

CLAIMS

What is claimed is:

1. An apparatus for transferring wafers from station to station in a multi-station semiconductor processing chamber, the apparatus comprising:

- 5 a rotational indexer for simultaneously moving multiple wafers between equidistantly-spaced locations along a circular path when the wafers are placed upon the rotational indexer and the rotational indexer is activated, the rotational indexer including:
- 10 a base;
- a first motor;
- a second motor;
- a first hub;
- N indexer arm assemblies, each indexer arm assembly including a) a wafer support and b) an indexer arm having a proximal end fixedly connected
- 15 with the first hub and a distal end rotatably connected with the wafer support; and
- an actuation mechanism, wherein:
- the first motor is configured to rotate the first hub about a center axis of the first hub and relative to the base,
- 20 the second motor is configured to provide rotational input to the actuation mechanism,
- N is an integer greater than or equal to two,
- each wafer support is configured to rotate relative to the indexer arm of the corresponding indexer arm assembly and about a
- 25 rotational axis of that wafer support,
- the rotational axis of each wafer support is located so as to pass through a center of a corresponding one of the wafers when the wafer supports are supporting the wafers, and
- 30 the actuation mechanism is configured to cause the wafer supports of the indexer arms to simultaneously rotate by the same amounts, in the same rotational directions, and about the corresponding rotational axes of the wafer supports relative to the indexer arms responsive to rotation of: the first motor without rotation of the second motor, the second motor without rotation of

the first motor, or the first motor and the second motor such that the actuation mechanism actuates.

2. The apparatus of claim 1, wherein:

5 the actuation mechanism includes a second hub that is configured to rotate about the center axis of the first hub responsive to actuation by the second motor, and

 each indexer arm assembly further includes a tie-rod with a proximal end that is rotatably connected with the second hub by a first rotatable interface and a
10 distal end that is rotatably connected with the wafer support of that indexer arm assembly by a second rotatable interface, wherein the actuation mechanism and indexer arm assemblies are configured such that relative rotation between the first hub and the second hub about the center axis causes the tie-rods to translate in a generally radial manner relative to the center axis, thereby causing each tie-rod to
15 rotate the wafer support to which that tie-rod is rotatably connected to rotate relative to the indexer arms and about the rotational axis of that wafer support.

3. The apparatus of claim 2, wherein the first hub and the second hub are configured to be rotatable relative to each other from a first relative rotational
20 position to a second relative rotational position.

4. The apparatus of claim 2, wherein the indexer arms, the tie-rods, and the wafer supports are made of a ceramic material.

25 5. The apparatus of claim 4, wherein:

 each indexer arm assembly includes a third rotatable interface that rotatably connects the wafer support for that indexer arm assembly with the indexer arm for that indexer arm assembly, and

 the first rotatable interfaces, the second rotatable interfaces, and the third
30 rotatable interfaces are all ceramic ball bearings.

6. The apparatus of claim 3, wherein:

 there are four indexer arm assemblies,

each of the wafer supports, when the first hub and the second hub are in the first relative rotational position, is in a third relative rotational position with respect to the first hub,

5 each of the wafer supports, when the first hub and the second hub are in the second relative rotational position, is in a fourth relative rotational position with respect to the first hub,

the third relative rotational positions and the fourth relative rotational positions are 90° out of phase with one another.

10 7. The apparatus of claim 6, further comprising a stop mechanism, wherein the stop mechanism is configured to limit relative rotational motion between the first hub and the second hub to between 90° and 95°.

8. The apparatus of claim 6, wherein:

15 the proximal end of each tie-rod has an uppermost surface directly above the first rotatable interface for that tie-rod,

each first rotatable interface is horizontally spaced apart from the nearest other first rotatable interface by a first distance,

20 each tie-rod includes an offset region extending between a first longitudinal distance from a rotational center of the first rotatable interface for that tie-rod and a second longitudinal distance from the rotational center of the first rotatable interface for that tie-rod,

the first longitudinal distances are less than the first distances and the second longitudinal distances are greater than the first distances, and

25 the offset region of each tie-rod has a lowermost surface that is higher than the uppermost surface of the distal end of the tie-rod from an adjacent indexer arm assembly, thereby allowing the distal end of the tie-rod from the adjacent indexer arm assembly to pass underneath that tie-rod when the first hub and the second hub are in the first relative rotational position.

30

9. The apparatus of claim 3, wherein:

each of the wafer supports, when the first hub and the second hub are in the first relative rotational position, is in a third relative rotational position with respect to the first hub,

each of the wafer supports, when the first hub and the second hub are in the second relative rotational position, is in a fourth relative rotational position with respect to the first hub,

the third relative rotational positions and the fourth relative rotational positions are $360^\circ/N$ out of phase with one another.

10. The apparatus of claim 1, wherein:

the hub includes a separate mounting interface for each indexer arm assembly;

each mounting interface includes a tensionable interface and three conical recesses arranged around the tensionable interface;

a sphere is nestled in each conical recess; and

each indexer arm includes:

an aperture through which the tensionable interface protrudes, and

three grooves radiating outward relative to the aperture, wherein each sphere of the corresponding mounting interface is also nestled in a corresponding groove of that indexer arm, wherein the tensionable interfaces are each configured to compress the spheres between a corresponding one of the indexer arms and a corresponding one of the mounting interfaces.

11. The apparatus of claim 10, wherein the tensionable interface associated with each indexer arm comprises a threaded component and a spring that is configured to compress that indexer arm against the spheres interposed between that indexer arm and the mounting interface that connects that indexer arm with the first hub when the threaded component is tightened and placed in tension.

12. The apparatus of claim 1, further comprising:

a motor housing containing the first motor and the second motor and supporting the first hub via a first hub rotational interface; and

a z-axis drive system configured to translate the motor housing along a vertical axis responsive to actuation of the z-axis drive system.

13. A system comprising:

the apparatus of claim 1; and

a semiconductor processing chamber housing, the semiconductor processing chamber housing having N processing stations, wherein:

each processing station includes a pedestal configured to support a semiconductor wafer, and

5 the apparatus is configured to transfer semiconductor wafers from pedestal to pedestal within the semiconductor processing chamber housing.

14. The system of claim 13, wherein the processing stations are configured for performing a semiconductor processing operation selected from the group
10 consisting of: deposition operations, etch operations, curing operations, and heat treatment operations.

15. The system of claim 13, further comprising a controller having a memory and one or more processors, wherein:

15 the memory and the one or more processors are communicatively connected,

 the one or more processors are configured to control the first motor and the second motor, and

 the memory stores computer-executable instructions for controlling the one
20 or more processors to cause one or more of the first motor, the second motor, and the first motor and the second motor to be selectively actuated to cause:

 the first hub and the indexer arm assemblies to rotate such that each wafer support moves from a corresponding one of the processing stations to a neighboring processing station of the processing stations,

25 first relative rotational motion between the first hub and the actuation mechanism such that each wafer support rotates about the rotational axis of that wafer support and relative to the first hub by a first amount in a first direction during movement from processing station to processing station, while the wafer supports are resident at each processing
30 station, or during both movement from processing station to processing station and while the wafer supports are resident at each processing station, and

 second relative rotational motion between the first hub and the actuation mechanism such that each wafer support rotates about the
35 rotational axis of that wafer support and relative to the first hub by a first amount in a second direction opposite the first direction during movement from processing station to processing station, while the wafer supports are

resident at each processing station, or during both movement from processing station to processing station and while the wafer supports are resident at each processing station.

- 5 16. The system of claim 15, wherein $N = 4$ and the memory stores further computer-executable instructions for controlling the one or more processors to cause the first motor to rotate the first hub by 90° in the first direction while the second hub is kept stationary.
- 10 17. A method for handling wafers in a semiconductor processing apparatus, the method comprising:
- a) picking a plurality of wafers up off of a corresponding plurality of pedestals using an indexer having a corresponding plurality of wafer supports, each wafer support rotatably mounted to a distal end of an indexer arm of the indexer and each
- 15 indexer arm fixedly mounted to a hub of the indexer, wherein the wafers are supported by the wafer supports;
- b) rotating the hub and the indexer arms about a first rotational axis to move each wafer support from a position above each of the pedestals to a position above an adjacent one of the pedestals;
- 20 c) placing the wafers onto the pedestals after (b); and
- d) rotating the wafer supports relative to the indexer arms and about rotational axes of wafer supports in between (a) and (c), wherein the rotational axis of each wafer support passes through the center of the wafer supported by that wafer support when the wafers are supported by the wafer supports.
- 25 18. The method of claim 17, wherein the indexer has four indexer arms and (b) comprises rotating the hub and the indexer arms by 90° and (d) comprises rotating the wafer supports relative to the indexer arms by 90° .
- 30 19. The apparatus of claim 11, wherein, for each indexer arm:
- the corresponding aperture is located in the distal end of the indexer arm,
- the indexer arm is fixedly connected with the first hub by way of the corresponding mounting interface,
- each mounting interface fixedly connects the corresponding indexer arm with
- 35 the first hub such that a) the corresponding indexer arm and the first hub can undergo different amounts of thermal expansion without direct sliding contact

between the indexer arm and the first hub and b) the corresponding indexer arm is held fixedly in place relative to the first hub, at least in part, by the compression exerted on the indexer arm by the threaded component and the spring of the tensionable interface of the corresponding mounting interface.

5

20. The method of claim 17, wherein each indexer arm is fixedly mounted to the hub of the indexer by a mounting interface such that a) the corresponding indexer arm and the hub can undergo different amounts of thermal expansion without direct sliding contact between the indexer arm and the hub and b) the corresponding
- 10 indexer arm is held fixedly in place relative to the hub, at least in part, by the compression exerted on the indexer arm by a threaded component and a spring of a tensionable interface of the corresponding mounting interface.