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OPTICAL ELEMENT ACTUATION DEVICE, CAMERA MODULE, AND CAMERA-EQUIPPED DEVICE

Abstract

An ultrasonic driving device includes a power transmission part including: a pair of plates disposed on a movable part, each made of a hard material, and including main surfaces configured to make contact respectively with a pair of arms of an ultrasonic motor; and a pair of support members disposed on the movable part, the pair of support members being configured to bias the pair of plates and press the pair of plates against the pair of arms by pressing opposite surfaces of the pair of plates opposite to the main surfaces. The power transmission part is configured to transmit the vibration of the resonant portion via the pair of plates.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application is a Continuation of U.S. patent application Ser. No. 17/907,410 filed on Sep. 27, 2022, which is a National Phase of PCT Patent Application No. PCT/JP2021/013592 having International filing date of Mar. 30, 2021, which claims the benefit of priority of U.S. Provisional Patent Application No. 63/002,305 filed on Mar. 30, 2020, U.S. Provisional Patent Application No. 63/051,917 filed on Jul. 15, 2020, and U.S. Provisional Patent Application No. 63/078,357 filed on Sep. 15, 2020. The contents of the above applications are all incorporated by reference as if fully set forth herein in their entirety.

TECHNICAL FIELD
[0002] The present invention relates to an optical-element driving device, a camera module, and a camera-mounted device.
BACKGROUND ART
[0003] In general, a small-sized camera module is mounted in mobile terminals, such as smartphones. An optical-element driving device having an autofocus function of automatically performing focusing during capturing of a subject (hereinafter referred to as “Auto Focus (AF) function”) and a shake-correcting function (hereinafter referred to as “Optical Image Stabilization (OIS) function”) for reducing irregularities of an image by correcting shake (vibration) caused during capturing of an image is applied in such a camera module (see e.g., Patent Literature (hereinafter referred to as “PTL”) 1).
[0004] The optical-element driving device having the AF and OIS functions is provided with an autofocus driving unit for moving a lens part in the optical-axis direction (hereinafter, the autofocus driving unit is referred to as “AF driving unit”) and a shake-correcting driving unit for swaying the lens part in a plane orthogonal to the optical-axis direction (hereinafter, the shake-correcting driving unit is referred to as “OIS driving unit”). In PTL 1, a voice coil motor (VCM) is employed in the AF driving unit and the OIS driving unit.
[0005] In recent years, a camera module including a plurality of optical-element driving devices (typically, two optical-element driving devices) has been put into practical use (so-called dual camera). The dual cameras offer various possibilities according to situations where each of the dual cameras is used, such as a possibility that two images at different focal lengths can be captured at the same time, a possibility that a still image and a video image can be captured simultaneously, and the like.
CITATION LIST
Patent Literature
PTL 1
[0006] Japanese Patent Application Laid-Open No. 2013-210550
PTL 2
[0007] WO2015/123787
SUMMARY OF INVENTION
Technical Problem

[0008] However, the optical-element driving device utilizing the VCM as in PTL 1 is affected by external magnetism. Thus, there is a possibility that high-precision operation is impaired. In particular, in a dual camera in which optical-element driving devices are placed side by side, it is highly likely that magnetic interference occurs between the optical-element driving devices.
[0009] Meanwhile, PTL 2 discloses an optical-element driving device in which an ultrasonic motor is applied to an AF driving unit and an OIS driving unit. The optical-element driving device disclosed in PTL 2 is a magnetless device, and is thus capable of reducing the influence of external magnetism. However, its structure is complicated, and it is difficult to reduce the size and height.
[0010] An object of the present invention is to provide an optical-element driving device, a camera module, and a camera-mounted device capable of achieving a reduction in size and height and improving driving performance.
Solution to Problem
[0011] An optical-element driving device according to the present invention includes: [0012] a first fixing part; [0013] a first movable part disposed radially inside of the first fixing part; [0014] a first supporting part interposed between the first fixing part and the first movable part, and supporting the first movable part with respect to the first fixing part; [0015] a Z-direction driving part including an ultrasonic motor for converting a vibration into a linear motion, the Z-direction driving part being configured to move the first movable part in an optical-axis direction by the linear motion; and [0016] a first biasing part disposed on the first fixing part and configured to bias the first supporting part toward the first movable part, in which [0017] the first biasing part includes an elastic member that biases the supporting part, and a spacer disposed between the elastic member and the supporting part.
[0018] A camera module according to the present invention includes: [0019] the above-described optical-element driving device; [0020] an optical element to be attached to the movable part; and [0021] an image capturing part configured to capture a subject image imaged by the optical element.
[0022] A camera-mounted device according to the present invention is [0023] a camera-mounted device that is an information apparatus or a transporting apparatus, the camera-mounted device including: [0024] the above-described camera module; and [0025] an image processing part configured to process image information obtained by the camera module.
Advantageous Effects of Invention
[0026] According to the present invention, it is possible to reduce the size and height of the optical-element driving device, the camera module, and the camera-mounted device, and to improve the driving performance.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0027] FIGS. **1**A and **1**B illustrate a smartphone in which a camera module according to one embodiment of the present invention is mounted;
[0028] FIG. **2** is a perspective view of an external appearance of the camera module;
[0029] FIGS. **3**A and **3**B are external perspective views of an optical-element driving device according to the embodiment;
[0030] FIG. **4** is an exploded perspective view of the optical-element driving device according to the embodiment;
[0031] FIG. **5** is an exploded perspective view of the optical-element driving device according to the embodiment;
[0032] FIG. **6** is a plan view illustrating an interconnection structure of a base;
[0033] FIGS. **7**A and **7**B are perspective views of an OIS driving unit;

[0034] FIG. **8** is an exploded perspective view of an OIS movable part;
[0035] FIG. **9** is an exploded perspective view of the OIS movable part;
[0036] FIG. **10** is an exploded perspective view of the OIS movable part;
[0037] FIGS. **11**A and **11**B are perspective views of an AF driving unit;
[0038] FIG. **12** is a diagram illustrating a reference axis for movement of the AF movable part and the OIS movable part;
[0039] FIGS. **13**A and **13**B are diagrams illustrating a first Z-direction reference axis;
[0040] FIGS. **14**A and **14**B are diagrams illustrating a second Z-direction reference axis;
[0041] FIGS. **15**A to **15**C illustrate first and second X-direction reference axes;
[0042] FIGS. **16**A to **16**C illustrate first and second Y-direction reference axes;
[0043] FIG. **17** is a diagram illustrating one example of an OIS power transmission part;
[0044] FIGS. **18**A and **18**B are diagrams illustrating one example of a closed state of a ball housing;
[0045] FIGS. **19**A and **19**B are diagrams illustrating one exemplary AF power transmission part;
[0046] FIG. **20** is a diagram illustrating one example of second Z-direction reference balls;
[0047] FIG. **21** is a perspective view of an AF driving unit according to Modification 1;
[0048] FIG. **22** is an exploded perspective view of the AF driving unit according to Modification 1;
[0049] FIG. **23**A is a top view of the AF driving unit according to Modification 1;
[0050] FIG. **23**B is a side view of the AF driving unit;
[0051] FIG. **23**C is a sectional view of the AF driving unit as seen in the direction of arrow A-A in FIG. **23**A;
[0052] FIGS. **24**A and **24**B are perspective views of an OIS driving unit according to Modification 1;
[0053] FIG. **25** is a plan view of an OIS movable part according to Modification 2 as viewed from the light reception side in the optical-axis direction;
[0054] FIG. **26** is an exploded perspective view of the OIS movable part according to Modification 2;
[0055] FIGS. **27**A and **27**B are plan views of an AF movable part and a first stage according to Modification 2;
[0056] FIGS. **28**A and **28**B are enlarged views of a cross section and a longitudinal section of the OIS movable part according to Modification 2;
[0057] FIGS. **29**A and **29**B are views illustrating a biasing mode of biasing the AF movable part with respect to the first stage; and
[0058] FIGS. **30**A and **30**B illustrate an automobile as a camera-mounted device in which an in-vehicle camera module is mounted.

DESCRIPTION OF EMBODIMENTS

[0059] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.
[0060] FIGS. **1**A and **1**B illustrate smartphone M (one example of a camera-mounted device) in which camera module A according to one embodiment of the present invention is mounted. FIG. **1**A is a front view of smartphone M and FIG. **1**B is a rear view of smartphone M.
[0061] Smartphone M includes a dual camera consisting of two back side cameras OC**1** and OC**2**. In the present embodiment, camera module A is applied to back side cameras OC**1** and OC**2**.
[0062] Camera module A has an AF function and an OIS function, and can capture an image without image blurring by automatically performing focusing at the time of capturing a subject and by optically correcting shake (vibration) caused at the time of capturing the image.
[0063] FIG. **2** is a perspective view of an external appearance of camera module A. FIGS. **3**A and **3**B are external perspective views of optical-element driving device **1** according to the embodiment. FIG. **3**B illustrates optical-element driving device **1** rotated 180° around the Z-axis from the state of FIG. **3**A. As illustrated in FIGS. **2**, **3**A, and **3**B, the embodiment will be described

using an orthogonal coordinate system (X, Y, Z). The same orthogonal coordinate system (X, Y, Z) is also used for illustration of below-mentioned figures.

[0064] Camera module A is mounted such that the vertical direction (or horizontal direction) is the X-direction, the horizontal direction (or vertical direction) is the Y-direction, and the front-rear direction is the Z-direction, for example, during actually capturing an image with smartphone M. That is, the Z-direction is the optical-axis direction, the upper side (+Z side) in the figures is the light reception side in the optical-axis direction, and the lower side (−Z side) is the image formation side in the optical-axis direction. In addition, the X- and Y-directions orthogonal to the Z-axis are referred to as “optical-axis-orthogonal directions” and the XY plane is referred to as “optical-axis-orthogonal plane.”

[0065] As illustrated in FIGS. **2**, **3**A, and **3**B, camera module A includes: optical-element driving device **1** that implements the AF function and the OIS function; lens part **2** composed of a cylindrical lens barrel and a lens housed therein; image capturing part **3** configured to capture a subject image imaged by lens part **2**; and the like. That is, optical-element driving device **1** is a so-called lens driving device that drives lens part **2** as an optical element.

[0066] Image capturing part **3** is disposed on the image formation side of optical-element driving device **1** in the optical-axis direction. Image capturing part **3** includes, for example, image sensor board **301**, image capturing element **302**, and control part **303** mounted on image sensor board **301**. Image capturing element **302** is composed of, for example, a Charge-Coupled Device (CCD) image sensor, a Complementary Metal Oxide Semiconductor (CMOS) image sensor, or the like, and captures a subject image imaged by lens part **2**. Control part **303** is composed, for example, of a control IC, and performs a drive control of optical-element driving device **1**. Optical-element driving device **1** is mounted on image sensor board **301** and is mechanically and electrically connected to the image sensor board. Note that control part **303** may be disposed on image sensor board **301**, or may be disposed on a camera-mounted apparatus on which camera module A is mounted (smartphone M in the embodiment).

[0067] Optical-element driving device **1** is externally covered by cover **24**. Cover **24** as seen in plan view in the optical-axis direction is a capped rectangular cylindrical member. In the embodiment, cover **24** as seen in plan view in the optical-axis direction has a square shape. Cover **24** includes, in its upper surface, substantially circular opening **241**. Lens part **2** faces the outside via opening **241** of cover **24** and is configured to protrude from an opening surface of cover **24** on the light reception side, for example, with movement in the optical-axis direction. Cover **24** is fixed, for example, adhesively to base **21** (see FIG. **4**) of OIS fixing part **20** of optical-element driving device **1**.

[0068] FIGS. **4** and **5** are exploded perspective views of optical-element driving device **1** according to the embodiment. FIG. **5** illustrates the optical-element driving device rotated 180° around the Z-axis from the state of FIG. **4**. FIG. **4** illustrates the optical-element driving device to which OIS driving unit **30** and sensor board **22** are attached, and FIG. **5** illustrates the optical-element driving device from which OIS driving unit **30** and sensor board **22** are detached.

[0069] As illustrated in FIGS. **4** and **5**, in the present embodiment, optical-element driving device **1** includes OIS movable part **10** (second movable part), OIS fixing part **20** (second fixing part), OIS driving unit **30** (XY-direction driving part) and OIS supporting part **40** (second supporting part). OIS driving unit **30** includes first OIS driving unit **30**X (X-direction driving unit) and second OIS driving unit **30**Y (Y-direction driving unit).

[0070] OIS movable part **10** is a part that sways in the optical-axis-orthogonal plane during shake correction. OIS movable part **10** includes an AF unit, second stage **13**, and X-direction reference balls **42**A to **42**C (see FIG. **8** or the like). The AF unit includes AF movable part **11** (first movable part), first stage **12** (first fixing part), AF driving unit **14** (Z-direction driving part), and AF supporting part **15** (first supporting part) (see FIGS. **8** to **10**).

[0071] OIS fixing part **20** is a part to which OIS movable part **10** is connected via OIS supporting part **40**. OIS fixing part **20** includes base **21**.

[0072] OIS movable part **10** is disposed to be spaced apart from OIS fixing part **20** in the optical-axis direction, and is coupled to OIS fixing part **20** via OIS supporting part **40**. Further, OIS movable part **10** and OIS fixing part **20** are biased in a direction approaching each other by OIS biasing members **50**. In the present embodiment, OIS biasing members **50** are disposed at four corners of optical-element driving device **1** as seen in plan view.

[0073] In the present embodiment, for the movement in the Y-direction, entire OIS movable part **10** including the AF unit moves as a movable body. In addition, for the movement in the X-direction, only the AF unit moves as a movable body. That is, for the movement in the X-direction, second stage **13** together with base **21** constitutes OIS fixing part **20**, and X-direction reference balls **42**A to **42**C function as OIS supporting part **40**.

[0074] Base **21** is formed of, for example, a molded material made of polyarylate (PAR), a PAR alloy that is a mixture of multiple resin materials containing PAR (e.g., PAR/PC), or a liquid crystal polymer. Base **21** is a rectangular member in plan view, and includes circular opening **211** at the center of base **21**.

[0075] Base **21** includes first base portion **212** and second base portions **213** forming the main surface of base **21**. Second base portions **213** are disposed correspondingly to portions of OIS movable part **10** protruding on the image formation side in the optical-axis direction, i.e., protruding portions **112**A to **112**D of AF movable part **11** and AF motor fixing portion **125** of first stage **12** (see FIGS. **8** and **9**). Second base portions **213** as seen in plan view are formed to be one size larger than protruding portions **112**A to **112**D and AF motor fixing portion **125**, respectively, in order not to cause interference during shake correction. Sensor board **22** is disposed in an area of second base portions **213** where terminal metal fixture **23**B is disposed, such that the second base portions are partly exposed (such that (portions corresponding to protruding portions **112**B and **112**C are exposed). Second base portions **213** are formed to be recessed with respect to first base portion **212**, thereby ensuring a movement stroke of AF movable part **11** and achieving reduction of the height of optical-element driving device **1**.

[0076] In the present embodiment, sensor board **22** is disposed in a region where AF driving unit **14** and OIS driving unit **30** are not disposed, i.e., in a region corresponding to one side (fourth side) of a rectangle that is a planar shape of base **21**. Thus, it is possible to integrate power supply lines and signal lines for magnetic sensors **25**X, **25**Y, and **25**Z, so as to simplify the interconnection structure in base **21** (see FIG. **6**).

[0077] Base **21** includes OIS motor fixing portion **215** on which second OIS driving unit **30**Y is disposed. OIS motor fixing portion **215** is disposed, for example, at the corner of base **21**, is formed to protrude from first base portion **212** toward the light reception side in the optical-axis direction, and has a shape allowing second OIS driving unit **30**Y to be held.

[0078] Terminal metal fixtures **23**A to **23**C are disposed in base **21**, for example, by insert molding. Terminal metal fixture **23**A includes a power supply line for AF driving unit **14** and first OIS driving unit **30**X. For example, terminal metal fixture **23**A is exposed in openings **216** formed in the four corners of base **21** and is electrically connected to OIS biasing members **50**. Power supply to AF driving unit **14** and first OIS driving unit **30**X is performed via OIS biasing members **50**. Terminal metal fixture **23**B includes power supply lines (e.g., four power supply lines) for magnetic sensors **25**X, **25**Y, and **25**Z and signal lines (e.g., six signal lines). Terminal metal fixture **23**B is electrically connected to interconnections (not illustrated) formed in sensor board **22**. Terminal metal fixture **23**C includes a power supply line for second OIS driving unit **30**Y.

[0079] Further, base **21** includes Y-direction reference ball holding portions **217**A to **217**C in which Y-direction reference balls **41**A to **41**C constituting OIS supporting part **40** are disposed (see FIGS. **16**A to **16**C). Y-direction reference ball holding portions **217**A to **217**C are formed to be recessed in the shape of a rectangle extending in the Y-direction. Y-direction reference ball holding portions **217**A to **217**C are formed substantially in a V-shape (tapered shape) in a section such that the groove width tapers toward the bottom side.

[0080] In the present embodiment, Y-direction reference ball holding portions **217**A and **217**B are disposed in the side (third side) of base **21** where second OIS driving unit **30**Y is disposed, and Y-direction reference ball holding portion **217**C is disposed in the side (fourth side) where sensor board **22** is disposed. OIS movable part **10** (second stage **13**) is supported at three points by Y-direction reference balls **41**A to **41**C.

[0081] Sensor board **22** includes the interconnections (not illustrated) including the power supply lines and the signal lines for magnetic sensors **25**X, **25**Y, and **25**Z. Magnetic sensors **25**X, **25**Y, and **25**Z are mounted on sensor board **22**. Magnetic sensors **25**X, **25**Y, and **25**Z are, for example, composed of a Hall element, Tunnel Magneto Resistance (TMR) sensor, or the like, and are electrically connected to terminal metal fixture **23**B via the interconnections (not illustrated) formed in sensor board **22**. Further, opening **221** is formed in a portion of sensor board **22** corresponding to Y-direction reference ball holding portion **217**C.

[0082] Magnets **16**X and **16**Y are disposed on first stage **12** of OIS movable part **10** at positions facing magnetic sensors **25**X and **25**Y (see FIG. **10**). Position detecting parts composed of magnetic sensors **25**X and **25**Y and magnets **16**X and **16**Y detect the position of OIS movable part **10** in the X- and Y-directions.

[0083] Further, magnet **16**Z is disposed on AF movable part **11** of OIS movable part **10** at a position facing magnetic sensor **25**Z (see FIG. **10**). A position detecting part composed of magnetic sensor **25**Z and magnet **16**Z detects the position of AF movable part **11** in the Z-direction. Note that, in place of magnets **16**X, **16**Y, and **16**Z and magnetic sensors **25**X, **25**Y, and **25**Z, an optical sensor such as a photoreflector may detect the position of OIS movable part **10** in the X-and Y-directions and the position of AF movable part **11** in the Z-direction.

[0084] OIS biasing members **50** include, for example, tension coil springs, and couple OIS movable part **10** to OIS fixing part **20**. In the present embodiment, one ends of OIS biasing members **50** are connected to terminal metal fixture **23**A of base **21**, and the other ends are connected to interconnections **17**A and **17**B of first stage **12**. OIS biasing members **50** are subjected to a tensile load when OIS movable part **10** is coupled to OIS fixing part **20**, and act on OIS movable part **10** and OIS fixing part **20** such that OIS movable part **10** and OIS fixing part **20** approach each other. That is, OIS movable part **10** is held to be capable of swaying in the XY plane by OIS biasing members **50** while biased in the optical-axis direction (while pressed against base **21**). Thus, it is possible to hold OIS movable part **10** stably without rattling.

[0085] Moreover, in the present embodiment, OIS biasing members **50** function as power supply lines for AF driving unit **14** and first OIS driving unit **30**X.

[0086] OIS supporting part **40** supports OIS movable part **10** with respect to OIS fixing part **20** in a state where OIS movable part **10** is spaced apart from OIS fixing part **20** in the optical-axis direction. In the present embodiment, OIS supporting part **40** includes three Y-direction reference balls **41**A to **41**C interposed between OIS movable part **10** (second stage **13**) and base **21**.

[0087] Further, OIS supporting part **40** includes three X-direction reference balls **42**A to **42**C interposed between first stage **12** and second stage **13** in OIS movable part **10** (see FIG. **8** or the like).

[0088] In the present embodiment, restricting the directions in which Y-direction reference balls **41**A to **41**C and X-direction reference balls **42**A to **42**C (total of six balls) are rollable allows OIS movable part **10** to sway in the XY plane accurately. Note that, the number of Y-direction reference balls and X-direction reference balls constituting OIS supporting part **40** can be appropriately changed.

[0089] OIS driving unit **30** is an actuator that moves OIS movable part **10** in the X- and Y-directions. Specifically, OIS driving unit **30** is composed of first OIS driving unit **30**X (first XY-direction driving unit) for moving OIS movable part **10** (AF unit alone) in the X-direction, and second OIS driving unit **30**Y (second XY-direction driving unit) for moving entire OIS movable

part **10** in the Y-direction.
[0090] Each of first OIS driving unit **30**X and second OIS driving unit **30**Y is composed of an ultrasonic motor. First OIS driving unit **30**X is fixed to OIS motor fixing portion **124** extending along the X-direction of first stage **12** (see FIG. **9**). Second OIS driving unit **30**Y is fixed to OIS motor fixing portion **215** of base **21** in such a manner as to extend along the Y-direction. That is, first OIS driving unit **30**X and second OIS driving unit **30**Y are disposed along the sides orthogonal to each other.
[0091] The configuration of OIS driving unit **30** is illustrated in FIGS. **7**A and **7**B. FIG. **7**A illustrates OIS driving unit **30** whose members are assembled, and FIG. **7**B illustrates OIS driving unit **30** whose members are disassembled. Note that, although FIGS. **7**A and **7**B illustrate second OIS driving unit **30**Y, the illustrations are treated as illustrations of OIS driving unit **30** since the principal configuration of first OIS driving unit **30**X, specifically, the configuration excluding the shape of OIS electrode **33**, is the same as that of second OIS driving unit **30**Y.
[0092] As illustrated in FIGS. **7**A and **7**B, OIS driving unit **30** includes OIS resonant portion **31**, OIS piezoelectric elements **32**, OIS electrode **33**, and OIS power transmission part **34**. The driving force of OIS driving unit **30** is transmitted to second stage **13** via OIS power transmission part **34**. Specifically, first OIS driving unit **30**X is connected to second stage **13** via first OIS power transmission part **34**X, and second OIS driving unit **30**Y is connected to second stage **13** via second OIS power transmission part **34**Y. That is, in OIS driving unit **30**, OIS resonant portion **31** is an active element, and OIS power transmission part **34** is a passive element.
[0093] OIS piezoelectric elements **32** are, for example, plate-shaped elements formed of a ceramic material, and generate a vibration under high-frequency voltage application. Two OIS piezoelectric elements **32** are disposed to sandwich body portion **311** of OIS resonant portion **31**.
[0094] OIS electrode **33** holds OIS resonant portion **31** and OIS piezoelectric elements **32** in between, and applies a voltage to OIS piezoelectric elements **32**. OIS electrode **33** of first OIS driving unit **30**X is electrically connected to interconnection **17**A of first stage **12**, and OIS electrode **33** of second OIS driving unit **30**Y is electrically connected to terminal metal fixture **23**C of base **21**.
[0095] OIS resonant portion **31** is formed of a conductive material and resonates with the vibration of OIS piezoelectric elements **32** to convert the vibrational motion into a linear motion. OIS resonant portion **31** is formed, for example, by laser processing, etching processing, press working, or the like of a metal plate. In the present embodiment, OIS resonant portion **31** includes substantially rectangular body portion **311** sandwiched by OIS piezoelectric elements **32**, two arm portions **312** extending in the X- or Y-direction from the upper and lower portions of body portion **311**, protruding portion **313** extending in the X- or Y-direction from the central portion of body portion **311**, and energization portion **314** extending from the central portion of body portion **311** on the opposite side of protruding portion **313**. Two arm portions **312** have symmetrical shapes whose free end portions make contact with OIS power transmission part **34** and symmetrically deform in resonance with the vibration of OIS piezoelectric elements **32**. Energization portion **314** of first OIS driving unit **30**X is electrically connected to interconnection **17**A of first stage **12**, and energization portion **314** of second OIS driving unit **30**Y is electrically connected to terminal metal fixture **23**C of base **21**.
[0096] OIS piezoelectric elements **32** are bonded to body portion **311** of OIS resonant portion **31** in the thickness direction and are held in between by OIS electrode **33**, so that these are electrically connected to one another. For example, one side of a power supply path is connected to OIS electrode **33**, and the other side is connected to energization portion **314** of OIS resonant portion **31**. A voltage is applied to OIS piezoelectric elements **32**, and a vibration is thus generated.
[0097] OIS resonant portion **31** has at least two resonant frequencies, and deforms in behaviors different between the resonant frequencies. In other words, the entire shape of OIS resonant portion **31** is set such that OIS resonant portion **31** deforms in behaviors different between the two resonant

frequencies. The different behaviors include a behavior causing OIS power transmission part **34** to move forward in the X- or Y-direction, and a behavior causing OIS power transmission part **34** to move backward in the X- or Y-direction.

[0098] OIS power transmission part **34** is a chucking guide extending in one direction, whose one end is connected to arm portions **312** of OIS resonant portion **31** and whose other end is connected to second stage **13**. OIS power transmission part **34** includes OIS motor contact portions **341**, stage fixing portion **343**, and coupling portion **342**. OIS motor contact portions **341** make contact with the free end portions of arm portions **312** of OIS resonant portion **31**. Stage fixing portion **343** is disposed at an end portion of OIS power transmission part **34** and is fixed to OIS chucking guide fixing portion **135** of second stage **13** (see FIG. **8** and the like). Coupling portion **342** is a portion that couples OIS motor contact portions **341** to stage fixing portion **343**, and is formed to branch into two and extend from stage fixing portion **343** such that the two branch portions are substantially parallel with each other.

[0099] The width between OIS motor contact portions **341** is set wider than the width between the free end portions of arm portions **312** of OIS resonant portion **31**. For example, it is possible to widen the width between OIS motor contact portions **341** by interposing, between two branches of coupling portion **342** at a connecting portion between coupling portion **342** and stage fixing portion **343**, spacing portion **344** that is larger than the width between connection end portions. Thus, when OIS power transmission part **34** is attached between arm portions **312** of OIS resonant portion **31**, coupling portion **342** functions as leaf springs, and a biasing force acts on arm portions **312** in the direction of pushing out arm portion **312**. This biasing force allows OIS power transmission part **34** to be held between the free end portions of arm portions **312**. Accordingly, the driving force from OIS resonant portion **31** is efficiently transmitted to OIS power transmission part **34**. Spacing portion **344** is formed integrally with stage fixing portion **343**, for example.

[0100] Note that, although attached portions of coupling portion **342** are released on one side at stage fixing portion **343** in the example illustrated in FIGS. **7**A and **7**B, stage fixing portion **343** may have a structure for sandwiching the base of coupling portion **342** (the end portions of the coupling portion on the stage fixing portion **343** side) as illustrated in FIG. **17**. In this case, it is possible to prevent coupling portion **342** from being displaced over time to come off, and the reliability is thus improved.

[0101] OIS resonant portion **31** and OIS power transmission part **34** are only in contact with each other in a biased state; hence, it is possible to lengthen the movement stroke of OIS movable part **10** only by increasing the contact portions in the X- or Y-direction without enlarging the outer shape of optical-element driving device **1**.

[0102] First OIS driving unit **30**X is fixed to OIS movable part **10** (first stage **12**) and is connected to second stage **13** via OIS power transmission part **34**X, and moves together with OIS movable part **10** during shake correction performed by second OIS driving unit **30**Y in the Y-direction. On the other hand, second OIS driving unit **30**Y is fixed to OIS fixing part **20** (base **21**) and is connected to second stage **13** via OIS power transmission part **34**Y, and is not affected by shake correction performed by first OIS driving unit **30**X in the X-direction. That is, the movement of OIS movable part **10** by one of OIS driving units **30** is not hindered by the structure of the other one of OIS driving units **30**. Therefore, it is possible to prevent rotation of OIS movable part **10** around the Z-axis, so as to allow OIS movable part **10** to sway in the XY plane accurately.

[0103] FIGS. **8** to **10** are exploded perspective views of OIS movable part **10**. FIG. **9** illustrates OIS movable part **10** rotated 180° around the Z-axis from the state of FIG. **8**. FIG. **10** is a lower perspective view illustrating OIS movable part **10** rotated 180° around the Z-axis from the state of FIG. **8**. Note that, FIG. **9** illustrates a state where AF driving unit **14** and first OIS driving unit **30**X are detached from first stage **12**.

[0104] In the following, in a rectangle that is a planar shape of optical-element driving device **1**, the side where AF driving unit **14** is disposed is referred to as “first side,” the side where first OIS driving unit **30**X is disposed is referred to as “second side,” the side where second OIS driving unit **30**Y is disposed is referred to as “third side,” and the remaining one side is referred to as “fourth side.”

[0105] As illustrated in FIGS. **8** to **10**, in the present embodiment, OIS movable part **10** includes AF movable part **11**, first stage **12**, second stage **13**, AF driving unit **14**, AF supporting part **15**, and the like. For the movement in the Y-direction, entire OIS movable part **10** including first stage **12** and second stage **13** is a movable body, whereas for the movement in the X-direction, second stage **13** functions as OIS fixing part **20** and only the AF unit (AF movable part **11** and first stage **12**) functions as OIS movable part **10**. Further, first stage **12** functions as an AF fixing part for supporting AF movable part **11**.

[0106] AF movable part **11** is a lens holder for holding lens part **2** (see FIG. **2**), and moves in the optical-axis direction during focusing. AF movable part **11** is disposed to be spaced radially inward from first stage **12** (AF fixing part), and is supported via AF supporting part **15** while biased toward first stage **12**.

[0107] AF movable part **11** is formed of, for example, polyarylate (PAR), a PAR alloy that is a mixture of multiple resin materials containing PAR, a liquid crystal polymer, or the like. AF movable part **11** includes cylindrical lens housing **111**. Lens part **2** is fixed to the inner peripheral surface of lens housing **111**, for example, adhesively.

[0108] AF movable part **11** includes, at the outer circumferential surface of lens housing **111**, protruding portions **112**A to **112**D protruding radially outward and extending in the optical-axis direction. It is preferable that protruding portions **112**A to **112**D be disposed symmetrically with respect to the optical axis. In the present embodiment, protruding portions **112**A to **112**D are disposed around the optical axis at approximately 90° intervals. Protruding portions **112**A to **112**D protrude on the image formation side in the optical-axis direction beyond the lower surface of lens housing **111**, and make contact with second base portions **213** of base **21**, to restrict the movement of AF movable part **11** on the image formation side (lower side) in the optical-axis direction. In the present embodiment, protruding portions **112**A to **112**D make contact with second base portions **213** of base **21** in a reference state in which AF driving unit **14** is not driven.

[0109] Protruding portions **112**A and **112**B on the AF driving unit **14** side, together with first stage **12**, hold AF supporting part **15** (see FIGS. **13**A to **13**C and **14**A to **14**C). In one of the protruding portions (protruding portion **112**A), first Z-direction reference ball holding portion **112***a* for accommodating first Z-direction reference balls **15**A constituting AF supporting part **15** is formed. In the other one of the protruding portions (protruding portion **112**B), second Z-direction reference ball holding portion **112***b* for accommodating second Z-direction reference balls **15**B constituting AF supporting part **15** is formed. Further, first pressurization ball holding portion **112***c* and second pressurization ball holding portion **112***d* for respectively accommodating first pressurization balls **15**C and second pressurization balls **15**D constituting AF supporting part **15** are formed respectively in the surfaces of protruding portions **112**A and **112**B which are respectively opposite to first Z-direction reference ball holding portion **112***a* and second Z-direction reference ball holding portion **112***b*.

[0110] First Z-direction reference ball holding portion **112***a*, second Z-direction reference ball holding portion **112***b*, first pressurization ball holding portion **112***c*, and second pressurization ball holding portion **112***d* as seen in cross section are formed substantially in a V-shape (tapered shape) such that the groove widths decrease in the pressing direction of the balls. Further, light-reception-side stopper **112***e* and image-formation-side stopper **112***f* for preventing AF supporting part **15** from falling off are disposed respectively on a light-reception-side end portion and an image-formation-side end portion of each of protruding portions **112**A and **112**B in the optical-axis direction.

[0111] Further, magnet housing **114** for housing magnet **16**Z for Z position detection is disposed on the outer circumferential surface of lens housing **111**. Magnet **16**Z is disposed in magnet housing **114**. Magnetic sensor **25**Z for Z position detection is disposed on sensor board **22** at a position facing magnet **16**Z in the optical-axis direction (see FIG. **4**).

[0112] In addition, in AF movable part **11**, driving-unit housing **115** is disposed between protruding portions **112**A and **112**B. AF power transmission part **144**, which is a passive element of AF driving unit **14**, is disposed on driving-unit housing **115**. AF power transmission part **144** is a chucking guide having a predetermined length in the Z-direction, and has sidewalls facing each other in the X-direction and protruding (on the −side) in the Y-direction. Arm portions **141***b* of resonant portion **141** of AF driving unit **14** make contact with AF power transmission part **144** to push out the sidewalls of AF power transmission part **144**, and the power of AF driving unit **14** is transmitted to AF movable part **11**. When two arm portions **141***b* make contact with the sidewalls of AF power transmission part **144**, the sidewalls of AF power transmission part **144** function as leaf springs, whereby the driving force generated by deformation of resonant portion **141** is efficiently transmitted.

[0113] Note that, the structure of AF power transmission part **144** can be arbitrarily changed as appropriate. For example, as illustrated in FIGS. **19**A and **19**B, sidewalls **144***a* extending in the Z-direction may be folded back in a hairpin shape to be inclined inward with respect to the Z-direction to form leaf springs **144***b* such that biasing forces are exerted in directions of pushing back arm portions **141***b* of AF driving unit **14**. With this configuration, the driving force caused by the deformation of AF resonant portion **141** is more efficiently transmitted to AF power transmission part **144**.

[0114] In the present embodiment, AF power transmission part **144** is formed by a member separate from AF movable part **11**. AF power transmission part **144** has a U-shape in plan view, for example, and is fixed, at the bottom surface portion, to the outer circumferential surface of lens housing **111** in a state where the side surface portions face each other in the X-direction. AF power transmission part **144** is formed of a metal material such as, for example, titanium copper, nickel copper, stainless steel. Thus, as compared with the case where arm portions **141***b* of AF driving unit **14** make contact with AF movable part **11** that is a resin molded article, the driving force of AF driving unit **14** is efficiently transmitted. Note that, AF power transmission part **144** may be integrally molded with AF movable part **11**.

[0115] First stage **12** supports AF movable part **11** via AF supporting part **15**. Second stage **13** is disposed on the image formation side of first stage **12** in the optical-axis direction via X-direction reference balls **42**A to **42**C. First stage **12** moves in the X-and Y-directions during shake correction, and second stage **13** moves only in the Y-direction during shake correction.

[0116] First stage **12** as seen in plan view in the optical-axis direction is a member having a substantially rectangular shape, and is formed of, for example, a liquid crystal polymer. First stage **12** has substantially circular opening **121** at a portion corresponding to AF movable part **11**. Cutout portions **122** corresponding to protruding portions **112**A to **112**D and magnet housing **114** of AF movable part **11** are formed in opening **121**. A portion of first stage **12** corresponding to first OIS driving unit **30**X (the outer surface of the sidewall along the second side) is formed to be recessed radially inward such that first OIS driving unit **30**X can be disposed without protruding radially outward (OIS motor fixing portion **124**). Further, a portion of first stage **12** corresponding to second OIS driving unit **30**Y (the outer surface of the sidewall along the third side) is also similarly formed to be recessed radially inward.

[0117] First stage **12** includes, at the lower surface, X-direction reference ball holding portions **123**A to **123**C for holding X-direction reference balls **42**A to **42**C (see FIGS. **15**B and **15**C). X-direction reference ball holding portions **123**A to **123**C are formed to be recessed in a rectangular shape extending in the X-direction. X-direction reference ball holding portions **123**A to **123**C face X-direction reference ball holding portions **133**A to **133**C of second stage **13** in the Z-direction. X-direction reference ball holding portions **123**A and **123**B are formed substantially in a V-shape (tapered shape) in a section such that the groove width tapers toward the bottom side, and X-direction reference ball holding portion **123**C is formed substantially in a U-shape.

[0118] In first stage **12**, first Z-direction reference ball holding portion **122***a* and first pressurization ball holding portion **122***c* are disposed on the inner surface of cutout portion **122** corresponding to protruding portion **112**A of AF movable part **11** (see FIGS. **13**A and **13**B). First Z-direction reference ball holding portion **122***a* holds first Z-direction reference balls **15**A between first Z-direction reference ball holding portion **122***a* and first Z-direction reference ball holding portion **112***a* of AF movable part **11**. First pressurization ball holding portion **122***c* holds first pressurization balls **15**C between first pressurization ball holding portion **122***c* and first pressurization ball holding portion **112***c* of AF movable part **11**.
[0119] Further, in first stage **12**, second Z-direction reference ball holding portion **122***b* and second pressurization ball holding portion **122***d* are disposed on the inner surface of cutout portion **122** corresponding to protruding portion **112**B of AF movable part **11** (see FIGS. **14**A and **14**B). Second Z-direction reference ball holding portion **122***b* holds second Z-direction reference balls **15**B between second Z-direction reference ball holding portion **122***b* and second Z-direction reference ball holding portion **112***b* of AF movable part **11**. Second pressurization ball holding portion **122***d* holds second pressurization balls **15**D between second pressurization ball holding portion **122***d* and second pressurization ball holding portion **112***d* of AF movable part **11**.
[0120] First Z-direction reference ball holding portion **122***a* is formed substantially in a V-shape (tapered shape) in cross section such that the groove width decreases toward the bottom surface side. Second Z-direction reference ball holding portion **122***b*, first pressurization ball holding portion **122***c*, and second pressurization ball holding portion **122***d* are formed to have a substantially U-shaped section. Further, light-reception-side stopper **112***e* and image-formation-side stopper **112***f* for preventing AF supporting part **15** from falling off are disposed on the light-reception-side end portion and the image-formation-side end portion of each of first Z-direction reference ball holding portion **122***a* and first pressurization ball holding portion **122***c* in the optical-axis direction, and on the light-reception-side end portion and the image-formation-side end portion of each of second Z-direction reference ball holding portion **122***b* and second pressurization ball holding portion **122***d* in the optical-axis direction.
[0121] In first stage **12**, AF motor fixing portion **125** in which AF resonant portion **141**, which is an active element of AF driving unit **14**, and the like are disposed is formed on one sidewall along the X-direction (sidewall along the first side). AF motor fixing portion **125** includes an upper fixing plate (whose reference numeral is omitted) and lower fixing plate **125***a*, and AF resonant portion **141** is sandwiched between these plates. AF resonant portion **141** is inserted into, for example, an insertion hole (whose reference numeral is omitted) formed in the upper fixing plate and lower fixing plate **125***a*, and fixed by adhesion. The upper fixing plate is formed by a part of interconnection **17**B, and AF resonant portion **141** is electrically connected to interconnection **17**B.
[0122] Magnets **16**X and **16**Y for detecting the XY position are disposed on one of the sidewalls of first stage **12** extending along the Y-direction (the sidewall along the fourth side). For example, magnet **16**X is magnetized in the X-direction, and magnet **16**Y is magnetized in the Y-direction. Magnetic sensors **25**X and **25**Y for detecting the XY position are disposed on sensor board **22** at positions facing magnets **16**X and **16**Y in the optical-axis direction (see FIG. **4**).
[0123] In addition, interconnections **17**A and **17**B are embedded in first stage **12**, for example, by insert molding. Interconnections **17**A and **17**B are disposed, for example, along the first side and the second side. Interconnections **17**A and **17**B are exposed at the four corners of first stage **12**, and one ends of OIS biasing members **50** are connected to this exposed portions. Power supply to first OIS driving unit **30**X is performed via interconnection **17**A, and power supply to AF driving unit **14** is performed via interconnection **17**B.
[0124] Second stage **13** as seen in plan view in the optical-axis direction is a member having a substantially rectangular shape, and is formed of, for example, a liquid crystal polymer. Inner peripheral surface **131** of second stage **13** is formed correspondingly to the external shape of AF movable part **11**. Portions of second stage **13** corresponding to first OIS driving unit **30**X and

second OIS driving unit **30**Y (the outer surfaces of the sidewalls along the second side and the third side) are formed to be recessed radially inward as in first stage **12**.

[0125] Second stage **13** includes, at the lower surface, Y-direction reference ball holding portions **134**A to **134**C for housing Y-direction reference balls **41**A to **41**C (see FIGS. **16**A and **16**B). Y-direction reference ball holding portions **134**A to **134**C are formed to be recessed in the shape of a rectangle extending in the Y-direction. Y-direction reference ball holding portions **134**A to **134**C face Y-direction reference ball holding portions **217**A to **217**C of base **21** in the Z-direction. Y-direction reference ball holding portions **134**A and **134**B are formed substantially in a V-shape (tapered shape) in a section such that the groove width tapers toward the bottom side, and Y-direction reference ball holding portion **134**C is formed substantially in a U-shape.

[0126] In addition, second stage **13** includes, at the upper surface, X-direction reference ball holding portions **133**A to **133**C for holding X-direction reference balls **42**A to **42**C (see FIGS. **15**A to **15**C). X-direction reference ball holding portions **133**A to **133**C are formed to be recessed in a rectangular shape extending in the X-direction. X-direction reference ball holding portions **133**A to **133**C face X-direction reference ball holding portions **123**A to **123**C of first stage **12** in the Z-direction. X-direction reference ball holding portions **133**A to **133**C are formed substantially in a V-shape (tapered shape) in a section such that the groove width tapers toward the bottom side. In the present embodiment, X-direction reference ball holding portions **133**A and **133**B are disposed in the side (second side) where first OIS driving unit **30**X of second stage **13** is disposed, and X-direction reference ball holding portion **133**C is disposed in the side (first side) where AF driving unit **14** is disposed. First stage **12** is supported at three points by X-direction reference balls **42**A to **42**C.

[0127] Y-direction reference balls **41**A to **41**C constituting OIS supporting part **40** are held at multiple contact points between Y-direction reference ball holding portions **217**A to **217**C of base **21** and Y-direction reference ball holding portions **134**A to **134**C of second stage **13**. Therefore, Y-direction reference balls **41**A to **41**C roll stably in the Y-direction.

[0128] Further, X-direction reference balls **42**A to **42**C are held at multiple contact points between X-direction reference ball holding portions **133**A to **133**C of second stage **13** and X-direction reference ball holding portions **123**A to **123**C of first stage **12**. Therefore, X-direction reference balls **42**A to **42**C roll stably in the X-direction.

[0129] AF supporting part **15** is a portion for supporting AF movable part **11** with respect to first stage **12** (AF fixing part). As illustrated in FIGS. **13**A to **13**C and **14**A to **14**C, AF supporting part **15** is composed of first Z-direction reference balls **15**A, second Z-direction reference balls **15**B, first pressurization balls **15**C, and second pressurization balls **15**D. In the present embodiment, each set of first Z-direction reference balls **15**A, second Z-direction reference balls **15**B, first pressurization balls **15**C, and second pressurization balls **15**D is composed of a plurality of balls (three balls in the present embodiment) disposed side by side in the Z-direction.

[0130] First Z-direction reference balls **15**A are rollably interposed between first Z-direction reference ball holding portions **112***a* and **122***a* of AF movable part **11** and first stage **12**. Second Z-direction reference balls **15**B are rollably interposed between second Z-direction reference ball holding portions **112***b* and **122***b* of AF movable part **11** and first stage **12**. First pressurization balls **15**C are rollably interposed between first pressurization ball holding portions **112***c* and **122***c* of AF movable part **11** and first stage **12**. Second pressurization balls **15**D are rollably interposed between second pressurization ball holding portions **112***d* and **122***d* of AF movable part **11** and first stage **12**.

[0131] At least upper and lower two balls of first Z-direction reference balls **15**A, second Z-direction reference balls **15**B, first pressurization balls **15**C, and second pressurization balls **15**D only need to be held between AF movable part **11** and first stage **12**. That is, the intermediate balls are provided to secure a spacing distance between the two upper and lower balls, and may have a smaller diameter than the two upper and lower balls.

[0132] Further, as illustrated in FIG. **20**, in second Z-direction reference balls **15**B, the intermediate ball may have a larger diameter than the upper and lower two balls. In this case, two large-diameter balls of first Z-direction reference balls **15**A and one large-diameter ball of second Z-direction reference balls **15**B come into contact with AF movable part **11** and function as AF supporting part **15**. Therefore, since AF movable part **11** is supported at three points by these three balls, AF movable part **11** is held in a more stable attitude.
[0133] As illustrated in FIG. **13**A, biasing part **18** for biasing AF movable part **11** is disposed between first pressurization balls **15**C and first pressurization ball holding portion **122***c* of first stage **12**. Similarly, as illustrated in FIG. **14**A, biasing part **18** for biasing AF movable part **11** is disposed between second pressurization balls **15**D and second pressurization ball holding portion **122***d* of first stage **12**. AF movable part **11** is supported by first stage **12** in a biased state via first Z-direction reference balls **15**A, second Z-direction reference balls **15**B, first pressurization balls **15**C, and second pressurization balls **15**D, and is held in a stable attitude.
[0134] Biasing part **18** includes leaf spring **181** (biasing member) formed, for example, from a metal material and spacer **182** (interference member) formed of a ceramic material having a small coefficient of friction. Leaf spring **181** is disposed on the first stage **12** side, and spacer **182** is disposed on the AF movable part **11** side. By interposing ceramic spacer **182** between leaf spring **181** and first pressurization balls **15**C or second pressurization balls **15**D, the balls can be smoothly rolled and durability is also improved. The material of spacer **182** is not limited to a ceramic material having a small coefficient of friction as long as the spacer allows the balls to roll smoothly, and may be a material having an appropriate coefficient of friction such as a copper alloy or stainless steel, for example.
[0135] AF driving unit **14** is an actuator that move AF movable part **11** in the Z-direction. Like OIS driving units **30**, AF driving unit **14** is composed of an ultrasonic motor. AF driving unit **14** is fixed to AF motor fixing portion **125** of first stage **12** such that arm portions **141***b* extend in the Z-direction.
[0136] The configuration of AF driving unit **14** is illustrated in FIGS. **11**A and **11**B. FIG. **11**A illustrates AF driving unit **14** whose members are assembled, and FIG. **11**B illustrates AF driving unit **14** whose members are disassembled. The configuration of AF driving unit **14** is substantially the same as that of OIS driving units **30**.
[0137] As illustrated in FIGS. **11**A and **11**B, AF driving unit **14** includes AF resonant portion **141**, AF piezoelectric elements **142**, AF electrode **143**, and AF power transmission part **144**. The driving force of AF driving unit **14** is transmitted to AF movable part **11** via AF power transmission part **144**. That is, in AF driving unit **14**, AF resonant portion **141** is an active element, and AF power transmission part **144** is a passive element.
[0138] AF piezoelectric elements **142** are, for example, plate-shaped elements formed of a ceramic material, and generate a vibration under high-frequency voltage application. Two AF piezoelectric elements **142** are disposed to sandwich body portion **141***a* of AF resonant portion **141**.
[0139] AF electrode **143** holds AF resonant portion **141** and AF piezoelectric elements **142** in between, and applies a voltage to AF piezoelectric elements **142**.
[0140] AF resonant portion **141** is formed of a conductive material and resonates with the vibration of AF piezoelectric elements **142** to convert the vibrational motion into a linear motion. AF resonant portion **141** is formed, for example, by laser processing, etching processing, press working, or the like of a metal plate. In the present embodiment, AF resonant portion **141** includes substantially rectangular body portion **141***a* sandwiched between AF piezoelectric elements **142**, two arm portions **141***b* extending in the Z-direction from body portion **141***a*, energization portion **141***c* extending in the Z-direction from the central portion of body portion **141***a* and electrically connected to the power supply path (interconnections **17**B (upper fixing plate) of first stage **12**), and stage fixing portion **141***d* extending from the central portion of body portion **141***a* toward the opposite side of energization portion **141***c*. Two arm portions **141***b* has symmetrical shapes, and

symmetrically deform in resonance with the vibration of AF piezoelectric elements **142**. AF driving unit **14** is disposed such that two arm portions **141***b* extend in the Z-direction and sandwich AF power transmission part **144** at the free end portions.

[0141] AF piezoelectric elements **142** are bonded to body portion **141***a* of AF resonant portion **141** in the thickness direction and are held in between by AF electrode **143**, so that these are electrically connected to one another. When energization portion **141***c* of AF resonant portion **141** and AF electrode **143** are connected to interconnection **17**B of first stage **12**, a voltage is applied to AF piezoelectric elements **142** and a vibration is thus generated.

[0142] Like OIS resonant portion **31**, AF resonant portion **141** has at least two resonant frequencies, and deforms in behaviors different between the resonant frequencies. In other words, the entire shape of AF resonant portion **141** is set such that AF resonant portion **141** deforms in behaviors different between the two resonant frequencies.

[0143] In optical-element driving device **1**, when a voltage is applied to AF driving unit **14**, AF piezoelectric elements **142** vibrate, and AF resonant portion **141** deforms in a behavior corresponding to the frequency. The driving force of AF driving unit **14** causes sliding of AF power transmission part **144** in the Z-direction. Accordingly, AF movable part **11** moves in the Z-direction, and focusing is performed. Since AF supporting part **15** is composed of balls, AF movable part **11** can move smoothly in the Z-direction. Moreover, AF driving unit **14** and AF power transmission part **144** are only in contact with each other in a biased state; hence, it is possible to lengthen the movement stroke of AF movable part **11** easily only by increasing a contact portion in the Z-direction without preventing height reduction for optical-element driving device **1**.

[0144] In optical-element driving device **1**, when a voltage is applied to OIS driving unit **30**, OIS piezoelectric elements **32** vibrate, and OIS resonant portion **31** deforms in a behavior corresponding to the frequency. The driving force of OIS driving unit **30** causes sliding of OIS power transmission part **34** in the X- or Y-direction. Accordingly, OIS movable part **10** moves in the X- or Y-direction, and shake correction is performed. Since OIS supporting part **40** is composed of balls, OIS movable part **10** can move smoothly in the X- or Y-direction.

[0145] Specifically, when first OIS driving unit **30**X is driven and OIS power transmission part **34** moves in the X-direction, power is transmitted to second stage **13** from first stage **12** in which first OIS driving unit **30**X is disposed. At this time, balls **41** sandwiched between second stage **13** and base **21** are incapable of rolling in the X-direction, and the position of second stage **13** with respect to base **21** in the X-direction is maintained. On the other hand, balls **42** sandwiched between first stage **12** and second stage **13** are capable of rolling in the X-direction, first stage **12** moves with respect to second stage **13** in the X-direction. That is, second stage **13** serves as a component of OIS fixing part **20**, and first stage **12** serves as components of OIS movable part **10**.

[0146] Further, when second OIS driving unit **30**Y is driven and OIS power transmission part **34** moves in the Y-direction, power is transmitted to second stage **13** from base **21** where second OIS driving unit **30**Y is disposed. At this time, balls **42** sandwiched between first stage **12** and second stage **13** are incapable of rolling in the Y-direction, and the position of first stage **12** with respect to the second stage in the Y-direction is maintained. On the other hand, balls **41** sandwiched between second stage **13** and base **21** are capable of rolling in the Y-direction, second stage **13** moves with respect to base **21** in the Y-direction. First stage **12** also moves in the Y-direction following second stage **13**. That is, base **21** serves as a component of OIS fixing part **20**, and the AF unit including first stage **12** and second stage **13** serves as a component of OIS movable part **10**.

[0147] As described above, OIS movable part **10** sways in the XY plane, and shake correction is performed. Specifically, an energization voltage to OIS driving units **30**X and **30**Y is controlled based on a detection signal indicative of an angular shake from a shake detection part (for example, a gyro sensor (not illustrated)) such that the angular shake of camera module A is canceled. In this case, it is possible to accurately control the translational movement of OIS movable part **10** by feeding back the detection result of the XY position detecting part composed of magnets **16**X and **16**Y and magnetic sensors **25**X and **25**Y.

[0148] FIG. **12** is a diagram illustrating a reference axis for movement of the AF movable part and the OIS movable part. FIG. **12** is a plan view of optical-element driving device **1** as seen from the light reception side in the optical-axis direction and from which cover **24** is removed.

[0149] As illustrated in FIG. **12**, in optical-element driving device **1**, AF movable part **11** moves along first Z-direction reference axis Z**1** and second Z-direction reference axis Z**2**. First Z-direction reference axis Z**1** is a rolling axis of first Z-direction reference balls **15**A, and second Z-direction reference axis Z**2** is a rolling axis of second Z-direction reference balls **15**B.

[0150] First Z-direction reference axis Z**1** is illustrated in FIGS. **13**A and **13**B, and second Z-direction reference axis Z**2** is illustrated in FIGS. **14**A and **14**B. FIGS. **13**A and **13**B are a longitudinal sectional view and a cross-sectional view of a portion of AF movable part **11** around protruding portion **112**A in which first Z-direction reference balls **15**A are disposed, and FIGS. **14**A and **14**B are a longitudinal sectional view and a cross sectional view of a portion of AF movable part **11** around protruding portion **112**B in which second Z-direction reference balls **15**B are disposed. FIGS. **13**B and **14**B illustrate the structure in a simplified form.

[0151] First Z-direction reference balls **15**A are sandwiched by first Z-direction reference ball holding portions **112***a* and **122***a* of the AF movable part **11** and first stage **12**, and are restricted from moving in the direction perpendicular to the optical axis (the rotation of AF movable part **11**) as illustrated in FIGS. **13**A and **13**B. As a result, AF movable part **11** can be moved in a stable manner in the optical-axis direction.

[0152] Meanwhile, second Z-direction reference balls **15**B are sandwiched by second Z-direction reference ball holding portions **112***b* and **122***b* of AF movable part **11** and first stage **12**, and are allowed to move in the direction perpendicular to the optical axis as illustrated in FIGS. **14**A and **14**B. With this configuration, it is possible to absorb the dimensional tolerances of AF movable part **11** and first stage **12**, and to improve the stability during movement of AF movable part **11**.

[0153] In the present embodiment, first Z-direction reference axis Z**1** and second Z-direction reference axis Z**2** are disposed on the side of AF driving unit **14**, which is a driving force generating source, with reference to center O of circular opening **118** in AF movable part **11**, and AF driving unit **14** is positioned between first Z-direction reference axis Z**1** (first Z-direction reference balls **15**A) and second Z-direction reference axis Z**2** (second Z-direction reference balls **15**B) in the circumferential direction. That is, AF supporting part **15** and AF driving unit **14** are disposed on the same-half side of optical-element driving device **1** as seen in plan view in the optical-axis direction. The "same-half side" means the same side with respect to reference line RL serving as a boundary that passes through center O of opening **118** in AF movable part **11**.

[0154] When AF driving unit **14** is close to first Z-direction reference axis Z**1** and second Z-direction reference axis Z**2**, that is, when AF driving unit **14** is close to AF supporting part **15**, the rotational moment with respect to the supporting position is suppressed, and thus the moving operation of AF movable part **11** is stabilized. For example, even when some kind of frictional resistance occurs, AF movable part **11** is less likely to be inclined, and can be moved straight in the optical-axis direction.

[0155] It is preferable that angle θ formed by first Z-direction reference axis Z**1**, second Z-direction reference axis Z**2**, and center O of opening **118** in AF movable part **11** be 45° to 180°. Further, it is preferable that first Z-direction reference axis Z**1** and second Z-direction reference axis Z**2** be disposed symmetrically with respect to AF driving unit **14**. With such a configuration, the stability of the moving operation of AF movable part **11** can be further improved.

[0156] Further, in the present embodiment, first Z-direction reference balls **15**A and second Z-direction reference balls **15**B (hereinafter referred to as "Z-direction reference balls **15**A and **15**B") roll without slippage being caused as AF movable part **11** moves.

[0157] That is, image-formation-side stopper **112***f* of AF movable part **11** is located on the image formation side of image-formation-side stopper **122**_f_ of first stage **12** in the optical-axis direction in the reference state, and is spaced apart from the lower end of Z-direction reference balls **15**A and **15**B (hereinafter referred to as the "ball lower end"). The separation distance between image-formation-side stopper **112**_f_ of AF movable part **11** and the ball lower end is set to be larger than the maximum value of the movement stroke of AF movable part **11**.

[0158] Light-reception-side stopper **122**_e_ of first stage **12** is spaced apart from the upper end of Z-direction reference balls **15**A and **15**B (hereinafter referred to as "ball upper end"). The separation distance between light-reception-side stopper **122**_e_ of first stage **12** and the ball upper end is set to be larger than the maximum value of the movement displacement of Z-direction reference balls **15**A and **15**B (smaller than the maximum movement stroke of AF movable part **11**) accompanying the movement of AF movable part **11**.

[0159] Z-direction reference balls **15**A and **15**B are sandwiched between, for example, light-reception-side stopper **112**_e_ of AF movable part **11** and image-formation-side stopper **122**_f_ of first stage **12** in the reference state.

[0160] Thus, when AF movable part **11** moves, image-formation-side stopper **112**_f_ of AF movable part **11** does not reach the ball lower end. Accordingly, first Z-direction reference balls **15**A and second Z-direction reference balls **15**B roll without slippage being caused. The friction between, on one hand, AF movable part **11** and first stage **12** and, on the other hand, Z-direction reference balls **15**A and **15**B is not the sliding friction but the rolling friction, and AF movable part **11** moves smoothly. Thus, the stable operation of AF movable part **11** can be further improved. Further, by disposing light-reception-side stoppers **112**_e_ and **122**_e_ and image-formation-side stoppers **112**_f_ and **122**_f_, it is possible to suppress intrusion of foreign matter such as dust, and to prevent rolling of Z-direction reference balls **15**A and **15**B from being hindered by the foreign matter.

[0161] Light-reception-side stopper **122**_e_ of first stage **12** is formed by, for example, slide cover **19** (see FIGS. **18**A and **18**B). FIG. **18**A illustrates a state in which slide cover **19** is attached, and FIG. **18**B illustrates a state in which slide cover **19** is removed.

[0162] As illustrated in FIG. **18**B, slide cover **19** has protruding pieces **19**_a_ and **19**_b_ having different protrusion lengths on opposite sides in a sliding direction. Meanwhile, in first stage **12**, the ball housings (whose reference symbol is omitted) that house first Z-direction reference balls **15**A, first pressurization balls **15**C, second Z-direction reference balls **15**B, and second pressurization balls **15**D are open on the light reception side in the optical-axis direction, and recessed portion **126** is disposed at an open end portion.

[0163] After slide cover **19** is disposed such that protruding piece **19**_a_ having a longer protrusion length is inserted in insertion hole **126**_a_ formed in one end of recessed portion **123** in the sliding direction, slide cover **19** is slid such that protruding piece **19**_b_ having a shorter protrusion length is inserted into insertion hole **126**_b_ formed at the other end of recessed portion **126**. Protruding pieces **19**_a_ and **19**_b_ of slide cover **19** are engaged with insertion holes **126**_a_ and **126**_b_ of recessed portion **126**, and slide cover **19** closes the light reception side of the ball housing in the optical-axis direction. Although not illustrated in the figures, for example, a roughened structure may be formed on contact surfaces of recessed portion **126** and slide cover **19** such that the slide cover is non-slidably locked at a predetermined position.

[0164] As described above, by forming light-reception-side stopper **122**_e_ of first stage **12** using slide cover **19**, AF movable part **11** can be inserted from the light reception side of first stage **12** in the optical-axis direction in a state in which first and second Z-direction reference balls **15**A and **15**B and first and second pressurization balls **15**C and **15**D are disposed on protruding portions **112**A and **112**B of AF movable part **11**. Thus, the workability at the time of assembly is improved.

[0165] As illustrated in FIG. **12**, in optical-element driving device **1**, OIS movable part **10** (only the AF unit) moves along first X-direction reference axis X**1** and second X-direction reference axis X**2**. First X-direction reference axis X**1** is a rolling axis of X-direction reference balls **42**A and **42**B, and second X-direction reference axis X**2** is a rolling axis of X-direction reference ball **42**C. First X-direction reference axis X**1** may be a plurality of axes (first X-direction reference axes X**11** and X**12**) as in the present embodiment, or may be a single axis. The same applies to second X-direction reference axis X**2**.

[0166] X-direction reference axes X**1** and X**2** are illustrated in FIGS. **15**A to **15**C. FIG. **15**A is a plan view of optical-element driving device **1** as seen from the light reception side in the optical-axis direction and from which AF movable part **11** and first stage **12** are removed. FIG. **15**B illustrates a longitudinal section of X-direction reference ball holding portions **133**A and **133**B taken along the Y-direction, and FIG. **15**C is a longitudinal section of X-direction reference ball holding portion **133**C taken along the Y-direction. In FIGS. **15**C and **15**B, the structure is illustrated in a simplified form.

[0167] As illustrated in FIG. **15**B, X-direction reference balls **42**A and **42**B are sandwiched between X-direction reference ball holding portions **133**A and **133**B of second stage **13** and X-direction reference ball holding portions **123**A and **123**B of first stage **12**, and are restricted from moving in the Y-direction. As a result, OIS movable part **10** (AF movable part **11** and first stage **12**) can be moved in the X-direction in a stable behavior.

[0168] Meanwhile, as illustrated in FIG. **15**C, X-direction reference ball **42**C is allowed to move in the Y-direction by X-direction reference ball holding portions **133**C and **123**C of second stage **13** and first stage **12**. With this configuration, it is possible to absorb the dimensional tolerances of second stage **13** and first stage **12**, and to improve the stability during movement of OIS movable part **10** in the X-direction.

[0169] Pressure is applied to X-direction reference balls **42**A to **42**C in the Z-direction by OIS biasing members **50**.

[0170] In the present embodiment, first X-direction reference axes X**1** (X**11**, X**12**) are provided on the side of first OIS driving unit **30**X, which is a driving force generating source, with reference to center O of circular opening **118** in AF movable part **11**. As a result, the moment for causing rotation around the optical-axis direction is suppressed. Thus, the movement of OIS movable part **10** in the X-direction is stabilized.

[0171] Further, in the present embodiment, OIS movable part **10** (first stage **12**) is supported at three points with respect to OIS fixing part **20** (second stage **13**) by X-direction reference balls **42**A to **42**C disposed to surround center O of circular opening **118** in AF movable part **11**. As a result, even if warpage or the like is caused in a part, first stage **12** reliably makes contact with X-direction reference balls **42**A to **42**C. Thus, the attitude of first stage **12** is stabilized.

[0172] As illustrated in FIG. **12**, in optical-element driving device **1**, OIS movable part **10** (the AF unit and second stage **13**) moves along first Y-direction reference axis Y**1** and second Y-direction reference axis Y**2**. First Y-direction reference axis Y**1** is a rolling axis of Y-direction reference balls **41**A and **41**B, and second Y-direction reference axis Y**2** is a rolling axis of Y-direction reference ball **41**C. Note that first Y-direction reference axis Y**1** may be a single axis as in the present embodiment, or may be a plurality axes. The same applies to second Y-direction reference axis Y**2**.

[0173] Y-direction reference axes Y**1** and Y**2** are illustrated in FIGS. **16**A to **16**C. FIG. **16**A is a plan view of optical-element driving device **1** (mainly, base **21**) as viewed from the light reception side in the optical-axis direction and from which AF movable part **11**, first stage **12**, and second stage **13** are removed. FIG. **16**B illustrates a longitudinal section along the X-direction of Y-direction reference ball holding portions **217**A and **217**B, and FIG. **16**C illustrates a longitudinal section along the X-direction of Y-direction reference ball holding portion **217**C. In FIGS. **16**B and **16**C, the structure is illustrated in a simplified form.

[0174] As illustrated in FIG. **16**B, Y-direction reference balls **41**A and **41**B are sandwiched between Y-direction reference ball holding portions **217**A and **217**B of base **21** and Y-direction reference ball holding portions **134**A and **134**B of second stage **13**, and are restricted from moving in the X-direction. As a result, OIS movable part **10** (AF movable part **11**, first stage **12**, and second stage **13**) can be moved in the Y-direction in a stabilized behavior.

[0175] Meanwhile, as illustrated in FIG. **16**C, Y-direction reference ball **41**C is allowed to move in the X-direction by Y-direction reference ball holding portions **217**C and **134**C of base **21** and second stage **13**. With this configuration, it is possible to absorb the dimensional tolerances of base **21** and second stage **13**, and to improve the stability during movement of OIS movable part **10** in the Y-direction.
[0176] Pressure is applied to X-direction reference balls **42**A to **42**C in the Z-direction by OIS biasing members **50**.
[0177] In the present embodiment, first Y-direction reference axis Y**1** is provided on the side of second OIS driving unit **30**Y, which is a driving force generating source, with reference to center O of circular opening **118** in AF movable part **11**. As a result, the moment for causing rotation around the optical-axis direction is suppressed. Thus, the movement of OIS movable part **10** in the Y-direction is stabilized.
[0178] Further, in the present embodiment, OIS movable part **10** (second stage **13**) is supported at three points with respect to OIS fixing part **20** (base **21**) by Y-direction reference balls **41**A to **42**C disposed to surround center O of circular opening **118** in AF movable part **11**. Thus, even if warpage or the like occurs in a part, second stage **13** reliably makes contact with Y-direction reference balls **41**A to **41**C. Thus, the attitude of second stage **13** is stabilized.
[0179] As is understood, optical-element driving device **1** according to the embodiment includes first stage **12** (first fixing part), AF movable part **11** (first movable part) disposed radially inside of first stage **12**, AF supporting part **15** (first supporting part) for supporting AF movable part **11** with respect to first stage **12**, AF driving unit **14** (Z-direction driving part) disposed on first stage **12** and configured to move AF movable part **11** with respect to first stage **12** in the optical-axis direction. The optical-element driving device has a rectangular shape in plan view when viewed from the optical-axis direction.
[0180] AF driving unit **14** includes an ultrasonic motor that converts a vibrational motion into a linear motion, and is disposed on the first side of a rectangle so as to transmit the linear motion to AF movable part **11**.
[0181] AF supporting part **15** includes first Z-direction reference balls **15**A (first reference balls), second Z-direction reference ball **15**B (second reference balls), and leaf spring **181** (first biasing member and second biasing member) that biases AF movable part **11** to first stage **12** via first Z-direction reference balls **15**A and second Z-direction reference balls **15**B.
[0182] AF movable part **11** and first stage **12** include, at the first-side side of center O of circular opening **118** in AF movable part **11**, first Z-direction reference ball holding portions **112***a* and **122***a* (first reference ball holding portions) and second Z-direction reference ball holding portions **112***b* and **122***b* (second reference ball holding portions) that are formed along the optical-axis direction and accommodate first Z-direction reference balls **15**A and second Z-direction reference balls **15**B, respectively. AF driving unit **14** is positioned between first Z-direction reference balls **15**A and second Z-direction reference balls **15**B in the circumferential direction.
[0183] In optical-element driving device **1**, biasing part **18** includes leaf spring **181** (elastic member) that biases AF supporting part **15**, and spacer **182** disposed between leaf spring **181** and AF supporting part **15**.
[0184] Further, in optical-element driving device **1**, AF driving unit **14** (Z-direction driving part) extends linearly in a plane orthogonal to the optical-axis direction, and AF supporting part **15** (first supporting part) and AF driving unit **14** are disposed on the same-half side of optical-element driving device **1** as seen in plan view in the optical-axis direction.
[0185] Further, optical-element driving device **1** includes: OIS fixing part **20** (second fixing part); OIS movable part **10** (second movable part) that includes first stage **12** (first fixing part), AF movable part **11** (first movable part), and AF supporting part **15** (first supporting part) and that is disposed to be spaced apart from OIS fixing part **20** in the optical-axis direction; and OIS driving unit **30** (XY-direction driving part) that includes an ultrasonic motor that converts a vibration into a

linear motion and moves OIS movable part **10** in a direction orthogonal to the optical-axis direction by the linear motion. AF driving unit **14** (Z-direction driving part) is disposed in a region (first linear region) along the first side in a plane orthogonal to the optical-axis direction, and OIS driving unit **30** (XY-direction driving part) is disposed in a region (second linear region) along a second side orthogonal to the first side and a region (third linear region) along a third side parallel to the first side.

[0186] Further, optical-element driving device **1** includes sensor board **22** on which magnetic sensors **25**X, **25**Y, and **25**Z (detecting sensors) for detecting the position of AF movable part **11** (first movable part) in the optical-axis direction and the position of OIS movable part **10** (second movable part) in the direction perpendicular to the optical axis are mounted. Sensor board **22** is disposed in a region other than the first to the third linear regions.

[0187] According to optical-element driving device **1**, since AF driving unit **14** is composed of an ultrasonic motor, it is possible to reduce an influence of external magnetism, and to reduce the size and height.

[0188] In addition, arm portions **141***b* of AF driving unit **14** extend in the optical-axis direction and are sandwiched by AF power transmission part **144**, and the driving force of AF driving unit **14** is transmitted to AF movable part **11** to the maximum extent. Thus, the driving force for moving AF movable part **11** can be efficiently obtained. Moreover, by bringing the position of AF driving unit **14** and the position of AF supporting part **15** close to each other, the rotational moment with respect to the supporting position is suppressed. Thus, the moving operation of AF movable part **11** is stabilized. Therefore, the driving performance of optical-element driving device **1** is remarkably improved.

[0189] Even when camera modules A having optical-element driving device **1** are disposed close to each other as in smartphone M, no magnetic influence is caused. Thus, the optical-element driving device is extremely suitable for use in a dual camera.

Modification 1

[0190] As described in the embodiment, the structure of AF power transmission part **144** (passive element) of AF driving unit **14** can be arbitrarily changed as appropriate. In the embodiment, as illustrated in FIGS. **19**A and **19**B, AF power transmission part **144** includes leaf springs **144***b*, and AF resonant portion **141** and AF power transmission part **144** are held in contact with each other by their own biasing function. In this case, biasing loads by leaf springs **144***b* change with the movement of AF movable part **11** in the optical-axis direction. For example, when AF movable part **11** is displaced toward the image formation side in the optical-axis direction, the biasing loads by leaf springs **144***b* increase. Conversely, when AF movable part **11** is displaced toward the light reception side in the optical-axis direction, the biasing loads by leaf springs **144***b* decrease. Therefore, in order to transmit a predetermined power from AF resonant portion **141** to AF power transmission part **144**, a device such as that for increasing the rigidity of leaf springs **144***b* is required. Modification 1 is improved such that the biasing loads of the AF power transmission part with respect to AF resonant portion **141** are constant regardless of the displacement of AF movable part **11**.

[0191] FIGS. **21**, **22**, and **23**A to **23**C illustrate the configuration of AF driving unit **14** according to Modification 1. FIG. **21** is a perspective view of AF driving unit **14** according to Modification 1. FIG. **22** is an exploded perspective view of AF driving unit **14** according to Modification 1. FIG. **23**A is a top view of AF driving unit **14** according to Modification 1, FIG. **23**B is a side view of the AF driving unit, FIG. **23**C is a sectional view of the AF driving unit as seen in the direction of arrow A-A in FIG. **23**A.

[0192] As illustrated in FIGS. **21** and the like, AF driving unit **14** according to Modification 1 is disposed in driving-unit housing **115** of AF movable part **11** as in the embodiment. AF movable part **11** is provided with plate housings **116** that bulge radially outward, with driving-unit housing **115** being interposed therebetween.

[0193] The configuration of AF driving unit **14** on the active side (such as AF resonant portion **141**) is the same as that of the embodiment. Modification 1 differs from the embodiment in that plates **61** are interposed between AF resonant portion **141** and biasing member **62**, and the power from AF resonant portion **141** is transmitted to AF movable part **11** via plates **61**. That is, in Modification 1, two plates **61** function as AF power transmission part **144** that is a passive element of AF driving unit **14**.

[0194] Plates **61** are, for example, a hard plate-like member made of a metal material such as titanium copper, nickel copper, or stainless steel. Plates **61** are disposed in AF movable part **11** along the moving direction such that the main surfaces of the plates make contact with arm portions **141***b* of AF resonant portion **141**, and are movable integrally with AF movable part **11**. In Modification 1, plates **61** are disposed in plate housings **116** of AF movable part **11** and are physically locked. Specifically, plates **61** are fixed to AF movable part **11**, with guide insertion portions **611** being loosely fitted in guide grooves **116***a* formed in AF movable part **11** and fixation pieces **612** being disposed between the bottom surfaces of recessed portion **116***c* and locking piece **116***b*.

[0195] Plates **61** only need to be fixed to AF movable part **11** to be capable of following the attachment state (individual difference in attachment position) of AF resonant portion **141**. The plates do not have to be bonded, or may be bonded with an elastically deformable soft adhesive (for example, silicone rubber).

[0196] Biasing member **62** is a member for biasing plates **61** toward arm portions **141***b* of AF resonant portion **141**, and includes two spring portions **621**. Spring portions **621** are configured to press plates **61** against arm portions **141***b* with the same biasing forces.

[0197] In Modification 1, biasing member **62** is formed by, for example, sheet metal processing, and spring portions **621** are formed from leaf springs extending from coupling portion **622**. Specifically, the leaf springs of spring portions **621** are formed to extend from a lower portion of coupling portion **622** toward the −side in the Z-direction, to be folded back outward in a hairpin shape, and to be inclined inward with respect to the Z-direction.

[0198] Biasing member **62** is fixed to AF movable part **11** by placing coupling portion **622** on spring placement portions **115***a* disposed on driving-unit housing **115** and disposing spring portions **621** in recessed portions **116***c* of plate housings **116**. Plates **61** are positioned at hairpin portions of biasing member **62**, and are biased toward the inside (toward the arm portion **141***b* side) by spring portions **621**. In Modification 1, biasing member **62** is not bonded to AF movable part **11** so as to be capable of following the attachment position of AF driving unit **14**. That is, biasing member **62** is movable along an attachment surface of driving-unit housing **115**, and is held at a position where the biasing loads of two spring portions **621** are uniform when the biasing member sandwiches AF driving unit **14** (AF resonant portion **141** and plates **61**)

[0199] Note that the configuration of biasing member **62** is one example and can be changed as appropriate. For example, the configuration of AF power transmission part **144** illustrated in FIGS. **19**A and the like may be applied. Alternatively, an elastic body such as a coil spring or a hard rubber may be used.

[0200] As is understood, in Modification 1, AF driving unit **14** (Z-direction driving part) includes AF piezoelectric elements **142** that generate vibration under application of voltage, AF resonant portion **141** (active element) that resonates with the vibration of AF piezoelectric elements **142** and converts the vibration into a linear motion, AF power transmission part **144** (passive element) that is disposed in AF movable part **11** (first movable part) and moves relatively to AF resonant portion **141** in response to the linear motion of AF resonant portion **141**, and biasing member **62** (second biasing part) that is disposed on AF movable part **11** and biases AF power transmission part **144** toward AF resonant portion **141**, in which AF power transmission part **144** is composed of plates **61** making contact with AF resonant portion **141**. Specifically, AF power transmission part **144** makes contact with two arm portions **141***b* of AF resonant portion **141**, receives the power of arm portions **141***b*, and moves relatively to AF resonant portion **141**. Biasing member **62** biases AF power transmission part **144** toward arm portions **141***b*. AF power transmission part **144** is composed of two plates **61** that are disposed in AF movable part **11** along the moving direction, and make contact respectively with arm portions **141***b*, and plates **61** are biased respectively toward arm portions **141***b* by biasing member **62**.

[0201] Accordingly, biasing member **62** presses plates **61** against arm portions **141***b* with the same biasing forces. Thus, even when AF movable part **11** moves in the optical-axis direction, a biased state (biasing loads) between arm portions **141***b* of AF resonant portion **141** as the active element and plates **61** as the passive element is not changed. Therefore, the power from AF resonant portion **141** can be stably transmitted to AF movable part **11** via plates **61** as compared with the case where AF power transmission part **144** also functions as a spring as in the embodiment.

[0202] Further, in the case where AF power transmission part **144** also functions as a spring as in the embodiment, it is difficult to employ a material having high rigidity. Unlike this, in Modification 1, it is easy to increase the rigidity of plates **61**. Further, as compared with the embodiment, the power transmission path from AF resonant portion **141** to AF movable part **11** is short. Therefore, the power transmission efficiency of power transmission from AF resonant portion **141** to AF movable part **11** can be improved.

[0203] Further, since plates **61** have a flat surface, any surface treatment can be appropriately performed. For example, when a coating layer such as diamond-like carbon (DLC) or ceramic is formed on the surface, the abrasion resistance is remarkably improved.

[0204] In addition, in AF driving unit **14** of Modification 1, AF power transmission part **144** (passive element) includes two plates **61**. Biasing member **62** includes two spring portions **621** for biasing respective plates **61**. AF resonant portion **141** (active element) and plates **61** (passive element) are sandwiched by spring portions **621**.

[0205] As a result, AF driving unit **14** is held in a state in which the biasing forces of two spring portions **621** are balanced. Thus, uniform biasing forces can be easily applied to left and right plates **61**.

[0206] Further, biasing member **62** is formed from a single member, and is disposed on AF movable part **11** to be capable of following the attached state of AF driving unit **14**.

[0207] As a result, alignment is easily performed in accordance with the attached state of AF driving unit **14**. Thus, the stability of the operation is further improved.

[0208] The above-described configuration of AF driving unit **14** can also be applied to OIS driving unit **30** as illustrated in FIGS. **24**A and **24**B. In FIGS. **24**A and **4**B, biasing member **62** is composed of a member having a simple U-shaped section. Plates **61** are fixed to second stage **13**. That is, by applying the combination of plates **61** and biasing member **62** in place of OIS power transmission part **34** of the embodiment, it is possible to easily cope with the long stroke, and the stability of the operation is improved.

Modification 2

[0209] FIG. **25** is a plan view of OIS movable part **10** according to Modification 2 as seen from the light reception side in the optical-axis direction. FIG. **26** is an exploded perspective view of OIS movable part **10** according to Modification 2. In FIGS. **25** and **26**, illustration of second stage **13** is omitted. FIGS. **27**A and **27**B are plan views of AF movable part **11** and first stage **12** according to Modification 2. FIGS. **28**A and **28**B are enlarged views of a cross section and a longitudinal section of OIS movable part **10** according to Modification 2. FIG. **28**A is a sectional view taken along line C-C and seen in the direction indicated by the arrows in FIG. **28**B, and FIG. **28**B is a sectional view taken along line B-B and seen in the direction indicated by the arrows in FIG. **25**. FIGS. **29**A and **29**B are enlarged views illustrating the placement of AF supporting part **15**.

[0210] The same or corresponding constituent elements as those of optical-element driving device **1** illustrated with respect to the embodiment and Modification 1 are denoted by the same reference numerals, and description thereof will be omitted.

[0211] As illustrated in FIGS. **25** and the like, in Modification 2, AF movable part **11** includes, on the circumferential surface portion of lens housing **111**, protruding portions **112**C, **112**D, **117**A, and **117**B protruding toward first stage **12**. Protruding portions **112**C and **112**D are the same as that of the embodiment. Protruding portions **117**A and **117**B are disposed to face each other in the X-direction, and form one space extending in the tangential direction (here, the X-direction) of lens housing **111**.
[0212] Protruding portions **117**A and **117**B, together with first stage **12**, hold Z-direction reference balls **15**A and **15**B being AF supporting part **15**. First Z-direction reference ball holding portion **117***a* for accommodating first Z-direction reference balls **15**A is formed in protruding portion **117**A of protruding portions **117**A and **117**B. Second Z-direction reference ball holding portion **117***b* for accommodating second Z-direction reference balls **15**B is formed in protruding portion **117**B of protruding portions **117**A and **117**B. First Z-direction reference ball holding portion **117***a* and second Z-direction reference ball holding portion **117***b* are formed substantially in a V-shape (tapered shape) in a section such that the groove widths decrease toward the groove bottoms.
[0213] In addition, in AF movable part **11**, a space formed by protruding portions **117**A and **117**B serves as driving-unit housing **115** in which AF driving unit **14** is disposed. The holding structure for holding AF driving unit **14** is, for example, the same as that of Modification 1. That is, plates **61** being a passive element of AF driving unit **14** are interposed between AF resonant portion **141** and biasing member **62**. AF driving unit **14** is sandwiched between two plates **61**, and the power from AF resonant portion **141** is transmitted to AF movable part **11** via plates **61**.
[0214] In Modification 2, protruding portions **117**A and **117**B have both functions of a function of protruding portions **112**A and **112**B in the embodiment for housing Z-direction reference balls **15**A and **15**B and a function of plate housings **116** in Modification 1 for housing plates **61**.
[0215] In first stage **12**, AF motor fixing portion **125** is formed by cutting out portions corresponding to protruding portions **117**A and **117**B of AF movable part **11** and corresponding to the space sandwiched between the protruding portions. Further, first Z-direction reference ball holding portion **127***a* and second Z-direction reference ball holding portion **127***b* are formed continuously to both sides of AF motor fixing portion **125**.
[0216] First Z-direction reference ball holding portion **127***a* is formed along tangential direction D**1** of lens housing **111** (see FIG. **29**A). Further, the inner surface of first Z-direction reference ball holding portion **127***a* (the surface on the AF motor fixing portion **125** side) is formed to have a substantially V-shaped (tapered) sectional shape such that the groove width decreases toward the groove bottom.
[0217] Second Z-direction reference ball holding portion **127***b* is formed to be inclined with respect to tangential direction D**1** of lens housing **111** (see FIG. **29**B). Further, the inner surface of second Z-direction reference ball holding portion **127***b* (the surface on the AF motor fixing portion **125** side) is formed to have a substantially U-shaped section. Biasing part **18** (leaf spring **181** and spacer **182**) for biasing AF movable part **11** via second Z-direction reference balls **15**B is disposed together with second Z-direction reference balls **15**B in second Z-direction reference ball holding portion **127***b*. Note that, FIG. **27**B illustrates a state in which leaf spring **181** is removed.
[0218] Second Z-direction reference balls **15**B are biased obliquely with respect to tangential direction D**1** of lens housing **111** (see FIG. **29**B). Thus, AF movable part **11** is pressed via second Z-direction reference balls **15**B in the X-direction and the Y-direction, which are two directions orthogonal to each other, and is held in a stable attitude in the optical-axis-orthogonal plane. Letting the angle between tangential direction D**1** and biasing direction D**2** be θ and the pressure by leaf spring **181** be F, the pressing force in the Y-direction is F**1**=F.Math.sin θ, and the pressing force in the X-direction is F**2**=F.Math.cos θ.
[0219] Here, angle θ formed by tangential direction D**1** and biasing direction D**2** is, for example, 0° to 45° (excluding 0°). Biasing direction D**2** is set in balance with pressure F, for example, such that the rotation of AF movable part **11** about the optical axis is restricted. For example, when angle θ

formed between biasing direction D**2** and tangential direction D**1** is increased, the pressing force in the Y-direction is increased. Accordingly, pressure F by leaf spring **181** can be reduced. However, increased angle θ causes disadvantages in terms of space, such as a need to increase the protrusion length of protruding portions **117**A and **117**B. On the contrary, it is advantageous in terms of space when angle θ formed between biasing direction D**2** and tangential direction D**1** is small. However, the pressing force in the Y-direction is reduced, and it is thus necessary to increase the pressure by leaf spring **181**.

[0220] First Z-direction reference balls **15**A are held between first Z-direction reference ball holding portions **117***a* and **127***a* of AF movable part **11** and first stage **12** in a rollable manner. Further, second Z-direction reference balls **15**B are held between spacer **182** disposed in second Z-direction reference ball holding portion **127***b* of first stage **12** and second Z-direction reference ball holding portion **117***b* of AF movable part **11** in a rollable manner. AF movable part **11** is supported and held in a stable attitude by first stage **12** while biased via first Z-direction reference balls **15**A and second Z-direction reference balls **15**B. In Modification 2, second Z-direction reference balls **15**B also function as pressurization balls.

[0221] First Z-direction reference balls **15**A are sandwiched between AF movable part **11** and first stage **12**, and are restricted from moving in the direction perpendicular to the optical axis (the rotation of AF movable part **11**). As a result, AF movable part **11** can be moved in a stable manner in the optical-axis direction.

[0222] Meanwhile, second Z-direction reference balls **15**B are sandwiched between AF movable part **11** and first stage **12** via leaf spring **181** and spacer **182**, and are allowed to move in the direction perpendicular to the optical axis. With this configuration, it is possible to absorb the dimensional tolerances of AF movable part **11** and first stage **12**, and the stability during movement of AF movable part **11** is improved.

[0223] Further, first Z-direction reference balls **15**A and second Z-direction reference balls **15**B are composed of two balls, and the diameters thereof are set to be larger than those in the embodiment and Modification 1. In this case, the rolling resistances of first Z-direction reference balls **15**A and second Z-direction reference balls **15**B are smaller than those in the embodiment and Modification 1.

[0224] As described above, in Modification 2, AF supporting part **15** that supports AF movable part **11** (movable part) with respect to first stage **12** (fixing part) includes first Z-direction reference balls **15**A (first reference balls), second Z-direction reference balls **15**B (second reference balls), and leaf spring **181** (biasing member) that biases AF movable part **11** to first stage **12** via second Z-direction reference balls **15**B. AF movable part **11** includes cylindrical lens housing **111** (circumferential surface portion) and protruding portions **117**A and **117**B (first protruding portion and second protruding portion) disposed on lens housing **111** to protrude toward first stage **12** and forming one space extending in the X-direction (tangential direction D**1** of lens housing **111**). AF driving unit **14** (driving unit) is sandwiched between protruding portions **117**A and **117**B, and first Z-direction reference balls **15**A and second Z-direction reference balls **15**B are disposed on sides of protruding portions **117**A and **117**B opposite to sides where AF driving unit **14** is disposed.

[0225] AF supporting part **15** (first supporting part) is disposed at two places on opposite sides across AF driving unit **14** in the extending direction of AF driving unit **14** (Z-direction driving part), and biasing part **18** (first biasing part) is disposed on one AF supporting part **15** side.

[0226] In the embodiment and Modification 1, AF movable part **11** includes protruding portions **112**A and **112**B protruding from cylindrical lens housing **111**, and protruding portions **112**A and **121**B are sandwiched respectively between first Z-direction reference balls **15**A and first pressurization balls **15**C and between second Z-direction reference balls **15**B and second pressurization balls **15**D. That is, AF movable part **11** is supported at two places with respect to first stage **12**.

[0227] When AF movable part **11** is moved in the optical-axis direction, a moment is generated in

AF movable part **11** in accordance with a distance from a force point (a contact point between AF resonant portion **141** and AF power transmission part **144**) where the AF movable part receives the driving force of AF driving unit **14** to a rotational axis (a center of first Z-direction reference balls **15**A). Therefore, AF movable part **11** needs to be pressed against first stage **12** by a pressure that can cancel the moment.

[0228] In the embodiment and Modification 1, AF movable part **11** is configured to be supported with respect to first stage **12** at two places. It is thus possible to receive an external force while dispersing the external force. However, there is a limit in reducing the moment by reducing the distance from the force point to the rotational axis to reduce the pressure.

[0229] As opposed thereto, Modification 2 is configured such that a portion of AF movable part **11** where AF driving unit **14** is disposed is sandwiched between first Z-direction reference balls **15**A and second Z-direction reference balls **15**B, and the pressure is applied to second Z-direction reference balls **15**B, that is, AF movable part **11** is supported at one place with respect to first stage **12**.

[0230] Thus, as compared with the embodiment and Modification 1, it is easier to reduce the distance between, on one hand, the force point at which the driving force of AF driving unit **14** is applied, and, on the other hand, the rotational axis, and it is possible to reduce the moment to reduce the pressure. Further, second Z-direction reference balls **15**B function as pressurization balls, and first and second pressurization balls **15**C and **15**D in the embodiment are not required. It is thus possible to reduce the rolling resistance. Therefore, the driving efficiency of AF driving unit **14** is improved, and also becomes suitable for an optical-element driving device for a large diameter lens. In addition, in the condition of the same pressure, the tilt resistance is higher.

[0231] In Modification 2, biasing direction D**2** in which second Z-direction reference balls **15**B are biased by leaf spring **181** intersects tangential direction D**1**. Specifically, angle θ between tangential direction D**1** and biasing direction D**2** is 0° to 45°. Since the extending direction of AF driving unit **14** is the same as tangential direction D**1**, it can also be said that biasing part **18** (first biasing part) is disposed such that the biasing direction in plan view intersects the extending direction of AF driving unit **14** and such that the biasing part biases AF driving unit **14**.

[0232] As a result, AF movable part **11** is pressed via second Z-direction reference balls **15**B in the X-direction and the Y-direction, which are two directions orthogonal to each other. Thus, the attitude in the optical-axis-orthogonal plane can be stabilized.

[0233] In Modification 2, both first Z-direction reference balls **15**A and second Z-direction reference balls **15**B include two balls.

[0234] As a result, the rolling resistances of first Z-direction reference balls **15**A and second Z-direction reference balls **15**B can be reduced as compared with the embodiment and Modification 1, and the driving efficiency of AF driving unit **14** can be further improved.

[0235] While the invention made by the present inventors has been specifically described based on the preferred embodiment, it is not intended to limit the present invention to the above-mentioned preferred embodiment, but the present invention may be further modified within the scope and spirit of the invention defined by the appended claims.

[0236] For example, while smartphone M serving as a camera-equipped mobile terminal has been described in the embodiment as an example of the camera-mounted device including camera module A, the present invention is applicable to a camera-mounted device including a camera module and an image processing part that processes image information obtained by the camera module. The camera-mounted device encompasses an information apparatus and a transporting apparatus. Examples of the information apparatus include a camera-mounted mobile phone, a note-type personal computer, a tablet terminal, a mobile game machine, a web camera, and a camera-mounted in-vehicle device (for example, a rear-view monitor device or a drive recorder device). In addition, examples of the transporting apparatus include an automobile.

[0237] FIGS. **30**A and **30**B illustrate automobile V serving as the camera-mounted device in which in-vehicle camera module VC (Vehicle Camera) is mounted. FIG. **30**A is a front view of automobile V and FIG. **30**B is a rear perspective view of automobile V. In automobile V, camera module A described in the embodiment is mounted as in-vehicle camera module VC. As illustrated in FIGS. **30**A and **30**B, in-vehicle camera module VC may, for example, be attached to the windshield so as to face forward, or to the rear gate so as to face backward. In-vehicle camera module VC is used for rear monitoring, drive recording, collision avoidance control, automatic drive control, and the like.

[0238] In the embodiment, AF movable part **11** and first stage **12** are provided respectively with first Z-direction reference ball holding portions **112***a* and **122***a* and with second Z-direction reference ball holding portions **112***b* and **122***b*. However, either AF movable part **11** or first stage **12** may be provided with the first Z-direction reference ball holding portion and the second Z-direction reference ball holding portion.

[0239] Further, in the embodiment, first Z-direction reference balls **15**A and second Z-direction reference balls **15**B are disposed symmetrically in the circumferential direction with respect to AF driving unit **14**, but may be disposed asymmetrically. In this case, in order to stabilize the moving operation of AF movable part **11**, it is preferable that first Z-direction reference balls **15**A be on the AF driving unit **14** side.

[0240] Further, in the embodiment, AF driving unit **14** is disposed along the X-direction, but the aspect of placement of AF driving unit **14** is not limited to this. For example, the AF driving unit may be disposed along the Y-direction, or may be disposed to be inclined with respect to the X-direction and the Y-direction.

[0241] In addition, the present invention can be applied not only to autofocus but also to a case where a movable part is moved in the optical-axis direction, such as zoom.

[0242] Further, the support structure of the AF unit is not limited to the case where the driving source is composed of an ultrasonic motor as in AF driving unit **14**, but can also be applied to an optical-element driving device including a driving source (e.g., voice coil motor (VCM)) other than an ultrasonic motor.

[0243] In addition, although the embodiment has been described in relation to optical-element driving device **1** that drives lens part **2** as an optical element, the optical element to be driven may be an optical element other than a lens, such as a mirror or a prism.

[0244] The embodiment disclosed herein is merely an exemplification in every respect and should not be considered as limitative. The scope of the present invention is specified by the claims, not by the above-mentioned description. The scope of the present invention is intended to include all modifications in so far as they are within the scope of the appended claims or the equivalents thereof.

[0245] The disclosures of U.S. Provisional Patent Application No. 63/002,305 filed on Mar. 30, 2020, U.S. Provisional Patent Application No. 63/051,917 filed on Jul. 15, 2020, and U.S. Provisional Patent Application No. 63/078,357 filed on Sep. 15, 2020, including the specification, drawings and abstract is incorporated herein by reference in its entirety.

REFERENCE SIGNS LIST

[0246] **1** Optical-element driving device [0247] **10** OIS movable part (second movable part) [0248] **11**, **51** AF movable part (first movable part) [0249] **12** First stage (first fixing part) [0250] **13** Second stage [0251] **14** AF driving unit (Z-direction driving part) [0252] **141** AF resonant portion (active element) [0253] **142** AF piezoelectric element [0254] **143** AF electrode [0255] **144** AF power transmission part (passive element) [0256] **15** AF supporting part (first supporting part) [0257] **15**A First Z-direction reference ball (first reference ball) [0258] **15**B Second Z-direction reference ball (second reference ball) [0259] **18** Biasing part (first biasing part) [0260] **181** Leaf spring (elastic member) [0261] **182** Spacer [0262] **20** OIS fixing part (second fixing part) [0263] **21** Base [0264] **30** OIS driving unit (XY-direction driving part) [0265] **31** OIS resonant portion (active element) [0266] **32** OIS piezoelectric element (active element) [0267] **33** OIS electrode [0268] **34**

OIS power transmission part (passive element) [0269] **40** OIS supporting part (second supporting part) [0270] **50** OIS biasing member [0271] **61** Plate (passive element) [0272] **62** Biasing member [0273] **112***a*, **122***a* First Z-direction reference ball holding portion (first reference ball holding portion) [0274] **112***b*, **122***b* Second Z-direction reference ball holding portion (second reference ball holding portion) [0275] A Camera module [0276] M Smartphone (camera-mounted device)

Claims

1. An ultrasonic driving device, comprising: a movable part; an ultrasonic motor disposed on a fixing part and including a resonant portion including a pair of arms configured to vibrate by power supplied to a piezoelectric element; and a power transmission part configured to make contact with the resonant portion in a biased state, convert vibration of the resonant portion into linear motion, and transmit the linear motion to the movable part, wherein the power transmission part includes: a pair of plates disposed on the movable part, each made of a hard material, and including main surfaces configured to make contact respectively with the pair of arms, and a pair of support members disposed on the movable part, the pair of support members being configured to bias the pair of plates and press the pair of plates against the pair of arms by pressing opposite surfaces of the pair of plates opposite to the main surfaces, and the power transmission part is configured to transmit the vibration of the resonant portion via the pair of plates.
2. The ultrasonic driving device according to claim 1, wherein the main surfaces are inner surfaces of the pair of plates, and the opposite surfaces are outer surfaces of the pair of plates.
3. The ultrasonic driving device according to claim 1, wherein the pair of plates are disposed in a plate housing fixed to the movable part being an object to be moved.
4. The ultrasonic driving device according to claim 1, wherein the pair of plates are disposed in a guide groove formed along a moving direction of the movable part being an object to be moved.
5. The ultrasonic driving device according to claim 1, wherein the pair of support members include a leaf spring configured to make contact with the pair of plates in a folded and inclined state.
6. The ultrasonic driving device according to claim 1, wherein: each of the resonant portion and the pair of plates are formed by a flat plate parallel to the moving direction of the movable part being an object to be moved, the flat plate forming the resonant portion is disposed along an opposing surface being a part of an outer circumferential surface of the movable part, and a pair of the flat plates forming the pair of plates are disposed in parallel to each other to protrude outward from the opposing surface.
7. A camera module, comprising: the ultrasonic driving device according to claim 1; and an optical element to be attached to the movable part; and an image capturing part configured to capture a subject image imaged by the optical element.
8. A camera-mounted device that is an information apparatus or a transporting apparatus, the camera-mounted device comprising: the camera module according to claim **7**; and an image processing part configured to process image information obtained by the camera module.