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(54) **OPTICAL PICKUP AND DISC DRIVE DEVICE**

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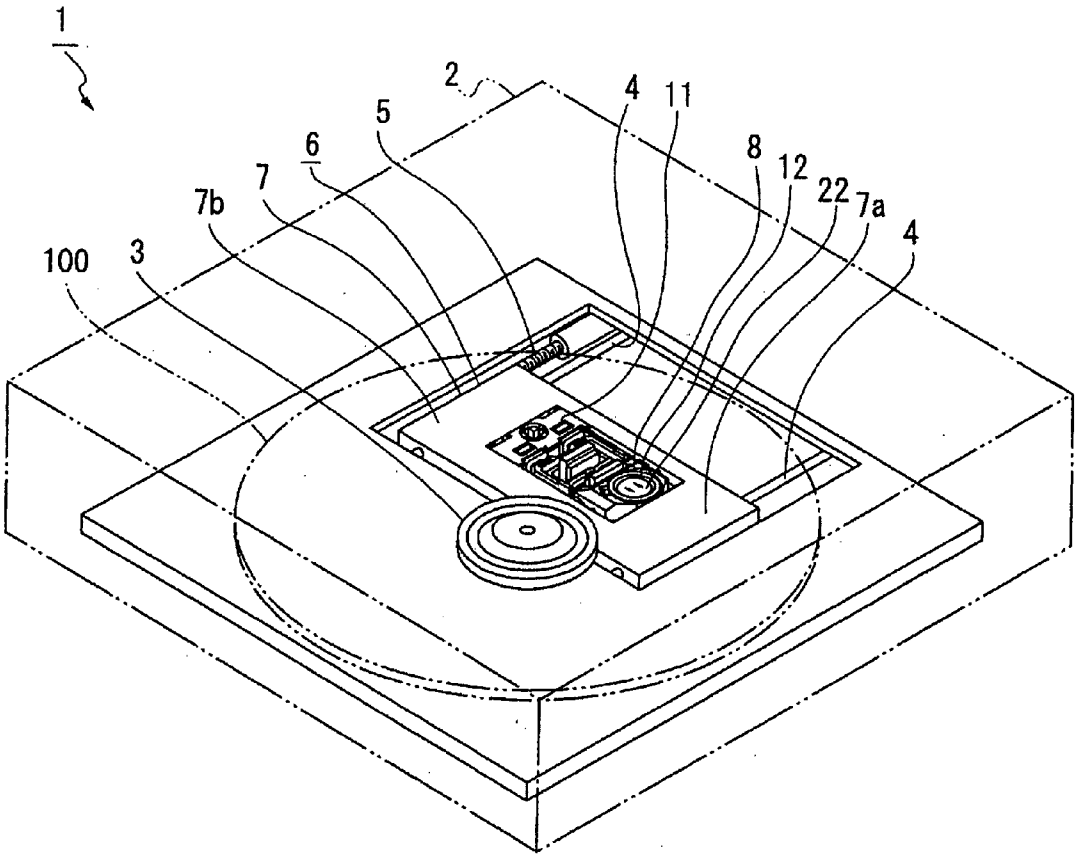
(57) **ABSTRACT**

An objective lens driving device is to be improved in sensitivity and reduced in size and thickness. To this end, an objective lens driving device includes a stationary block arranged on a stationary plate provided on a movable base, a movable block holding an objective lens and moved along the focusing direction, the tracking direction and the tilt direction, support springs for supporting the movable block with respect to the stationary block, a first magnetic circuit for causing movement of the movable block along the focusing direction and along the tracking direction, and a second magnetic circuit for causing movement of the movable block along the tilt direction. The second magnetic circuit includes a pair of tilt magnets, each having two poles so that N poles and S poles lie along the tangential direction, and a pair of tilt coils facing the tilt magnets and each having an axis of winding wire direction along the tangential direction. The tilt magnets and the tilt coils are mounted to the movable block and the stationary block, respectively. An objective lens and the second magnetic circuit are arranged on the opposite sides along the tangential direction with the first magnetic circuit in-between.



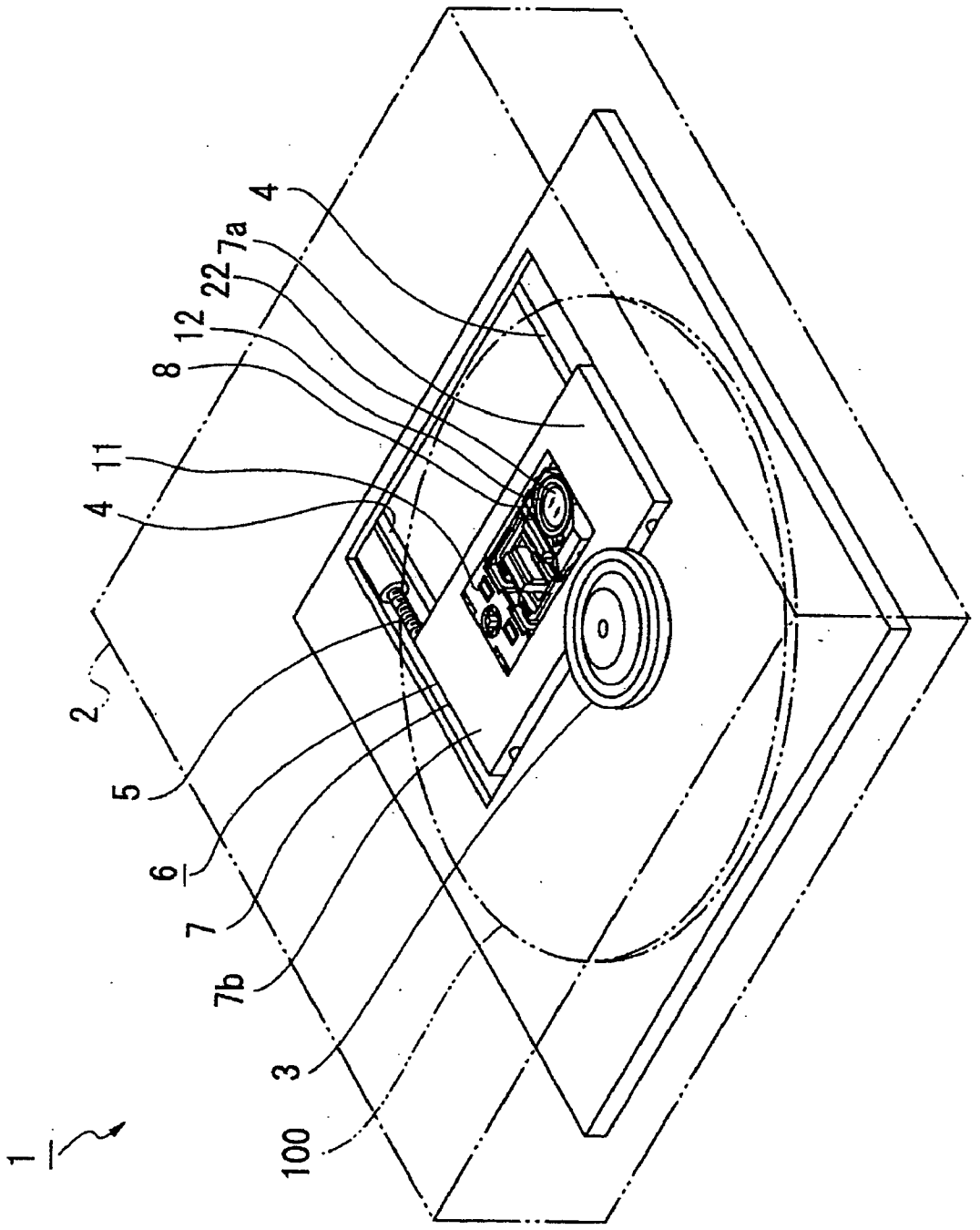


FIG.1

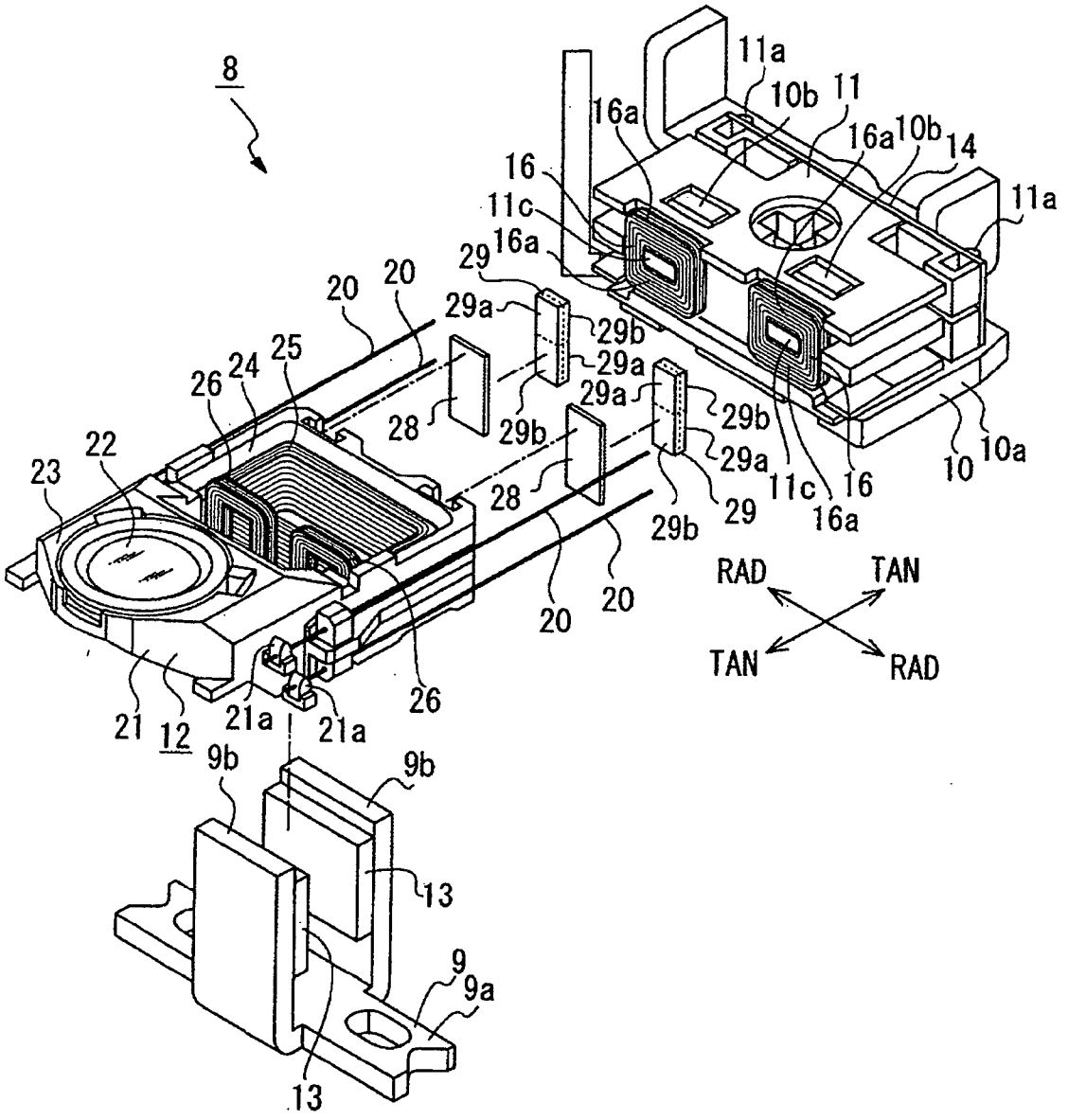

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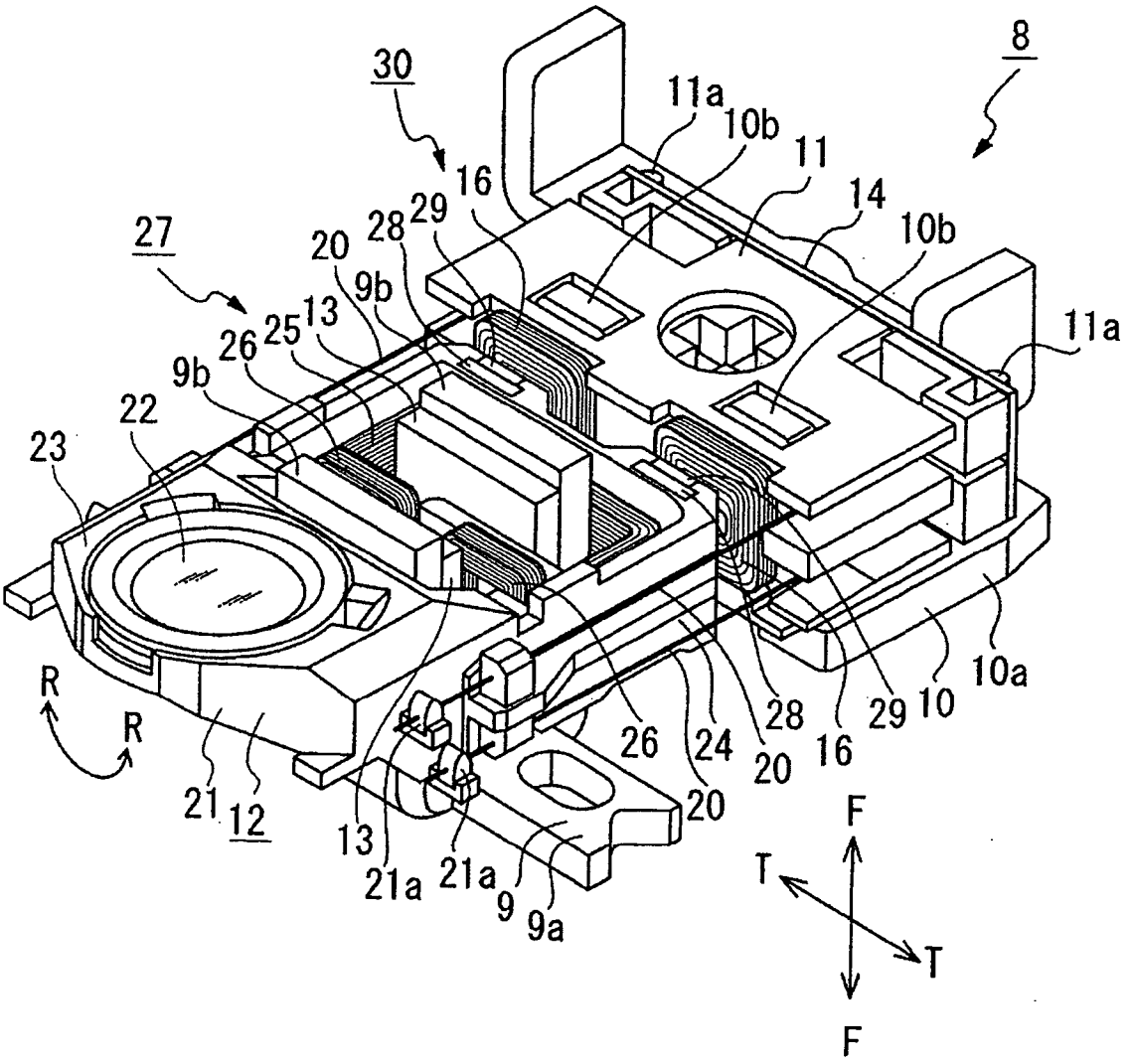
FIG.2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9b
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R
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9a
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10a
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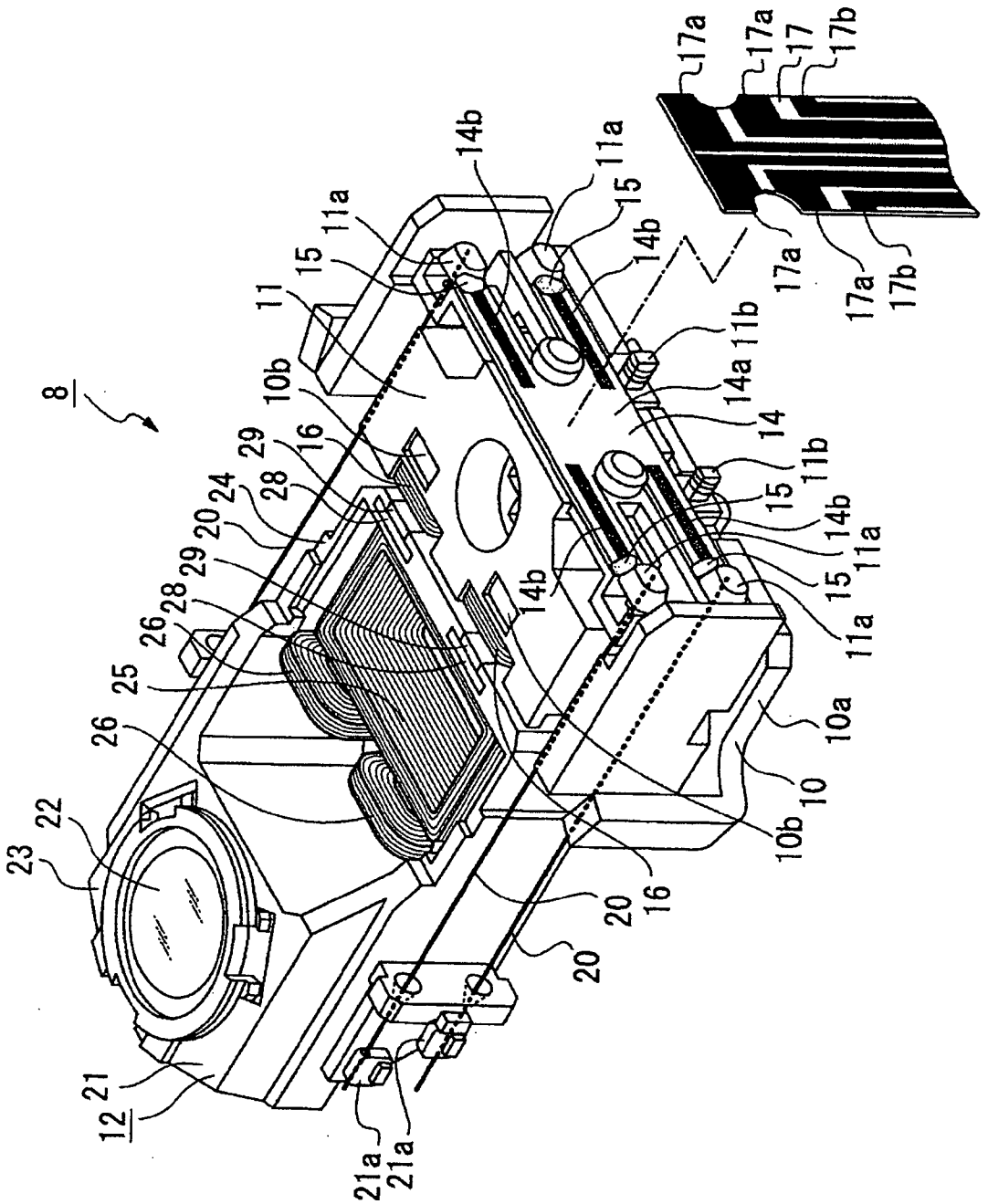
T
F

FIG.3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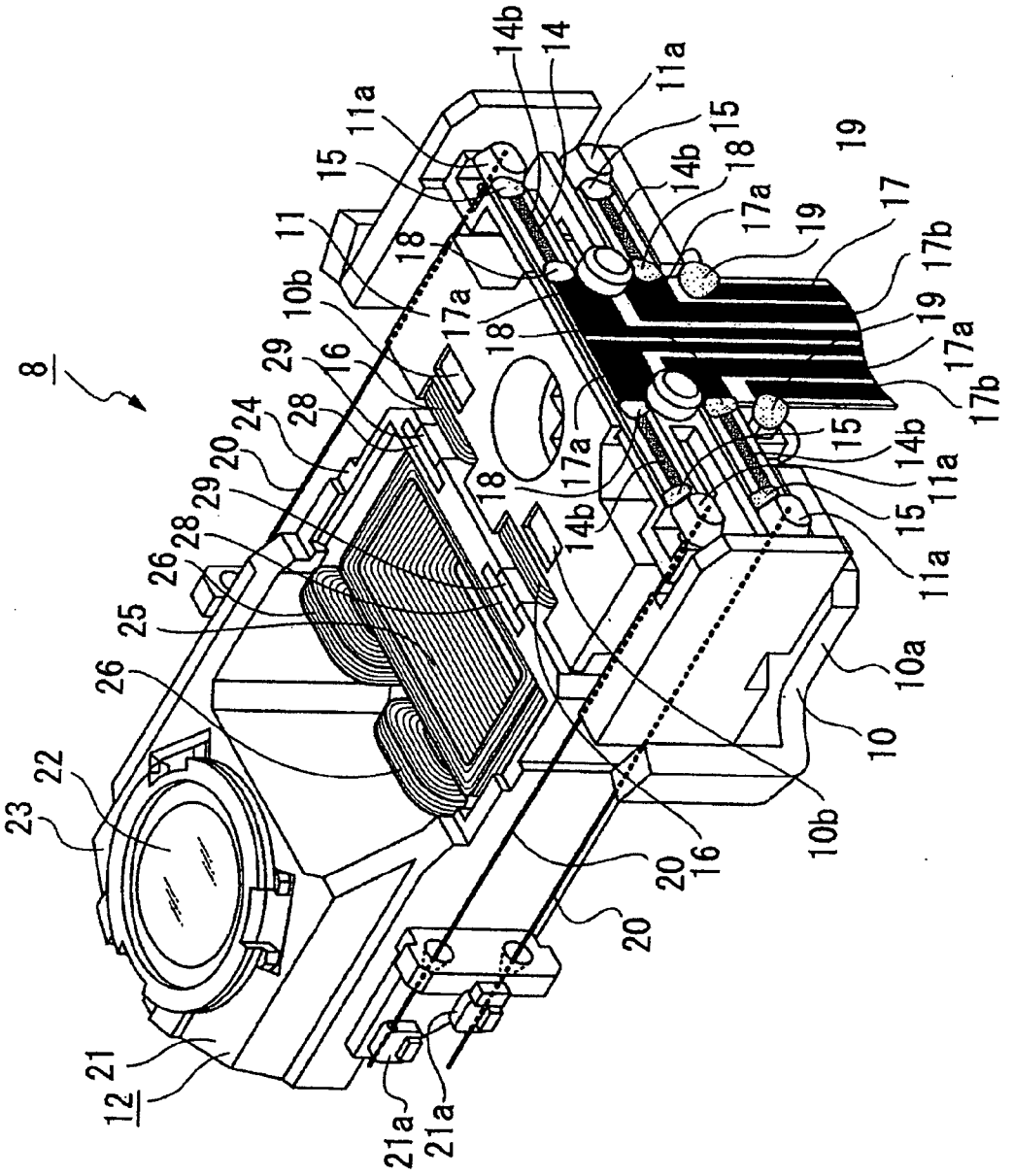
17
17b

FIG.4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11a
14b
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11a
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14b
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17a
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17b
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17b
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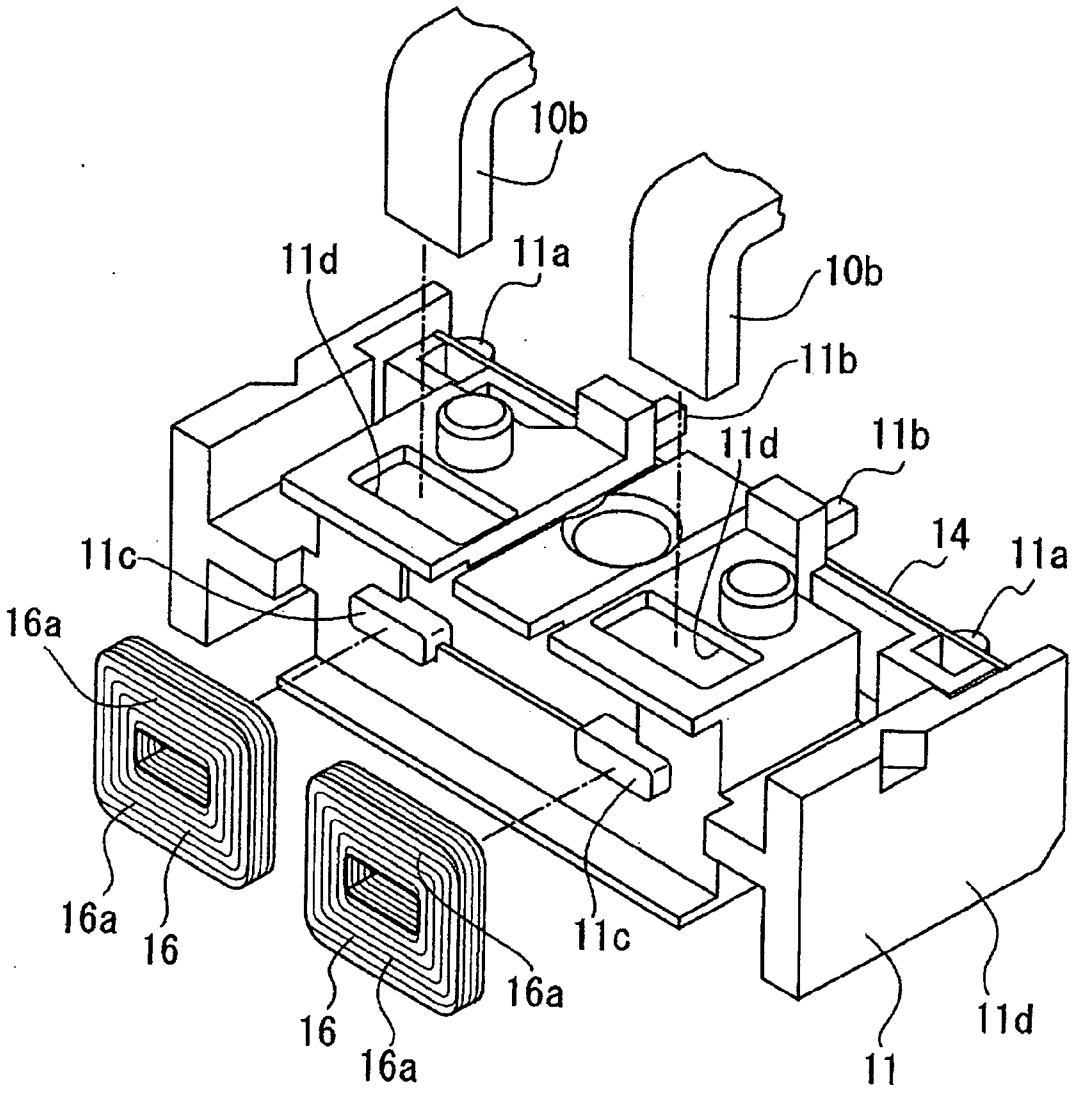
20
18
17a
18
17a
18

FIG.5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11d
11a
10b
11b
11d
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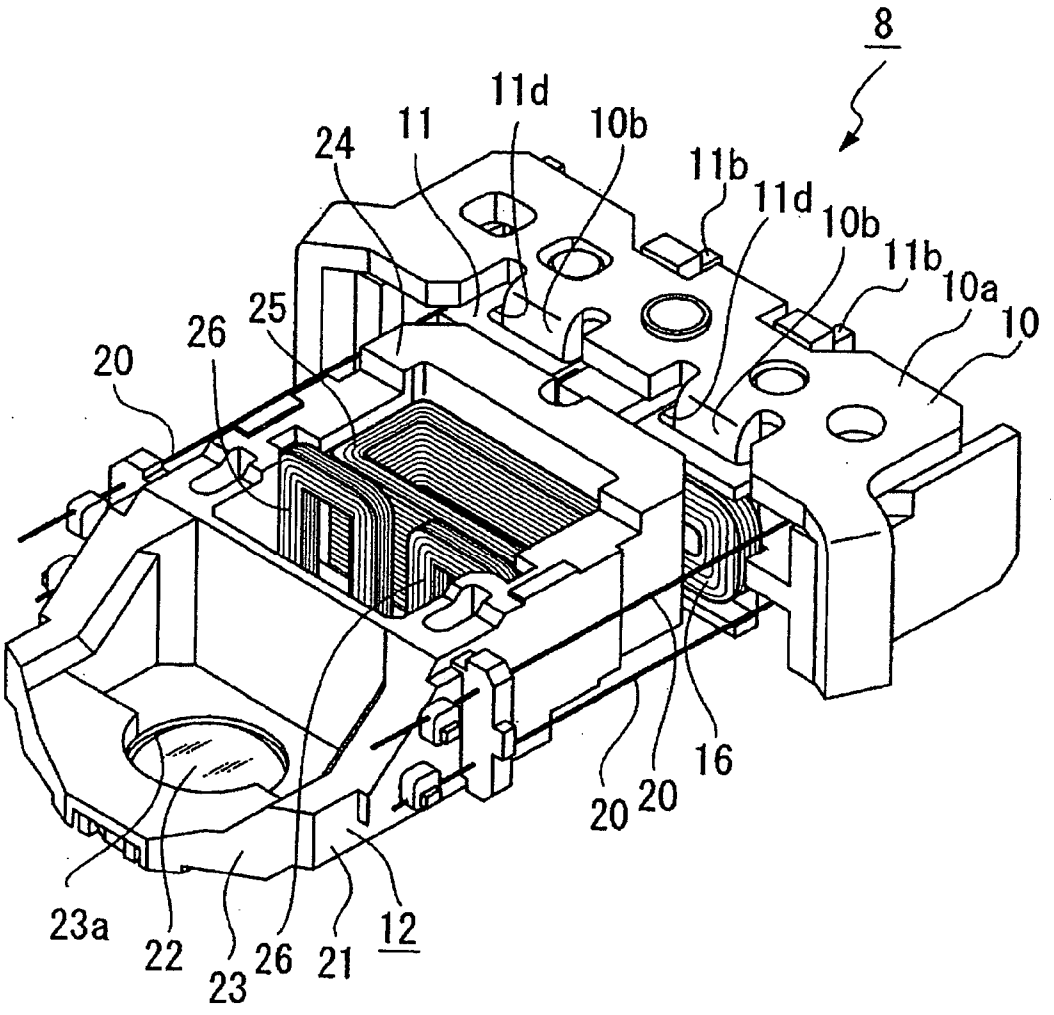
11a
11c
16a
16a
16
16
16a
16a
11c
11
11d

FIG.6


8
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11b
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23a
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12

FIG.7

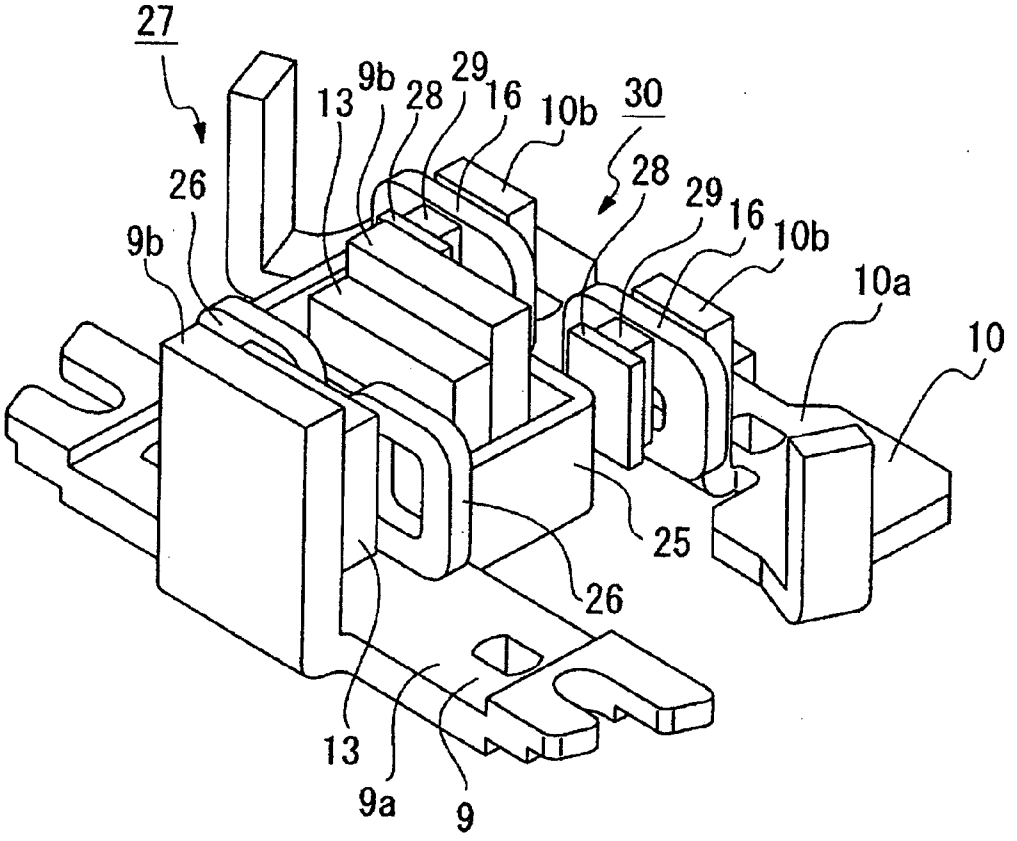

FIG.8

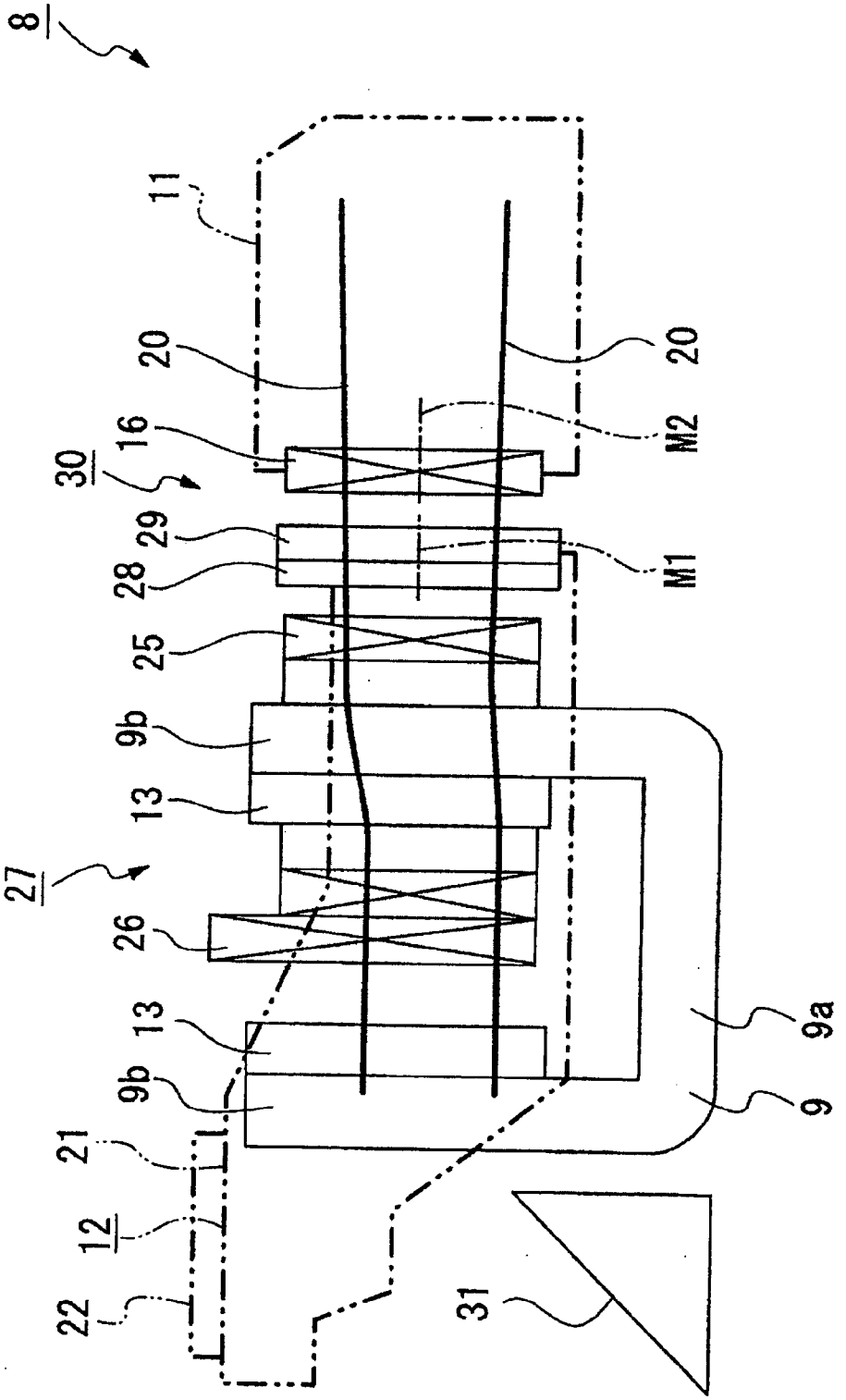

FIG.9

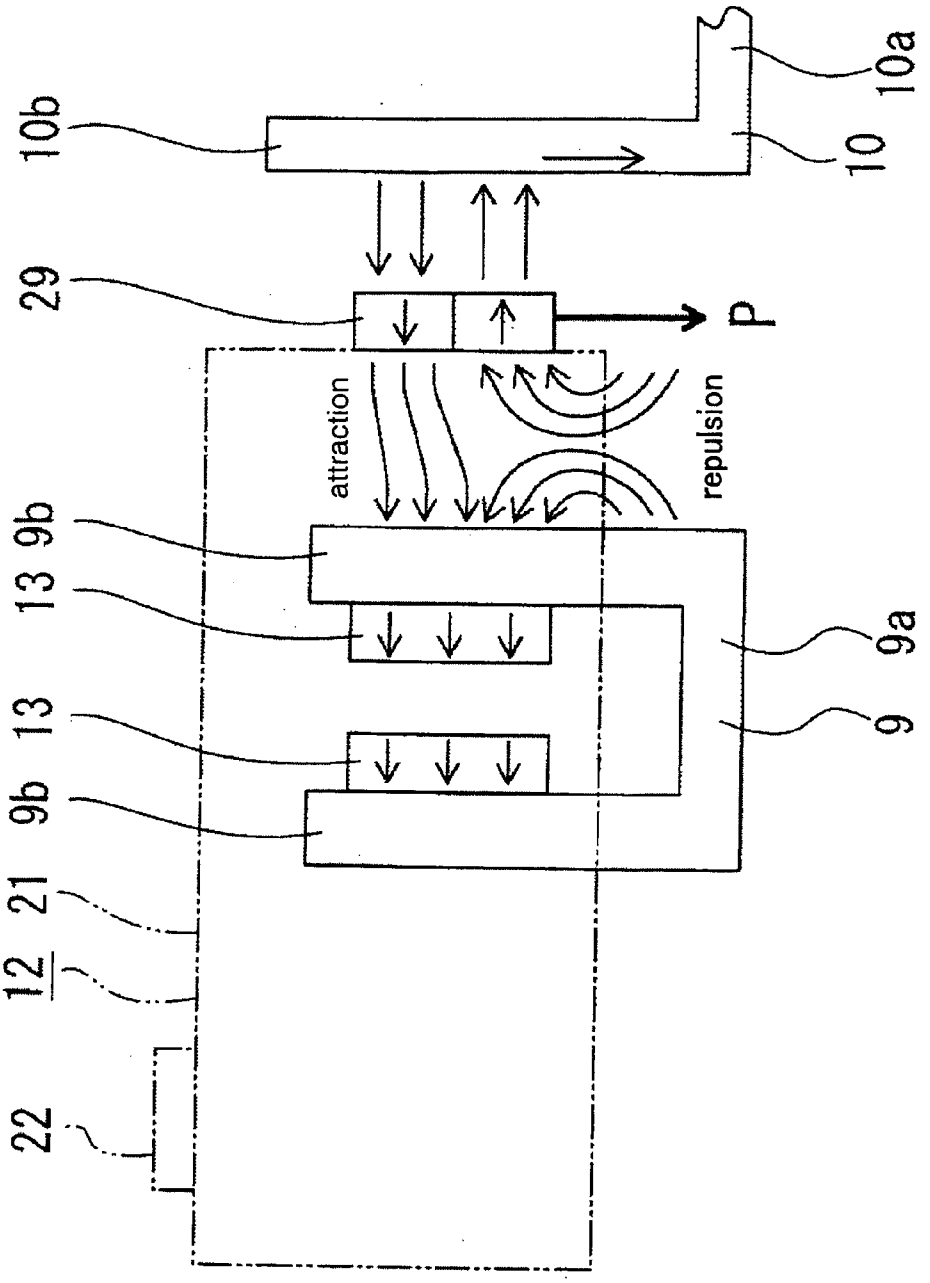

FIG.10

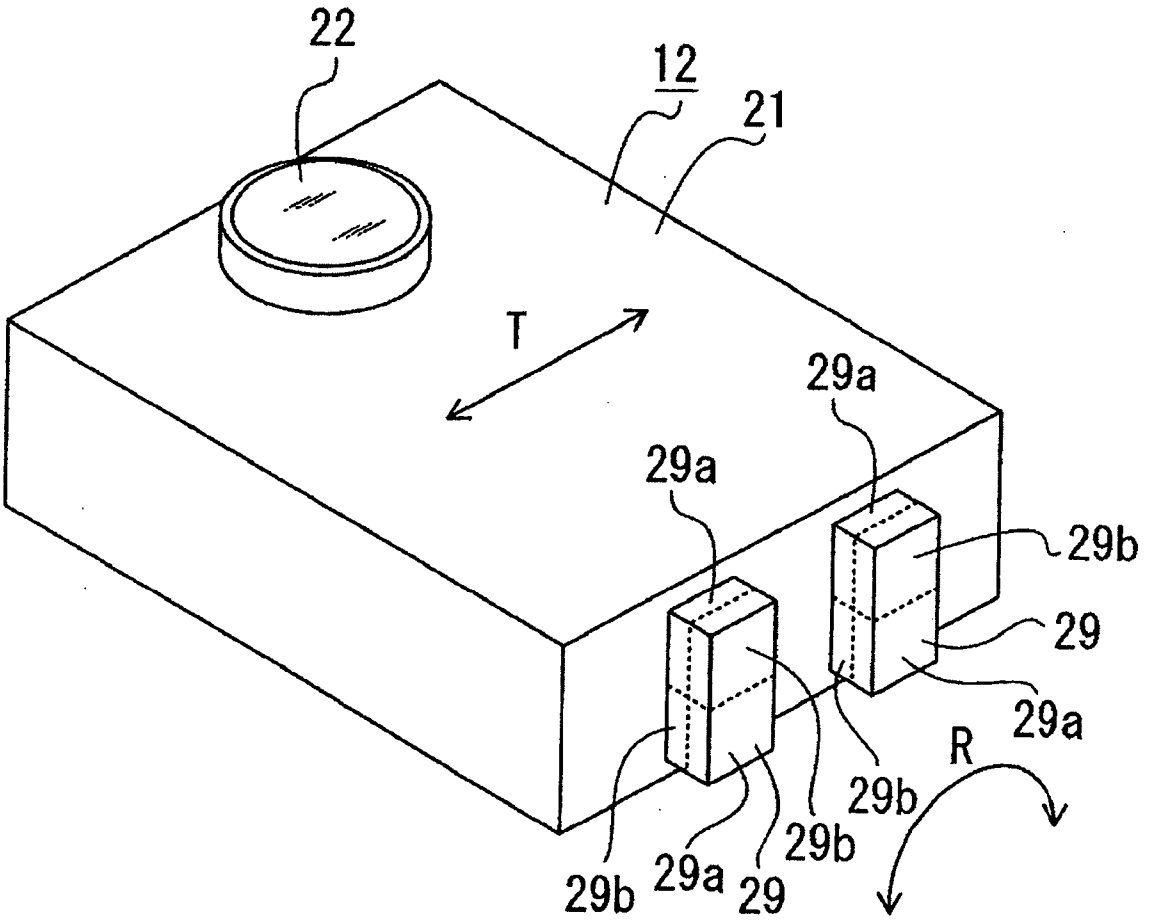

FIG.11

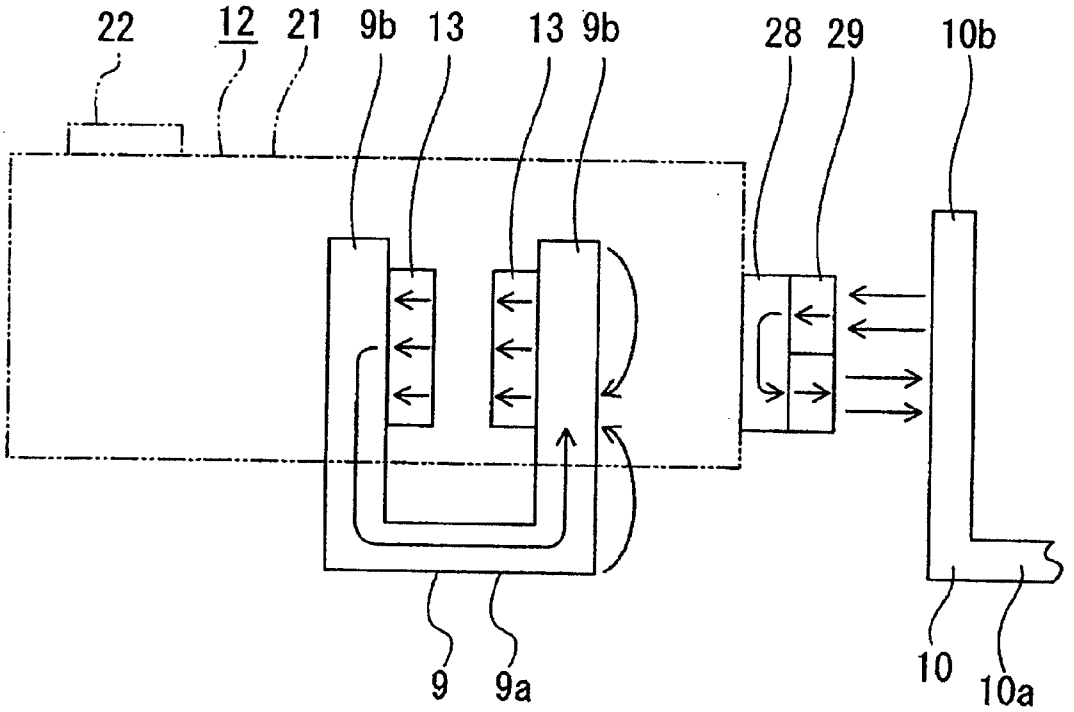

FIG. 12

OPTICAL PICKUP AND DISC DRIVE DEVICE

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] The present invention contains subject matter related to Japanese Patent Application JP 2004-117647 filed in the Japanese Patent Office on Apr. 13, 2004, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to an optical pickup and a disc drive device. More particularly, it relates to an optical pickup having a driving device for an objective lens in which a movable block is moved in the three directions of focusing, tracking and tilt with respect to a stationary block and to a disc drive device having the optical pickup.

[0004] 2. Description of Related Art

[0005] The disc drive device records and/or reproduces information signals for a disc-shaped recording medium, such as an optical disc. This disc drive device is provided with an optical pickup that is moved radially of the disc-shaped recording medium for illuminating laser light thereon.

[0006] The optical pickup is provided with an objective lens driving device, and by this objective lens driving device, the objective lens held by the movable block is moved along the focusing direction or is moved along the tracking direction, in order to condense the spot of the laser light illuminated via the objective lens on the disc-shaped recording medium on a recoding track thereof. The focusing direction is the direction along which the objective lens held by the movable block of the objective lens driving device is moved towards and away from the recording surface of the disc-shaped recording medium by way of a focusing adjustment, and the tracking direction is substantially the radial direction of the disc-shaped recording medium along which the objective lens is moved for tracking adjustment.

[0007] The practice in the optical pickup has been to effect focusing adjustment and tracking adjustment by the objective lens driving device. Recently, there has been developed an objective lens driving device, also called a tri-axial actuator, which enables an adjustment for surface plane deviation of the rotating disc-shaped recording medium by allowing a movable block to be tilted relative to the recording surface of the disc-shaped recording medium in addition to a biaxial adjustment of a focusing adjustment and a tracking adjustment, for improving the follow-up characteristics of the laser light spot with respect to the recording track. Thus, with the objective lens driving device, called a tri-axial actuator, the movable block is moved along the focusing direction, the tracking direction and a tilt direction which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium.

[0008] As the objective lens driving device, called the tri-axial actuator, the following type devices have been developed so far.

[0009] For example, a movable block holding an objective lens is movably carried on a stationary block via a support spring, a tilt coil for tilting the movable block relative to the stationary block is provided to the movable block, and a tilt magnet positioned facing the tilt coil is provided to the stationary block. The device type in which the tilt coil is provided to the movable block is termed a moving-coil-type device.

[0010] With the moving-coil-type objective lens driving device, two support springs each are needed for supplying driving currents to the focusing coils for focusing adjustment, the tracking coils for tracking adjustment and the tilt coil for tilt adjustment provided to the movable block side, such that the movable block is carried by the stationary block with a sum total of six support springs.

[0011] On the other hand, with a tri-axial actuator, which is of the type different from the moving-coil-type device, the movable block holding the objective lens is movably supported by the stationary block via support springs, while a tilt coil for tilting the movable block relative to the stationary block is provided to the stationary block, and a tilt magnet positioned facing the tilt coil is provided to the movable block (see, for example, the Patent Publication 1 (Japanese Laid-Open Patent Publication 2000-222755)). The device type in which the tilt magnet is provided to the movable block is called a moving-magnet-type device.

[0012] With the moving-magnet-type objective lens driving device, in which the tilt magnet is provided to the movable block, the weight of the movable block becomes larger than that of the moving-coil-type device. However, the moving-magnet-type device does not need a support spring for supplying the driving current to the tilt coil and hence is meritorious when compared to the moving-coil-type device, in that the number of component parts may be reduced and in that the assembly operation can be facilitated.

SUMMARY OF THE INVENTION

[0013] Problems to be Solved by the Invention

[0014] With the objective lens driving device described in patent Publication 1, the tilt magnet provided to the movable block has a single N pole and a single S pole, while the tilt coil provided to the stationary block has the winding core direction corresponding to the focusing direction, and hence the movable block is moved along the tilt direction under cooperation between the driving current flowing in about one-fourth part of the tilt coil wound in the from of a square tube and the magnetic flux of the magnet. Consequently, the portion of the tilt coil used for tilt adjustment is small, and hence the device may be lowered in sensitivity.

[0015] For combating the decrease in sensitivity, it becomes necessary to use a magnet of a high magnetic force or to supply a large driving current to the tilt coil. However, this raises the manufacturing cost or power consumption of the objective lens driving device.

[0016] Moreover, should the tilt coil be arranged so that the winding core direction corresponds to the focusing direction, the space in which to mount the tilt coil along the tangential direction is correspondingly increased and the objective lens driving device is increased in size along the tangential direction in a manner deterrent to size reduction. In addition, the supporting state of the movable block tends to be unstable.

[0017] With the objective lens driving device, the laser light radiated from a light source is conducted to the objective lens via an uplift mirror arranged on the opposite side of the disc-shaped recording medium with the movable block in-between. If in such case a magnetic circuit formed by, for example, a coil or a magnet is arranged about the objective lens, the optical path of the laser light radiated from the light source so as to be incident on the uplift mirror needs to be provided below the magnetic circuit, with the result that the objective lens driving device is increased in thickness, contrary to the demand for reducing its thickness. In particular, in an optical pickup provided to a device for a mobile phone, in which there is raised a high demand for a reduction in thickness, deterrence of the reduction in thickness is a major problem.

[0018] To overcome the above problem, it is desirable to provide an objective lens driving device that may be improved in sensitivity and reduced in size and thickness.

[0019] Means to Solve the Problem

[0020] For accomplishing the above problem, the present invention provides an optical pickup and a disc drive device in which an objective lens driving device includes a stationary plate provided on the movable base; a stationary block arranged on the stationary plate and secured to the movable base; a movable block for holding the objective lens and operated relative to the stationary block along a focusing direction, which is a direction towards and away from a recording surface of the disc-shaped recording medium, along a tracking direction, which is a radial direction of the disc-shaped recording medium, and along a tilt direction which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium; a plurality of support springs for movably supporting the movable block relative to the stationary block; a first magnetic circuit for causing movement of the movable block along the focusing direction or along the tracking direction; and a second magnetic circuit for causing movement of the movable block along the tilt direction. The second magnetic circuit includes a pair of tilt magnets each magnetized to two poles so that N and S poles are arranged along the focusing direction. The paired tilt magnets are spaced apart from each other along the radial direction. The second magnetic circuit also includes a pair of tilt coils arranged facing the paired tilt magnets, with each of the tilt coils having an axis of the winding wire direction corresponding to the tangential direction. The paired tilt magnets are provided to the movable block, the paired tilt coils are provided to the stationary block, while the objective lens and the second magnetic circuit are located on both sides of the first magnetic circuit along the tangential direction.

[0021] Hence, with the optical pickup and the disc drive device, according to the present invention, the portion of the tilt coil usable for tilt adjustment may be increased.

[0022] The present invention also provides an optical pickup including a movable base moved along the radial direction of a disc-shaped recording medium loaded on a disc table and an objective lens driving device arranged on the movable base. The objective lens driving device comprises a stationary plate provided on the movable base; a stationary block arranged on the stationary plate and secured to the movable base; a movable block for holding the objective lens operated relative to the stationary block along a focusing direction, which is a direction towards and away from a recording surface of the disc-shaped recording medium, along a tracking direction, which is a radial direction of the disc-shaped recording medium, and along a tilt direction, which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium; a plurality of support springs for movably supporting the movable block relative to the stationary block; a first magnetic circuit for causing movement of the movable block along the focusing direction or along the tracking direction; and a second magnetic circuit for causing movement of the movable block along the tilt direction. The second magnetic circuit includes a pair of tilt magnets each magnetized to two poles so that N and S poles are arranged along the focusing direction. The paired tilt magnets are spaced apart from each other along the radial direction. The second magnetic circuit also includes a pair of tilt coils arranged facing the paired tilt magnets and each having an axis of the winding wire direction corresponding to the tangential direction. The paired tilt magnets are provided to the movable block, while the paired tilt coils are provided to the stationary block. The objective lens and the second magnetic circuit are located on both sides of the first magnetic circuit along the tangential direction.

[0023] Since the tilt coils are arranged with the winding core direction extending along the tangential direction, the portion of the tilt coils usable for generating the force of thrust in the movable block along the tilt direction may be increased to improve the sensitivity of the movable block at the time of tilt adjustment.

[0024] Moreover, since the movable block may be improved in sensitivity, it is unnecessary to use the magnet with a stronger magnetic force, while the driving current supplied to the tilt coils may be smaller, with the result that the power consumption as well as the manufacture costs of the objective lens driving device may be lowered.

[0025] Additionally, since the winding core direction of the tilt coils is not the focusing direction, the tilt coil mounting space along the tangential direction may be smaller, and hence the size of the objective lens driving device along the tangential direction may be reduced.

[0026] Since the objective lens and the second magnetic circuit are arranged on opposite sides along the tangential direction with the first magnetic circuit in-between, the uplift mirror may be provided at the same height level as the first magnetic circuit, and hence the objective lens driving device may be correspondingly reduced in thickness. This reduction in thickness is particularly desirable in an optical pickup used for mobile equipment.

[0027] Furthermore, since the tilt magnets and the tilt coils are provided to the movable block and to the stationary block, respectively, the support springs for supplying the current to the tilt coils may be dispensed with, thereby reducing the number of component parts and simplifying the assembling performance of the objective lens driving device.

[0028] Since there is provided a tilt yoke by bending a portion of the stationary plate on the opposite side of the tilt magnet along the tangential direction with the tilt coil in-between, there is no need to provide dedicated separate

tilt yokes, while the portion for securing the stationary block and the tilt yokes may be used in common, thus reducing the number of component parts. Since a back yoke is provided on the surface of the tilt magnet opposite to the surface thereof facing the tilt coil, it is possible to improve the sensitivity of the movable block at the time of tilt adjustment.

[0029] Additionally, the stray magnetic flux from the tilt magnets may be reduced, and the second magnetic circuit does not tend to be affected by the first magnetic circuit, while the movable block may be prevented from being tilted relative to the stationary block under the effect of the stray magnetic flux.

[0030] The present invention also provides a disc drive device comprising a disc table for loading a disc-shaped recording medium thereon and an optical pickup for radiating laser light via an objective lens to the disc-shaped recording medium loaded on the disc table. The optical pickup includes a movable base, moved along the radial direction of a disc-shaped recording medium, and loaded on a disc table, and an objective lens driving device arranged on the movable base. The objective lens driving device includes a stationary plate provided on the movable base; a stationary block arranged on the stationary plate and secured to the movable base; and a movable block for holding the objective lens and operated relative to the stationary block along a focusing direction, which is a direction towards and away from a recording surface of the disc-shaped recording medium, along a tracking direction, which is a radial direction of the disc-shaped recording medium, and along a tilt direction, which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium. The objective lens driving device includes a plurality of support springs for movably supporting the movable block relative to the stationary block, a first magnetic circuit for causing movement of the movable block along the focusing direction or along the tracking direction, and a second magnetic circuit for causing movement of the movable block along the tilt direction. The second magnetic circuit includes a pair of tilt magnets each magnetized to two poles so that N and S poles are arranged along the focusing direction, with the paired tilt magnets being spaced apart from each other along the radial direction. The second magnetic circuit also includes a pair of tilt coils arranged facing the paired tilt magnets, each of the tilt coils having an axis of the winding wire direction corresponding to the tangential direction. The paired tilt magnets are provided to the movable block, and the paired tilt coils are provided to the stationary block. The objective lens and the second magnetic circuit are located on both sides of the first magnetic circuit along the tangential direction.

[0031] Since the tilt coils are arranged with the winding core direction corresponding to the tangential direction, the portion of the tilt coils usable for generating the force of thrust in the movable block along the tilt direction is larger, thus improving the sensitivity of the movable block at the time of tilt adjustment.

[0032] Moreover, since the movable block may be improved in sensitivity, it is unnecessary to use the magnet with a stronger magnetic force, while the driving current supplied to the tilt coils may be reduced, with the result that the power consumption as well as the manufacturing costs of the objective lens driving device may be lowered.

[0033] Additionally, since the winding core direction of the tilt coils is not the focusing direction, the tilt coil mounting space along the tangential direction may be smaller, and hence the size of the objective lens driving device along the tangential direction may be reduced.

[0034] Since the objective lens and the second magnetic circuit are arranged on opposite sides along the tangential direction with the first magnetic circuit in-between, the uplift mirror may be provided at the same height level as the first magnetic circuit, and hence the objective lens driving device may be correspondingly reduced in thickness. This reduction in thickness is particularly desirable in an optical pickup used for mobile equipment.

[0035] In addition, since the tilt magnets and the tilt coils are provided to the movable block and the stationary block, respectively, the support springs for supplying the current to the tilt coils may be dispensed with, thereby reducing the number of component parts and simplifying the assembling performance of the objective lens driving device.

[0036] Since a tilt yoke is provided by bending a portion of the stationary plate on the opposite side of the tilt magnet along the tangential direction with the tilt coil in-between, there is no need to provide dedicated separate tilt yokes, while the portion for securing the stationary block and the tilt yokes may be used in common, thus reducing the number of component parts.

[0037] Since a back yoke is provided on the surface of the tilt magnet opposite to the surface thereof facing the tilt coil, it is possible to improve the sensitivity of the movable block at the time of tilt adjustment.

[0038] Additonally, the stray magnetic flux from the tilt magnets may be reduced, and the second magnetic circuit is not liable to be affected by the first magnetic circuit, while the movable block may be prevented from being tilted relative to the stationary block under the effect of the stray magnetic flux.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] **FIG. 1** shows, in conjunction with **FIGS. 2 and 12**, the best mode of carrying out the present invention and, specifically, is a schematic cross-sectional view of a disc drive device of the present invention.

[0040] **FIG. 2** is a partially-exploded, enlarged perspective view showing a portion of an objective lens driving device.

[0041] **FIG. 3** is an enlarged perspective view of the objective lens driving device.

[0042] **FIG. 4** is an enlarged perspective view showing the objective lens driving device from which a power feed base plate has been detached.

[0043] **FIG. 5** is an enlarged perspective view showing the objective lens driving device, as viewed from a direction different from the viewing direction of **FIG. 3**.

[0044] **FIG. 6** is an enlarged exploded perspective view showing a stationary block.

[0045] **FIG. 7** is an enlarged perspective view showing the objective lens driving device, as viewed from a direction different from the viewing directions of **FIGS. 3 and 5**, with a portion thereof being removed.

[0046] **FIG. 8** is an enlarged perspective view showing a first magnetic circuit and a second magnetic circuit.

[0047] **FIG. 9** is a schematic enlarged side view showing an objective lens driving device.

[0048] **FIG. 10** is a schematic view showing the direction of the magnetic force in the case where there is provided no back yoke.

[0049] **FIG. 11** is a schematic view for illustrating the operation which may occur in the case where there is provided no back yoke.

[0050] **FIG. 12** is a schematic view showing the direction of the magnetic force in the case where there is provided a back yoke.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0051] The best mode of an optical pickup and a disc drive device according to the present invention is now explained with reference to the drawings.

[0052] The disc drive device **1** includes respective components and units in an outer casing **2**, as shown in **FIG. 1**. In the outer casing is formed a disc entrance opening, not shown. Within the outer casing **2**, there is mounted a chassis, not shown. A disc table **3** is secured to a motor shaft of a spindle motor mounted on the chassis.

[0053] On the chassis, there are mounted guide shafts **4**, **4** for extending parallel to each other and a lead screw **5** rotated by a feed screw, not shown.

[0054] An optical pickup **6** includes a movable base **7**, optical components provided on the movable base **7**, and an objective lens driving device **8** arranged on the movable base **7**. The ends of the movable base **7** are fitted with bearings **7***a*, **7***b*, which are slidably supported by the guide shafts **4**, **4**.

[0055] A nut member, not shown, is provided on the movable base **7**. When the lead screw **5** is rotated by a feed motor, the nut member is fed in a direction consistent with the direction of rotation of the lead screw **5**, such that the optical pickup **6** is moved along the radial direction of a disc-shaped recording medium **100** that is to be loaded on the disc table **3**.

[0056] The objective lens driving device **8** includes a base member **9**, a stationary plate **10**, a stationary block **11** and a movable block **12** operated relative to the stationary block **11** (see **FIGS. 2 and 3**).

[0057] The base member **9** is formed of, for example, SPCC (cold rolled stainless steel sheet) or a silicon steel sheet and, as shown in **FIG. 2**, made up by a base part **9***a* secured to the movable base **7** and yoke parts **9***b*, **9***b* bent from the base part **9***a* perpendicularly thereto. The yoke parts **9***b*, **9***b* are provided spaced apart from each other in the fore-and-aft direction, that is, in the tangential direction (TA) of the disc-shaped recording medium **100**.

[0058] The surfaces of the yokes **9***b*, **9***b* facing each other are fitted with magnets **13**, **13**.

[0059] The stationary plate **10** is provided spaced apart along the tangential direction (towards rear) with respect to the base member **9** and secured to the movable base **7**. The stationary plate **10** is formed by a sheet of a magnetic metal material, for example, SPCC (cold rolled stainless steel) or a silicon steel and made up by a plate base **10***a* secured to the movable base **7** and tilt yokes **10***b*, **10***c*, bent from a forward end part of the base plate **10***a* and spaced apart from each other along the radial direction (RAD) of the disc-shaped recording medium **100**.

[0060] The stationary block **11** is secured to the plate base **10***a* of the stationary plate **10**. On the left and right ends of the back surface of the stationary block **11**, there are provided a sum total of four terminals **11***a*, **11***a*, . . . in a vertically-spaced apart relation relative to each other, as shown in **FIGS. 4 and 5**.

[0061] The lower end of the stationary block **11** is provided with terminal pins **11***b*, **11***b* protruded towards the rear from the back surface thereof (see **FIG. 4**). These terminal pins **11***b*, **11***b* are located spaced apart in the left and right directions.

[0062] On the forward surface of the stationary block **11**, there are formed forwardly protruded positioning lugs **11***c*, **11***c* spaced apart from each other in the left and right directions (see **FIG. 6**).

[0063] On the rear surface of the stationary block **11** is mounted a relay substrate **14** (see **FIG. 4**). The relay substrate **14** is made up by a basic part **14***a* and four connecting parts **14***b*, **14***b*, . . . protruded in the left and right directions from the basic part **14***a*. The foremost parts of the connecting parts **14***b*, **14***b*, . . . of the relay substrate **14** are connected with, for example, solders **15**, **15**, . . . to the terminals **11***a*, **11***a*, . . . respectively.

[0064] A pair of tilt coils **16**, **16** are mounted to the front surface of the stationary block **11** on the left and right sides thereof, that is, the tilt coils are spaced apart along the radial direction of the disc-shaped recording medium **100** (see **FIGS. 3 and 6**). These tilt coils **16**, **16** are mounted to the stationary block **11** by being fitted on positioning lugs **11***c*, **11***c* provided on the front surface of the stationary block **11**. Thus, by providing the positioning lugs **11***c*, **11***c* to the stationary block **11**, the tilt coils **16**, **16** may readily be mounted in position to the stationary block **11**.

[0065] The tilt coils **16**, **16** are formed substantially to a square tubular shape with a thin wall thickness and mounted to the stationary block **11** so that the direction of winding cores thereof coincides with the fore-and-aft direction, that is, with the aforementioned tangential direction. The tilt coils **16**, **16** are provided with upper and lower portions **16***a*, **16***a*, . . . operating for generating the force of thrust in the movable block **12** along the tilt direction. Meanwhile, the tilt direction is the direction of deviation of the plane of the disc-shaped recording medium **100** from its intended plane (direction indicated by R in **FIG. 3**), that is, the direction of rotation of the disc-shaped recording medium about an axis extending along the tangential direction.

[0066] One end of the tilt coils **16**, **16** is mounted by being coiled about the terminal pins **11***b*, **11***b* provided to the back surface of the stationary block **11** (see **FIG. 4**).

[0067] To the relay substrate **14** mounted to the back surface of the stationary block **11**, there is fixedly connected a substrate for power supply **17**, connected in turn to a power supply circuit, not shown (see **FIGS. 4 and 5**). The substrate for power supply **17** is, for example, a flexible printed circuit board and includes four connecting parts (lines) **17***a*, **17***a*, . . . and two connecting parts (lines) **17***b*, **17***b*. The connecting lines **17***a*, **17***a*, . . . are connected by, for example, solders **18**, **18**, . . . to the connecting lines **14***b*, **14***b*, . . . of the relay substrate **14**, respectively, while the connecting lines **17***b*, **17***b* are connected by, for example, solders **19**, **19** to one end of the tilt coils **16**, **16** mounted to the terminal pins **11***b*, **11***b*. Thus, the driving current for tilt adjustment is supplied to the tilt coils **16**, **16** from a power supply circuit via connecting lines **17***b*, **17***b* of the substrate for power supply **17**.

[0068] In this manner, one end of the tilt coils **16**, **16** is coiled around the terminal pins **11***b*, **11***b*, and the one end of the tilt coils **16**, **16** is secured to the connecting lines **17***b*, **17***b* by the solders **19**, **19**, and hence the substrate for power supply **17** can be secured to the tilt coils **16**, **16** extremely readily, thus simplifying the operation of connecting the substrate for power supply **17** to the tilt coils **16**, **16** and improving the connection reliability.

[0069] Towards the forward end of the stationary block **11** are formed vertically-extending openings for yokes **11***d*, **11***d* (see **FIGS. 6 and 7**) within which are arranged tilt yokes **10***b*, **10***b* of the stationary plate **10** introduced from below. The tilt yokes **10***b*, **10***b* are arranged directly in rear of the tilt coils **16**, **16**.

[0070] To the terminals **11***a*, **11***a*, . . . of the stationary block **11** are attached the rear ends of support springs **20**, **20**, . . . (see **FIGS. 3 and 4**). These support springs **20**, **20**, . . . are connected via terminals **11***a*, **11***a*, . . . and connecting parts **14***b*, **14***b*, . . . of the relay substrate **14** to the connecting lines **17***a*, **17***a*, . . . of the substrate for power supply **17**. The support springs **20**, **20**, . . . are protruded forward from the stationary block **11**.

[0071] The movable block **12** includes a movable holder **21** and an objective lens **22** held thereby (see FIGS. **3** to **5**).

[0072] The movable holder **21** is formed as one with a lens mounting unit **23** and a coil holder **24** mounted to the rear side of the lens mounting unit **23**.

[0073] The lens mounting unit **23** is formed with a vertically extending through-opening **23***a* (see **FIG. 7**), and the objective lens **22** is mounted overlying the through-opening **23***a*.

[0074] The coil holder **24** is formed as a vertically perforated substantially rectangular frame, and a focusing coil **25** and a pair of tracking coils **26**, **26** are held in the inside of the coil holder **24** formed on perforation.

[0075] The focusing coil **25** is used for causing movement of the movable block **12** along the focusing direction, that is, in the direction towards and away from the disc-shaped recording medium **100** (direction F in **FIG. 3**). The tracking coils **26**, **26** are used for causing movement of the movable block **12** along the tracking direction, that is, in the direction substantially along the radius of the disc-shaped recording medium **100** (direction T in **FIG. 3**).

[0076] The focusing coil **25** and the tracking coils **26**, **26** are each in the form of a substantially square-shaped tube, with the focusing coil **25** having a winding core extending in the up-and-down direction (focusing direction), and with the tracking coils **26**, **26** having winding cores extending in the fore-and-aft direction (tangential direction). The tracking coils **26**, **26** are provided spaced apart from each other on the front side of the focusing coil **25**.

[0077] The ends of the focusing coil **25** and the tracking coils **26**, **26** are connected to connection terminals **21***a*, **21***a*, . . . provided on both lateral sides of the movable holder **21**. To the connection terminals **21***a*, **21***a*, . . . are connected forward ends of the support springs **20**, **20**, ... Hence, the movable block **12** is connected by the support springs **20**, **20**, . . . and maintained in the hollow state.

[0078] If, in the objective lens driving device **8**, the movable block **12** is maintained in the hollow state relative to the stationary block **11** by the support springs **20**, **20**, . . . , as described above, and the movable block **12** is moved in a direction in which the focusing direction is the up-and-down direction, the movable block **12** is moved downwards under its own gravity and the support springs **20**, **20**, . . . become flexed such that the forward ends of the support springs **20**, **20**, . . . are at a lower position than the rear ends thereof. With the objective lens driving device **8**, the position thereof in which the movable block **12** is moved downwards under its own weight is set as a neutral position along the focusing direction of the movable block **12**. Thus, in the neutral position along the focusing direction, the center in the up-and-down direction of tilt magnets **29**, **29**, that is, the neutral line **M1** between the magnetic poles, coincides with the center **M2** in the up-and-down direction of the tilt coils **16**, **16**.

[0079] By setting the position of the movable block **12**, which has taken its own gravity into account, as the neutral position thereof along the focusing direction, variations in tilt characteristics of the movable block **12** attendant on the focusing movements become symmetrical in the up-and-down direction, thereby assuring reliability in the tilt movements of the objective lens driving device **8**.

[0080] Meanwhile, in case the objective lens driving device **8** is used in a state in which the focusing direction is not the up-and-down direction, it is sufficient if the position of the movable block **12** when the driving current supplied to the focusing coil **25** as the focusing servo is applied to the movable block **12** is zero is set as the neutral position of the movable block **12** along the focusing direction.

[0081] The support springs **20**, **20**, . . . are supplied from a power supply circuit with driving currents for focusing adjustment or for tracking adjustment via connecting lines **17***a*, **17***a*, . . . of the substrate for power supply **17** and via connecting parts **14***b*, **14***b*, . . . of the relay substrate **14**. Thus, two each of the support springs **20**, **20**, . . . operate as power supply members for supplying power to the focusing coil **25** and the tracking coils **26**, **26**.

[0082] The forward sides of the focusing coil **25** and both the forward and rear sides of the tracking coils **26**, **26** are associated with a pair of magnets **13**, **13**, secured to the yoke parts **9***b*, **9***b* (see **FIG. 8**). By arranging the magnets **13**, **13** in this manner, a first magnetic circuit **27** for causing movement of the movable block **12** in the focusing direction or in the tracking direction is formed by the magnets **13**, **13**, yoke parts **9***b*, **9***b*, focusing coil **25** and the tracking coils **26**, **26**.

[0083] On the rear side upper surface of the coil holder **24** of the movable holder **21**, there are mounted back yokes **28**, **28** and the tilt magnets **29**, **29** in vertically stacked states, with the back yokes being spaced apart from the magnets in the left and right direction (see **FIGS. 2 and 3**). The tilt magnets **29**, **29** are magnetized to N poles **29***a*, **29***a* and S poles **29***b*, **29***b* separated from the N poles along the focusing direction, as shown in **FIG. 2**.

[0084] The tilt magnets **29**, **29** are positioned facing the tilt coils **16**, **16** mounted on the forward surface of the stationary block **11** (see **FIG. 8**). With the tilt magnets **29**, **29** positioned facing the tilt coils **16**, **16** in this manner, a second magnetic circuit **30** for causing movement of the movable block **12** along the tilt direction is formed by the tilt magnets **29**, **29**, back yokes **28**, **28**, tilt coils **16**, **16** and the tilt yokes **10***b*, **10***b*.

[0085] When the driving current is supplied to the focusing coil **25** or to the tracking coils **26**, **26** from the power supply circuit through the substrate for power supply **17**, the relay substrate **14** and the support springs **20**, **20**, . . . , the movable block **12** is moved in the focusing direction (direction F in **FIG. 3**) or in the tracking direction (direction T in **FIG. 3**), depending on the relationship between the direction of the driving current and the direction of the magnetic flux generated in the magnets **13**, **13** and the yoke parts **9***b*, **9***b*.

[0086] Moreover, when the driving current is supplied from the power supply circuit through the substrate for power supply **17** to the tilt coils **16**, **16**, the movable block **12** is moved in the tilt direction (direction R in **FIG. 3**) by the relationship between the direction of the driving current and the direction of the magnetic flux generated in the back yokes **28**, **28** and the tilt magnets **29**, **29** and the tilt yokes **10***b*, **10***b*. It is noted that tilt adjustment is effected by the movable block **12** being moved along the tilt direction by the force of thrust generated in opposite directions (up-and-down direction) on the left and right sides of the movable block in case the driving current is supplied to the tilt coils **16**, **16**.

[0087] When the movable block **12** is moved in the focusing direction, the tracking direction or in the tilt direction, the support springs **20**, **20** are elastically deformed.

[0088] An uplift mirror **31** is arranged below the objective lens **22** mounted to the movable holder **21** (see **FIG. 9**).

[0089] In the above-described disc drive device **1**, if the disc table **3** is run in rotation with the rotation of a spindle motor, not shown, the disc-shaped recording medium **100**, mounted on the disc table **3** is run in rotation at the same time as the optical pickup **6** is moved along the radius of the disc-shaped recording medium **100**, by way of recording and/or reproducing the disc-shaped recording medium **100**.

[0090] If, during this recording and/or reproducing operation, the driving current is supplied to the focusing coil **25**, the movable block **12** of the objective lens driving device **8** is moved along the focusing direction F-F in **FIG. 3** relative to the stationary block **11**, so that the light spot of laser light radiated from a light source, not shown, and illuminated via objective lens **22** is condensed substantially vertically, in order to cope with the warping of the disc-shaped recording medium **100**, by way of performing the focusing adjustment.

[0091] When the driving current is supplied to the tracking coils **26**, **26**, the movable block **12** of the objective lens driving device **8** is moved along the tracking direction T-T, shown in **FIG. 3**, relative to the stationary block **11**, so that the light spot of laser light radiated from the light source and illuminated via the objective lens **22** is condensed on a recording track of the disc-shaped recording medium **100**, by way of performing the tracking adjustment.

[0092] When the driving current is supplied to the tilt coils **16**, **16**, the movable block **12** of the objective lens driving device **8** is moved along the tilt direction R-R, shown in **FIG. 3**, with respect to the stationary block **11**, such that the spot of the laser light radiated from the light source and illuminated via objective lens **22** is condensed on the recording track of the disc-shaped recording medium **100**, by way of performing tilt adjustment.

[0093] With the optical pickup **6**, described above, in which there are provided the tilt magnets **29**, **29** having N poles **29***a*, **29***a* and S poles **29***b*, **29***b* separated from the N poles along the focusing direction, and in which the direction of the winding cores of the tilt coils **16**, **16** is the tangential direction, about one-half portions **16***a*, **16***a*, . . . of the entire tilt coils **16**, **16** may be used as portions responsible for producing the force of thrust along the tilt direction in the movable block **12**, thereby improving the sensitivity of the movable block **12** at the time of tilt adjustment.

[0094] Since the movable block **12** may be improved in sensitivity, there is no need to use magnets with correspondingly strong magnetic force, while there is also no necessity for supplying high driving current to the tilt coils **16**, **16**, thereby reducing manufacturing costs of the objective lens driving device **8** and power consumption.

[0095] Additionally, since the direction of the winding cores of the tilt coils **16**, **16** is not the focusing direction, a small mounting space for the tilt coils **16**, **16** along the tangential direction suffices, with the result that the size of the objective lens driving device along the tangential direction may be reduced.

[0096] Moreover, with the objective lens driving device **8**, in which the objective lens **22** and the second magnetic circuit **30** for tilt adjustment are arranged on opposite sides along the tangential direction of the first magnetic circuit **27** responsible for focusing adjustment and tracking adjustment, the uplift mirror **31** may be of the same height level as the first magnetic circuit **27**, and hence the objective lens driving device **8** may correspondingly be reduced in thickness. This reduction in thickness is particularly suitable for an optical pickup used for a portable apparatus.

[0097] With the objective lens driving device **8** in which the tilt magnets **29**, **29** are provided to the movable block **12** and the tilt coils **16**, **16** are provided to the stationary block **11**, there is no necessity for providing a support spring for supplying the power to the tilt coils **16**, **16**, with the result that the number of component parts may correspondingly be reduced to simplify the assembly process for the objective lens driving device **8**.

[0098] In addition, with the objective lens driving device **8** in which the stationary plate **10** for securing the stationary block **11** is bent to form the tilt yokes **10***b*, **10***b* there is no need to provide dedicated tilt yokes, and the plate base **10***a* and the tilt yokes **10***b*, **10***b*, as components for securing the

stationary block **11**, may be used in common, with the consequence that the number of component parts may be reduced further.

[**0099**] With the objective lens driving device **8**, the back yokes **28**, **28** are provided on the surfaces of the tilt magnets **29**, **29** opposite to the surfaces thereof facing the tilt coils **16**, **16**.

[**0100**] The result is that the movable block **12** may be improved in sensitivity at the time of tilt adjustment.

[**0101**] Except where the back yokes **28**, **28** are provided, the upper portions of the tilt magnets **29**, **29** are attracted towards the first magnetic circuit **27**, while the lower portions thereof are repulsed by the first magnetic circuit **27**, given the relationship of the directions of the magnetic force produced in relevant parts, as shown in **FIG. 10**. Hence, the tilt magnets **29**, **29** are subjected to the force of downward movement P, with the result that the movable block **12** is moved downwards to affect the focusing operation.

[**0102**] The objective lens driving device **8** is provided with paired tilt magnets **29**, **29** and paired tilt coils **16**, **16** spaced apart from the paired tilt magnets along the tracking direction (direction T shown in **FIG. 11**) such that, when the movable block **12** has been moved along the tracking direction by the tracking operation, the positional relationships between the tilt magnets **29**, **29** and the first magnetic circuit **27** are changed, so that, should the tilt magnets **29**, **29** be affected by the first magnetic circuit **27**, the force of movement acting on the tilt magnets **29**, **29** on the left side differs from that on the right side. In such a case, there is the fear that the movable block **12** is tilted in the direction indicated by R shown in **FIG. 11** to tilt the optical axis of the laser light illuminated via objective lens **22** on the disc-shaped recording medium **100**.

[**0103**] Moreover, if in the objective lens driving device **8**, the spring force of the support springs **20**, **20** differs on the left and right sides due to manufacturing tolerances, the position of the base member **9** along the tracking direction is adjusted in general so that the tilt in the R-direction of the movable block **12** during the focusing movement will be optimum (zero). In this case, the positional relationships between the tilt magnets **29**, **29** and the first magnetic circuit **27** may again be changed, as above, such that the force of movement acting on the tilt magnets **29**, **29** on the left side differs from that on the right side, and hence the movable block **12** may be tilted in the R-direction shown in **FIG. 11**.

[**0104**] However, with the objective lens driving device **8** in which the back yokes **28**, **28** are provided on the surfaces of the tilt magnets **29**, **29** opposite to the surfaces thereof facing the tilt coils **16**, **16**, as described above, the stray magnetic flux from the tilt magnets **29**, **29** is decreased, as shown in **FIG. 12**, so that the second magnetic circuit **30** is not liable to be affected by the first magnetic circuit **27**, and hence it is possible to prevent the movable block **12** from being tilted in the R-direction.

[**0105**] The objective lens driving device **8** does not necessarily need to be provided with the back yokes **28**, **28**. In such a case, the objective lens **22** may be maintained spaced apart from the disc-shaped recording medium **100** by taking advantage of the force of movement generated in the tilt magnets **29**, **29** in a direction towards the base member **9** (towards below), in the non-use state in which no driving current is supplied to the focusing coil **25**, without a dependency upon the posture during use of the movable block **12**, so that the disc-shaped recording medium **100** may be prevented from contacting with the objective lens **22**.

[**0106**] In the foregoing, the focusing and tracking directions are assumed to be the up-and-down direction and the left and right direction, respectively. This is merely for the sake of illustration so that the present invention is not limited to these specific directions.

[**0107**] It should be noted that the particular shape as well as the structure of respective parts shown in the best mode for carrying out the invention is merely exemplary, so that the technical scope of the invention is not to be limited by the merely exemplary shape or structure.

[**0108**] That is, it should be understood by those skilled in the art that various modifications, combinations subcombinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

1. An optical pickup having a movable base moved along the radial direction of a disc-shaped recording medium loaded on a disc table; and an objective lens driving device arranged on said movable base, wherein the objective lens driving device comprises:

a stationary plate provided on said movable base;

a stationary block arranged on said stationary plate and secured to said movable base;

a movable block holding said objective lens and operated relative to said stationary block along a focusing direction, which is a direction towards and away from a recording surface of the disc-shaped recording medium, along a tracking direction, which is a radial direction of said disc-shaped recording medium, and along a tilt direction, which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium;

a plurality of support springs for movably supporting said movable block relative to said stationary block;

a first magnetic circuit for causing movement of said movable block along said focusing direction or along said tracking direction; and

a second magnetic circuit for causing movement of said movable block along said tilt direction;

said second magnetic circuit including

a pair of tilt magnets each magnetized to two poles so that N and S poles are arranged along the focusing direction, said paired tilt magnets being spaced apart from each other along said radial direction, and a pair of tilt coils arranged facing said paired tilt magnets, each of said tilt coils having an axis of winding wire direction corresponding to the tangential direction;

said paired tilt magnets being provided to said movable block;

said paired tilt coils being provided to said stationary block; and

said objective lens and the second magnetic circuit being located on both sides of said first magnetic circuit along the tangential direction.

2. The optical pickup according to claim 1, wherein

there is provided a tilt yoke by bending a portion of said stationary plate on the opposite side of said tilt magnet along the tangential direction with said tilt coil in-between.

3. The optical pickup according to claim 1, wherein a back yoke is provided on the surface of said tilt magnet opposite to the surface thereof facing said tilt coil.

4. An optical pickup having a movable base moved along the radial direction of a disc-shaped recording medium loaded on a disc table and an objective lens driving device arranged on said movable base, wherein said objective lens driving device comprises:

a stationary block secured to said movable base;

a movable block holding said objective lens and operated relative to said stationary block along a focusing direction, which is a direction towards and away from a recording surface of the disc-shaped recording medium, along a tracking direction, which is a radial direction of said disc-shaped recording medium, and along a tilt direction, which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium;

a plurality of support springs for movably supporting said movable block relative to said stationary block;

a first magnetic circuit for causing movement of said movable block along said focusing direction or along said tracking direction; and

a second magnetic circuit for causing movement of said movable block along said tilt direction;

said second magnetic circuit including

a pair of tilt magnets each magnetized to two poles so that N and S poles are arranged along the focusing direction, said paired tilt magnets being spaced apart from each other along said radial direction, and a pair of tilt coils arranged facing said paired tilt magnets, each of said tilt coils having an axis of winding wire direction corresponding to the tangential direction;

said paired tilt magnets being provided to said movable block;

said paired tilt coils being provided to said stationary block; and

a back yoke being arranged on the surface of said tilt magnet opposite to the surface thereof facing said tilt coil.

5. A disc drive device comprising a disc table for loading a disc-shaped recording medium thereon and an optical pickup for radiating laser light via an objective lens to the disc-shaped recording medium loaded on said disc table, said optical pickup including a movable base moved along the radial direction of a disc-shaped recording medium loaded on a disc table, and an objective lens driving device arranged on said movable base, wherein said objective lens driving device comprises:

a stationary plate provided on said movable base;

a stationary block arranged on said stationary plate and secured to said movable base;

a movable block for holding said objective lens and operated relative to said stationary block along a focusing direction, which is a direction towards and away from a recording surface of the disc-shaped recording medium, along a tracking direction, which is a radial direction of said disc-shaped recording medium, and along a tilt direction, which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium;

a plurality of support springs for movably supporting said movable block relative to said stationary block;

a first magnetic circuit for causing movement of said movable block along said focusing direction or along said tracking direction; and

a second magnetic circuit for causing movement of said movable block along said tilt direction;

said second magnetic circuit including

a pair of tilt magnets each magnetized to two poles so that N and S poles are arranged along the focusing direction, said paired tilt magnets being spaced apart from each other along said radial direction, and a pair of tilt coils arranged facing said paired tilt magnets, each of said tilt coils having an axis of winding wire direction corresponding to the tangential direction;

said paired tilt magnets being provided to said movable block;

said paired tilt coils being provided to said stationary block; and

said objective lens and the second magnetic circuit being located on both sides of said first magnetic circuit along the tangential direction.

6. The disc drive device according to claim 4, wherein

there is provided a tilt yoke by bending a portion of said stationary plate on the opposite side of said tilt magnet along the tangential direction with said tilt coil in-between.

7. The disc drive device according to claim 4, wherein a back yoke is provided on the surface of said tilt magnet opposite to the surface thereof facing said tilt coil.

8. A disc drive device comprising a disc table for loading a disc-shaped recording medium thereon and an optical pickup for radiating laser light via an objective lens to the disc-shaped recording medium loaded on said disc table, said optical pickup including a movable base moved along the radial direction of a disc-shaped recording medium loaded on a disc table and an objective lens driving device arranged on said movable base wherein said objective lens driving device comprises:

a stationary block secured to said movable base;

a movable block holding said objective lens and operated relative to said stationary block along a focusing direc-

tion, which is a direction towards and away from a recording surface of the disc-shaped recording medium, along a tracking direction, which is a radial direction of said disc-shaped recording medium, and along a tilt direction, which is a direction about an axis extending along the tangential direction perpendicular to the radial direction of the disc-shaped recording medium;

a plurality of support springs for movably supporting said movable block relative to said stationary block;

a first magnetic circuit for causing movement of said movable block along said focusing direction or along said tracking direction; and

a second magnetic circuit for causing movement of said movable block along said tilt direction;

said second magnetic circuit including

a pair of tilt magnets each magnetized to two poles so that N and S poles are arranged along the focusing direction, said paired tilt magnets being spaced apart from each other along said radial direction, and a pair of tilt coils arranged facing said paired tilt magnets, each of said tilt coils having an axis of winding wire direction corresponding to the tangential direction;

said paired tilt magnets being provided to said movable block;

said paired tilt coils being provided to said stationary block; and

a back yoke being provided on the surface of said tilt magnet opposite to the surface thereof facing said tilt coil.

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