said cantilever is made of. Due to the different thermal expansion coefficients of both materials said additional material causes a defined stress moment acting directly onto said cantilever being bent out of the plane of said cantilever element.

Normally the cantilever is made entirely of silicon for good thermal and mechanical stability which is connected with said carrier element commonly produce of silicon also, so that the cantilever and the carrier element are made out of one piece. By using plasma enhanced chemical vapor deposition (PECVD) a silicon nitrite layer is deposited at the base section of the cantilever which fixes the cantilever to said carrier element. The silicon nitrite layer also extends into areas of said cantilever not being supported by said carrier element, so that a controlled stress-moment can be induced into said cantilever for bending out of the plane of the carrier element.

The advantage of the inventive idea is provide a secure contact between the tip of the cantilever and the surface of the storage media and providing at the same time a clear space between the plane carrier element and the storage media. Furthermore by applying a defined layer of silicon nitrite onto the cantilever the bending of the cantilever is well controlled so that a distinct loading force acts onto said storage media without causing any damage. Also the tip height must not be very huge for contacting the surface of the storage

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media so that the tip can be down sized with the advantage to be easier to fabricated and with a tighter tolerance and to reduce its mass so that ultrahigh frequency motions of the cantilever can be realized.

Beside of techniques for producing tips at the loose end of a cantilever by applying additional tip material to the cantilever it is proposed that the tip will be formed out of the same material of which the cantilever is made of. Using a special mask and applying wet etching the structure of the tip can be formed out of the same material the cantilever is consisting of.

Due to the fact that the tip can be kept very small it doesn't protrude much from the surface of the cantilever which is an advantage during lever manufacture since the tip can be more easily protected.

Another way of producing a tinny tip is to oxidize edges of the cantilever which sharpens the edges of the lever after removing the layer. The tip lying in the plane of the cantilever is therefore called "in plane tip".

Combining the before described in plane tip and the idea of bending the cantilever, the tip and the cantilever making processes can be merged so that process steps can be reduced and yield can be increased. By this method, very controlled tip apex height can be done which is crucial for making 1D or 2D array of cantilever. Tight tip apex height tolerance is necessary in an array to have an homogenous contact with the tips across the array.

DESCRIPTION OF THE DRAWINGS

The invention is described in detail below with reference to the following schematic drawings. It is to be noted that the figures are not drawn to scale.

Fig. 1a,b,c schematically sketches describing a cantilever with a tip at it's loose end (prior art),

Fig. 2a, b top- and side-view of a cantilever arrangement in a pre-bend situation,

Fig. 3a,b,c several cantilever arrangements in side-view, and

Fig. 4a-d Steps of fabrication of an in plane tip.

DESCRIPTION OF PREFERRED EMBODIMENTS:

Fig. 1 was described in the above abstract and shows schematically sketches explaining the thermomechanical writing and thermal reading process.

Fig. 2a shows the top-view of a cantilever arrangement 3 which provides two separate lever arms 31, 32 connected at its base sections 33, 34 with the carrier element 4 having a flat plane shape (see also Figure 2b showing a cross-section view). The carrier element 4 and also the cantilever 3 can be arranged multiple in a two-dimensional array which provides a two-dimensional cantilever array chip. At the loose end of the lever arms 31, 32 a heater platform 35 with a tip 2 on top is provided. The cantilever 3 is made preferably entirely of silicon for good thermal and mechanical stability. The two legs 31 and 32 of the cantilever 3 act as a mechanical spring and also for electrical connection to the heater platform where the tip 2 is provided.

In the side-view of Fig. 2b the cantilever 3 stands out of the plane of the carrier element 4 due to an additional layer 5 of stress controlled nitride which bends the cantilever upwards. The stress between the additional layer 5 and the cantilever is built at the cantilever-film interface and bends the cantilever.

The cantilever 3 which is shown in fig. 2a, b can be arranged in a 2-dimensional array consisting of a multitude of the before described cantilevers. Applying the inventive pre-bending stress of each single cantilever in a 2-dimensional cantilever array chip a uniform contact between each single tip and the storage media can be realized.

Fig. 3a shows a conventional cantilever arrangement consisting of carrier element 4, a cantilever 3 and a tip 2. The cantilever 3 is directed straight without bending in a preferred direction. Attaching an additional material onto the upper surface of the cantilever 3 like it is the case in Fig. 3b, the additional layer 5 consists of a material inducing, during its deposition, a tensile stress into the cantilever 3 for bending the cantilever 3 in a preferred

direction such as it is the case in Fig. 3b in the upward direction. In difference to the embodiment of Fig. 3a in which the tip protrudes perpendicular over the surface of the cantilever the tip of the embodiment of Fig. 3b does not protrude the surface of the cantilever 3 at all but arises over the surface of the carrier element 3 due to the bending stress caused by the layer of additional material 5. See detailed sketch in Fig. 3b showing the tip 2 in macroscopic view. The so called 'in plane tip' can be manufactured within one and the same process step in which the cantilever itself is manufactured. Forming the tip at the end of the cantilever wet etching and thermal oxidation is used for providing a special tip structure at the cantilever.

Another way of bending the cantilever and arranging the tip 2 onto the cantilever's surface is shown in Fig. 3c. Here the cantilever is bent about 180° along its normal direction so that the tip which is at its backside still arise in an upwards direction.

Using different kind of additional materials 5 having compressive or tensile thermal expansion coefficients comparing to the thermal expansion coefficient of the cantilever's material the form of the cantilever can take on different kind of curves.

Fig. 4 represents several steps of producing a cantilever in detail:

Fig. 4a shows a crosssection of a carrier element 4 which is made of silicon onto its surface a protection layer 6 like SiO_2 is attached. The protection layer 6 protects the carrier element from being etched while producing the cantilever layer 3 using etching like wet etching.

Fig. 4b shows a way of forming an in-plane tip. For sharpening the edge of the cantilever layer 3 the surface of the cantilever 3 is oxidized by attaching an additional layer of oxide for example SiO_2 . After removing the additional oxide layer 6 the edge is sharp enough for providing an in-plane tip 2.

Fig 4c shows the step after depositing a stress layer 5 onto the cantilever 3 at its base section. Fig. 4d shows the effect of the stress layer 5 onto the cantilever 3 which is released by removing parts of the carrier element under the loose end of the cantilever 3. The loose end of the cantilever 3 bends out of the plane of the carrier element 4.

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The underlying idea of the invention for improving a device for thermomechanical writing and thermal readout of binary information in a storage media, like a thin polymer film, is based on bending the cantilever out of the plane of the carrier element, so that the distance between the surface of the storage media and the carrier element is sufficiently great to prevent the carrier element from contacting the surface although the tip gets in close contact to the surface of the storage media. Fundamentally this idea is applicable to a multitude of other techniques which have the same situation of positioning nano- or micrometer scaled objects, like tips or other scanning probes (e.g. Scanning tunneling microscopy, near field optic microscopy), in close contact to a surface and at the same time the carrier elements of the objects have to be in sure distance to said surface.

For example for imaging systems, lithography systems, or surface modification systems the inventive bending of the cantilever with special scanning probes at it's loose end leads to the same advantages as described before in connection with the device for thermomechanical writing and thermal readout of binary information in a storage media.

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LIST OF REFERENCE NUMBERS

1	storage media
2	tip
3	cantilever
31, 32	lever arm
33, 34	base section
4	carrier element
5	layer of additional material
6	protection layer

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CLAIMS

1. Device for contacting and/or modifying a surface, said device comprising:
a cantilever connected to an almost plane carrier element staying apart from said surface; and
a tip at the loose end of said cantilever, said tip being closely contactable to said surface,
wherein said cantilever stands out of the plane of said carrier element, and
wherein said cantilever is at least partially attached with additional material, said additional material has a thermal expansion coefficient c_1 which is different to the thermal expansion coefficient c_2 of the material of which said cantilever is made.
2. Device according to claim 1,
wherein said cantilever is bent along a longitudinal direction of said cantilever.
3. Device according to claim 1,
wherein said additional material causes a defined stress moment whereby said cantilever is bent out of the plane of said carrier element.
4. Device according to claim 1,
wherein said cantilever provides a base section which is fixed to said carrier element, said additional material being attached onto said base section and extending into areas of said cantilever not being supported by said carrier element.
5. Device according to claim 1,
wherein said cantilever is made of silicon and said additional material is of silicon nitride.
6. Device according to claim 1,
wherein said additional material is attached directly onto said cantilever as a layer defined by thickness and length.

7. Device for contacting and/or modifying a surface, said device comprising
a cantilever connected to an almost plane carrier element staying apart from
said surface; and
a tip at the loose end of said cantilever, said tip being closely contactable to
said surface,
wherein said cantilever stands out of the plane of said carrier element, and
wherein the cantilever is made of a material or a material composition
providing an intrinsic stress such that the cantilever bends out of the plane of said
carrier element.
8. Device according to claim 7,
wherein said intrinsic stress is provided by a thermal treatment of said
cantilever.
9. Device according to claim 7,
wherein said intrinsic stress is provided by implantation in the cantilever.
10. Device according to claim 1,
wherein said tip is directed approximately perpendicular to said cantilever
and protrudes from the surface of said cantilever.
11. Device according to claim 1,
wherein said tip is provided on a side of said cantilever being turned away
from said surface and said cantilever is bent along the longitudinal direction thereof
by about 180° so that said tip is contactable to said surface.
12. Device according to claim 1,
wherein said tip and the direction of said cantilever enclose an angle between
0° and 90°.
13. Device according to claim 12,
wherein said cantilever is bent along its longitudinal direction by about 90°.

14. Device according to claim 1,
wherein said tip and said cantilever are made of the same material.
15. Device according to claim 1,
wherein said tip and said cantilever are made of different materials.
16. Device according to claim 1,
wherein said tip does not protrude above the plane of said cantilever and is integrally formed with said cantilever.
17. Device according to claim 1,
wherein said surface is a storage medium, into which thermomechanical writing and/or thermal readout of binary information takes place by said tip.
18. Device according to claim 17 wherein said storage medium is a thin polymer film.
19. Device according to claim 1,
wherein said surface is a surface onto which lithographic and imaging techniques are applicable using said tip.
20. Device according to claim 1,
wherein said surface is of a nature which is modifiable by said tip.
21. A method for producing a cantilever connected to a plane carrier element staying apart from a surface, said cantilever having a tip at a loose end thereof and being closely contactable to said surface, the method comprising the step of:
bending said cantilever such that said cantilever stands out of the plane of said carrier element.
22. The method according to claim 21,

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wherein said bending is realized by inducing a controlled stress in the cantilever by a procedure selected from the group consisting of:

- treating thermally said cantilever,
- by a stress controlled of the cantilever material deposition,
- by implantation of additional material in said cantilever, and
- by adding a layer or film of additional material on the cantilever.

23. The method according to claim 21,
wherein manufacturing of said cantilever and forming said tip takes place in common process steps.

24. The method according to claim 23,
wherein said tip is formed out of the material the cantilever consists of.

25. The method according to claim 23,
wherein said process steps are selected from the group consisting of lithography, selective etching and film deposition.

26. The method according to claim 23,
wherein said process steps comprise oxidation sharpening of a box-like silicon structure.