

Flat Voice Coil Motor

TECHNICAL FIELD

The present invention relates to semiconductor processing equipment and, more particularly, to a flat voice coil motor.

BACKGROUND

Flat voice coil motors made in accordance with the Ampere force law are suited to use in servo control applications requiring high speeds, high accelerations, linear force or torque response, because of their structural simplicity, convenient maintenance, high reliability, high energy conversion efficiency, fixed strokes, direct drivability, smooth force-stroke outputs, linear controllability, low electrical and mechanical time constants, high thrust/mass ratios, absence of slot effects, no need for direction adjustments, theoretically unlimited degrees of position sensitivity, and absence of cogging and delayed response. These features also make the flat voice coil motors suitable for use in precision positioning components for photolithography tools which require high speed, high-precision positioning.

In recent years, with the increasing integration degree of semiconductor devices, wafer positioning stages with multiple degrees of freedom used in photolithography tools for semiconductor processing are required to achieve a positioning precision on the order of sub-microns. In order to reduce vibration and increase positioning accuracy of these wafer stages, voice coil motors are generally used for their actuation. In addition, the voice coil motors may also be used as actuating mechanisms for focusing of objectives in photolithography tools in order to improve photolithography accuracy.

However, due to absence of mover gravity compensation of conventional flat

above the small, weak magnet in the two primary magnetic pole units.

The two primary magnets that are disposed above the small, weak magnet may exert a vertically upward resultant magnetic attraction force on the small, weak magnet, and the two primary magnets that are disposed under the small, weak magnet may exert a vertically upward resultant magnetic repulsion force on the small, weak magnet.

The two primary magnetic pole units may be disposed above and under the coil unit to create a vertical primary magnetic field; the coil unit may include two energized conductor portions cutting the vertical primary magnetic field; and the two energized conductor portions may be arranged horizontally with respect to each other.

The small, weak magnet may have a magnetization direction same as a direction of the Ampere force exerted on the coil unit.

The two primary magnets in the two primary magnetic pole units that are disposed above the small, weak magnet in the two primary magnetic pole units may exert a vertically upward resultant magnetic attraction force on the small, weak magnet, and the two primary magnets that are disposed under the small, weak magnet may exert a vertically upward resultant magnetic repulsion force on the small, weak magnet.

The flat voice coil motor may further include spacer magnets and back irons, each of the spacer magnets is disposed between two primary magnets of a corresponding pair of primary magnets, and each of the spacer magnets together with the corresponding pair of primary magnets are fixed on a corresponding one of the back irons.

The flat voice coil motor may further include spacer magnets, wherein each of the spacer magnets is disposed between the two primary magnets of a corresponding pair of primary magnets, a left one of the spacer magnets having a magnetization

magnet, which neither has influence on the Ampere force acting on the coil in the coil unit nor adversely leads to motor overheating caused by a structural addition. In this way, a flat voice coil motor with mover gravity compensation is entailed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a flat voice coil motor in accordance with Embodiment 1 of the present invention.

FIG. 2 schematically shows forces exerting on a weak magnet in the flat voice coil motor in accordance with Embodiment 1 of the present invention.

FIG. 3 is a perspective view of the weak magnet in the flat voice coil motor in accordance with Embodiment 1 of the present invention.

FIG. 4 shows a transverse cross section of the weak magnet in the flat voice coil motor in accordance with Embodiment 1 of the present invention.

FIG. 5 shows a longitudinal cross section of the weak magnet in the flat voice coil motor in accordance with Embodiment 1 of the present invention.

FIG. 6 is a schematic illustration of a flat voice coil motor in accordance with Embodiment 2 of the present invention.

FIG. 7 schematically shows forces acting on a weak magnet in the flat voice coil motor in accordance with Embodiment 2 of the present invention.

FIG. 8 is a perspective view of the weak magnet in the flat voice coil motor in accordance with Embodiment 2 of the present invention.

FIG. 9 shows a transverse cross section of the weak magnet in the flat voice coil motor in accordance with Embodiment 2 of the present invention.

FIG. 10 shows a longitudinal cross section of the weak magnet in the flat voice coil motor in accordance with Embodiment 2 of the present invention.

FIG. 11 is a schematic illustration of a flat voice coil motor in accordance with

Referring to FIG. 1, a flat voice coil motor with gravity compensation constructed in accordance with this Embodiment includes a coil unit and two primary magnetic pole units which exert an Ampere force T on the coil unit. The coil unit includes a small, weak magnet 107, a coil 104 and a bobbin 105. The two primary magnetic pole units exert a vertically upward resultant force on the small, weak magnet 107 to provide gravity compensation for the coil unit.

In this Embodiment, as the coil unit includes the weak magnet 107, the magnetic repulsion or attraction forces between the weak magnet 107 and the primary magnetic pole units always ensure a vertically upward force on the coil unit to provide gravity compensation. In addition, this arrangement is simply achieved by replacing an internal portion of the coil unit with the small, weak magnet 107, which neither has influence on the Ampere force acting on the coil 104 in the coil unit nor adversely leads to motor overheating caused by a structural addition. In this way, a flat voice coil motor with mover gravity compensation is entailed.

Referring to FIG. 1, in conjunction with FIGs. 3 to 5, the primary magnetic pole units each have at least a pair of primary magnets, indicated respectively at 101a and 102a and at 101b and 102b. The primary magnets 101a, 101b, 102a and 102b are equidistant with respect to the coil unit, so that the two primary magnetic pole units are symmetric relative to said coil unit.

In the two primary magnetic pole units, those two primary magnets that are symmetric to each other have the same magnetization direction, i.e., according to this Embodiment, the primary magnets 101a and 101b have the same magnetization direction and the primary magnets 102a and 102b have the same magnetization direction. On the other hand, the two primary magnets in each primary magnetic pole unit have opposite magnetization directions, i.e., according to this Embodiment, the primary magnets 101a and 102a have opposite magnetization directions and the

those of the primary magnets 102a and 102b are both horizontally to the right. Additionally, the small, weak magnet 107 has the same magnetization direction as the two primary magnets 101a and 101b disposed above it. Specifically, as indicated by the illustrated magnetization directions in the figures, the primary magnets 101a and 101b and the small, weak magnet 107 each have a north pole on the left side and a south pole on the right side. For this reason, upward angular magnetic attraction forces, as shown in FIG. 2, are generated between their south and north poles. Since the horizontal components of these forces cancel out each other in the horizontal direction, the two primary magnets 101a and 101b apply a vertically upward force on the small, weak magnet 107 and thus the coil unit. For the similar reason, due to their horizontal, right-bound magnetization directions, the primary magnets 102a and 102b create magnetic repulsion forces with the small, weak magnet 107 which are combined into a vertically upward force on the coil unit.

Referring to FIG. 1, the flat voice coil motor further includes spacer magnets 103 and back irons 106. The spacer magnets 103 and the pairs of primary magnets 101 and 102 are fixed on the back irons 106. Each of the spacer magnets 103 is disposed between the magnets of one of the pairs of primary magnets 101 and 102. The magnetization directions of the spacer magnets 103 are perpendicular to the magnetization directions of the primary magnets 101 and 102. The spacer magnets 103 in the two primary magnetic pole units, i.e., magnets 103a and 103b, according to this Embodiment, have opposite magnetization directions.

Referring to FIG. 1, the magnetization direction of the spacer magnet 103a left to the small, weak magnet 107 is opposite to the direction of the Ampere force exerted on the coil unit, i.e., vertically downward, while the magnetization direction of the spacer magnet 103b right to the small, weak magnet 107 is the same as the direction of the Ampere force exerted on the coil unit, i.e., vertically upward.

unit. The two primary magnets 101a and 102a above the coil unit exert a vertically upward magnetic attraction force on the small, weak magnet 107, while the two primary magnets 101b and 102b under the coil unit exert a vertically upward magnetic repulsion force on the small, weak magnet 107. The upward magnetic attraction force exerted on the small, weak magnet 107 and hence the coil unit is a force resulting from the combination of upward angular forces F_{102a} and F_{101a} , as shown in FIG. 7, by mutual cancellation of their horizontal components. The upward angular forces are generated due to attraction between opposite south and north poles. In addition, as the primary magnets 101b and 102b under the coil unit have the same magnetization direction as the primary magnets 101a and 102a above the coil unit, north and south poles of the primary magnets 101b and 102b are situated proximate the north and south poles of the small, weak magnet 107, respectively. Repulsion between the like poles leads to F_{102b} and F_{101b} , as shown in FIG. 7, which are combined into an upward angular force on the small, weak magnet 107 and hence the coil unit.

In this Embodiment, the flat voice coil motor further includes spacer magnets 103 each disposed between the magnets of one of the pairs of primary magnets 101 and 102, with a lower spacer magnet 103b having the same magnetization direction as the direction of the Ampere force exerted on the coil unit and an upper spacer magnet 103a having a magnetization direction opposite to the direction of the Ampere force exerted on the coil unit.

This Embodiment is similar to Embodiment 1 in the rest part of the flat voice coil motor. Specifically, the flat voice coil motor according to this Embodiment also includes back irons 106 and magnets 103, and the coil unit according to this Embodiment is structurally identical to that of Embodiment 1, as schematically illustrated in FIGs. 8 to 10.

difference, this Embodiment is similar to Embodiment 3 in the rest portion of the flat voice coil motor.

The present invention provides an improved solution for the overheating issue of voice coil motors of a fine-motion vector motor responsible for outputting vertical forces. The fine-motion vector motor consists of six voice coil motors, including three for horizontal outputs and three for vertical outputs, and is designed to bear a load of 20 kilograms. After allocation of the load to the three voice coil motors for vertical outputs, each of these motors needs to output a force as great as 66 N in order to levitate the load even without acceleration. In this state, each motor will generate heat at 50 W (even more when required to accelerate the load), thus creating a great challenge to the water-cooling system.

Voice coil motors are single-phase short-stroke motors with only one degree of freedom. When outputting a vertical force (FIG. 1), a rather portion of their power consumption is attributable to the load gravity, and the consumption will keep if there is no change in the load. In this case, when a flat voice coil motor with gravity compensation according to the present invention is used, a most part of the gravity will be cancelled out by the force provided by the magnets, and the motor will only need to cover the rest small part. In addition, only if an upward acceleration is required, then will be needed an increase in its working current. This improvement can lead to an approximately about 90% reduction in power consumption of the voice coil motors.

To sum up, according to the present invention, the coil unit is provided with a small, weak magnet disposed therein, which creates magnetic repulsion and attraction forces with the primary magnetic pole units, thereby always ensuring a vertically upward force on the coil unit to provide gravity compensation. In addition, this arrangement is achieved simply by replacing an internal portion of the coil unit with

CLAIMS

1. A flat voice coil motor, comprising a coil unit and two primary magnetic pole units exerting an Ampere force on the coil unit, wherein the coil unit comprises a small, weak magnet, and the Ampere force exerted by the two primary magnetic pole units on the small, weak magnet is a vertically upward resultant force.

2. The flat voice coil motor according to claim 1, wherein each of the two primary magnetic pole units at least comprises a pair of primary magnets equidistant from the coil unit, the two primary magnetic pole units being symmetric with respect to the coil unit.

3. The flat voice coil motor according to claim 2, wherein in the two primary magnetic pole units, every two primary magnets that are symmetric to each other have a same magnetization direction, and wherein the pair of primary magnets in each of the two primary magnetic pole units have opposite magnetization directions.

4. The flat voice coil motor according to claim 3, wherein: the two primary magnetic pole units are disposed left and right to the coil unit to create a horizontal primary magnetic field; the coil unit comprises two energized conductor portions cutting the horizontal primary magnetic field; and the two energized conductor portions are arranged vertically with respect to each other.

5. The flat voice coil motor according to claim 4, wherein the two primary magnetic pole units exert a vertically upward Ampere force on the coil unit, and the small, weak magnet has a magnetization direction same as magnetization directions of two primary magnets that are disposed above the small, weak magnet in the two primary magnetic pole units.

6. The flat voice coil motor according to claim 5, wherein the two primary magnets that are disposed above the small, weak magnet exert a vertically upward

on the coil unit and a right one of the spacer magnets having a magnetization direction same as the direction of the Ampere force exerted on the coil unit.

12. The flat voice coil motor according to claim 7, further comprising spacer magnets, wherein each of the spacer magnets is disposed between the two primary magnets of a corresponding pair of primary magnets, a lower one of the spacer magnets having a magnetization direction same as a direction of the Ampere force exerted on the coil unit and an upper one of the spacer magnets having a magnetization direction opposite to the direction of the Ampere force exerted on the coil unit.

13. The flat voice coil motor according to claim 4 or 7, wherein the small, weak magnet has a dimension extending along a direction in which the small, weak magnet faces the energized conductor portions cutting the primary magnetic field that is greater than a dimension of the small, weak magnet extending along a direction in which the small, weak magnet faces the primary magnets.

14. The flat voice coil motor according to claim 1, wherein: the coil unit further comprises a bobbin and a coil wound on the bobbin; the small weak magnet is disposed in the bobbin.

15. The flat voice coil motor according to claim 14, further comprising back irons, wherein: each pair of primary magnets is fixed on a corresponding one of the back irons; the coil is wound on the bobbin around an axis that is parallel to the primary magnetic field created by the two primary magnetic pole units and perpendicular to the back irons.