

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
21 August 2008 (21.08.2008)

PCT

(10) International Publication Number
WO 2008/100232 A1

(51) International Patent Classification:
G11B 5/02 (2006.01) **G11B 5/31** (2006.01)

(74) Agent: **DREW & NAPIER LLC**; 20 Raffles Place,
#17-00 Ocean Towers, Singapor 048620 (SG).

(21) International Application Number:
PCT/SG2008/000057

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date:
15 February 2008 (15.02.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2007-037233 17 February 2007 (17.02.2007) JP

(71) Applicant (*for all designated States except US*): **SEIKO INSTRUMENTS INC.** [JP/JP]; 8, Nakase 1-chome, Mihama-Ku, Chiba-shi, Chiba (JP).

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **PARK, Majung** [KR/JP]; Seiko Instruments Inc., 8, Nakase 1-chome, Mihama-ku, Chiba-shi, Chiba (JP). **OUMI, Manabu** [JP/JP]; Seiko Instruments Inc., 8, Nakase 1-chome, Mihama-ku, Chiba-shi, Chiba (JP). **HIRATA, Masakazu** [JP/SG]; Seiko Instruments Inc., Singapore Representative Office, 11 Biopolis Way, Helios #08-12, Singapore 138 667 (SG).

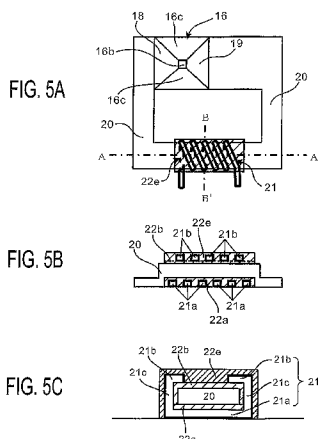
Declaration under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report*

(54) Title: NEAR - FIELD OPTICAL HEAD AND INFORMATION RECORDING/REPRODUCING APPARATUS



(57) Abstract: The invention is a near-field optical head for heating a magnetic recoding medium rotated in a constant direction by generating near-field light from an introduced light flux and recording information by bringing about a switching of magnetization by applying a magnetic field to the magnetic recording medium, the near-field optical head including a slider arranged in a state of being floated up from a surface of the magnetic recording medium by a predetermined distance and having an opposed face opposed to the surface of the magnetic recording medium, a near-field light generating element formed on the opposed face for generating the near-field light, a magnetic pole formed above the near-field light generating element, a plurality of lower wirings formed above the opposed face, a magnetic circuit in a shape of a thin film arranged at a position of covering the plurality of lower wirings and connected to the magnetic pole, a plurality of upper wirings arranged on a side reverse to a side of arranging the plurality of lower wirings in both sides of the magnetic circuit, an insulating layer for insulating the respective of the lower side wirings, the magnetic circuit and the upper side wirings, and a coil wound around a surrounding of the magnetic circuit by connecting the lower wirings and the upper wirings alternately in series.

WO 2008/100232 A1

NEAR - FIELD OPTICAL HEAD AND INFORMATION RECORDING / REPRODUCING APPARATUS

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to a near-field optical head capable of recording various kinds of information to a magnetic recording medium by an ultra high density by utilizing near-field light and an information recording/reproducing apparatus having the near-field optical head.

10

Description of the Related Art

In recent years, in accordance with an increase in a capacity of a hard disk or the like in a computer apparatus, a recording density of information in a single recording area has been increased. For example, in
15 order to increase a recording capacity per unit area of a magnetic disk, it is necessary to increase an areal recording density. However, with an increase in a recording density, an occupied recording area per 1 bit is reduced on a recording medium. When a bit size is reduced, an energy provided to information of 1 bit is near a thermal energy at room
20 temperature to pose a problem of thermal demagnetization in which recorded information is inverted by thermal fluctuation or vanishes.

Although inplane recording system which has been generally used is a method of recording magnetism such that a direction of a magnetization is directed in an inplane direction of the recording medium, according to the
25 method, vanishment of the record information by thermal demagnetization

is liable to be brought about. Hence, in order to resolve such a drawback, the recording system is shifting to a perpendicular recording method of recording a magnetizing signal in a direction perpendicular to a record medium. The system is a system of recording magnetic information by a principle of making a single magnetic pole proximate to a recording medium. According to the system, a recording magnetic domain is directed in a direction substantially perpendicular to a recording film. According to the system, in the recording magnetic domain, an N pole and an S pole are difficult to produce a loop, and therefore, a stability is easy to be maintained in view of energy. Therefore, the perpendicular recording system is resistant to thermal demagnetization compared with the inplane recording system.

However, according to a recording medium of recent years, in view of needs of intending to record and reproduce information of a large amount and a higher density, higher density recording has been requested. Therefore, a recording medium having a strong coercivity is started to be adopted in order to minimize an influence of magnetic domains contiguous to each other or thermal fluctuation. Therefore, even in the perpendicular recording system, it is difficult to record information at a recording medium.

Hence, in order to resolve the drawback, there is provided a hybrid magnetic recording system for reducing a coercivity temporarily by locally heating a magnetic domain by near-field light and carrying out writing during the time period (near-field light assisting magnetic recording system). The hybrid magnetic recording system is a system of utilizing near-field light generated by an interaction between a small region and an

optical opening formed by a size equal to or smaller than a wavelength of light formed at a near-field optical head. In this way, by utilizing a near-field optical head having a small optical aperture exceeding a diffraction limit of light, that is, a near-field light generating element,
5 optical information in a region equal to or smaller than a wavelength of light which is regarded to be a limit in an optical system of a background art can be dealt with. Therefore, high density formation of a recording bit exceeding an optical information recording/reproducing apparatus or the like of the background art can be achieved.

10 Further, a near-field light generating element may be constituted not only by the above-described optical small aperture but also, for example, a projected portion formed by a nanometer size. By the projected portion, near-field light can be generated similar to the optical small aperture.

Although various kinds of recording heads by the hybrid magnetic
15 recording system have been provided, as one of them, a magnetic recording head increasing a recording density by reducing a size of a light spot is known (refer to, for example, Patent Reference 1 (JP-A-2004-158067) and Patent Reference 2 (JP-A-2005-4901)).

The magnetic recording head mainly includes a main magnetic pole,
20 an auxiliary magnetic pole, a coil winding provided in a spiral shape on the same plane and formed with a conductor pattern of a structure in which the main magnetic pole passes through a center axis of the spiral at an inner portion of an insulating member, a metal scattering member for generating near-field light from irradiated laser beam, a planar laser source for
25 irradiating laser beam to the metal scattering member, and a lens for

focusing the irradiated laser beam. The respective constituent products are attached to a front end face of a slider fixed to a front end of a beam.

According to the main magnetic pole, one end side thereof constitutes a face opposed to a recording medium, and other end side thereof is connected to the auxiliary magnetic pole. That is, the main magnetic pole and the auxiliary magnetic pole constitute a single magnetic pole type vertical head arranged with one piece of a magnetic pole (single magnetic pole) in a vertical direction. Further, the coil winding is fixed to the auxiliary magnetic pole such that a portion thereof passes through between the main magnetic pole and the auxiliary magnetic pole. The main magnetic pole, the auxiliary magnetic pole and the coil winding constitute an electromagnet as a whole.

A front end of the main magnetic pole is attached with the metal scattering member comprising gold or the like. Further, the planar laser source is arranged at a position remote from the metal scattering member, and the lens is arranged between the planar laser light source and the metal scattering member.

The respective constituent products are attached from a side of a front end face of a slider in an order of the auxiliary magnetic pole, the coil winding, the main magnetic pole, the metal scattering member, the lens, and the planar laser source.

When the magnetic recording head constituted in this way is utilized, various kinds of information are recorded to the recording medium by applying a recording magnetic field simultaneously with generating near-field light.

That is, the laser beam is irradiated from the planar laser source. The laser beam is focused by the lens and is irradiated to the metal scattering member. Then, free electrons of inside of the metal scattering member are uniformly oscillated by an electric field of the laser beam, and
5 therefore, plasmon is excited and near-field light is generated at the front end portion. As a result, the magnetic recording layer of the recording medium is locally heated by the near-field light and the coercivity is temporarily reduced.

Further, a recording magnetic field is locally applied to the magnetic
10 recording layer of the recording medium proximate to the main magnetic field by supplying a drive current to the conductor pattern of the coil winding simultaneously with irradiating the laser beam. Thereby, various kinds of information can be recorded to the magnetic recording layer the coercivity of which is temporarily reduced. That is, recording can be
15 carried out to the recording medium by cooperating the near-field light and the magnetic field.

Further, there is also known a magnetic recording head further integrating a preheating mechanism to the magnetic recording head (refer to, for example, Patent Reference 3 (JP-A-02005-78689)).

20 The magnetic recording head includes a resistance heater constituting the preheating mechanism between the main magnetic pole and the auxiliary magnetic pole. The resistance heater is provided with a front end area larger than those of the main magnetic pole and the metal scattering member, and therefore, an object region to be heated is wide and
25 a temperature gradient is low. Therefore, the resistance heater is made to

be able to apply only heat to a degree of previously preheating the magnetic recording layer of the recording medium.

According to the magnetic recording head constituted in this way, the magnetic recording layer can be preheated previously by the resistance heater, and therefore, heat generation of the metal scattering member for
5 generating near-field light can be reduced. Therefore, a possibility or the like of deteriorating or damaging the metal scattering member by a temperature rise can be reduced and a durability can be promoted.

10

BRIEF SUMMARY OF THE INVENTION

15

However, the following problems still remain in the magnetic recording head of the background art. That is, although according to the magnetic recording head described in Patent References 1 and 2, near-field light is generated by irradiating laser beam from the planar laser source to
the metal scattering member, in order to efficiently generate the near-field light, it is necessary to irradiate the laser beam to the front end of the metal scattering member as much as possible.

On the other hand, it is necessary to arrange laser beam, the lens or the planar laser source so as not to interfere with the recording medium.

20

Therefore, the magnetic recording head described in Patent Reference 1 satisfies the above-described condition by irradiating laser beam from the planar laser source skewedly to the metal scattering member and using the lens in a semicircular shape.

25

However, in order to satisfy the condition, an optical axis of the laser beam is obliged to be skewed relative to the metal scattering member and

the lens in the semicircular shape is obliged to use. Therefore, it is difficult to efficiently generate near-field light and output of laser beam is obliged to be increased. As a result, there is a concern that the planar laser light source or the metal scattering member excessively generates heat, which is inferior in a reliability.

Further, although it is necessary to arrange the lens and the planar laser light source in parallel in a state of being spaced apart from the main magnetic pole by a predetermined distance therebetween, actually, it is difficult to produce such an arrangement at a front end of the slider, and even when produced assumedly, the arrangement cannot be summarized compact and it is difficult to achieve small-sized formation.

Further, although it is conceivable to irradiate the laser beam linearly to the metal scattering member by using an optical waveguide or utilizing a mirror in place of the planar laser source or the lens, the constitution is further complicated and it is still difficult to achieve small-sized formation.

Further, the metal scattering member is provided on an outer side of the main magnetic pole to be disposed at the rearmost end in a scanning direction, and therefore, when information is recorded to the magnetic recording layer, it is difficult to efficiently heat a position applied with the recording magnetic field. That is, the magnetic recording layer is moved in an order of the auxiliary magnetic pole, the magnetic pole, and the metal scattering member in accordance with rotation of the recording medium, and therefore, the recording magnetic field is applied before heating by the near-field light. Therefore, a peak position of a heating temperature by the

near-field light is disposed at outside of a region of applying the recording magnetic field and a reliability of writing is inferior.

Particularly, the temperature gradient by the near-field light tends to be retarded in the scanning direction of the recording medium, and therefore, it is conceivable that the peak position of the heating temperature is shifted from the position right below the metal scattering member. When the point is taken into consideration, actually, the peak position of the heating temperature is shifted in a direction of being deviated from the region of applying the recording magnetic field and there is a high possibility that accurate writing cannot be carried out.

On the other hand, the magnetic recording head described in Patent Reference 3 includes the preheating mechanism of the resistance heater or the like between the main magnetic pole and the auxiliary magnetic pole, and therefore, the magnetic recording head is constructed by a constitution of resolving the problem of efficiency of generating the near-field light and the problem of the reliability of writing, on the contrary, the preheating mechanism is added further as the constituent product, and therefore, there is a drawback of making the constitution further complicated and large-sized.

On the other hand, the magnetic recording head described in Patent References 1, 2 and 3 includes a coil winding structure wound with the conductor spirally on the same plane. An intensity of a magnetic field generated on a center axis of the coil can be explained by Equation (1) shown below. Notation H designates a magnetic field, notation i designates a current flowing in a coil, and notation r designates a distance

from a center axis of a coil to a winding.

$$H = i/2r \quad (1)$$

The magnetic field intensity H is inversely proportional to r , and therefore, the larger the r , the smaller the H , and a difference of magnetic field intensities generated by a winding proximate to the coil center axis and a winding remote therefrom is large. Therefore, a loss of a generated magnetic field relative to the flowing current i is large and a magnetic field generating efficiency is comparatively inferior.

Hence, the invention has been carried out in view of the above-described point and it is an object thereof to provide a near-field optical head capable of efficiently generating near-field light and capable of generating a magnetic field which is stronger and with a higher efficiency while achieving small-sized formation.

In order to resolve the problem, a near-field optical head of the invention is a near-field optical head for heating a magnetic recording medium rotated in a constant direction by generating near-field light from an introduced light flux and recording information by bringing about a switching of magnetization by applying a magnetic field to the magnetic recording medium, the near-field optical head including a slider arranged in a state of being floated up from a surface of the magnetic recording medium by a predetermined distance and having an opposed face opposed to the surface of the magnetic recording medium, a near-field light generating element formed on the opposed face for generating the near-field light, a magnetic pole formed above the near-field light generating element, a plurality of lower wirings formed above the opposed face, a magnetic circuit

in a shape of a thin film arranged at a position of covering the plurality of lower wirings and connected to the magnetic pole, a plurality of upper wirings arranged on a side reverse to a side of arranging the plurality of lower wirings in both sides of the magnetic circuit, an insulating layer for
5 insulating the respective of the lower side wirings, the magnetic circuit and the upper side wirings, and a coil wound around a surrounding of the magnetic circuit by connecting the lower wirings and the upper wirings alternately in series.

Further, according to the invention, the near-field light generating
10 element includes an aperture for generating the near-field light, wherein the magnetic pole includes a first magnetic pole and a second magnetic pole constituting portions of edge portions surrounding the aperture, and wherein the first magnetic pole and the second magnetic pole are arranged to be opposed to each other.

15 Further, according to the invention, the magnetic circuit is formed to connect the first magnetic pole and the second magnetic pole.

Further, according to the invention, a plurality of pieces of the magnetic circuits are formed above the opposed face, and the coils are respectively wound around surroundings of the plurality of pieces of the
20 magnetic circuits.

Further, according to the invention, a plurality of pieces of the coils are wound around a surrounding of the magnetic circuit.

Further, according to the invention, the lower wiring and the upper wiring comprise pluralities of wirings insulated from each other piece by
25 piece.

Further, according to the invention, the first magnetic pole and the second magnetic pole are separated from each other, the first magnetic pole and the second magnetic pole are respectively formed with the magnetic circuits, and the coils are respectively wound around surroundings of the magnetic circuits.

Further, according to the invention, the coil is wound around a coil axis orthogonal to a direction of laminating the upper wirings and the lower wirings, and respective sectional areas along the direction orthogonal to the coil axis are substantially the same.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a schematic view showing a first embodiment of an information recording/reproducing apparatus having a near-field optical head according to the invention.

Fig.2 illustrates an enlarged sectional view of the near-field optical head shown in Fig.1 and an enlarged sectional view centering on a core.

Fig.3 is a view viewing the near-field optical head shown in Fig.2 from a side of a disk face.

Fig.4 is a perspective view viewing the core of the near-field optical head shown in Fig.3 from a side of an end face thereof.

Fig.5 illustrates an enlarged view of a magnetic recording portion of the near-field optical head shown in Fig.3 and a sectional view showing sections of a coil and a magnetic circuit.

Fig.6 is a sectional view showing a method of fabricating the coil and the magnetic circuit shown in Fig.5.

Fig.7 is an enlarged view showing a second embodiment of a near-field optical head according to the invention viewed from a side of a disk face of a magnetic recording portion.

Fig.8 illustrates enlarged views showing a third embodiment of the near-field optical head according to the invention viewed from a side of a disk face of a magnetic recording portion.

Fig.9 illustrates an enlarged view and a sectional view showing a fourth embodiment of a near-field optical head according to the invention viewed from a side of a disk face of a magnetic recording portion.

Fig.10 is a sectional view showing a method of fabricating a magnetic circuit shown in Fig.9.

Fig.11 is an enlarged view showing a fifth embodiment of a near-field optical head according to the invention viewed from a side of a disk face of a magnetic recording portion.

Fig.12 illustrates an enlarged view showing a sixth embodiment of a near-field optical head according to the invention viewed from a side of a disk face of a magnetic recording portion and a sectional view showing sections of a coil and a magnetic circuit.

Fig.13 illustrates sectional views showing the sections of the coil and the magnetic circuit of the magnetic recording portion shown in Fig.12.

DETAILED DESCRIPTION OF THE INVENTION

(Embodiment 1)

A first embodiment of a near-field optical head and an information recording/reproducing apparatus according to the invention will be

explained in reference Fig.1 through Fig.6 as follows. Further, the information recording/reproducing apparatus 1 of the embodiment will be explained by taking an example of a case of writing a disk (magnetic recording medium) D having a magnetic recording layer d3 by an inplane
5 recording method.

Fig.1 shows an outline of the information recording/reproducing apparatus 1 according to the embodiment. The information recording/reproducing apparatus 1 includes a near-field optical head 2, a beam 3 made to be movable in XY directions in parallel with a surface of the
10 disk D (a surface of a magnetic recording medium) for supporting the near-field optical head 2 on a front end side thereof in a state of being in parallel with the surface of the disk D and pivotable around two axes (X axis, Y axis) orthogonal to each other, an optical signal controller (light source) 5 for making a light flux L (shown in Fig.2) incident on an optical waveguide 4
15 from a base end side of the optical waveguide 4, an actuator 6 for supporting a base end side of the beam 3 and scanning to move the beam 3 in XY directions in parallel with the surface of the disk D, a spindle motor (rotation driving portion) 7 for rotating the disk D in a constant direction, a control portion 8 for supplying a current modulated in accordance with
20 information to a coil 21, mentioned later, and controlling an operation of the optical signal controller 7, and a housing 9 for containing the respective constituent products at inside thereof.

The housing 9 is formed by a quadrangular shape in an upper view thereof by a metal material of aluminum or the like and is formed with a
25 recessed portion 9a for containing the respective constituent products on an

inner side thereof. Further, the housing 9 is fixed with a lid, not illustrated, attachably and detachably to close an opening of the recessed portion 9a. The spindle motor 7 is attached to substantially a center of the recessed portion 9a and the disk D is attachably and detachably fixed by fitting a center hole thereof to the spindle motor 7. The actuator 6 is attached to a corner portion of the recessed portion 9a. A carriage 11 is attached to the actuator 6 by way of a bearing 10, and the beam 3 is attached to a front end of the carriage 11. Further, both of the carriage 11 and the beam 3 are made to be movable in the XY directions by being driven by the actuator 6. Further, the carriage 11 and the beam 3 are made to be escaped from above the disk D by being driven by the actuator 6 when the disk D stops rotating. Further, a suspension 12 is constituted by the near-field optical head 2 and the beam 3. Further, the optical signal controller 5 is attached to inside of the recessed portion 9a to be contiguous to the actuator 6. Further, the control portion 8 is attached contiguous to the actuator 6.

A detailed structure of the near-field optical head 2 will be explained by showing a sectional view of the near-field optical head 2 and the disk D in Fig.2(a) and an enlarged view of a core 16 and a vicinity thereof of Fig.2(a) in Fig.2 (b).

The near-field optical head 2 heats the disk D by generating near-field light R from the introduced light flux L and records information by producing a switching of magnetization by applying a magnetic field to the disk D. That is, the near-field optical head 2 includes a slider 15 arranged in a state of being floated up from a disk face D1 by a predetermined distance H and having an opposed face 15a opposed to the disk face D1, the

core 16 fixed to the slider 15 for generating the near-field optical light R,
light flux introducing means 17 for introducing the light flux L into the core
16, a first magnetic pole 18 and a second magnetic pole 19 formed at the
core 16, and a magnetic circuit 20 for connecting the two magnetic poles 18
5 and 19.

The slider 15 is formed substantially by a shape of a parallelepiped by
a light transmitting material of quartz glass or the like. The slider 15 is
supported to hang down from a front end of the beam 3 by way of a gimbal
portion 25 in a state of making the opposed face 15a opposed to the disk D.
10 The gimbal portion 25 is a part a movement of which is restricted to
displace only in Z direction orthogonal to the disk face D1, around X axis
and around Y axis. Thereby, the slider 15 is made to be pivotable around
two axes (X axis, Y axis) in parallel with the disk face D1 and orthogonal to
each other.

15 The opposed face 15a of the slider 15 is formed with a projected
portion 15b for generating a pressure for being floated up from a viscosity of
an air flow produced by the rotating disk D. According to the embodiment,
an example is taken by a case of forming two of the projected portions 15b
extended along a longitudinal direction to align in a shape of rails.
20 However, the invention is not limited to the case but any recessed and
projected shape will do so far as the disk 15 is designed to be floated up in
an optimum state by adjusting a positive pressure of separating the slider
15 from the disk face D1 and a negative pressure of attracting the slider 15
to the disk face D1. Further, a surface of the projected portion 15b is
25 referred to as ABS (Air Bearing Surface).

The slider 15 receives a force of being floated up from the disk D1 by the two projected portions 15b and receives a force of being pressed to a side of the disk face D1 by the beam 3. The slider 15 is made to be floated up in a state of being separated from the disk face D1 by a predetermined distance H as described above by a balance of the both forces.

Further, an end face 16b of the core 16 is formed by a size of generating the near-field light R when the light flux L is introduced to inside thereof. That is, the end face 16b of the core 16 is designed to constitute a size far smaller than a wavelength of the light flux L (for example, a size of one side thereof of about several tens nm), which does not transmit normal propagating light but the near-field light R is made to be able to leak out to a vicinity thereof.

Further, an upper face of the slider 15 is formed with a lens 26 at a position right above the core 16. The lens 16 is an aspherical microlens formed by etching using a grey scale mask. Further, the upper face of the slider 15 is attached with the light waveguide 4 of an optical fiber or the like. The optical waveguide 4 is constituted by a mirror face 4a cut by substantially 45 degrees at a front end thereof and a position of attaching the optical waveguide 4 is adjusted such that the mirror face 4a is disposed right above the lens 26. Further, the optical waveguide 4 is led out to be connected to the optical signal controller 5 by way of the beam 3 and the carriage 11 or the like.

Thereby, the optical waveguide 4 is made to be able to introduce the light flux L incident from the optical signal controller 5 to the front end side, change a direction thereof by reflecting the light flux L by the mirror face 4a

and thereafter, emits the light flux L to the lens 26. Further, the emitted light flux L is made to be focused by the lens 26, thereafter, transmitted to the slider 15 to be introduced to a bottom face 16a of the core 16. That is, the optical waveguide 4 and the lens 26 constitute the above-described light
5 flux introducing means 17.

Further, as shown by Fig.2 and Fig.3, a front end face 15c of the slider 15 is formed with a magnetoresistance effect film 27, an electric resistance thereof is changed in accordance with a magnitude of a magnetic field leaked out from the magnetic recording layer d3 of the disk D. The
10 magetoresistance effect film 27 is formed with a width substantially the same as that of the end face 16b of the core 16. The magnetoresistance effect film 27 is supplied with a bias current from the control portion 8 by way of a lead film or the like, not illustrated. Thereby, the control portion 8 can detect a change in the magnetic field leaked out from the disk D as a
15 change in a voltage, and a signal is reproduced from the change in the voltage. That is, the magetoresistance effect film 27 is made to function as a reproducing element.

As shown by Fig.2, the disk D of the embodiment is successively formed with a under layer d2, the magnetic recording layer d3, a protecting
20 layer d4 and a lubricating layer d5 above a substrate d1. The substrate d1 is, for example, an aluminum substrate, a glass substrate or the like. The under layer d2 is for producing an excellent magnetic property even when the magnetic recording layer d3 is thin, and, for example, Cr alloy species is used therefor. For example, a CoCr species alloy of CoCrPtTa or CoCrPtB
25 or the like is used for the magnetic recording layer d3 to increase a

coercivity. The protecting layer d4 is for protecting the magnetic recording layer d3, and, for example, a DLC (diamond-like carbon) film is used therefor. For example, a fluorine species liquid lubricant is used for the lubricating layer d5.

5 Fig.3 shows a structure of the near-field optical head 2 above the opposed face 15a. Further, Fig.4 shows an enlarged view of the core 16.

As shown by Fig.3 and Fig.4, the first magnetic pole 18 and the second magnetic pole 19 are formed on two side faces (side faces opposed to each other in a state of respectively having sides in fours of sides in parallel
10 with each other provided to the bottom face 16a and the end face 16b) 16c aligned along a direction of moving the disk D and opposed to each other in four of the side faces 16c formed at the core 16. The two magnetic poles 18 and 19 are formed on the side face 16c by a magnetic material by a thin film forming technology of vapor deposition or the like. In this way, by
15 arranging the first magnetic pole 18 and the second magnetic pole 19 to be opposed to each other by way of the aperture, a region of irradiating the near-field light to the disk D and a region of irradiating a leakage magnetic flux from the magnetic pole to the disk D can further be coincident with each other, and therefore, a reliability of writing can be promoted by
20 restraining the near-field light and the magnetic field from being widened.

The core 16 is formed by a light transmitting material of quartz glass or the like similar to the slider 15, the core 16 is formed by a shape of a frustrum of a quadrangular cone having the bottom 16a and the end face 16b and the four side faces (a plurality of side faces) 16c. Specifically, the
25 core 16 is worked to include the bottom face 16a formed by a rectangular

shape in a plane view thereof to include sides in parallel with each other, the end face 16b formed by the same shape (rectangular shape in plane view thereof) by an area smaller than that of the bottom face 16a and arranged at a position remote from the bottom face 16a by a predetermined distance, and the four side faces 16c formed by respectively connecting apexes of the bottom face 16a and the end face 16b.

However, the core 16 may be constituted by a core having a bottom face and an end face in a polygonal shape in plane views thereof (for example, hexagonal shape or octagonal shape), and a plurality of side faces connecting respective apexes of the bottom face and the end face (for example, 6 faces when the bottom face and the end face is constituted by a hexagonal shape). That is, a core in a shape of a frustrum of a pyramid in which a bottom face and an end face thereof are formed in a polygonal shape in plane views thereof will do. Further, the bottom face and the end face may not be constituted by shapes the same as each other.

As shown by Fig.2, the core 16 constituted in this way is fixed in a state of bringing the bottom face 15a into face contact with the opposed face 16a of the slider 15. At this occasion, the core 16 is fixed such that the two side faces 16c opposed to each other are aligned along a longitudinal direction of the slider 15, that is, the moving direction of the disk D. Further, the core 16 and the slider 15 may be formed separately from each other to be fixed to each other, or may integrally be fabricated from quartz glass or the like. Particularly, it is further preferable to integrally form the core 16 since a fabricating step can be simplified, a fabricating time period can be shortened and the like.

Further, since the bottom face 16a is brought into face contact with the opposed face 15a, also the end face 16b of the core 16 is similarly brought into a state of being in parallel with the opposed face 15a of the slider 15 and the disk face D1. At this occasion, a height of the core 16 is set such that a height of the end face 16b becomes the same as a height of the projected portion 15b.

Here, the end face 16b of the core 16 is formed by a shape the same as that of the bottom face 16a by a size smaller than that of the bottom face 16a as described above, and therefore, the four side faces 16c are brought into a state of inclined faces in which distances of the side faces 16c opposed to each other are gradually narrowed as proceeding to the end face 16b. Particularly, the size of the end face 16b of the core 16 is an extremely small size for generating the near-field light R, and therefore, an interval (magnetic gap) G between the two magnetic poles 18 and 19 at the end face 16b is brought into a state of being very short. That is, the small magnetic gap G is constituted.

Further, as shown by Fig.3, the magnetic circuit 20 is formed by being patterned at inside of the slider 15 by a magnetic material. Both ends of the magnetic circuit 20 are respectively connected to the first magnetic pole 18 and the second magnetic pole 19.

Further, the coil 21 is formed in a state of being wound in a spiral shape at a surrounding of a portion of the magnetic circuit 20. At this occasion, intervals of wires contiguous to each other of the coil 21 and an interval between the coil 21 and the magnetic circuit 20 are brought into an insulating state so as not to be shortcircuited. Further, the coil 21 is

electrically connected to the control portion 8 by way of the beam 3 or the carriage 11 and is supplied with a current modulated in accordance with information from the control portion 8. That is, the magnetic circuit 20 and the coil 21 constitute an electromagnet as a whole.

5 Fig.5(a) shows a detailed behavior of winding the coil 21 around the magnetic circuit 20. Further, Fig.5(b) shows a sectional view taken along a line A-A' of Fig.5(a), and Fig.5(c) shows a sectional view taken along a line B-B' thereof. The coil 21 is constituted by a structure similar to that of a coil winding a conductor substantially on a circular cylinder in a spiral
10 shape, or a so-to-speak solenoid coil structure.

In this way, there is constructed not a constitution of winding the coil 21 in the spiral shape on the same plane as in a constitution of the background art but a constitution of winding the coil 21 around the magnetic circuit 20. Thereby, a size of a coil of an amount of one turn
15 (single coil) of the coil 21 becomes substantially the same as a size of other single coil, an intensity of a magnetic field generated by the single coil of the coil is not extremely reduced more than an intensity of a magnetic field generated by the other single coil, and therefore, a magnetic field intensity of a total of the coil 21 can be made to be higher than that of the structure of
20 the background art. That is, loss of a generated magnetic field relative to a current made to flow in the coil 21 can be made to be smaller than that of the coil structure winding the conductor in the spiral shape on a plane mounted to the magnetic recording head of the background art and a magnetic field which is stronger and with higher efficiency can be
25 generated.

Next, an explanation will be given as follows of a case of recording/reproducing various kinds of information at the disk D by the information recording/reproducing apparatus 1 constituted in this way.

First, the disk D is rotated in a constant direction by driving the spindle motor 7. Next, the beam 3 is scanned in XY directions by way of the carriage 11 by operating the actuator 6. Thereby, as shown by Fig.1, the near-field optical head 2 can be disposed at a desired position on the disk D. At this occasion, the near-field optical head 2 receives a force of being floated up by the two projected portions 15b formed at the opposed face 15a of the slider 15 and is pressed by a predetermined force to the side of the disk D by the beam 3 or the like. The near-field optical head 2 is floated up to a position separated above the disk D by the predetermined distance H as shown by Fig.2 by a balance of the both forces.

Further, the near-field optical head 2 is constituted such that even when the near-field optical head 2 receives air pressure generated by being caused by a waveness of the disk D, the near-field optical head 2 can be displaced in Z direction or around XY axes of the gimbal portion 25, and therefore, the near-field optical head 2 can absorb the air pressure caused by the waveness. Therefore, the near-field optical head 2 can be floated up in a stable state.

Here, when information is recorded, the control portion 8 operates the optical signal controller 5 and supplies a current modulated in accordance with the information to the coil 21.

The optical signal controller 5 makes the light flux L incident from the base end side of the optical waveguide 4 by receiving an instruction from

the control portion 8. The incident light flux L propagates to the front end side at inside of the optical waveguide 4 and is emitted from inside of the optical waveguide 4 by changing the direction by the mirror face 4a substantially by 90 degrees as shown by Fig.2. The emitted light flux L
5 transmits through an inner portion of the slider 15 in a state of being focused by the lens 26 and is incident on an inner portion of the core 16 provided substantially right below the lens 26 from a side of the bottom face 16a. That is, the light flux L is introduced to the core 16 linearly from the side of the upper face of the slider 15 by the light flux introducing means 17.

10 The light flux L introduced to the inner portion of the core 16 propagates from the side of the bottom face 16a to the side of the end face 16b and is leaked out to outside as the near-field light R from the end face 16b opposed to the disk face D1. That is, the near-field light R can be generated from the end face 16b of the core 16.

15 In this way, the light flux L can be introduced substantially linearly from the side of the upper face of the slider 15 to the end face 16b of the core 16, and therefore, different from a way of inputting light of the background art, the light flux L can easily be introduced from the upper face of the slider 15, and the near-field light R can efficiently be generated. By the
20 near-field light R, the magnetic recording layer d3 of the disk D is locally heated and the coercivity is lowered temporarily.

Further, it is preferable to form the two magnetic poles 18 and 19 formed at the side faces 16c of the core 16 by an optically nontransmitting material. Thereby, the light flux L can be prevented from leaked from the
25 side faces 16c formed with the two magnetic pole 18 and 19 to outside of the

core 16, and the near-field light R can efficiently be generated by converging the light flux L by the end face 16b.

On the other hand, when the current is supplied to the coil 21 by the control portion 8, by the principle of the electromagnet, the current
5 magnetic field generates the magnetic flux at inside of the magnetic circuit 20, and therefore, the magnetic field is generated between the two magnetic poles 18 and 19. Thereby, at the magnetic gap G between the two magnetic pole 18 and 19, as shown by Fig.2(b), the magnetic field is leaked out to the disk D. At this occasion, as described above, the magnetic gap G
10 constitutes the small gap by forming the two magnetic poles 18 and 19 at the side faces 16c of the core 16. Therefore, the leakage magnetic field generated at the magnetic gap G is locally operated to the magnetic recording layer d3 of the disk D.

Thereby, the leakage magnetic field can be operated with a pinpoint
15 accuracy to a local position of the magnetic recording layer d3 the coercivity of which is lowered by the near-field light R. Further, a direction of the leakage magnetic field is inverted in accordance with information to be recorded.

Further, when the magnetic recording layer d3 of the disk D receives
20 the leakage magnetic flux, a direction of magnetization is inverted in accordance with the direction of the leakage magnetic field. As a result, information can be recorded to the disk D. That is, information can be recorded by the near-field light assisting magnetic recording system for making the near-field light R and the leakage magnetic field generated at
25 two magnetic poles 18 and 19 cooperate with each other.

Next, when information recorded to the disk D is reproduced, the magnetoresistance effect film 27 formed at the front end face 15c of the slider 15 receives the magnetic field leaked out from the magnetic recording layer d3 of the disk D and an electric resistance thereof is changed in accordance with the magnitude. Therefore, a voltage of the magnetoresistance effect film 27 is changed. Thereby, the control portion 8 can detect a change in the magnetic field leaked out from the disk D as a change in the voltage. Further, the control portion 8 can reproduce information by reproducing a signal from the change in the voltage.

Further, according to the core 16 for generating the near-field light R, the bottom face 16a and the end face 16b are provided to be in parallel with the disk face D1 and the opposed face 15a of the slider 15, and therefore, the light flux introducing means 17 can easily and firmly introduce the light flux L from the upper face of the slider 15.

Further, by only fixing the core 16 to the opposed face 15a of the slider 15 and forming the two magnetic poles 18 and 19 at the side face 16c of the core 16, generation of the near-field light R and generation of the leaked magnetic field can simultaneously be achieved, and therefore, a simple structure can be constituted without constructing a complicated constitution as in the background art. Therefore, the constitution can be simplified and small-sized formation can be achieved.

Further, the light flux L introduced from the side of the bottom face 16a of the core 16 naturally propagates to the end face 16b, and therefore, the near-field light R can efficiently be generated. Therefore, the near-field light R and the leakage magnetic flux can further efficiently be made to

cooperate with each other.

Further, different from the background art, the near-field light R can be generated between the two magnetic poles 18 and 19, and therefore, a peak position of a heating temperature by the near-field light R can be disposed within a range of operating the leakage magnetic flux. Particularly, even when a peak position of a temperature gradient of heating by the near-field light R is shifted from the peak position of the leakage magnetic flux, the peak position of the heating temperature can be made to stay within the range of the leakage magnetic flux. Therefore, recording can be carried out firmly to a local position of the disk D, and promotion of reliability and higher recording density formation and the disk can be achieved. Further, the first magnetic pole 18 and the second magnetic pole 19 are aligned along the direction of moving the disk D, and therefore, the two magnetic poles 18 and 19 can be made to be disposed firmly above a track of the disk D. Therefore, information can accurately be recorded to a desired track without effecting an information recorded on a track contiguous thereto.

Fig.6 is an outline view of a method of fabricating the coil 21 wound around the magnetic circuit 20. Fig.6(a) shows a section taken along a line A-A' of Fig.5(a) and Fig.6(b) shows a section taken along a line B-B' of Fig.5(a). Respective rows of S1 through S6 show fabricating steps. First, at step S1, a lower wiring 21a is formed at a vicinity of the core 16 of the opposed face 15a of the slider 15 by a conductive material, for example, Au or the like. A film of the lower wiring 21a can be formed by means of sputtering, vacuum vapor deposition or the like. Patterning of the lower

wiring 21a can be carried out by forming a film of the conductive material, patterning a photoresist thereon, thereafter, using a dry etching method or a wet etching method. As other means of patterning the lower wiring 21a, there is also a method of patterning a photoresist on the opposed face 16a, forming a film of a conductive material on the patterned photoresist to be lifted off thereafter.

Next, at step S2, a lower insulating layer 22a arranged between the lower wiring 21a and the magnetic circuit 20 is formed. The lower insulating layer 22a can easily be formed when, for example, a photoresist of SU-8 or the like is used. Further, although after forming the lower insulating layer 22a, an upper face 22c may not be polished, when polished, by flattening the upper face 22c, the magnetic circuit 20 capable of achieving an always uniform film thickness and having an excellent pattern accuracy can be formed on the lower insulating layer.

Next, at step S3, the magnetic circuit 20 is formed on the lower insulating layer 22a by using a magnetic material of permalloy or the like. A film of the magnetic circuit 20 is formed by means of sputtering, vacuum vapor deposition or the like. Patterning of the magnetic circuit 20 can be carried out by forming a film of a magnetic material, patterning a photoresist thereon, thereafter, using a dry etching method or a wet etching method. Further, as other means of patterning the magnetic circuit 20, there is also a method of patterning a photoresist on the lower insulating layer 22a, forming a film of a magnetic material on the patterned photoresist to be lifted off thereafter. Next, at step S4, an upper insulating layer 22b is formed by a material and a method substantially similar to

those of the lower insulating layer 22a. Further, although after forming the upper insulating layer 22b, an upper face 22d may not be polished, when polished, by flattening the upper face 22d, an upper wiring 21b and a side wiring 21c (not illustrated) capable of forming always uniform film thicknesses and having an excellent pattern accuracy can be formed at an upper face and a side face of the upper insulating layer 22b.

Next, at step S5, the upper wiring 21b can be formed by a material and a method similar to those of the lower wiring 21a. The upper wiring 21b and the side wiring 21c can be formed simultaneously by using one photoresist, or only the side wiring 21c may be formed precedingly by using a photoresist patterning, thereafter, the upper wiring 21b may successively be formed.

Finally, at step S6, an outer insulating layer 22e for covering a total of the coil structure 21 fabricated up to the above-described is formed by a material and a method similar to those in forming the lower insulating layers 22a and 22b.

As described above, according to the near-field optical head 2 of the embodiment, the near-field light R can efficiently be generated while achieving small-sized formation, the magnetic field which is stronger and with a higher efficiency can be generated, and the reliability of writing can be promoted.

Further, according to information recording/reproducing apparatus 1 of the embodiment, the above-described near-field optical head 2 is provided, and therefore, the information recording/reproducing apparatus 1 per se can be downsized, further, high quality formation can be achieved by

promoting the reliability of writing.

Further, the core 16 of the near-field light optical head 2 may be formed with metal films respectively between the side face 16c and two magnetic poles 18 and 19, and the metal films may be formed on all of the side faces 16c other than the side face 16c formed with the two magnetic poles 18 and 19. Surface plasmon is excited from the surface of the metal film formed on the side face 16c to constitute the near-field light R having a high optical intensity to leak out to outside. The light flux L introduced to inside of the core 16 is not leaked out to outside of the core 16 in the midst of propagating to the end face 16b. Therefore, the light flux L can be converged to the end face 16b without loss and the near-field light R which is further efficient and having a higher optical intensity can be generated. As a result, the disk D can further efficiently be heated and information can further easily be recorded.

Further, although according to the above-described respective embodiments, an explanation has been given by taking an example of a case of carrying out recording by the inplane recording method, the invention is not limited to the recording method but is applicable also to the perpendicular recording method.

Further, according to the embodiment, an explanation has been given such that the coil 21 is wound around a coil axis orthogonal to a direction of laminating the upper wiring 21b and the lower wiring 21a, and respective sectional areas along the direction orthogonal to the coil axis are substantially the same. In this case, the "substantially the same" includes not only a case in which the respective sectional areas are completely the

same but also the respective sectional areas pertain to within ± 5 % relative to other sectional area.

(Embodiment 2)

Next, a second embodiment of a near-field optical head according to the invention will be explained in reference to Fig.7. Further, constitutions of the second embodiment the same as those of the first embodiment are attached with the same notations and an explanation thereof will be omitted.

Although in Fig.5(a), the structure of winding the coil 21 around the magnetic circuit 20 is shown, in Fig.7, a structure of providing a plurality of magnetic circuits on the opposed face 15a as in 20a and 20b. Thereby, the coils 21 can be wound around both of the magnetic circuits 20a and 20b, a magnetic field generating effect similar to that of the structure shown in Fig.5(a) is achieved, a magnetic field which is stronger than that of the structure shown in Fig.5(a) can be generated between the magnetic poles 18 and 19, and further stable magnetic recording can be carried out.

Further, also in a fabricating method, by only providing a pattern of forming pluralities of magnetic circuits and coils at the photomask used in fabricating the structure of Fig.5(a), the structure shown in Fig.7 can efficiently be fabricated by a method substantially the same as the method of fabricating the structure of Fig.5(a) without increasing fabricating steps.

Further, also a structure of winding surroundings of not portions of but substantially a total of the magnetic circuits 20a and 20b by the single coil 21 can also be constituted.

(Embodiment 3)

Next, a third embodiment of a near-field optical head according to the invention will be explained in reference to Fig.8. Further, constitutions of the third embodiment the same as those of the first embodiment and the second embodiment are attached with the same notations and an
5 explanation thereof will be omitted.

Fig.8(a) shows an example of a structure of respectively winding a plurality of the coils 21 at surroundings of the single magnetic circuit 20. With regard to an effect thereof, a leakage magnetic field which is stronger than that of the structure shown in Fig.5(a) can be generated between the
10 magnetic poles 18 and 19 and further stable magnetic recording can be carried out.

Further, also in a fabricating method, by changing only a coil fabricating pattern of a photomask used in fabricating into a plurality thereof, the structure can be fabricated efficiently by a method similar to
15 that of the fabricating method of the structure of Fig.5(a).

Further, Fig.8(b) shows an example of a structure of respectively winding a plurality of the coils 21 at surroundings of a plurality of magnetic circuits 20a and 20b. With regard to an effect thereof, a leakage magnetic field which is further stronger than that of the structure shown in Fig.7 can
20 be generated between the magnetic poles 18 and 19, and further stable magnetic recording can be carried out. Further, also with regard to a fabricating method, by changing only the coil fabricating pattern of the photomask used in fabricating to a plurality thereof, the structure can efficiently be fabricated by a method substantially similar to the method of
25 fabricating the structure of Fig.7.

Further, there may be constituted a structure connecting all of the plurality of the coils 21 in series as shown by Figs.8(a) and 8(b), or there may be constituted a structure of winding all of the surrounding of the magnetic circuit 20 in a state of connecting the plurality of coils 21 in series.

5 (Embodiment 4)

Next, a fourth embodiment of a near-field optical head according to the invention will be explained in reference to Fig.9. Further, constitutions of the fourth embodiment the same as those of the first embodiment through the third embodiment are attached with the same notations and an explanation thereof will be omitted.

Fig.9(a) shows an example of a so-to-speak double coil structure in which first, the coil 21 is wound at the surrounding of the magnetic field 20 and a coil 21' is further wound at surroundings of a portion of the coil 21 at a portion of the magnetic circuit 20. The coil 21' is insulated from the coil 21 and the magnetic circuit 20 so as not to be shortcircuited therewith.

Fig.9(b) shows a sectional view taken along a line A-A' and Fig.9(c) shows a sectional view taken along a line B-B' of Fig.9(a). The section B-B' is constituted by being cut skewedly relative to the section A-A' different from the section B-B' of Fig.5(a).

20 In comparison with the structure shown in Fig.5(a), the structure shown in Fig.9 can generate a stronger leakage magnetic field between the magnetic poles 18 and 19 and further stable magnetic recording can be carried out.

Fig.10 is an outline view of a method of fabricating the structure shown in Fig.9(a) (A-A' sectional view). Although the fabricating method is

25

similar to the fabricating method of the coil structure 21 shown in Fig.5, before providing the coil structure 21, steps of S1' and S2' are carried out and a lower wiring 21a' and a lower insulating layer 22a' are formed. The lower wiring 21a' and the lower insulating layer 22a' are formed by a method substantially the same as the method shown by steps S1 and S2 of Fig.6.

Next, the coil structure 21 comprising 21a, 21b and 21c shown in Fig.6(b) is fabricated above the lower insulating layer 22a' by a method similar to steps S1 through S6 of Fig.6. 21c does not appear in Fig.10. However, at S6, the upper insulating layer 22b is formed to constitute an area substantially similar to that of the lower insulating layer 22a' at step S2'. Thereby, the coil structure 21' comprising 21a', 21b' and 21c' is insulated from the magnetic circuit 20. 21c' does not appear in Fig.10.

Next, an upper face and a side face of the upper insulating layer 22e are formed with the upper wiring 21b' and the side wiring 21c' illustrated in Fig.9(c) by carrying out step S3'. At this occasion, similar to fabricating the coil structure 21, the upper wiring 21b' and the side wiring 21c' may simultaneously be patterned to form, or after forming the side wiring 21c' precedingly, the upper wiring 21b' may successively be formed. The forming is carried out by a method similar to the method of forming the upper wiring 21b and the side wiring 21c at step S3 of Fig.6.

Finally, an outer insulating layer 22e' is formed to cover a total of the coil structure 21' by carrying out step S4'. The forming is carried out by a method substantially similar to the method of forming the outer insulating layer 22e at step S6 of Fig.6.

(Embodiment 5)

Next, a fifth embodiment of a near-field optical head according to the invention will be explained in reference to Fig.11. Further, constitutions of the fifth embodiment the same as those of the first
5 embodiment through the fourth embodiment are attached with the same notations and an explanation thereof will be omitted.

Fig.11 shows an example of a structure of separating the magnetic circuit 20 shown in Fig.5(a) and arranging two independent magnetic circuits of 20c and 20d connected to the magnetic poles 18 and 19 and
10 arranged on the opposed face 15a. Further, the coil structures 21 similar to the coil structure shown in Fig.5(a) are respectively wound at surroundings of portions of the magnetic circuits 20c and 20d.

According to the structure shown in Fig.11, in comparison with the structure shown in Fig.5(a), a magnetic circuit portion can further be
15 reduced, and can be arranged also on a narrower opposed face of a further downsized slider.

Further, with regard to the fabricating method, by only changing the magnetic circuit fabricating pattern and the coil fabricating pattern of the photomask used in fabricating the structure of Fig.5(a), the structure can be
20 fabricated by a method similar to the method of fabricating the structure of Fig.5(a).

(Embodiment 6)

Next, a sixth embodiment of a near-field optical head according to the invention will be explained in reference to Fig.12 through Fig.13.
25 Further, constitutions of the sixth embodiment similar to those of the first

embodiment through the fifth embodiment are attached with the same notations and an explanation thereof will be omitted.

Fig.12 shows an example of constitutions of a coil 121, a magnetic circuit 120, and insulating layers 122a, 122b and 122e.

5 Fig.13 shows four examples of sectional views taken along a line B-B' of Fig.12(a).

A structure shown in Fig.12 is characterized in that although the structure is constituted by the structure of winding the coil 121 around the magnetic circuit 120 (structure similar to solenoid coil structure), shapes of
10 the insulating layers 122a and 122b differ from shapes of the insulating layers (122a, 122b, 122e) of the structure shown in Fig.5.

As an example, according to the insulating layers 122a and 122b shown in Fig.12(b) (sectional view taken along a line A-A' of Fig.12(a)) and Fig.13(a) (sectional view taken along a line B-B' of Fig.12(a)), shapes of side
15 faces 1122a and 1122b thereof are constituted by shapes of inclined faces having predetermined angles relative to the opposed face 15a in directions of being remote from the opposed face 15a. Thereby, a thickness of an inclined portion 1120 formed on the side face 1122a can be formed by a thickness similar to that of the magnetic circuit 120. Further, when a film
20 forming method of a sputtering method, a vapor deposition method or the like is used, there is frequently a case in which generally, film forming on a face in a direction substantially orthogonal to a direction of a film forming particle is easy and film forming on a face in a direction substantially in parallel with the direction of the film forming particle is difficult by a cause
25 of an edge coverage failure or the like and an adhering force of a film or a

film density is lowered. Therefore, by constituting the side face 1122a of the insulating layer 122a is not by a shape in which the side faces of the insulating layers (22a, 22b, 22e) are orthogonal to the opposed face 15a as shown by Fig.5 but by an inclined face, the inclined portion 1120 is promoted in a force of adhering to the side face 1122a or the film density.

Further, according to the insulating layers 122a and 122b shown in Fig.13(a) (sectional view taken along a line B-B' of Fig.12(a)), shapes of the side faces 1122a and 1122b are constituted by shapes of inclined faces having a predetermined angle relative to the opposed face 15a. Thereby, side faces wiring 121c of the coil 121 formed on the side faces 1122a and 1122b are promoted in the forces of adhering to the side faces 1122a and 1122b or in the film density by the above-described reason and a thickness thereof can be formed by a thickness similar to those of the lower wiring 121a and the upper wiring 121b.

Further, as shown by Fig.13(b) (sectional view taken along a line B-B' of Fig.12(a)), by constituting structures of vicinities of side faces 2122a 2122b of the insulating layers 122a and 122b by a stepped structure, the side face wiring 221c is promoted in the force of adhering to the side faces 2122a and 2122b or in the film density, and a thickness of a side face wiring 321c can be formed to be proximate to thicknesss of the lower wiring 121a and the upper wiring 121b.

Further, as shown by Fig.13(c) (sectional view taken along a line B-B' of Fig.12(a)), by constituting structures of vicinities of side faces 3122a and 3122b of the insulating layers 122a and 122b by a stepped structure having a shape of an inclined face, the side wiring 321c is promoted in the

force of adhering to the side faces 3122a and 3122b or in the film density, and a thickness of the side wiring 321c can be formed to be proximate to thicknesss of the lower wiring 120a and the upper wiring 120b.

Further, as shown by Fig.13(d) (sectional view taken along a line
5 B-B' of Fig.12(a)), by forming a side face 2120 of the magnetic circuit 120 by a shape of an inclined face, in forming the insulating layer 112b, a side face 4121b naturally becomes a shape of an inclined face. Further, by constituting structures of side faces 4122a and 4122b of the insulating layers 122a and 122b by a stepped structure having a shape of an inclined
10 face, a side face wiring 421c is promoted in the force of adhering to the side faces 4122a and 4122b or in the film density, and a thickness of the side face wiring 421c can be constituted by a thickness similar to those of the lower wiring 120a and the upper wiring 120b.

In this way, by providing the characteristic of the structure shown in
15 Fig.5 to the structures shown in Fig.12 and Fig.13 and constituting shapes of the side faces 1122a, 2122a, 3122a, 4122a and 1122b, 2122b, 3122b, 4122b by the shape of the inclined face or the stepped shape, the densities of the films of the magnetic circuit 120 and the coil 121 are not lowered at middles thereof, thicknesses thereof are not thinned, or the magnetic circuit
20 120 and the coil 121 are not disconnected. Further, a resistance value of the coil 121 is not increased at the middle of wiring by lowering the density of the film, a variation in the thickness or disconnection. Therefore, the magnetic field can be generated at the magnetic circuit 120 efficiently by the coil 121, and a stronger leakage magnetic field can be generated
25 between the magnetic poles 18 and 19. Therefore, magnetic recording can

be carried out further efficiently and stably.

Although the structures shown in Fig.12 and Fig.13 can be fabricated by a fabricating method similar to that of the structure shown in Fig.5, after skewedly working the side face of the lower insulating layer 22a formed at step S2 of Fig.6, when the magnetic circuit 20 is formed at step S3, the inclined portion 1120 of the magnetic circuit 120 of the shape of the inclined face as shown by Fig.12(b) can be formed.

Further, after step S4 of Fig.6, by skewedly working the side faces of the insulating layers 22a and 22b, the side faces 1122a and 1122b of the shape of the inclined face shown in Fig.13(a) can be provided.

The inclined face shape can easily be worked when a dry etching method utilizing reactive ion etching is used.

Further, by carrying out patterning such that an area of the upper insulating layer 22b shown in (b) of step S4 is smaller than an area of the lower insulating layer 22a shown in (b) of step S2 of Fig.6, the side faces 2122a and 2122b of the stepped structure shown in Fig.13(b) can be formed. Further, thereafter, when the side faces 2122a and 2122b are worked skewedly, the side faces 3122a and 3122b of the stepped structure having the inclined face shape as shown by Fig.13(c) can be formed.

Further, when a thin film forming method of sputtering, vapor deposition or the like utilizing a 2 layers resist lift off method for the magnetic circuit 20 formed at step S3 of Fig.6, the magnetic circuit 120 having the side face 2120 of the inclined face shown in Fig.13(d) can be formed.

Further, also in the structures shown in Figs.7, 8, 9 and 11, the

insulating layers 22a and 22b having the side faces in the inclined face shape or the stepped shape shown in Fig.12 and Fig.13 can be formed. Further, with regard to working or forming, a method similar to the method of fabricating the structure shown in Fig.12 and Fig.13 can be used.

5

INDUSTRIAL APPLICABILITY

According to the invention, near-field light can efficiently be generated while achieving small-sized formation, and a magnetic field which is stronger and with a higher efficiency can be generated.

10

What is claimed is:

1. A near-field optical head for heating a magnetic recoding medium rotated in a constant direction by generating near-field light from an introduced light flux and recording information by bringing about a switching of magnetization by
5 applying a magnetic field to the magnetic recording medium, the near-field optical head including:

a slider arranged in a state of being floated up from a surface of the magnetic recording medium by a predetermined distance and having an opposed face opposed to the surface of the magnetic recording medium;

10 a near-field light generating element formed on the opposed face for generating the near-field light;

a magnetic pole formed above the near-field light generating element;

a plurality of lower wirings formed above the opposed face;

a magnetic circuit in a shape of a thin film arranged at a position of
15 covering the plurality of lower wirings and connected to the magnetic pole;

a plurality of upper wirings arranged on a side reverse to a side of arranging the plurality of lower wirings in both sides of the magnetic circuit;

an insulating layer for insulating the respective of the lower side wirings, the magnetic circuit and the upper side wirings; and

20 a coil wound around a surrounding of the magnetic circuit by connecting the lower wirings and the upper wirings alternately in series.

2. The near-field optical head according to Claim 1, wherein the near-field light generating element includes an aperture for generating the near-field light;

wherein the magnetic pole includes a first magnetic pole and a second
25 magnetic pole constituting portions of edge portions surrounding the aperture; and

wherein the first magnetic pole and the second magnetic pole are arranged to be opposed to each other.

3. The near-field optical head according to Claim 2, wherein the magnetic circuit is formed to connect the first magnetic pole and the second magnetic pole.

4. The near-field optical head according to Claim 1, wherein a plurality of pieces of the magnetic circuits are formed above the opposed face, and the coils are
5 respectively wound around surroundings of the plurality of pieces of the magnetic circuits.

5. The near-field optical head according to Claim 1 or 4, wherein a plurality of pieces of the coils are wound around a surrounding of the magnetic circuit.

6. The near-field optical head according to Claim 1, wherein the lower wiring
10 and the upper wiring comprise pluralities of wirings insulated from each other piece by piece.

7. The near-field optical head according to Claim 2, wherein the first magnetic pole and the second magnetic pole are separated from each other, the first magnetic pole and the second magnetic pole are respectively formed with the
15 magnetic circuits, and the coils are respectively wound around surroundings of the magnetic circuits.

8. The near-field optical head according to Claim 2, wherein the coil is wound around a coil axis orthogonal to a direction of laminating the upper wirings and the lower wirings, and respective sectional areas along the direction orthogonal to
20 the coil axis are substantially the same.

9. The near-field optical head according to Claim 1, wherein the lower wirings and the upper wirings are connected alternately in series by side face wirings formed on a specific side face of the insulating layer to constitute a shape of the coil wound around the surrounding of the magnetic circuit.

25 10. The near-field optical head according to Claim 9, wherein at least a portion of the specific side face constitutes a shape of an inclined face having a predetermined angle relative to the opposed face.

11. The near-field optical head according to Claim 9, wherein at least a portion of the specific side face constitutes a stepped shape.

12. A fabricating method of a near-field optical head according to Claim 1, wherein a step of fabricating the near-field optical head includes a step of forming
5 a width of the magnetic circuit to successively reduce in a direction of being remote from an opposed face.

13. An information recording/reproducing apparatus including:

a near-field optical head according to any one of Claims 1 through 14;

a beam made to be movable in a direction in parallel with the surface of the
10 magnetic recording medium for supporting the near-field optical head on a front end side thereof in a state of being pivotable around two axes in parallel with the surface of the magnetic recording medium and orthogonal to each other;

light flux introducing means fixed to the slider in a state of being arranged in parallel with the slider for introducing the incident light flux to the near-field
15 light generating element;

a light source for making the light flux incident on the light flux introducing means;

an actuator for supporting a base end side of the beam and moving the beam in a direction in parallel with the surface of the magnetic recording medium;

20 a rotation driving portion for rotating the magnetic recording medium in the constant direction; and

a control portion for supplying a current to the coil and controlling an operation of the light source.

FIG. 3

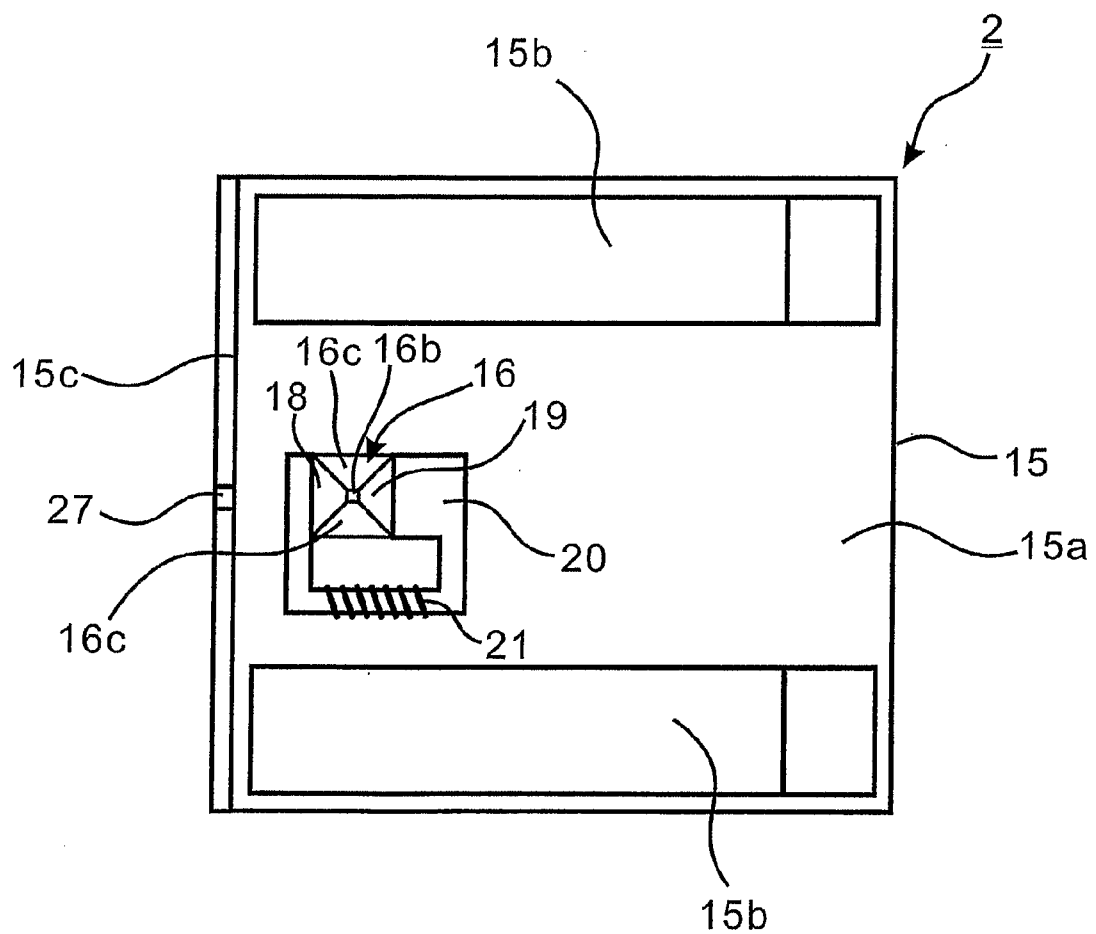


FIG. 4

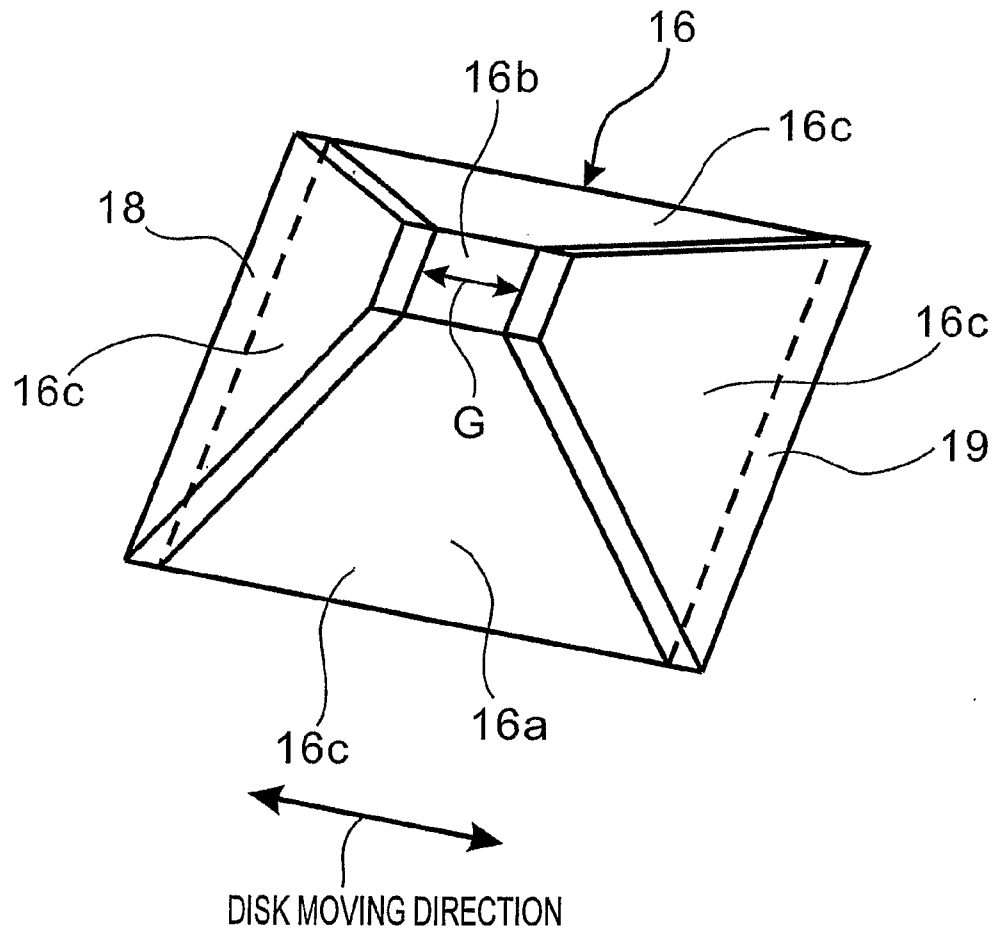


FIG. 5A

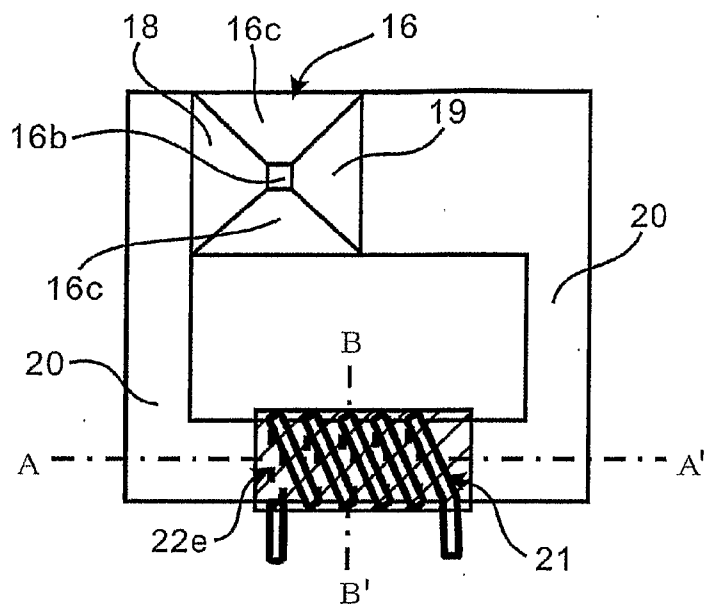


FIG. 5B

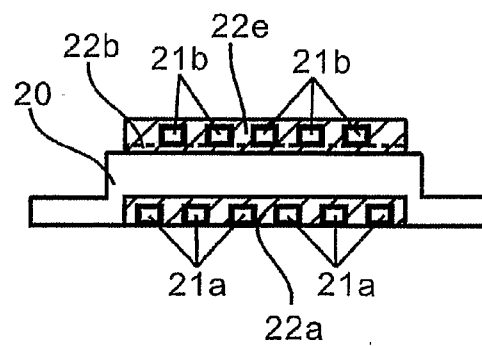


FIG. 5C

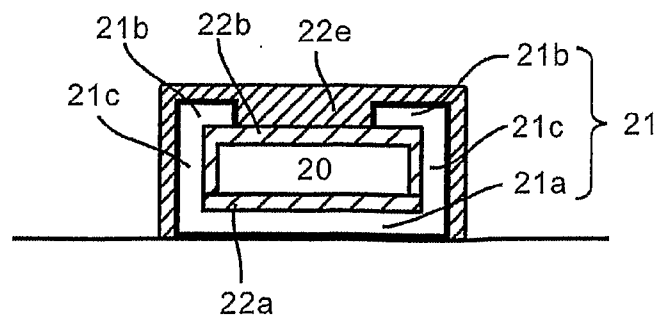


FIG. 6A

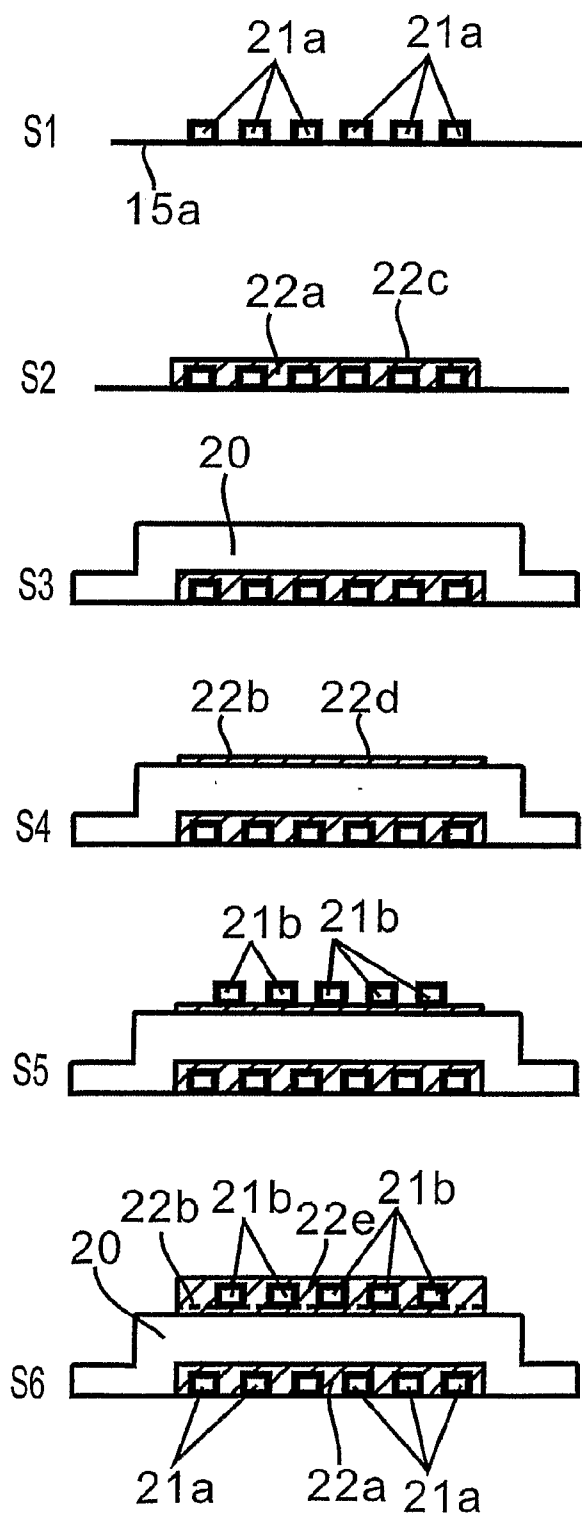


FIG. 6B

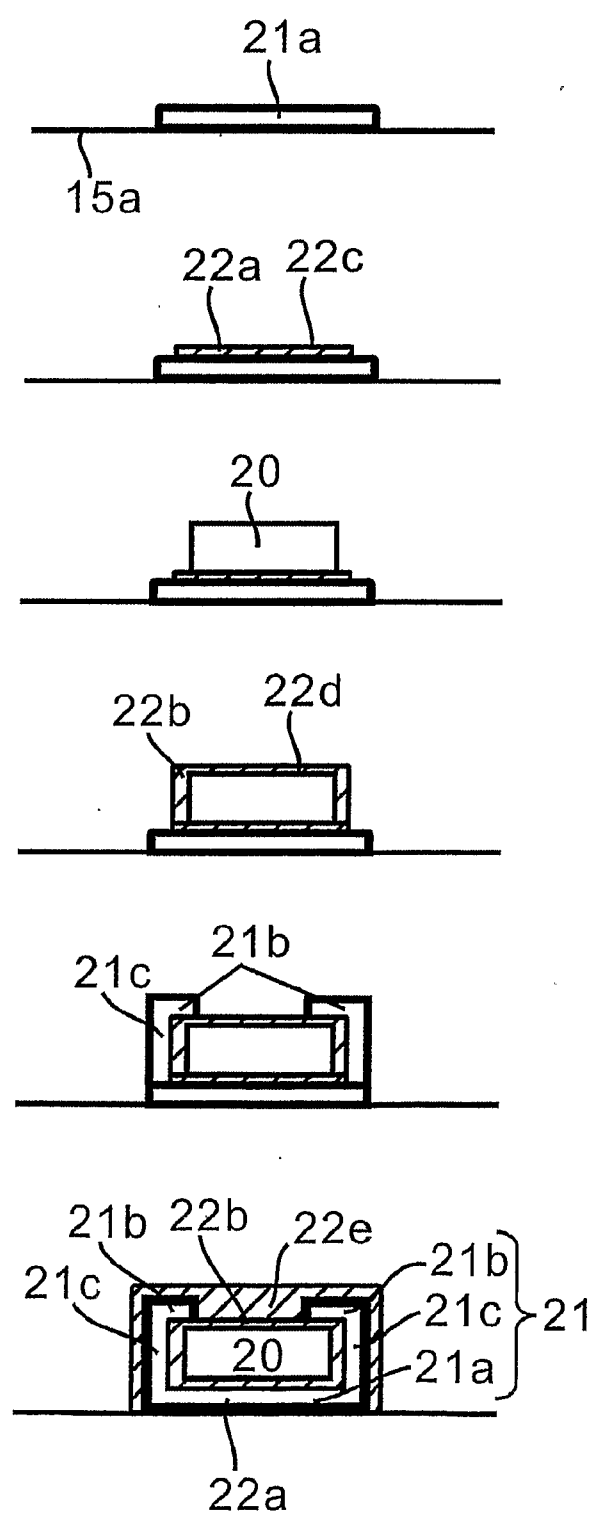


FIG. 7

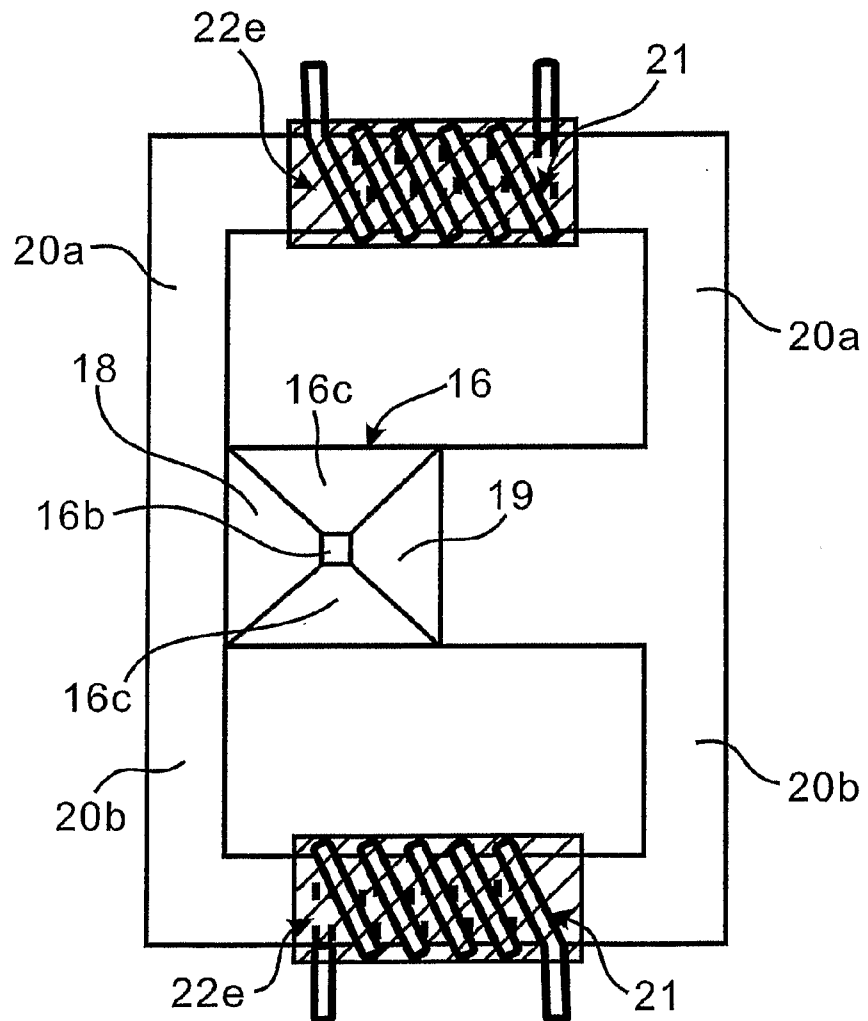


FIG. 8A

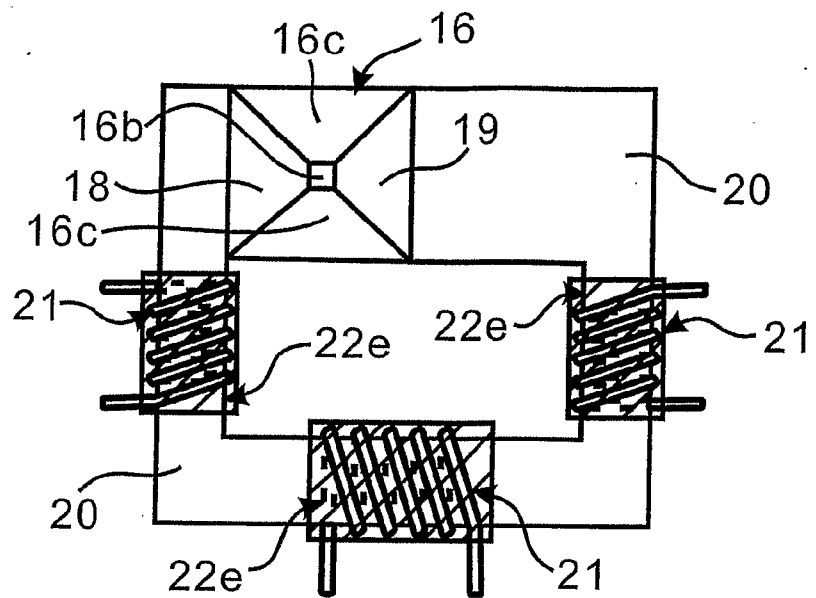


FIG. 8B

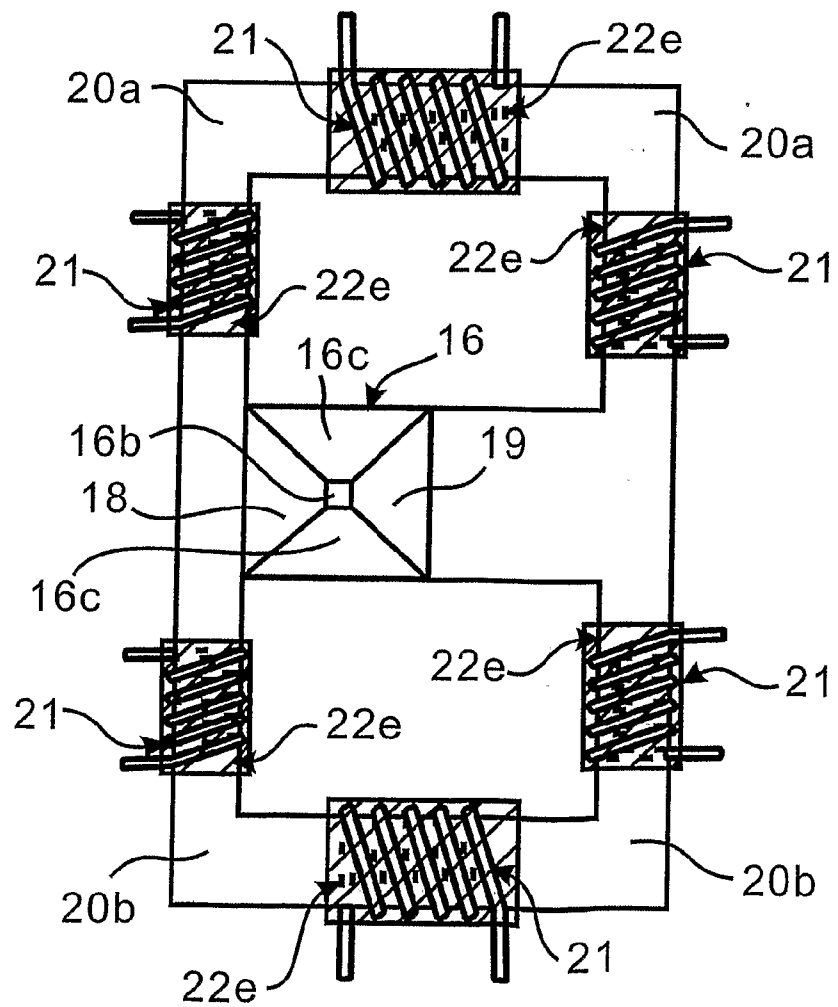


FIG. 9A

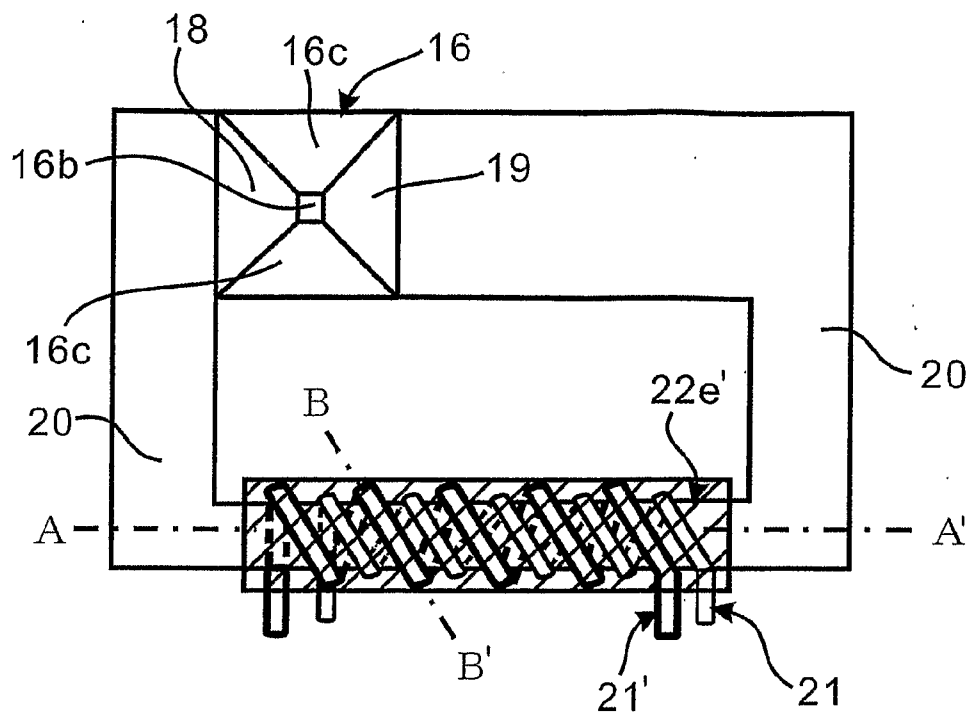


FIG. 9B

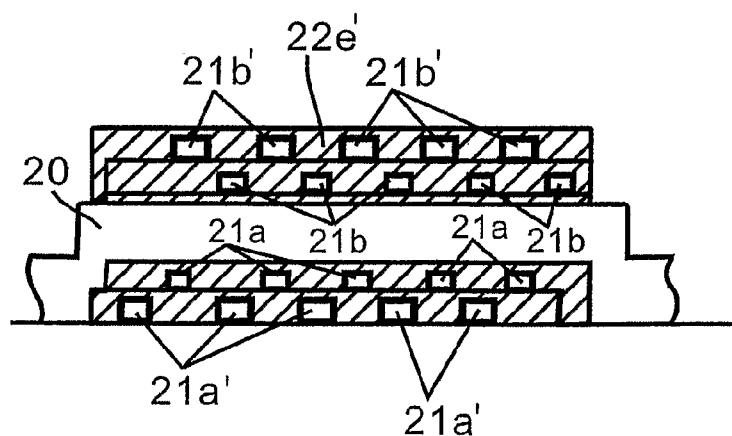


FIG. 9C

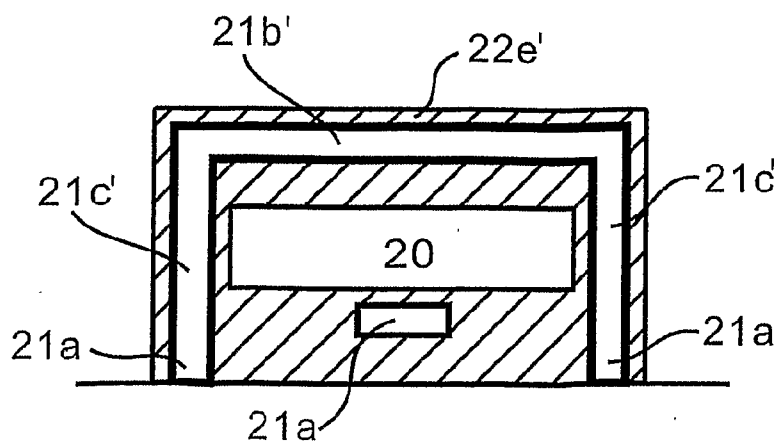


FIG. 10

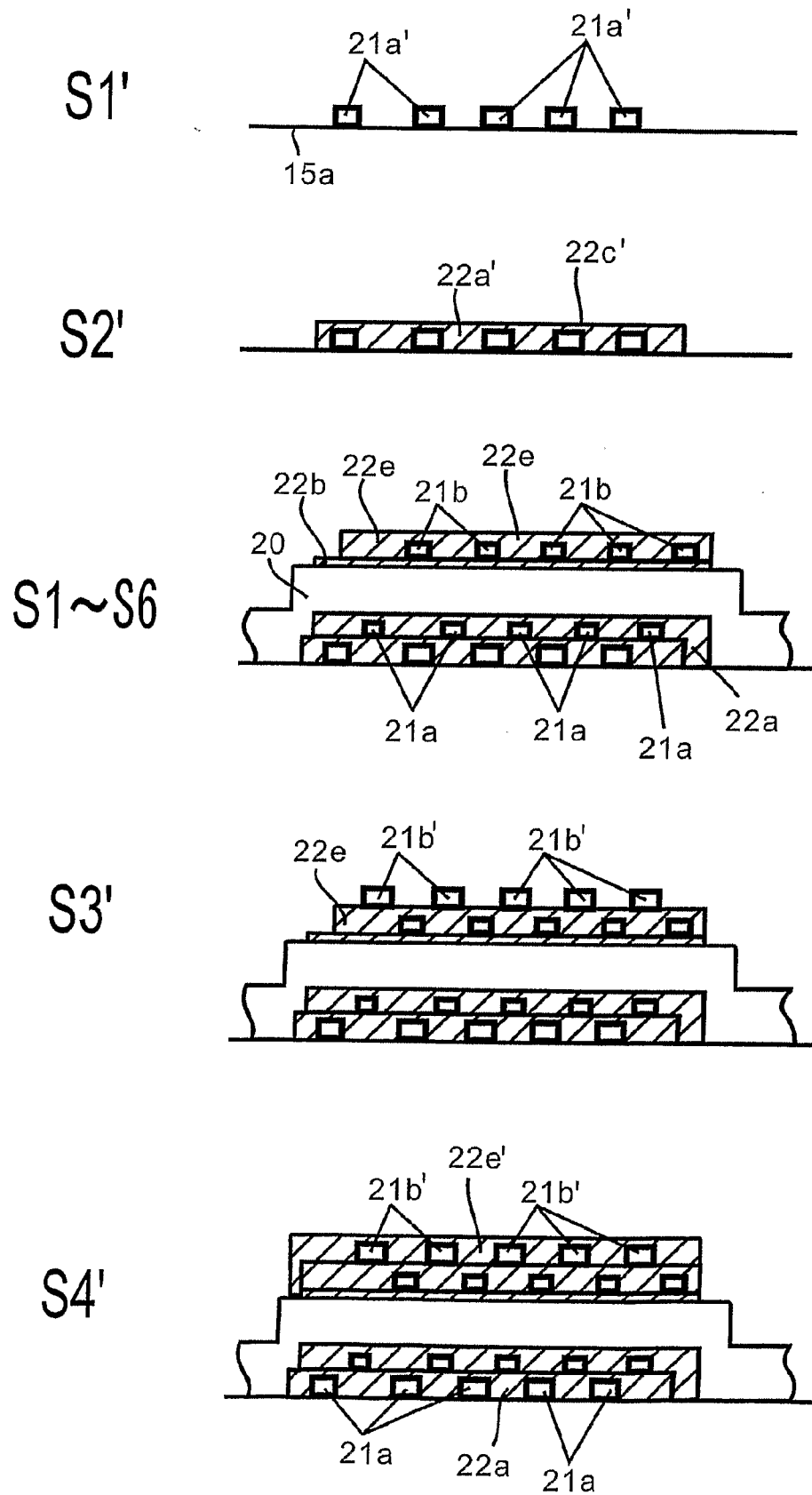


FIG. 11

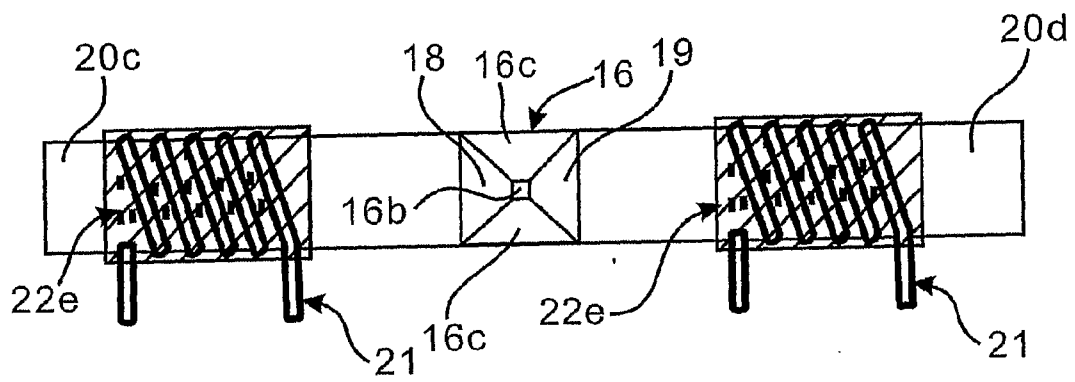


FIG. 12A

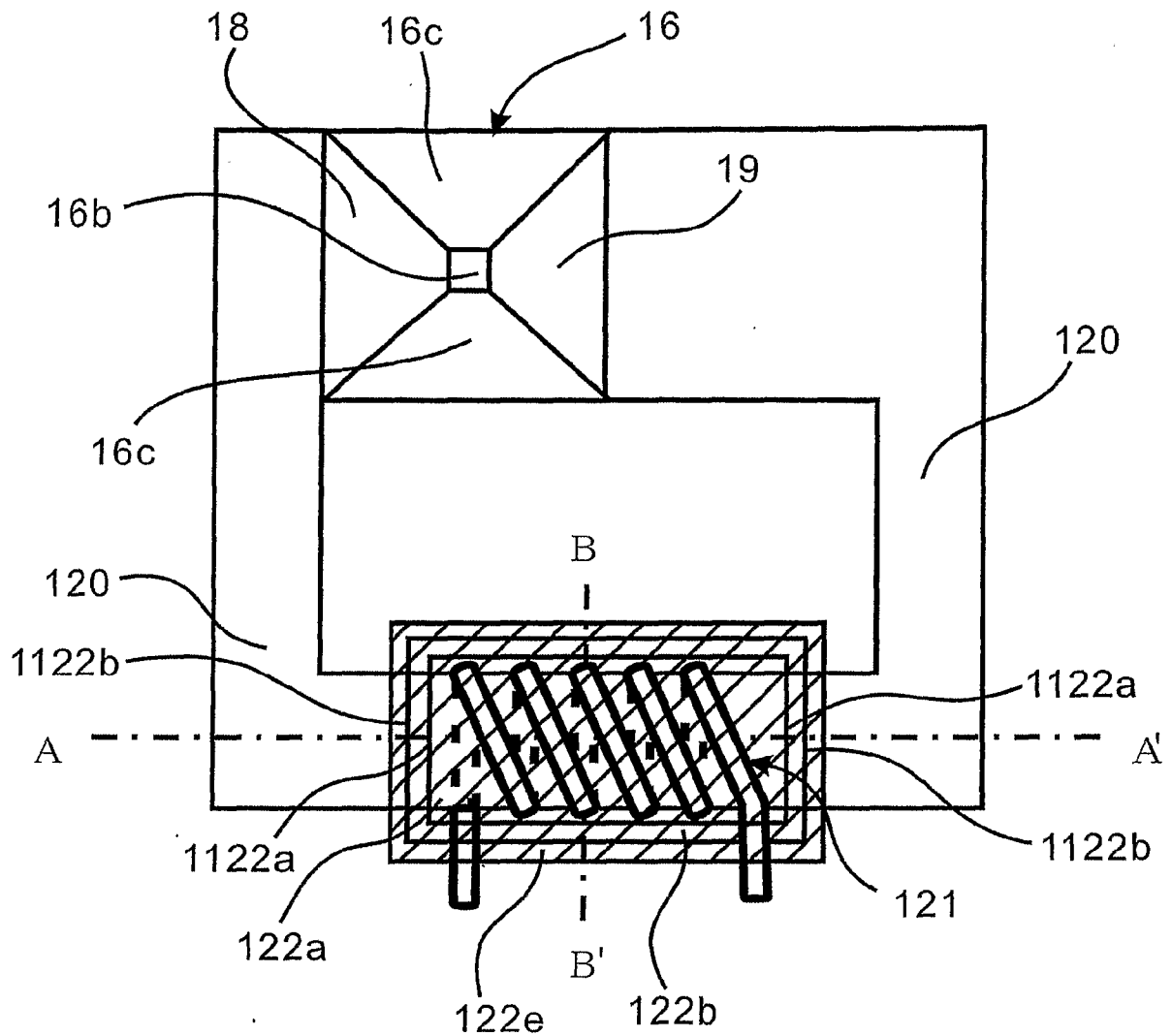


FIG. 12B

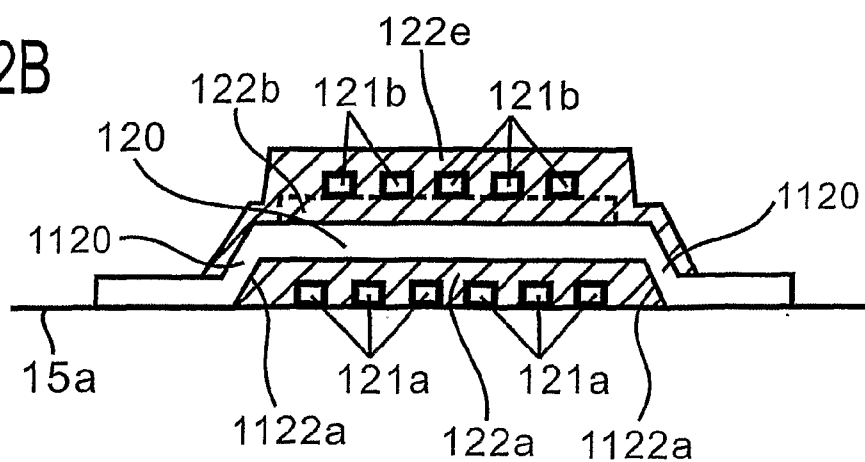


FIG. 13A

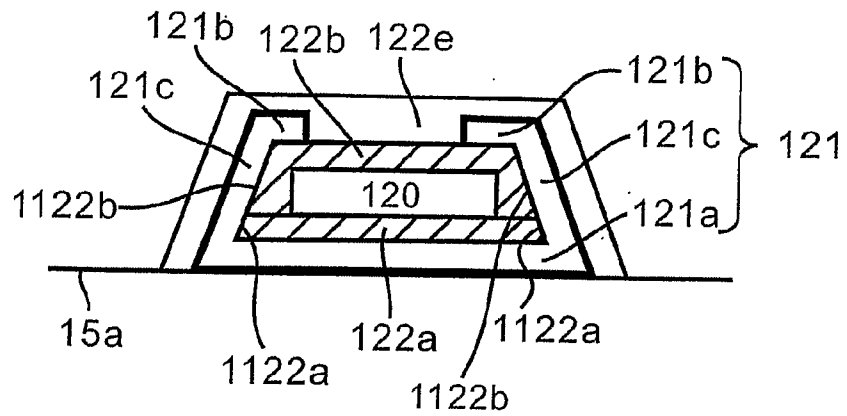


FIG. 13B

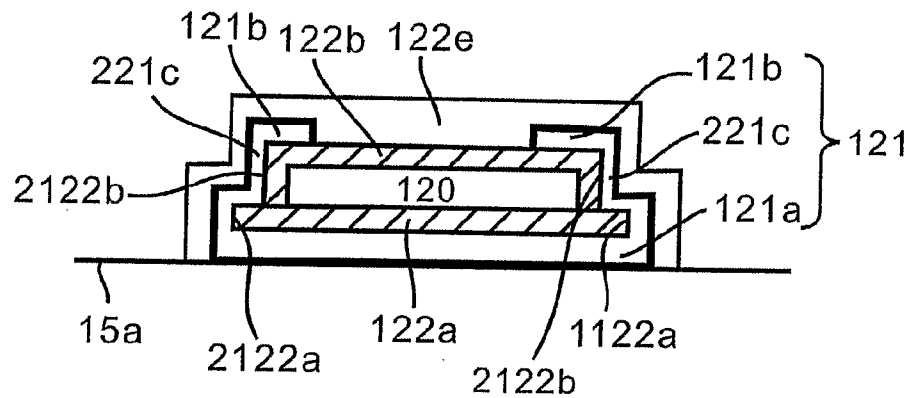


FIG. 13C

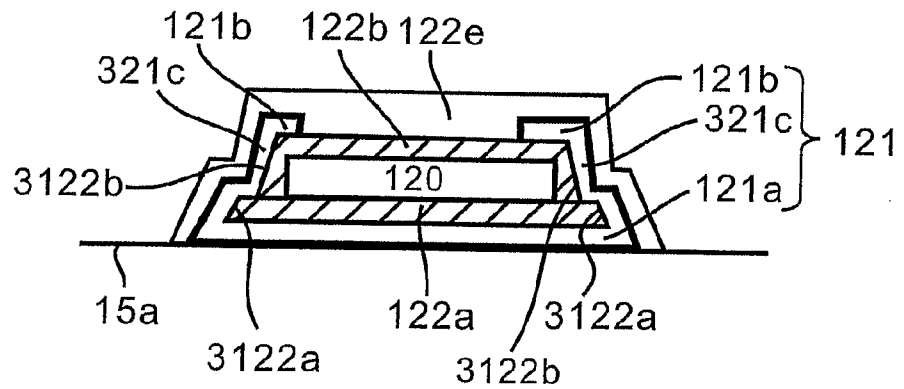
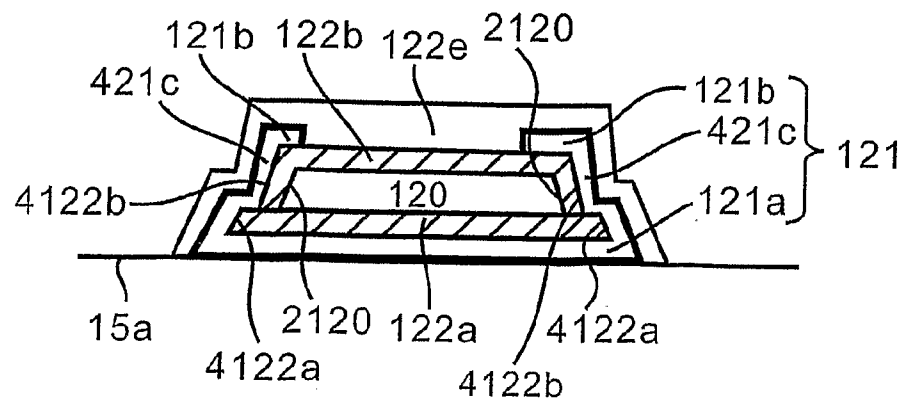


FIG. 13D



INTERNATIONAL SEARCH REPORT

International application No

PCT/SG2008/000057

A. CLASSIFICATION OF SUBJECT MATTER
INV.. G11B5/02 G11B5/31

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)

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/021211 A1 (UEYANAGI KIICHI [JP]) 13 September 2001 (2001-09-13) figures 7a-8b, 14a-14c, 18b, 19b the whole document	1-13
X	US 2001/040868 A1 (UEYANAGI KIICHI [JP] ET AL) 15 November 2001 (2001-11-15) figures 13b, 14b the whole document	1-13
X	US 2002/167870 A1 (AKIYAMA JUNICHI [JP] ET AL) 14 November 2002 (2002-11-14) figure 1 column 17, line 5 - line 9 the whole document	1-13
	----- -/--	

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

& document member of the same patent family

Date of the actual completion of the international search

15 April 2008

Date of mailing of the international search report

24/04/2008

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Malagoli, M

INTERNATIONAL SEARCH REPORT

International application No

PCT/SG2008/000057

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2001/006436 A1 (AKIYAMA JUNICHI [JP] ET AL) 5 July 2001 (2001-07-05) figure 17 the whole document -----	
A	JP 2003 272103 A (FUJI XEROX CO LTD) 26 September 2003 (2003-09-26) the whole document -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SG2008/000057

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
US 2001021211	A1	13-09-2001	JP	4019615 B2	12-12-2007
			JP	2001325756 A	22-11-2001
US 2001040868	A1	15-11-2001	JP	2001319365 A	16-11-2001
US 2002167870	A1	14-11-2002	JP	3903365 B2	11-04-2007
			JP	2002298302 A	11-10-2002
US 2001006436	A1	05-07-2001	JP	3677423 B2	03-08-2005
			JP	2001189002 A	10-07-2001
			KR	20010082611 A	30-08-2001
JP 2003272103	A	26-09-2003	JP	3948318 B2	25-07-2007