Claims:

1. A system for handling wafers~~ and film frames on which wafers or portions thereof are mounted~~, each wafer having a periphery and a surface area,~~ each film frame including a corresponding film on which a wafer or a portion thereof is mounted and which is supported by the film frame,~~ the system comprising:

a wafer table assembly comprising a wafer table providing a ~~an ultra-~~planar wafer table surface configured for carrying a wafer~~ or a film frame~~, the wafer table assembly configured for applying a negative pressure or a positive pressure to an underside of ~~a~~the wafer~~ or an underside of a film of a film frame on which the wafer is mounted~~; and

~~a film frame handling apparatus; and~~

~~at least one of:~~

a flattening apparatus configured for automatically applying a downward force to portions of a warped or non-planar wafer in a direction normal to the wafer table surface~~,~~;

~~a displacement limitation apparatus configured for automatically constraining or preventing uncontrolled lateral motion of a wafer relative to the wafer table surface after cessation of an applied negative pressure and application of a positive pressure to the underside of the wafer via the wafer table~~wherein the flattening apparatus eliminates a need for manual intervention when the warped or non-planar wafer cannot be reliably retained on the wafer table surface as a result of its warpage or non-planarity.

2. The system of claim 1, wherein the wafer table surface comprises a porous material.

~~3. The system of claims 1 or 2, wherein the film frame handling apparatus includes a rotational misalignment compensation apparatus comprising:~~

~~a first image capture device configured for capturing an image of portions of the wafer mounted on the film frame; and~~

~~a processing unit configured for determining an angular extent of rotational misalignment and a direction of rotational misalignment of the wafer mounted on the film frame with respect to (i) a field of view of the first image capture device and/or (ii) the film frame.~~

~~4. The system of any of claims 1 – 3, wherein the flattening apparatus eliminates a need for manual intervention when the warped or non-planar wafer cannot be reliably retained on the wafer table surface as a result of its warpage or non-planarity.~~

~~5. The system of any of claims 1 – 4, wherein the displacement limitation apparatus eliminates a need for manual intervention in response to uncontrolled lateral displacement of the wafer relative to the wafer table surface after cessation of an application of negative pressure and/or an application of positive air pressure to the underside of the wafer.~~

~~6. The system of any of claims 1 – 5, wherein the displacement limitation apparatus facilitates release of the very thin or ultra-thin wafer from the wafer table surface after an application of positive pressure in a manner that reliably avoids damaging a very thin or ultra-thin wafer by preventing uncontrolled lateral displacements of the ultra-thin wafer.~~

~~7~~3. The system of claim 1, wherein the ~~system includes a multi-function handling~~flattening apparatus ~~comprising~~comprises:

a main body positionable over the wafer table surface and displaceable along a vertical axis that is perpendicular to the wafer table surface;

a plurality of ~~capture~~ arms coupled to the main body, each ~~capture~~ arm within the plurality of ~~capture~~ arms having a tip element comprising a soft and resiliently deformable material coupled thereto, each arm controllably displaceable to multiple distinct positions transverse to and towards or away from the vertical axis;

~~a set of vacuum elements coupled to the plurality of capture arms and configured for controllably applying vacuum forces to portions of a periphery of a film frame to facilitate secure capture of the film frame by the plurality of capture arms; and~~

a vertical displacement driver configured for (a) controllably displacing the main body and consequently simultaneously displacing the plurality of ~~capture~~ arms and the tip elements coupled thereto along a vertical direction parallel to the vertical axis to ~~transport the film frame to the wafer table surface by directly placing the film frame thereon~~position the tip elements in accordance with an engagement assistance position corresponding to a dimension of the wafer upon the wafer table, such that a portion of each tip element is

disposed directly over an exposed upper surface of the wafer for engaging with or contacting a portion of the exposed surface of the wafer, and (b) controllably displacing the tip elements positioned in accordance with the engagement assistance position in a downward direction toward the wafer table surface.

~~8. The system of claim 7, wherein the multi-function handling apparatus further comprises a rotational misalignment compensation driver configured for precisely and simultaneously rotating the plurality of capture arms about the vertical axis to compensate for a rotational misalignment of a wafer mounted on the film frame relative to the film frame and/or a field of view of an image capture device, while the film frame is transported to the wafer table surface.~~

~~9. The system of any of claims 1 – 8, wherein the wafer table assembly excludes film frame registration elements configured for facilitating film frame alignment by way of mating engagement with a set of film frame reference features.~~

~~10. The system of claim 7 or 8, wherein the handling subsystem further comprising a capture arm tip coupled to each capture arm within the plurality of capture arms, each capture arm tip comprising a soft and resiliently deformable material, wherein the handling subsystem implements at least one of the flatting apparatus and the displacement limitation apparatus.~~

~~11. The system of claim 10, wherein the handling subsystem implements each of the flattening apparatus and the displacement limitation apparatus.~~

~~12. The system of claim 8, wherein the handling subsystem further comprising a capture arm tip coupled to each capture arm within the plurality of capture arms, each capture arm tip comprising a soft and resiliently deformable material, and the handling subsystem implements each of the flattening apparatus, the displacement limitation apparatus, and the film frame handling apparatus.~~

~~13~~4. The system of claim ~~10~~3, wherein the plurality of tip elements is displaceable to ~~at least one of:~~

~~(i)~~ a plurality of engagement assistance positions, each engagement assistance position disposing the ~~plurality of~~ tip elements away from each other across an area that is slightly less than a standard wafer diameter at the periphery of ~~a~~the wafer on the wafer table surface~~,~~; ~~and~~

~~(ii) a plurality of confinement positions, each confinement position disposing a each tip element within the plurality of tip elements beside and just beyond the periphery of a wafer on the wafer table surface,~~

wherein each engagement assistance position corresponds to a different standard wafer dimension ~~and each confinement position corresponds to a different standard wafer dimension~~.

5. The system of claim 1, further comprising a displacement limitation apparatus configured for automatically constraining or preventing uncontrolled lateral displacement of the wafer relative to the wafer table surface after cessation of an applied negative pressure and/or an application of a positive pressure to the underside of the wafer via the wafer table, to thereby eliminate a need for manual intervention in response to such uncontrolled lateral displacement of the wafer.

6. The system of claim 5, wherein the displacement limitation apparatus comprises

a main body positionable over the wafer table surface and displaceable along a vertical axis that is perpendicular to the wafer table surface;

a plurality of arms coupled to the main body, each arm within the plurality of arms having a tip element comprising a soft and resiliently deformable material coupled thereto, each arm controllably displaceable to multiple distinct positions transverse to and towards or away from the vertical axis; and

a vertical displacement driver configured for (a) controllably displacing the main body and consequently simultaneously displacing the plurality of arms and the tip elements coupled thereto along a vertical direction parallel to the vertical axis to position the tip elements in accordance with a confinement configuration corresponding to a dimension of the wafer upon the wafer table, such that each tip element is disposed slightly beyond the periphery of the wafer, and (b) controllably displacing the tip elements positioned in

accordance with the confinement configuration in a downward direction toward the wafer table surface.

7. The system of claim 6, wherein the tip elements are displaceable to a plurality of confinement configurations, each confinement configuration disposing the tip elements away from each other across a planar spatial confinement area that is marginally larger than the surface area of the wafer on the wafer table surface, wherein each confinement configuration corresponds to a different standard wafer dimension.

~~14~~8. The system of claim ~~1~~5, wherein the wafer table assembly includes a set of ejector pins displaceable along a vertical direction perpendicular to the wafer table surface, and wherein the displacement limitation apparatus comprises:

a control unit configured for controlling:

(a) an application of an air puff to the underside of the wafer essentially immediately after interruption or cessation of the application of the suction force to the underside of the wafer, the air puff applied from an air puff onset time to an air puff cessation time; and

(b) activation of the set of ejector pins to displace the set of ejector pins in an upward direction after a very brief ejector pin activation delay time following the air puff onset time to thereby lift the wafer off of the wafer table surface with minimal or negligible lateral displacement as a result of the very brief ejector pin activation delay time relative to the air puff onset time,

wherein the ejector pin activation delay time is precisely controlled relative to the air puff onset time such that the wafer is vertically raised away from the wafer table surface synchronous with the release of the wafer from the wafer table surface in response to the air puff.

~~15~~9. The system of claim ~~14~~8, wherein the ejector pin activation delay time is experimentally determined.

~~16~~10. The system of claim ~~14~~8, wherein the ejector pin activation delay time is between 5 – 50 msec.

~~17~~11. A method for handling wafers ~~and film frames on which wafers or portions thereof are mounted~~, each wafer having a periphery and a surface area, ~~each film frame including a corresponding film on which a wafer or a portion thereof is mounted and which is supported by the film frame,~~ the method comprising:

transporting a wafer ~~or a film frame~~ to a ~~an ultra~~ planar wafer table surface corresponding to a wafer table assembly comprising a wafer table configured for applying a negative pressure or a positive pressure to an underside of ~~a~~the wafer ~~or an underside of a film of a film frame on which the wafer is mounted~~; and

~~at least one of:~~

automatically remediating insufficient retention of the wafer upon the wafer table surface due to wafer warpage or non-planarity~~; and~~

~~automatically preventing uncontrolled lateral displacement of the wafer relative to the wafer table surface following interruption or cessation of the suction force to the underside of the wafer~~.

~~18. The method of claim 17, wherein the method further comprises automatically remediating rotational misalignment of the wafer relative to the film frame and/or a field of view of an image capture device.~~

~~19. The method of claim 17, further comprising:~~

~~removing the wafer from the wafer table by way of elevating a set of ejector pins and an end effector configured to capture the wafer from the elevated set of ejector pins; and~~

~~directly placing a film frame on the wafer table surface without the use of ejector pins following removal of the wafer from the wafer table without converting the wafer table for film frame handling by way of a conversion kit.~~

~~20. The method of claim 19, wherein directly placing the film frame on the wafer table surface comprises:~~

positioning a film frame transport apparatus over the film frame, the film frame transport apparatus comprising a housing coupled to a plurality of displaceable capture arms, each capture arm coupled to a soft and resiliently deformable tip element, each capture arm fluidly coupled to a vacuum or negative pressure source;

positioning the plurality of capture arms at a film frame capture position corresponding to a standard dimension of the film frame, such that the tip elements engage with portions of a film frame border;

applying a vacuum force or negative pressure to portions of the film frame border by way of the plurality of capture arms to securely capture the film frame;

positioning the captured film frame over the wafer table surface;

displacing the captured film frame downward toward the wafer table surface until the film frame contacts the wafer table surface;

applying a suction force to an underside of the film corresponding to the film frame by way of the wafer table; and

terminating the application of vacuum force or negative pressure to portions of the film frame border after defect inspection.

21. The method of claim 17, wherein automatically remediating a rotational misalignment of a wafer relative to a film frame on which the wafer is mounted comprises:

capturing an image of portions of the wafer mounted on the film frame using an image capture device;

determining a rotational misalignment angle and a rotational misalignment direction of the wafer relative to the film frame and/or the image capture device;

rotating the film frame across the rotational misalignment angle in a direction opposite to the rotational misalignment direction by way of a rotational compensation apparatus separate from the wafer table; and

placing the film frame on the wafer table.

22. The method of claim 21, wherein capturing an image of portions of the wafer comprises capturing an image of portions of the wafer using a first image capture device prior to placement of the film frame on the wafer table.

~~23. The method of claim 21, wherein capturing an image of portions of the wafer comprises capturing an image of portions of the wafer using a second image capture device that forms a portion of an inspection system after placement of the film frame on the wafer table.~~

~~24~~12. The method of claim ~~17~~11, wherein automatically remediating insufficient retention of the wafer upon the wafer table surface comprises:

automatically detecting insufficient retention of the wafer upon the wafer table surface; and

responsively applying a set of downward forces to portions of an exposed upper surface of the wafer concurrent with the application of the suction force to the underside of the wafer to facilitate secure retention of the wafer upon the wafer table surface.

~~25~~13. The method of claim ~~24~~12, wherein applying the set of downward forces comprises:

positioning a flattening apparatus above the wafer, the flattening apparatus comprising a housing coupled to a plurality of displaceable arms, each arm within the plurality of arms coupled to a tip element comprising a soft and resiliently deformable material;

positioning the tip elements in accordance with an engagement assistance position corresponding to a dimension of the wafer upon the wafer table, such that a portion of each tip element is disposed directly over the exposed upper surface of the wafer for engaging with or contacting a portion of the exposed surface of the wafer; and

displacing the tip elements disposed over the exposed upper surface of the wafer downward toward the wafer table surface.

~~26~~14. The method of claim ~~24 or 25~~12, further comprising:

detecting secure retention of the wafer upon the wafer table surface by way of ~~the~~a vacuum gauge; and

terminating the application of the set of downward forces to portions of the exposed upper surface of the wafer in response to secure retention of the wafer on the wafer table surface.

15. The method of claim 11, further comprising automatically preventing uncontrolled lateral displacement of the wafer relative to the wafer table surface following interruption or cessation of the suction force and/or an application of positive pressure to the underside of the wafer.

~~27~~16. The method of claim ~~17~~15, wherein automatically preventing uncontrolled lateral displacement of the wafer relative to the wafer table surface comprises:

positioning a confinement apparatus above the wafer, the confinement apparatus comprising a housing coupled to a plurality of displaceable arms, each arm within the plurality of arms coupled to a tip element comprising a soft and resiliently deformable material;

positioning the tip elements in accordance with a confinement ~~position~~configuration corresponding to a dimension of the wafer upon the wafer table, such that a portion of each tip element is disposed just beyond the periphery of the wafer;

interrupting or terminating the application of suction force to the underside of the wafer; and

activating a set of ejector pins corresponding to the wafer table in an upward direction to elevate the wafer away from the wafer table surface.

~~28~~17. The method of claim ~~17~~15, wherein automatically preventing uncontrolled lateral displacement of the wafer relative to the wafer table surface comprises:

interrupting or terminating the application of suction force to the underside of the wafer;

applying an air puff to the underside of the wafer essentially immediately after interruption or cessation of the application of the suction force to the underside of the wafer, the air puff applied from an air puff onset time to an air puff cessation time; and

activating a set of ejector pins corresponding to the vacuum table to displace the set of ejector pins in an upward direction after a very brief ejector pin activation delay time following the air puff onset time to thereby lift the wafer off of the wafer table surface with minimal or negligible lateral displacement as a result of the very brief ejector pin activation delay time relative to the air puff onset time, wherein the ejector pin activation delay time is precisely controlled relative to the air puff onset time such that the wafer is vertically raised away from the wafer table surface synchronous with the release of the wafer from the wafer table surface in response to the air puff.

~~29~~18. The method of claim ~~28~~17, wherein the ejector pin activation delay time is experimentally determined.

~~30~~19. The method of claim ~~28~~17, wherein the ejector pin activation delay time is between 5 – 50 msec.

~~31~~20. A method for handling a wafer in association with an inspection process, comprising:

retrieving the wafer from a wafer source;

transporting the wafer to a wafer prealigner;

disposing the wafer on a wafer table surface provided by a wafer table following prealignment of the wafer;

applying a negative pressure to an underside of the wafer; ~~and~~

~~at least one of:~~

automatically remediating insufficient retention of the wafer upon the wafer table surface due to wafer warpage or non-planarity by way of:

detecting whether the wafer is securely retained upon the wafer table surface prior to the initiation of the inspection process; and

automatically applying a downward force to portions of the wafer until secure retention of the wafer upon the wafer table surface is detected;

and

automatically preventing uncontrolled lateral displacement of the wafer along the wafer table surface following the inspection process as a result of cessation of the application of the negative pressure to the wafer by way of:

(a) automatically confining the wafer to reside within a confinement position on the wafer table; or

(b) coordinating the cessation of the application of the negative pressure to the underside of the wafer with an application of an air puff to the underside of the wafer and an activation of a set of ejector pins that is vertically displaceable relative to the wafer table surface, such that the wafer is vertically raised away from the wafer table surface synchronous with the release of the wafer from the wafer table surface in response to the air puff;

and

retrieving the wafer from the wafer table and transferring the wafer to a wafer destination.

~~32. A method for handling a film frame in association with an inspection process performable by an inspection system, the film frame having a wafer mounted thereon by way of a film corresponding to and supported by the film frame, the method comprising:~~

~~retrieving the film frame from a film frame source;~~

~~capturing an image of portions of the wafer mounted to the film frame using a first image capture device;~~

~~determining by way of image processing operations an angular misalignment magnitude and an angular misalignment direction of rotational misalignment of the wafer relative to the film frame and/or the first image capture device;~~

~~transferring the film frame to a multi-function handling apparatus configured for (i) automatically rotating the film frame on which the wafer is mounted to compensate for rotational misalignment of the wafer relative to the film frame and/or the first image capture device, and (ii) directly placing the film frame on a wafer table surface of a wafer table corresponding to the inspection system, wherein the multi-function handling apparatus is separate from the inspection system;~~

~~initiating the inspection process using a second image capture device corresponding to the inspection system following compensation for the rotational misalignment of the wafer relative to the film frame and/or the first image capture device by the multi-function handling apparatus; and~~

~~transferring the film frame to a film frame destination following completion of the inspection process.~~

~~33. The method of claim 32, further comprising rotating the film frame across the angular misalignment magnitude in a direction opposite to the angular misalignment direction while the multi-function handling apparatus transfers the film frame to the wafer table surface.~~

~~34. The method of claims 32 or 33, wherein capturing an image of portions of the wafer mounted on the film frame using the first image capture device occurs (a) while the film frame is being carried by an end effector of a robotic arm toward the multi-function handling apparatus, (b) after the film frame has been transferred to the multi-function handling apparatus and prior to placement of the film frame on the wafer table surface, or (c) after the film frame has been placed on the wafer table surface.~~

~~35. The method of any of claims 32 – 34, wherein transferring the film frame to the film frame destination comprises directly removing the film frame from the wafer table surface by way of the multi-function handling apparatus.~~