CLAIMS

1. A linear electrical substrate transporting machine comprising:

a semiconductor substrate transport vacuum chamber, having a plurality of transport ports that are each adapted to connect to a respective processing chamber, the semiconductor substrate transport vacuum chamber comprising a frame with a level reference plane and being capable of being sealed from the external environment in vacuum;

an array of electromagnets, connected to the frame to form a drive plane at a predetermined height relative to the level reference plane, the array of electromagnets being arranged so that a series of electromagnets of the array of electromagnets define at least one drive line within the drive plane, and each of the electromagnets being coupled to a power source energizing each electromagnet;

a substrate handler, comprising at least one reaction platen of conductive material, disposed to cooperate with the electromagnets of the array of electromagnets so that excitation of a plurality of the electromagnets generates levitation and propulsion forces against the at least one reaction platen that controllably levitate and propel the substrate handler along the at least one drive line, in a controlled attitude relative to the drive plane, and a an end effector for carrying a substrate, the end effector being configured to stably hold a semiconductor substrate for transport through the semiconductor transport vacuum chamber by way of movement of the reaction platen;

a controller operably coupled to the array of electromagnets and the power source and configured so as to excite individually the plurality of electromagnets with current so as to control six degrees of freedom of each reaction platen; and

wherein the controller is configured to calculate, for the substrate handler and the end effector, a trajectory, for propulsion and levitation through the semiconductor transport vacuum chamber, and an attitude along the trajectory, the trajectory and attitude being described via control in any combination of two or more of the six degrees of freedom based at least in part on the weight of the semiconductor substrate and a maximum acceleration of the semiconductor substrate,

so that via feedback control of the plurality of electromagnets the controller controls the substrate handler trajectory and attitude along the trajectory in the combination of two or more of the six

degrees of freedom in real time as the substrate handler moves along the at least one drive line to transport the semiconductor substrate through the transport vacuum chamber, and

wherein the six degrees of freedom are x, y, z, roll, pitch and yaw.

2. The linear electrical substrate transporting machine of claim 1, wherein the controller monitors and controls the location and movement of the end effector as the semiconductor substrate is carried and moved by way of the six degrees of freedom control of the substrate handler, generated by the array of electromagnets, so as to move the semiconductor substrate from a first known position with respect to the frame to a second different position with respect to the frame.

3. The linear electrical substrate transporting machine of claim 1, wherein the controller controls the six degrees of freedom of the substrate handler, generated by the array of electromagnets, so that when the substrate handler and semiconductor substrate travels from the first known position to the second different position, the controller controls at least one of yaw or roll of the substrate handler and the end effector so as to calculate a tilt of the end effector and a direction of movement of the semiconductor substrate in a way that biases the semiconductor substrate against slippage with respect to the end effector.

4. The linear electrical substrate transporting machine of claim 1, wherein the controller takes into account a friction coefficient between the semiconductor substrate and the end effector when calculating a threshold acceleration of the substrate handler.

5. The linear electrical substrate transporting machine of claim 1, wherein the controller controls the propulsion forces, generated by the array of electromagnets, across the substrate handler so as to:

> impart a controlled yaw moment on the substrate handler, yawing the substrate handler about a yaw axis, substantially normal to the drive plane, from a first predetermined orientation relative to the frame, to a second different predetermined orientation relative to the frame; or

impart a moment couple on the substrate handler effecting controlled yaw of the substrate handler so as to effect at least one of positioning and centering of a substrate payload on the substrate handler relative to a predetermined substrate holding location of the frame.

6. The linear electrical substrate transporting machine of claim 1, wherein the controller controls the levitation forces, generated by the array of electromagnets, so as to impart differential levitation forces across the at least one reaction platen that effect a controlled inclination of the substrate handler, relative to the drive plane, that controls a predetermined substrate handler attitude in at least one of substrate handler pitch and substrate handler roll.

7. The linear electrical substrate transporting machine of claim 1, wherein the controller controls the levitation forces, generated by the array of electromagnets, so as to effect a predetermined bias attitude of the substrate handler, relative to the drive plane, that imparts a bias reaction force, from a substrate handler payload seating surface on a payload supported by the substrate handler end effector, in a direction countering payload inertial force arising from acceleration of the substrate handler along the drive plane.

8. The linear electrical substrate transporting machine of claim 8, further comprising a plurality of position feedback sensors distributed on the frame, the position feedback sensors each being configured for sensing position of the substrate handler along the drive plane and communicably coupled to the controller so that the controller registers the sensed position of the substrate handler, wherein the controller is configured to sequentially excite the electromagnets of the array of electromagnets corresponding to the sensed position.

9. The linear electrical substrate transporting machine of claim 8, wherein the controller is configured to determine acceleration of the substrate handler along the drive plane at least from changes in the sensed position, and in response to the acceleration determined, control a bias attitude of the substrate handler to provide the predetermined bias attitude countering the payload inertial force arising from the acceleration of the at least one reaction platen.

10. The linear electrical substrate transporting machine of claim 1, wherein the controller controls excitation of the electromagnets of the array of electromagnets so as to set the substrate

handler attitude to bias the substrate handler against inertial forces tending to displace the semiconductor substrate, seated against the end effector on the substrate handler.

11. The linear electrical substrate transporting machine of claim 10, comprising at least one sensor that detects position information of the substrate handler not based on magnetic field, wherein the controller utilizes the position information to control the substrate handler in the six degrees of freedom.

12. The linear electrical substrate transporting machine of claim 10, comprising at least one camera that detects position information of the substrate handler, that position information being provided to the controller.

13. The linear electrical substrate transporting machine of claim 1, wherein the controller controls the substrate handler so that at least part of the end effector, carrying the substrate, travels from the semiconductor substrate transport vacuum chamber through the transport port and into the processing chamber, while carrying the semiconductor substrate through a transport port of the plurality of transport ports into the processing chamber, and a base portion of the substrate handler does not travel into the processing chamber.

14. The linear electrical substrate transporting machine of claim 1, wherein the controller controls the substrate handler so that at least part of the end effector, disposed to carry the substrate, travels from the processing chamber through a transport port of the plurality of transport ports into the semiconductor substrate transport vacuum chamber, and a base of the substrate handler does not travel into the processing chamber.

15. The linear electrical substrate transport machine of claim 1, wherein the end effector has self-centering supports for the semiconductor substrate.

16. The linear electrical substrate transport machine of claim 1, wherein the transport ports are each connected with a respective processing chamber.

17. The linear electrical substrate transport machine of claim 1, wherein the end effector extends laterally from a base of the substrate handler.

18. The linear electrical substrate transport machine of claim 1, wherein the end effector is substantially common with the at least one reaction platen that forms a base.

19. The linear electrical substrate carrier transport machine of claim 1, wherein the semiconductor substrate transport vacuum chamber comprises two separate transport chambers that are connected to one another by isolation stages.

20. The linear electrical substrate carrier transport machine of claim 1, herein the semiconductor substrate is a photolithography cell.

21. A method comprising:

providing a linear electrical substrate transporting machine comprising:

a semiconductor substrate transport vacuum chamber, having a plurality of transport ports that are each adapted to connect to a respective processing chamber, the semiconductor substrate transport vacuum chamber comprising a frame with a level reference plane and being capable of being sealed from the external environment in vacuum;

an array of electromagnets, connected to the frame to form a drive plane at a predetermined height relative to the level reference plane, the array of electromagnets being arranged so that a series of electromagnets of the array of electromagnets define at least one drive line within the drive plane, and each of the electromagnets being coupled to a power source energizing each electromagnet;

a substrate handler comprising at least one reaction platen of conductive material, disposed to cooperate with the electromagnets of the array of electromagnets so that excitation of a plurality of the electromagnets generates levitation and propulsion forces against the at least one reaction platen that controllably levitate and propel the substrate handler along the at least one drive line, in a controlled attitude relative to the drive plane, and an end effector that is configured to stably hold a semiconductor substrate for transport through the semiconductor transport vacuum chamber by way of movement of the substrate handler; and

a controller operably coupled to the array of electromagnets and the power source and configured so as to excite individually the plurality of electromagnets with current so as to control six degrees of freedom of the substrate handler; and

calculating, with the controller, for the substrate handler and the end effector, a trajectory, for propulsion and levitation through the semiconductor transport vacuum chamber, and an attitude along the trajectory, the trajectory and attitude being described via control in any combination of two or more of the six degrees of freedom based at least in part on the weight of the semiconductor substrate and the frictional forces between the semiconductor substrate and the end effector, so that via feedback control of the plurality of electromagnets the controller controls the substrate handler trajectory and attitude along the trajectory in the combination of two or more of the six degrees of freedom in real time as the substrate handler moves along the at least one drive line to transport the semiconductor substrate through the transport vacuum chamber;

wherein the six degrees of freedom are x, y, z, pitch, roll and yaw.

22. The method of claim 21, wherein the controller monitors and controls the location and movement of the end effector as the semiconductor substrate is carried and moved by way of the six degrees of freedom control of the substrate handler, generated by the array of electromagnets, so as to move the semiconductor substrate from a first known position with respect to the frame to a second different position with respect to the frame.

23. The method of claim 21, wherein the controller controls the six degrees of freedom of the substrate handler, generated by the array of electromagnets, so that with the substrate handler and semiconductor substrate travels from the first known position to the second different position, the controller controls at least one of yaw or roll of the substrate handler and the end effector so as to calculate a tilt of the substrate handler and a direction of movement of the end effector in a way that biases the semiconductor substrate against slippage with respect to the end effector.

24. The method of claim 21, wherein the controller takes into account a friction coefficient between the semiconductor substrate and the end effector when calculating a threshold acceleration of the end effector.

25. The method of claim 21, wherein the controller controls the propulsion forces, generated by the array of electromagnets, across the at least one reaction platen so as to:

impart a controlled yaw moment on the substrate handler, yawing the substrate handler about a yaw axis, substantially normal to the drive plane, from a first predetermined orientation relative to the frame, to a second different predetermined orientation relative to the frame; or

impart a moment couple on the substrate handler effecting controlled yaw of the substrate handler so as to effect at least one of positioning and centering of a substrate payload on the substrate handler relative to a predetermined substrate holding location of the frame.

26. The method of claim 21, wherein the controller controls the levitation forces, generated by the array of electromagnets, so as to impart differential levitation forces across the substrate handler that effect a controlled inclination of the substrate handler, relative to the drive plane, that controls a predetermined substrate handler attitude in at least one of substrate handler pitch and substrate handler roll.

27. The method of claim 21, wherein the controller controls the levitation forces, generated by the array of electromagnets, so as to effect a predetermined bias attitude of the substrate handler, relative to the drive plane, that imparts a bias reaction force, from the end effector on a payload supported by the end effector, in a direction countering payload inertial force arising from acceleration of the at least one reaction platen along the drive plane.

28. The method of claim 21, wherein the controller controls excitation of the electromagnets of the array of electromagnets so as to set the substrate handler attitude to bias the substrate handler against inertial forces tending to displace the semiconductor substrate, seated against the end effector.

29. The method of claim 21, wherein the controller controls the substrate handler so that at least part of the end effector, carrying the substrate, travels from the semiconductor substrate transport vacuum chamber through a transport port of the plurality of transport ports and into the processing chamber, while carrying the semiconductor substrate through the transport port into the

processing chamber, and a base of the substrate handler does not travel into the processing chamber.

30. The method of claim 21, wherein the controller controls the substrate handler so that the end effector that is disposed to carry the substrate, travels from the processing chamber through a transport port of the plurality of transport ports into the semiconductor substrate transport vacuum chamber, and a base of the substrate handler does not travel into the processing chamber.

31. The linear electrical substate transport machine of claim 1, wherein the transport chamber has a selectably variable length, the chamber being formed of a number of transport chamber modules, the variable length is selected by connecting a transport chamber module to the number of transport chamber modules, or removing the transport chamber module from the number of transport chamber modules, and effects an extension or reduction in the travel length of the at least one reaction platen, the semiconductor substrate carrier and the semiconductor substrate.