

Reaction Force Compensation Apparatuses for Motion Stage

TECHNICAL FIELD

The present invention relates to the field of photolithography and, more particularly, to reaction force compensation apparatuses for a motion stage.

BACKGROUND

Photolithography is a critical step in semiconductor device fabrication for exposing and thereby transferring a set of circuit patterns on a mask in succession onto corresponding layers of a silicon wafer. It is recognized as a core step in large-scale integration (LSI) fabrication. A semiconductor fabrication process involves a number of such complex and time-consuming photolithography steps which are mostly performed by corresponding photolithography tools.

Each of such photolithography tools is equipped with a motion stage configured principally for supporting a silicon wafer and carrying the silicon wafer to move under a projection objective in correspondence with the movements of a mask stage so that the wafer is exposed in a desired way. In case of the motion stage being disposed in an internal frame of the photolithography tool in which the mask stage is also accommodated, the movements of the motion stage and the mask stage will cause reaction forces which directly act on the internal frame and thus increase vibration of the internal frame. If magnitude of the vibration exceeds a corresponding threshold of the photolithography tool, successful exposure is rendered impossible.

A solution from the U.S. is to arrange a motor stator of the motion stage on an external frame of the photolithography tool so that reaction forces generated during the exposure process will pass on to the external frame via connections thereto and the impact on the internal frame of the photolithography tool will be reduced.

However, this solution imposes high structural requirements on both the photolithography tool frames and the motion stage by increasing difficulties in modularization of the motion stage and complicating the integration of the motion stage with the photolithography tool.

In another disclosed solution for structurally improving the motion stage, stators of two long-stroke motors for actuating the motion stage to move in two different directions are both disposed on the external frame of the photolithography tool, and a fine-motion portion of the stage is enabled to move without friction on a marble platform of the internal frame in virtue of a vertical air foot. In this way, the long-stroke and fine-motion portions are disposed on two separate frames, and the impact on the internal frame of the photolithography tool is therefore muted. This solution, however, leads to increases in structural complexity as well as in vertical dimension of the motion stage.

Further, there is another solution employing reaction force means in direct connection to the internal frame, in which, however, due to absence of decoupling means between the motion stage and dampers, the reaction force compensation is accompanied by the introduction of vibration from a ground base that is detrimental to movement accuracy of the motion stage. Additionally, as passive dampers subject to frictions are used in this solution, the motion stage is unable to return exactly to the starting point of its stroke during spring recovery.

SUMMARY OF THE INVENTION

The present invention provides reaction force compensation apparatuses for a motion stage, which can be mounted in a simple manner and have no structural impact on the motion stage.

In order to solve the above-described problems, a reaction force compensation

apparatus according to the present invention is mounted between a ground base and a motion stage. The motion stage is disposed on a base frame and includes a stator and a mover. The base frame is mounted on the ground base using dampers. The reaction force compensation apparatus is configured to compensate reaction forces acting on the motion stage by maintaining the stator substantially at a starting point of a stroke of the stator, and the reaction force compensation apparatus includes: a supporting frame mounted on the ground base; a linear guide rail disposed under the stator and maintained stationary relative to the ground base; a velocity measuring unit disposed on the stator and configured to measure a velocity of the stator; an active damping member having a first end in connection with the stator and a second end in connection with the supporting frame, the active damping member configured for fast attenuation of movement of the stator by applying an active control force according to a measurement of the velocity of the stator provided by the velocity measuring unit, the active damping member maintained stationary relative to the ground base; an elastic member having a first end in connection with the stator and configured to maintain the stator substantially at the starting point of the stroke; and a decoupling mechanism configured to decouple movement of the supporting frame relative to the motion stage, the decoupling mechanism having a first end in connection with the supporting frame and a second end in connection with a second end of the elastic member.

Preferably, the reaction force compensation apparatus further includes a tuning screw configured to adjust a tensile force of the elastic member by tuning the position of a support base mounted on the supporting frame.

Preferably, the reaction force compensation apparatus further includes two displacement measuring units disposed respectively between the mover and the base frame and between the mover and the stator and configured to establish an absolute

position coordinate for the motion stage.

Preferably, the reaction force compensation apparatus further includes a long-stroke assembly in connection with the mover, wherein a displacement of the long-stroke assembly relative to the starting point of the stroke is measureable by the displacement measuring units.

Preferably, the displacement measuring members are grating scales.

Preferably, the reaction force compensation apparatus further includes a control system, wherein the velocity measuring unit feeds the measurement of the velocity of the stator to the control system, and the control system controls a force exerted by the damping member based on the measurement of the velocity of the stator.

Preferably, the linear guide rail is a straight guide rail or an air-bearing guide rail that provides linear guidance.

Preferably, the decoupling mechanism is a laminated rubber structure.

Preferably, the active damping member is a voice coil motor which is connected to the stator using a connecting plate and secured on the supporting frame using a mounting plate.

Preferably, the velocity measuring unit is a velocity sensor.

The present also provides a reaction force compensation apparatus for a motion stage. The reaction force compensation apparatus is mounted between a ground base and the motion stage. The motion stage is disposed on a base frame and includes a first stator, a second stator, a first mover and a second mover. The base frame is mounted on the ground base using dampers. The reaction force compensation apparatus is configured to compensate reaction forces acting on the motion stage by maintaining the first and second stators substantially at starting points of strokes of the first and second stators, and the reaction force compensation apparatus includes: a first pair of supporting frames and a second pair of supporting frames, the first pair of

supporting frames mounted on both sides of the first stator, the second pair of supporting frames mounted on both sides of the second stator; a first linear guide rail and a second linear guide rail, disposed under the respective first and second stators and maintained stationary relative to the ground base; a first velocity measuring unit and a second velocity measuring unit, disposed on the respective first and second stators and configured to measure velocities of the respective first and second stators;

a first pair of active damping members and a second pair of active damping members, each of the first pair of active damping members having a first end in connection with the first stator and a second end in connection with a corresponding one of the first pair of supporting frames, each of the second pair of active damping members having a first end in connection with the second stator and a second end in connection with a corresponding one of the second pair of supporting frames, the first and second pairs of active damping members configured for fast attenuation of movement of the respective first and second stators by applying respective active control forces according to measurements of the velocities of the respective first and second stators provided by the respective first and second velocity measuring units, the first and second pairs of active damping members maintained stationary relative to the ground base;

a first pair of elastic members and a second pair of elastic members, each of the first pair of elastic members having a first end in connection with the first stator and configured to maintain the first stator substantially at the starting point of the stroke of the first stator, each of the second pair of elastic members having a first end in connection with the second stator and configured to maintain the second stator substantially at the starting point of the stroke of the second stator; and

a first pair of decoupling mechanisms and a second pair of decoupling mechanisms, configured to decouple movement of the respective first and second

pairs of supporting frames relative to the motion stage, each of the first pair of decoupling mechanisms having a first end in connection with a corresponding one of the first pair of supporting frames, each of the second pair of decoupling mechanisms having a first end in connection with a corresponding one of the second pair of supporting frames, each of the first pair of decoupling mechanisms having a second end in connection with a second end of a corresponding one of the first pair of elastic members, each of the second pair of decoupling mechanisms having a second end in connection with a second end of a corresponding one of the second pair of elastic members.

The present invention has the following advantages over the prior art solutions:

1. Connecting the stator to the motion stage using the linear guide rail allows structural separation of the motion stage from the reaction force compensation apparatus. This reduces the complexity of the motion stage and facilitates its structural modularization.

2. It entails a simple reaction force compensation approach and thus reduces the complexity in designing and assembling the photolithography tool frames and the motion stage.

3. The decoupling mechanism isolates vibration from the ground base and decouples movement of the motion stage relative to the base frame occurring during operation of the dampers.

4. The active damping member provides an active damping force in the Y direction, and the active damping force is controlled by using the velocity measuring unit to monitor in real time energy attenuation of the stator caused by the force.

5. The stator is maintained substantially at the starting point of its stroke by means of elastic members connected thereto on both sides.

The active damping technique for reaction force attenuation used in

combination with the decoupling mechanism reduces vibration transferring to the base frame and increases control precision of the motion stage.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustrating a photolithography tool in accordance with a specific embodiment of the present invention.

FIG. 2 is a schematic illustration of a reaction force compensation apparatus for a motion stage in accordance with a specific embodiment of the present invention.

FIG. 3 shows an elevational view of a reaction force compensation apparatus for a motion stage in accordance with a specific embodiment of the present invention.

FIG. 4 shows a top view of a reaction force compensation apparatus for a motion stage in accordance with a specific embodiment of the present invention.

FIG. 5 is a detailed view of a reaction force compensation apparatus for a motion stage in accordance with a specific embodiment of the present invention.

FIG. 6 is a diagram showing the properties of a laminated rubber structure in a reaction force compensation apparatus for a motion stage in accordance with a specific embodiment of the present invention.

FIG. 7 is a diagram explaining how a reaction force compensation apparatus for a motion stage in accordance with a specific embodiment of the present invention is controlled.

DETAILED DESCRIPTION

The forgoing objectives, features and advantages of the present invention will become apparent from the following detailed description of illustrative embodiments thereof, which is to be read in connection with the accompanying drawings. It is noted that these drawings are provided in a very simplified form not necessarily

presented to scale, with the only intention of facilitating convenience and clarity in explanation.

Although reaction force compensation apparatuses for a motion stage according to the present invention are described with reference to the following embodiments in the context of the motion stage being exemplified as a wafer stage of a photolithography tool, the invention is not limited in this regard, and it should be understood by those skilled in the art that the motion stage may also be any precision motion device other than a wafer stage, such as a mask stage.

FIG. 1 shows a projection photolithography tool having a main portion in which a mask stage 6 for supporting a mask, a wafer stage 4 (i.e., the motion stage) for supporting a silicon wafer and a projection objective 5 are arranged on a base frame 3 and are isolated from vibration from a ground base 1 by dampers 2. The ground base 1 is provided with a supporting frame 7, and the wafer stage 4 has a motor 9 comprised of a stator 9a and a mover 9b (FIG. 2), wherein reaction forces exerted on the stator 9a will directly act on the supporting frame 7, thereby on the one hand reducing the impact of the reaction forces on the base frame 3, and on the other hand, lowering the requirements on the performance of the dampers 2 in compensating for reaction forces caused by movements of the wafer stage 4. As a result, a low vibration environment is ensured for all the components of the base frame 3. A reaction force compensation apparatus according to the present invention is mounted between the ground base 1 and the motion stage. The invention will be described in detail below with reference to FIGs. 2 to 7.

As shown in FIGs. 2 and 3, the reaction force compensation apparatus according to the present invention includes essentially: a linear guide rail 101, an active damping member 102, a velocity measuring unit 105, an elastic member 103 and a decoupling mechanism 104, wherein:

the linear guide rail 101 is disposed under the stator 9a of the motion stage and maintained stationary relative to the ground base 1;

the active damping member 102 is connected on one side to the stator 9a and on the other side to the supporting frame 7, and the active damping member 102 is maintained stationary relative to the ground base 1;

the elastic member 103 is connected on one side to the stator 9a and on the other side to the decoupling mechanism 104;

the other side of the decoupling mechanism 104 is connected to the supporting frame 7; and

the velocity measuring unit 105 is disposed on the stator 9a and is configured to measure a velocity of the stator 9a.

Specifically, the motion stage is laterally connected to the supporting frame 7 by the active damping member 102 and the elastic member 103. When the motion stage is moving, the velocity measuring unit 105 measures the velocity of the stator 9a and feeds the measurement to a control system 8. The control system 8 then adjusts the magnitude of a damping force exerted by the active damping member 102 laterally connected to the stator 9a so that kinetic energy of the stator 9a is attenuated and the stator 9a returns to a starting point of its stroke under the effect of the elastic member 103. As the reaction force compensation apparatus is mounted entirely between the ground base 1 and the motion stage, when the motion stage moves with the damper 2, the decoupling mechanism 104 decouples the motion stage from the supporting frame 7, thereby effectively isolating vibration of the ground base 1 from the motion stage.

Preferably, the reaction force compensation apparatus according to the present invention achieves the aforementioned decoupling by means of its own structural features. Specifically, the elastic member 103 is rather stiff and provides a decoupling

effect that is inadequate to meet the needs for kinetic energy attenuation for the stator 9a. Therefore, as shown in FIG. 6, the decoupling mechanism 104 according to the present invention is implemented as a laminated rubber structure which is capable of withstanding a pressure on the order of 10^7 N/m in an axial (Y) direction, so that the mechanism is stiff enough in this direction to not affect stroke measurement for the stator 9a. Meanwhile, the laminated rubber structure is able to withstand a pressure on the order of 10^5 N/m in a radial (R) direction. This relatively low radial pressure withstanding ability allows free rotation of the structure, rendering it possible to satisfy the decoupling requirements. Preferably, the decoupling mechanism 104 is secured to the supporting frame 7 using a mounting plate 112.

With emphasized reference to FIG. 4, the reaction force compensation apparatus may further include a tuning screw 107 and displacement measuring units 106. The tuning screw 107 is mounted on the supporting frame 7 using a support base 108 in order to adjust a tensile force of the elastic member 103. The displacement measuring units 106 are disposed respectively between the mover 9b and the base frame 4 and between the mover 9b and the stator 9a in order to establish an absolute position coordinate for the wafer stage 4. Additionally, the displacement measuring units 106 may be implemented as grating scales. In a reaction force compensation apparatus for a motion stage shown in FIG. 4, four reaction force compensation apparatuses as defined above are arranged between the ground base 1 and motion stage 4 at the four corners of a rectangle in order to compensate for reaction forces acting on stators of two motors for driving the motion stage 4, thereby maintaining the two stators substantially at starting points of their strokes. The four reaction force compensation apparatuses include: four supporting frames disposed on the ground base at the four corners of a rectangle; two linear guide rails mounted under the respective stators, wherein the motion stage is disposed on the base frame via the

linear guide rails; two velocity measuring units disposed on the respective stators and configured to measure the velocities of the stators; four active damping members each having a first end in connection with one of the two stators and a second end in connection with a corresponding one of the four supporting frames, the four active damping members configured for fast attenuation of movement of the two stators by applying active control forces according to velocity measurements for the stators provided by the two velocity measuring units; four elastic members each having a first end in connection with one of the stators, the elastic members configured to maintain the stators substantially at the starting points of their strokes; and four decoupling mechanisms for decoupling movement of the four supporting frames relative to the motion stage, each of the decoupling mechanisms having a first end in connection with one of the four supporting frames and a second end in connection with a second end of a corresponding one of the four elastic members.

As shown in FIGs. 3 and 5, the linear guide rails 101 are symmetrically mounted on the base frame 3 and are provided with mounting plates 10 for the motors. That is, the stators 9a are connected to the linear guide rails 101 by means of the mounting plates 10. The movers 9b are connected to the long-stroke assemblies 111. The displacement measuring units 106 are connected to the long-stroke assemblies 111 via connecting plates 116 and connecting plates 110.

Further, as shown in FIG. 5, the active damping members 102 are secured to the supporting frame 7 using mounting plate 113, and the active damping members 102 are connected to the stators 9a residing on the mounting plates 10 using connecting plates 114 and connecting plates 115. The velocity measuring units 105 are fixed on the mounting plates 10 using connecting plates 109. Preferably, the active damping members 102 and the velocity measuring units 105 are implemented as voice coil motors and velocity sensors, respectively, and an absolute velocity feedback loop is

employed to pass information about the stators 9a obtained by the velocity sensors on to the control system 8. Preferably, the velocity sensors are absolute velocity sensors. Specifically, when the motion stage is moving, the velocity sensors measure velocities of the stators 9a and feed the measurements to the control system 8, based on which velocity feedback signals are produced to instruct the voice coil motors to provide desired damping forces. Each of the voice coil motors has a gap between its stator and mover. Based on this structural feature, the voice coil motors can also provide a decoupling effect. In other words, as the active damping members 102 each have a structure with a gap that is longer than strokes of the dampers 2 in all possible directions, the present invention can achieve the aforementioned decoupling also by such structural features of the active damping members 102.

Furthermore, with continuing reference to FIG. 5, the elastic members 103 may each be a spring having a linear range that covers the strokes of the stators 9a. At the same time, the springs may be so elastic as to meet the recovery requirements, i.e., able to cause the motion stage to return to the starting point of its stroke.

With emphasized reference to FIG. 7, the motion stage moves at a velocity varying with time and therefore renders the stators 9a subject to an always changing reaction force. According to the present invention, an absolute velocity feedback loop may be employed, in which the velocity sensors detect vibration signals from the stators 9a of the motion stage in a real-time manner, and the detected signals are then fed to a velocity feedback controller of the control system 8 after being compared with a reference signal. Thereafter, velocity feedback signals are produced to instruct the active damping members 102 to change their outputs in real time so as to provide desired damping forces for the reaction force compensation apparatus.

A detailed description is set forth below to explain how the reaction force compensation apparatus according to the present invention works.

As shown in FIGs. 3 and 5, before the motion stage is driven into movement, tensile forces of the elastic members 103 are adjusted by turning the tuning screws 107 so that the long-stroke assemblies 111 are positioned at starting points of their strokes in the Y direction. When the movers 9b of the motor 9 drive the long-stroke assemblies 111 to move linearly in the +Y direction, the stators 9a of the motor 9 will linearly move in the -Y direction along the linear guide rails 101.

During their movement, velocities of the stators 9a of the motor 9 are measured by the velocity measuring units 105 disposed on the mounting plates 10. The measurements are then fed to the control system 8, which subsequently adjusts forces exerted by the active damping members 102 so as to effectively attenuate kinetic energy of the stators 9a of the motor 9 during their effective journeys. During the movement of the stators, the elastic members 103 deployed in the -Y direction are compressed, so that after the kinetic energy has been attenuated, the stators 9a of the motor 9 will return to the starting points of their strokes under the effect of recovery of the elastic members 103. As the active damping members 102 are not subject to any damping forces during the retraction of the stators 9a, the stators 9a can always return to the starting points without significant deviations.

In addition, during the relative movement between the stators 9a and movers 9b of the motor 9, displacements of the long-stroke assemblies 111 relative to the starting points can be accurately calculated based on comparisons of displacements measured by those of the displacement measuring units 106 disposed between the movers 9b and stators 9a to displacements measured by those of the displacement measuring units 106 disposed between the base frame 3 and the movers 9b.

In summary, the reaction force compensation apparatus according to the present invention includes: the linear guide rail 101, the active damping member 102, the velocity measuring unit 105, the elastic member 103 and the decoupling mechanism,

wherein the linear guide rail 101 is mounted under the stator 9a of the motion stage; the active damping member 102 is connected on one side to the stator 9a and on the other side to the supporting frame 7; the elastic member 103 is connected on one side to the stator 9a and on the other side to the decoupling mechanism 104; the decoupling mechanism 104 is connected on the other side to the supporting frame 7, and the velocity measuring unit 105 is disposed on the stator 9a and configured to measure a velocity of the stator 9a. Compared to the prior art solutions, the present invention offers the following advantages:

1. Connecting the linear guide rail 101 to the stator 9a allows structural separation of the motion stage 4 from the reaction force compensation apparatus. This reduces the structural complexity of the motion stage 4 and facilitates the structural modularization of the motion stage 4.

2. An absolute position coordinate for the motion stage 4 is established by the displacement measuring units 106 disposed respectively between the mover 9b and the base frame 3 and between the mover 9b and the stator 9a.

3. The decoupling mechanism 104 isolates vibration from the ground base 1 and decouples movement of the motion stage relative to the base frame 3 occurring during operation of the dampers 2.

4. The active damping member 102 provides an active damping force in the Y direction, and the active damping force exerted by the active damping member 102 is controlled by using the velocity measuring unit 105 to monitor in real time energy attenuation of the stator 9a caused by the active damping force.

5. The stator 9a is maintained substantially at the starting point of its stroke by means of the elastic members 103 connected to the stator on both sides.

6. The active damping technique for reaction force attenuation used in combination with the decoupling mechanism 104 reduces vibration transferring to the

base frame 3 and increases control precision of the motion stage.

7. It entails a simple reaction force compensation approach and thus reduces the complexity in designing and assembling the photolithography tool frames and the motion stage.

8. The reaction force compensation apparatus is accommodated within the motion stage 4, thus reducing the difficulties in designing an interface to the photolithography tool frames, and has a short buffered stroke which does not lead to increases in dimensions of the motion stage 4 and the photolithography tool.

It is apparent that those skilled in the art may make various modifications and alterations without departing from the spirit and scope of the invention. Accordingly, it is intended that the invention be construed as including all such modifications and alterations insofar as they fall within the scope of the appended claims or equivalents thereof.

CLAIMS

1. A reaction force compensation apparatus mounted between a ground base and a motion stage, the motion stage disposed on a base frame and comprising a stator and a mover, the base frame mounted on the ground base using dampers, the reaction force compensation apparatus configured to compensate reaction forces acting on the motion stage by maintaining the stator substantially at a starting point of a stroke of the stator and comprising:

a supporting frame mounted on the ground base;

a linear guide rail disposed under the stator and maintained stationary relative to the ground base;

a velocity measuring unit disposed on the stator and configured to measure a velocity of the stator;

an active damping member having a first end in connection with the stator and a second end in connection with the supporting frame, the active damping member configured for fast attenuation of movement of the stator by applying an active control force according to a measurement of the velocity of the stator provided by the velocity measuring unit, the active damping member maintained stationary relative to the ground base;

an elastic member having a first end in connection with the stator and configured to maintain the stator substantially at the starting point of the stroke; and

a decoupling mechanism configured to decouple movement of the supporting frame relative to the motion stage, the decoupling mechanism having a first end in connection with the supporting frame and a second end in connection with a second end of the elastic member.

2. The reaction force compensation apparatus of claim 1, further comprising a tuning screw configured to adjust a tensile force of the elastic member by tuning a

position of a support base mounted on the supporting frame.

3. The reaction force compensation apparatus of claim 1, further comprising two displacement measuring units disposed respectively between the mover and the base frame and between the mover and the stator and configured to establish an absolute position coordinate for the motion stage.

4. The reaction force compensation apparatus of claim 3, further comprising a long-stroke assembly in connection with the mover, wherein a displacement of the long-stroke assembly relative to the starting point of the stroke is measureable by the displacement measuring units.

5. The reaction force compensation apparatus of claim 3, wherein the displacement measuring units are grating scales.

6. The reaction force compensation apparatus of claim 1, further comprising a control system, wherein the velocity measuring unit feeds the measurement of the velocity of the stator to the control system, and the control system controls a force exerted by the damping member based on the measurement of the velocity of the stator.

7. The reaction force compensation apparatus of claim 1, wherein the linear guide rail is a straight guide rail or an air-bearing guide rail that provides linear guidance.

8. The reaction force compensation apparatus of claim 1, wherein the decoupling mechanism is a laminated rubber structure.

9. The reaction force compensation apparatus of claim 1, wherein the active damping member is a voice coil motor which is connected to the stator using a connecting plate and secured on the supporting frame using a mounting plate.

10. The reaction force compensation apparatus of claim 1, wherein the velocity measuring unit is a velocity sensor.

11. A reaction force compensation apparatus for a motion stage, the apparatus mounted between a ground base and the motion stage, the motion stage disposed on a base frame and comprising a first stator, a second stator, a first mover and a second mover, the base frame mounted on the ground base using dampers, the reaction force compensation apparatus configured to compensate reaction forces acting on the motion stage by maintaining the first and second stators substantially at starting points of strokes of the first and second stators and comprising:

a first pair of supporting frames and a second pair of supporting frames, the first pair of supporting frames mounted on both sides of the first stator, the second pair of supporting frames mounted on both sides of the second stator;

a first linear guide rail and a second linear guide rail, disposed under the respective first and second stators and maintained stationary relative to the ground base;

a first velocity measuring unit and a second velocity measuring unit, disposed on the respective first and second stators and configured to measure velocities of the respective first and second stators;

a first pair of active damping members and a second pair of active damping members, each of the first pair of active damping members having a first end in connection with the first stator and a second end in connection with a corresponding one of the first pair of supporting frames, each of the second pair of active damping members having a first end in connection with the second stator and a second end in connection with a corresponding one of the second pair of supporting frames, the first and second pairs of active damping members configured for fast attenuation of movement of the respective first and second stators by applying respective active control forces according to measurements of the velocities of the respective first and second stators provided by the respective first and second velocity measuring units,

the first and second pairs of active damping members maintained stationary relative to the ground base;

a first pair of elastic members and a second pair of elastic members, each of the first pair of elastic members having a first end in connection with the first stator and configured to maintain the first stator substantially at the starting point of the stroke of the first stator, each of the second pair of elastic members having a first end in connection with the second stator and configured to maintain the second stator substantially at the starting point of the stroke of the second stator; and

a first pair of decoupling mechanisms and a second pair of decoupling mechanisms, configured to decouple movement of the respective first and second pairs of supporting frames relative to the motion stage, each of the first pair of decoupling mechanisms having a first end in connection with a corresponding one of the first pair of supporting frames, each of the second pair of decoupling mechanisms having a first end in connection with a corresponding one of the second pair of supporting frames, each of the first pair of decoupling mechanisms having a second end in connection with a second end of a corresponding one of the first pair of elastic members, each of the second pair of decoupling mechanisms having a second end in connection with a second end of a corresponding one of the second pair of elastic members.

12. The reaction force compensation apparatus of claim 11, further comprising a first pair of tuning screws and a second pair of tuning screws, wherein the first and second pairs of tuning screws are configured to adjust tensile forces of the respective first and second pairs of elastic members by tuning positions of respective first and second pairs of support bases mounted on the respective first and second pairs of supporting frames.

13. The reaction force compensation apparatus of claim 11, further comprising

a first pair of displacement measuring units and a second pair of displacement measuring units, wherein the first and second pairs of displacement measuring units are disposed respectively between the first mover and the base frame, between the first mover and the first stator, between the second mover and the base frame and between the second mover and the second stator and configured to establish an absolute position coordinate for the motion stage.

14. The reaction force compensation apparatus of claim 13, further comprising a first pair of long-stroke assemblies and a second pair of long-stroke assemblies, wherein the first and second pairs of long-stroke assemblies are connected to the respective first and second movers, and wherein displacements of the first and second pairs of long-stroke assemblies relative to the starting points of the respective strokes are measureable by the first and second pairs of displacement measuring units.

15. The reaction force compensation apparatus of claim 13, wherein the first and second pairs of displacement measuring units are grating scales.

16. The reaction force compensation apparatus of claim 11, further comprising a control system, wherein the first and second velocity measuring units feed the measurements of the velocities of the first and second stators to the control system, and the control system controls forces exerted by the first and second pairs of damping members based on the measurements of the velocities of the first and second stators.

17. The reaction force compensation apparatus of claim 11, wherein the first and second linear guide rails are straight guide rails or air-bearing guide rails that provide linear guidance.

18. The reaction force compensation apparatus of claim 11, wherein the first and second pairs of decoupling mechanisms are laminated rubber structures.

19. The reaction force compensation apparatus of claim 11, wherein the first

and second pairs of active damping members are voice coil motors which are connected to the respective first and second stators using respective connecting plates and secured on the respective first and second pairs of supporting frames using respective mounting plates.

20. The reaction force compensation apparatus of claim 11, wherein the first and second pairs of velocity measuring units are velocity sensors.