implementations, the clamping plates 113 (or other suitable device for affixing the end effector blades 112 and 114 to the end effector wrist unit 102) may instead clamp the end effector blades 112 and 114 to the second portion(s) of the actuation mechanism(s) used to move the end effector blades 112 and 114. In such implementations, the distal cleats may be both pivotable about the first axis and translatable along the axis parallel to an axis perpendicular to the first axis relative to the end effector wrist unit 102. The proximal cleat or cleats may also be translatable along such an axis if the actuator mechanism 132 is retained or may be fixed with respect to the end effector mount assembly 106 if the actuator mechanism 132 is omitted.

[0066] FIG. 4 shows the same assembly from an alternate perspective and in a non-exploded state (with the wrist unit housing 104' hidden from view). As can be seen, the rotational interfaces 110 allow the end effector mount to rotate about a first axis 176. The rotational interfaces 110, while shown as axles or pins in this example, may be provided using any appropriate rotational mechanism, including, for example, rotational flexure bearings, which may provide a small amount of rotational motion without undergoing or producing any rolling or sliding contact between mating surfaces (thereby reducing the risk of particulate generation).

[0067] Also visible in FIG. 4 is the placement of the arm portion of the second end effector mount 109 in between the first positive stop 152 and the second positive stop 154, as well as the assembled linkage that includes the rocker arm 168 and the draw link 162. In addition to the first axis 176, FIG. 4 also depicts a second axis 178, a third axis 180, a fourth axis 182, and a fifth axis 184. As shown, the rocker arm 168 is configured to pivot relative to the wrist unit housing 104 about the fifth axis 184 and is rotatably connected with a first end of the damper mechanism 156 such that the rocker arm 168 can rotate relative to the damper mechanism 156 about the fourth axis 182. The draw link 162, in turn, may be rotatably coupled with the rocker arm 168 so as to be able to rotate relative to the rocker arm 168 about the second axis 178 and is rotatably coupled at the other end with the first end effector mount 108 so as to be able to rotate about a third axis 180 relative to the first end effector mount 108.

[0068] FIG. 5 depicts the same view of FIG. 4, but with the end effector mount assembly rotated to the second rotational limit 148 (the position of the various components as shown in FIG. 4, e.g., at the first rotational limit 146, is shown in dotted lines in FIG. 5). The linkage may be used to increase the linear travel distance experienced by the damper mechanism in

wafer does not contact the cleats 720 and 720' except along the outer diameter and/or outer edges, i.e., to prevent the cleats 720 and 720' from contacting the bottom surface of the wafer except along the bottom edge.

[0074] As shown in FIG. 7, the first end effector blade 712 has been positioned above a wafer 701 housed on a pedestal 703, e.g., a pedestal that may be within a semiconductor processing chamber. The pedestal 703 may provide a recess or recesses around the circumference of the wafer 701 over which the wafer 701 may overhang.

[0075] During a wafer pick operation, the end effector wrist unit 702 may be caused to be lowered towards the pedestal 703 and the wafer 701. The first end effector blade 712 may, due to the weight of gravity, have rotated downward until it reaches a limit of an angular range in which it is configured to be rotatable within.

[0076] In FIG. 8, the end effector wrist unit 702 has been caused to be lowered further until the distal cleat 720 has come into contact with the pedestal 703. In FIG. 9, the end effector wrist unit 702 has been caused to continue its downward movement relative to the pedestal 703 until the proximal cleat 720' is located at an elevation that aligns with the wafer 701, e.g., such that the catch surface 724' is below, or at least somewhat below, the bottom edge of the wafer 701. It will be appreciated that the distal cleats 720 and the proximal cleat 720' are positioned in this configuration such that the catch surfaces 724 and 724' thereof are all able to be entirely outside of a circle having a diameter of the wafer 701.

[0077] In FIG. 10, the actuator mechanism 732 may be actuated so as to cause the proximal cleat 720' to move towards the distal cleat 720, thereby causing the catch surface 724' to pass underneath the bottom edge of the wafer 701. At the same time, the end effector wrist unit 702 may be caused to move in the opposite direction by a lesser amount such that the distal cleat 720 is similarly caused to move towards the proximal cleat 720' such that the catch surface 724 also passes underneath the bottom edge of the wafer 701. Such movement of the distal cleat 720 and the proximal cleat 720' may continue until, for example, the wafer 701 is unable to potentially shift and escape the catch surfaces 724 and 724' and the riser portions 722 and 722'. In such a configuration, the catch surfaces 724 and 724' may all overlap a circle that is of the same diameter as the wafer 701. Such circles, which may be referred to herein as reference circles, may have a diameter that is the same as the wafer 701 that is to be handled by the end effector, e.g., 200 mm, 300 mm, 450 mm, etc.

CLAIMS

1. An apparatus comprising:

an end effector wrist unit, the end effector wrist unit including:

a wrist unit housing;

an end effector mount assembly having a first end effector mount; and

one or more rotational interfaces, wherein:

the first end effector mount is configured to mechanically connect with a first end effector blade having a major surface defining a first plane,

the end effector mount assembly is connected with the wrist unit housing via the one or more rotational interfaces such that the end effector mount assembly is rotatable through a first angular range of motion relative to the wrist unit housing and about a first axis, and

the first axis is substantially parallel to the first plane when the first end effector blade is mounted to the first end effector mount.

2. The apparatus of claim 1, wherein the first end effector mount has a first planar end effector mounting surface that is configured to mate against the first end effector blade when the first end effector mount is mated to the first end effector blade and the first planar end effector mounting surface is parallel to the first axis.

3. The apparatus of claim 2, further comprising the first end effector blade.

4. The apparatus of claim 3, wherein the first end effector blade is made of a ceramic material.

5. The apparatus of claim 3, wherein the first end effector blade is made of silicon carbide.

6. The apparatus of claim 1, further comprising a first positive stop and a second positive stop, the first positive stop positioned so as to contact a portion of the end effector mount assembly when the end effector mount assembly is at a first rotational limit of the first angular range of motion and the second positive stop positioned so as to contact a portion of the end effector mount assembly when the end effector mount assembly is at a second rotational limit of the first angular range of motion.

7. The apparatus of claim 6, wherein one or both of the first positive stop and the second positive stop are adjustable.

8. The apparatus of claim 1, wherein the first angular range of motion is less than 10 degrees.

9. The apparatus of claim 1, further comprising a damper mechanism that is configured to damp rotational movement of the end effector mount assembly relative to the wrist unit housing.

10. The apparatus of claim 9, further comprising a draw link and a rocker arm, wherein:

the draw link has a first end rotatably coupled to a first end of the rocker arm so as to be rotatable about a second axis relative to the rocker arm and a second end rotatably coupled to the end effector mount assembly so as to be rotatable about a third axis relative to the end effector mount assembly, and

the rocker arm has a second end rotatably coupled with a first end of the damper mechanism so as to be rotatable about a fourth axis relative to the damper mechanism and is

mounted so as to be rotatable about a fifth axis that is fixed with respect to the wrist unit housing.

11. The apparatus of claim 10, wherein a first distance between the fifth axis and the fourth axis is greater than a second distance between the fifth axis and the second axis.

12. The apparatus of claim 11, wherein the first distance is at least 1.5 times the second distance.

13. The apparatus of claim 3, further comprising a second end effector blade that is fixed with respect to the end effector mount assembly.

14. The apparatus of claim 13, wherein:

the first and second end effector blades each have corresponding distal ends and corresponding proximal ends,

the proximal ends of the first and second end effector blades are fixedly mounted to the end effector mount assembly,

the distal ends of the first and second end effector blades each have a corresponding distal cleat mounted thereto,

each distal cleat has riser portion extending away from the corresponding end effector blade and a catch surface extending outward from the riser portion thereof, and

each catch surface is spaced apart from the corresponding end effector blade by at least a first gap distance.

15. The apparatus of claim 14, wherein each catch surface slopes away from the corresponding end effector blade with increasing distance from the riser portion from which that catch surface extends.

16. The apparatus of claim 15, further comprising an actuator mechanism and a proximal cleat, wherein:

the actuator mechanism has a first portion and a second portion,

the first portion of the actuator mechanism is fixed with respect to the end effector mount assembly,

the second portion of the actuator mechanism is configured to be movable between a first configuration and a second configuration relative to the first portion of the actuator mechanism,

the proximal cleat is fixed with respect to the second portion of the actuator mechanism and has a catch surface that faces in substantially the same direction as the catch surfaces of the distal cleats,

the catch surface of the proximal cleat and the catch surfaces of the distal cleats, in the first configuration, do not overlap a first reference circle when the second portion of the actuator mechanism is in the first configuration,

the catch surface of the proximal cleat and the catch surfaces of the distal cleats, in the second configuration, all overlap a second reference circle when the second portion of the actuator mechanism is in the second configuration, and

the first reference circle and the second reference circle have the same diameter.

17. The apparatus of claim 16, wherein the first reference circle has a diameter selected from the group consisting of 200 mm, 300 mm, and 450 mm.

18. The apparatus of claim 1, wherein the end effector wrist unit is configured such that:

when the end effector wrist unit is positioned in a first orientation with the first axis horizontal and the first plane substantially horizontal, the end effector mount assembly moves to the first rotational limit of the first angular range of motion due solely to gravitational loading, and

when the end effector wrist unit is positioned in a second orientation opposite the first orientation, the end effector mount assembly also moves to the second rotational limit of the first angular range of motion due solely to gravitational loading.

19. The apparatus of claim 1, further comprising a base, one or more robot arm links, and a wrist drive unit, wherein:

the one or more robot arm links include a first robot arm link that is configured to be rotatable relative to the base and about a base axis,

the wrist drive unit is supported by the one or more robot arm links and includes a wrist mount that is rotatable about an axis that is perpendicular to an axis that is parallel to the base axis, and

the end effector wrist unit is mounted to the wrist mount.

20. The apparatus of claim 1, further comprising a base, one or more robot arm links, and a wrist drive unit, wherein:

the one or more robot arm links include a first robot arm link that is configured to be rotatable relative to the base,

the wrist drive unit is supported by the one or more robot arm links and includes a wrist mount that is rotatable about an axis that is perpendicular to the first axis, and

the end effector wrist unit is mounted to the wrist mount.

21. A method comprising:

a) moving an end effector wrist unit to a first position relative to a wafer resting on a pedestal, the end effector wrist unit supporting one or more end effector blades that are rotationally mounted with respect to the end effector wrist unit by way of one or more rotational interfaces, wherein:

the one or more end effector blades are rotatable about a first axis relative to the end effector wrist unit, and

the one or more end effector blades have distal cleats mounted to a distal end or ends thereof;

b) lowering the end effector wrist unit from the first position to a second position in which the distal cleats first contact the pedestal; and

c) further lowering the end effector wrist unit from the second position to a third position, thereby causing the one or more end effector blades to rotate about the first axis relative to the end effector wrist unit.

22. The method of claim , wherein, in the third position, a proximal cleat that is supported by the end effector wrist unit is positioned with a catch surface thereof positioned such that at least part of the catch surface is at a lower elevation than an edge of the wafer with respect to a normal vector of the wafer.

23. The method of claim , further comprising moving at least one cleat of the distal cleats and the proximal cleat radially inward with respect to the wafer such that the catch surface of the proximal cleat and catch surfaces of the distal cleats all overlap the wafer when viewed along an axis perpendicular to the wafer.

24. The method of claim , further comprising raising the end effector wrist unit by a fourth distance after moving the at least one cleat of the distal cleats and the proximal cleat radially inward with respect to the wafer, thereby lifting the wafer off of the pedestal.

25. The method of claim , further comprising rotating the end effector wrist unit by 180° about a second axis perpendicular to the first axis and substantially parallel to the wafer after raising the end effector wrist unit by the fourth distance.