What is claimed is:

1. A vacuum transfer module (VTM) for an automated thin film deposition system configured for batch processing of substrates, the VTM comprising:

   a vacuum chamber having a plurality of openings configured to be coupled to thin film deposition process modules; and

   a robotic arm located within the chamber, the robotic arm having an end effector configured to couple to a transportable substrate rack, the transportable substrate rack configured to hold a plurality of substrates, the transportable substrate rack including a base with a bottom surface and an interface that protrudes therefrom, the interface including coupling features for coupling to a turntable, wherein the end effector includes first and second opposed sides that are configured to come into contact with the base and that define an opening that has a shape that is complementary to an outer shape of the interface;

   wherein the robotic arm is configured to selectively move the transportable substrate rack through one or more of the openings and deposit the transportable substrate rack within a corresponding one of the thin film deposition process modules for processing the plurality of substrates loaded on the transportable substrate rack.

2. The VTM of claim 1, wherein the robotic arm is configured to couple to a base of the transportable substrate rack and transport the transportable substrate rack in a vertical orientation into and out of the VTM vacuum chamber.

3. The VTM of claim of claim 2, wherein the transportable substrate rack holds a column of substrates, the column of substrates being held in a vertical orientation as the transportable substrate rack is moved between the VTM and thin film deposition process modules.

4. The VTM of claim 1, wherein the end effector is a universal end effector configured to couple to a plurality different-sized ones of the transportable substrate racks for concurrently processing a plurality of substrate sizes in corresponding thin film deposition process modules.

5. A semiconductor processing system, comprising:

a vacuum transfer module (VTM) that includes a vacuum chamber, a robotic arm located in the vacuum chamber, and a plurality of openings;

a plurality of thin film deposition process modules including a preheat chamber, a reactor, a load lock, and a load station;

at least one transportable wafer rack, the at least one transportable wafer rack configured to hold a plurality of semiconductor wafers;

wherein the preheat chamber, reactor, and load lock are each coupled to a corresponding respective one of the plurality of openings and the load station is coupled to the load lock, wherein the load lock includes a turntable for rotating the at least one transportable wafer rack between a first and a second rotational position, wherein the robotic arm is configured to automatedly and selectively transfer the transportable wafer rack between the load lock, preheat chamber, and reactor for automated batch processing of a plurality of wafers loaded on the transportable wafer rack.

6. The system of claim 5, wherein the load station includes a robotic arm configured to transfer wafers from a wafer cassette to the transportable wafer rack when the transportable wafer rack is disposed in the load lock and in one of the first and second positions.

7. The system of claim 5, wherein the load lock includes ~~a turntable that is designed and configured to support the at least one transportable wafer rack, the load lock including~~ a rotary drive system for controlling a rotational position of the turntable and the at least one transportable wafer rack between ~~a~~the first rotational position for loading wafers onto the wafer rack and ~~a~~the second rotational position for coupling the transportable wafer rack to the VTM robotic arm for transport of the transportable wafer rack by the VTM robotic arm from the load lock to the VTM vacuum chamber.

8. The system of claim 5, wherein the at least one transportable wafer rack includes a first transportable wafer rack configured to hold a first wafer size and a second transportable wafer rack configured to hold a second wafer size.

9. The system of claim 8, wherein each of the first and second transportable wafer racks includes a base having a universal interface configured to couple to the VTM robotic arm.

10. The system of claim 8, wherein the VTM robotic arm includes a universal end effector configured to couple to and transport both the first transportable wafer rack and the second transportable wafer rack.

11. The system of claim 5, wherein the at least one transportable wafer rack includes a plurality of transportable wafer racks each loaded with a plurality of wafers, wherein the system is configured to concurrently process the plurality of transportable wafer racks by simultaneously locating each of the plurality of transportable wafer racks in a corresponding respective one of the plurality of thin film deposition process modules.

12. The system of claim 11, wherein the VTM robotic arm is configured to sequentially transport the plurality of transportable wafer racks into and out of the plurality of thin film deposition process modules according to a thin film deposition manufacturing process.

13. The system of claim 11, wherein the system is configured to increase wafer processing throughput by separately and simultaneously performing a pre-heat phase, a thin film deposition phase, and a cool-down phase of a wafer processing process on corresponding respective ones of the plurality of transportable wafer racks.

14. A method of performing a thin film deposition process with a thin film deposition system that includes a vacuum transfer module (VTM), a VTM robot located in the VTM, a load lock that includes a turntable, a preheat chamber, a thin film deposition reactor, and at least one transportable wafer rack, the method comprising:

a first transfer, with the VTM robot, of the at least one transportable wafer rack from the turntable of the load lock, when the turntable is in a first position, through the VTM, to the preheat chamber, the at least one transportable wafer rack loaded with a plurality of wafers;

heating the at least one transportable wafer rack and the plurality of wafers in the preheat chamber;

a second transfer, with the VTM robot, of the at least one transportable wafer rack and the plurality of wafers from the preheat chamber, through the VTM, to the reactor;

performing a thin film deposition process on the plurality of wafers in the reactor;

a third transfer, with the VTM robot, of the at least one transportable wafer rack and the plurality of wafers from the reactor, through the VTM, to the load lock; and

performing a controlled cool down process on the at least one transportable wafer rack and plurality of wafers in the load lock.

15. The method of claim 14, wherein the thin film deposition system further includes a load station, the load station including a load port and a robotic arm, the method further comprising:

sequentially transferring, with the load station robotic arm, the plurality of wafers between a wafer cassette located in the load port and the at least one transportable wafer rack when the at least one transportable wafer rack is located on the turntable in the load lock when the turntable is in a second position that is different than the first position.

16. The method of claim 15, ~~wherein the load lock includes a turntable configured to support the at least one transportable wafer rack, the method~~ further comprising:

positioning the turntable and the at least one transportable wafer rack at ~~a~~the ~~first~~second rotational position for the sequentially transferring step; and

positioning the turntable and the at least one transportable wafer rack at ~~a~~the ~~second~~first rotational position for the first transfer and the third transfer.

17. The method of claim 14, wherein the at least one transportable wafer rack includes a plurality of transportable wafer racks, each of the plurality of transportable wafer racks loaded with a corresponding plurality of wafers, the method further comprising:

concurrently performing the heating step on a first one of the plurality of transportable wafer racks loaded with a first plurality of wafers, the thin film deposition process on a second one of the plurality of transportable wafer racks loaded with a second plurality of wafers, and the controlled cool down process on a third one of the plurality of transportable wafer racks loaded with a third plurality of wafers.

18. The method of claim 17, wherein at least one of the first, second, and third plurality of wafers have a different size than another one of the first, second, and third plurality of wafers.

19. A control system for controlling a thin film deposition system, the thin film deposition system including a vacuum transfer module (VTM), a VTM robot located in the VTM, a load lock that includes a turntable, a preheat chamber, a thin film deposition reactor, and at least one transportable wafer rack, the control system comprising:

a processor and a memory containing machine-readable instructions for causing the processor to control the thin film deposition system to perform operations comprising:

a first transfer, with the VTM robot, of the at least one transportable wafer rack from the turntable of the load lock, when the turntable is in a first position, through the VTM, to the preheat chamber, the at least one transportable wafer rack loaded with a plurality of wafers;

heating the at least one transportable wafer rack and the plurality of wafers in the preheat chamber;

a second transfer, with the VTM robot, of the at least one transportable wafer rack and the plurality of wafers from the preheat chamber, through the VTM, to the reactor;

performing a thin film deposition process on the plurality of wafers in the reactor;

a third transfer, with the VTM robot, of the at least one transportable wafer rack and the plurality of wafers from the reactor, through the VTM, to the load lock; and

performing a controlled cool down process on the at least one transportable wafer rack and plurality of wafers in the load lock.

20. The control system of 19, wherein the thin film deposition system further includes a load station, the load station including a load port and a robotic arm, the operations further comprising:

sequentially transferring, with the load station robotic arm, the plurality of wafers between a wafer cassette located in the load port and the at least one transportable wafer rack when the at least one transportable wafer rack is located on the turntable in the load lock when the turntable is in a second position that is different than the first position.

21. The control system of claim 20, ~~wherein the load lock includes a turntable configured to support the at least one transportable wafer rack, the operations~~ further comprising:

positioning the turntable and the at least one transportable wafer rack at ~~a first~~the second rotational position for the sequentially transferring step; and

positioning the turntable and the at least one transportable wafer rack at ~~a second~~the first rotational position for the first transfer and the third transfer.

22. The control system of claim 19, wherein the at least one transportable wafer rack includes a plurality of transportable wafer racks, each of the plurality of transportable wafer racks loaded with a corresponding plurality of wafers, the operations further comprising:

concurrently performing the heating step on a first one of the plurality of transportable wafer racks loaded with a first plurality of wafers, the thin film deposition process on a second one of the plurality of transportable wafer racks loaded with a second plurality of wafers, and the controlled cool down process on a third one of the plurality of transportable wafer racks loaded with a third plurality of wafers.

23. The control system of claim 22, wherein at least one of the first, second, and third plurality of wafers have a different size than another one of the first, second, and third plurality of wafers.

24. A non-transitory machine-readable storage medium containing machine-readable instructions configured to cause a processor of thin film deposition system that includes a vacuum transfer module (VTM), a VTM robot located in the VTM, a load lock that includes a turntable, a preheat chamber, a thin film deposition reactor, and at least one transportable wafer rack, to perform operations comprising:

a first transfer, with the VTM robot, of the at least one transportable wafer rack from the turntable of the load lock, when the turntable is in a first position, through the VTM, to the preheat chamber, the at least one transportable wafer rack loaded with a plurality of wafers;

heating the at least one transportable wafer rack and the plurality of wafers in the preheat chamber;

a second transfer, with the VTM robot, of the at least one transportable wafer rack and the plurality of wafers from the preheat chamber, through the VTM, to the reactor;

performing a thin film deposition process on the plurality of wafers in the reactor;

a third transfer, with the VTM robot, of the at least one transportable wafer rack and the plurality of wafers from the reactor, through the VTM, to the load lock; and

performing a controlled cool down process on the at least one transportable wafer rack and plurality of wafers in the load lock.

25. The non-transitory machine-readable storage medium of claim 24, wherein the thin film deposition system further includes a load station, the load station including a load port and a robotic arm, the operations further comprising:

sequentially transferring, with the load station robotic arm, the plurality of wafers between a wafer cassette located in the load port and the at least one transportable wafer rack when the at least one transportable wafer rack is located on the turntable in the load lock when the turntable is in a second position that is different than the first position.

26. The non-transitory machine-readable storage medium of claim 25, ~~wherein the load lock includes a turntable configured to support the at least one transportable wafer rack,~~ the operations further comprising:

positioning the turntable and the at least one transportable wafer rack at ~~a first~~the second rotational position for the sequentially transferring step; and

positioning the turntable and the at least one transportable wafer rack at ~~a second~~the first rotational position for the first transfer and the third transfer.

27. The non-transitory machine-readable storage medium of claim 24, wherein the at least one transportable wafer rack includes a plurality of transportable wafer racks, each of the plurality of transportable wafer racks loaded with a corresponding plurality of wafers, the operations further comprising:

concurrently performing the heating step on a first one of the plurality of transportable wafer racks loaded with a first plurality of wafers, the thin film deposition process on a second one of the plurality of transportable wafer racks loaded with a second plurality of wafers,

and the controlled cool down process on a third one of the plurality of transportable wafer racks loaded with a third plurality of wafers.

28. The non-transitory machine-readable storage medium of claim 27, wherein at least one of the first, second, and third plurality of wafers have a different size than another one of the first, second, and third plurality of wafers.

29. A transportable wafer rack, comprising:

a base plate, a top plate, and a plurality of columns disposed between the base and top plates, each of the plurality of columns including a plurality of recesses for supporting a plurality of wafers slidably disposed between the base plate and the top plate; and

an interface disposed on the base plate, the interface configured and dimensioned to couple to an end effector of a robotic arm for transporting the transportable wafer rack and the plurality of wafers disposed thereon between a plurality of thin film deposition process modules for processing the wafers~~.~~;

wherein the interface is further configured to couple to a turntable.

30. A load lock, comprising:

an enclosure that defines a load lock chamber, a load station opening configured and dimensioned to be coupled to load station, and a vacuum transfer module opening configured and dimensioned to be coupled to a vacuum transfer module (VTM); and

a turntable rotatably disposed in the load lock, wherein the turntable is configured to removably couple to and support a transportable wafer rack for transferring wafers between the load station and the transportable wafer rack and for transporting the transportable wafer rack between the load lock and the VTM.

~~30.~~31. The load lock of claim 30, wherein the load lock includes a rotary drive system for controlling a rotational position of the turntable and the at least one transportable wafer rack between a first rotational position for loading wafers onto the wafer rack and a second rotational position for coupling the transportable wafer rack to a robotic arm of the VTM for transport of the transportable wafer rack by the VTM robotic arm from the load lock to the VTM.