

CLAIMS

What is claimed is:

1. A method for finding a center of a wafer in a device having an interior and a plurality of entrances, the interior containing a robotic arm, and the device including a plurality of sensors, each one of the sensors adapted to detect a presence of the wafer at a predetermined location within the interior of the device, the method comprising:
 - retrieving the wafer from outside the interior through a first one of the plurality of entrances;
 - retracting the wafer into the interior and detecting a presence of the wafer with a first one of the plurality of sensors;
 - rotating the robotic arm;
 - extending the wafer out of the interior through a second one of the plurality of entrances and detecting an absence of the wafer with the first one of the plurality of sensors; and
 - determining a location of a center of the wafer relative to the robotic arm using sensor data from the plurality of sensors and position data from the robotic arm.
2. The method of claim 1 wherein the plurality of sensors include optical sensors.
3. The method of claim 2 wherein the plurality of sensors include light emitting diodes.
4. The method of claim 2 wherein the plurality of sensors include auto focusing photodiode detectors.
5. The method of claim 1 wherein determining a location includes applying a Kalman Filter to the position data from the robotic arm.

6. The method of claim 5 further comprising updating the Kalman Filter based upon the sensor data.
7. The method of claim 1 wherein the wafer is substantially circular.
8. The method of claim 1 wherein the wafer includes an alignment notch.
9. The method of claim 1 wherein the plurality of sensors include at least one detector positioned opposite a light emitting diode such that a light path from the light emitting diode to the light detector includes a predetermined position within the interior.
10. The method of claim 1 wherein the plurality of sensors include at least one detector positioned such that light from a light emitting diode, when reflected off of the wafer at a predetermined location, is detected by the detector.
11. The method of claim 1 wherein retracting includes retracting in a linear motion.
12. The method of claim 1 wherein extending includes extending in a linear motion.
13. The method of claim 1 wherein rotating includes rotating about a center axis of the robotic arm.
14. A method for finding a center of a wafer in a device having an interior and a plurality of entrances, the interior containing a robotic arm, and the device including a plurality of sensors, each one of the sensors adapted to detect a presence of the wafer at a predetermined location within the interior of the device, the method comprising:
 - retrieving the wafer from outside the interior through a first one of the plurality of entrances;
 - retracting the wafer into the interior;
 - rotating the robotic arm;

extending the wafer out of the interior through a second one of the plurality of entrances;

detecting the presence of the wafer at a predetermined location of at least one sensor during the retracting, rotating, and extending, thereby providing sensor data, and

determining a location of a center of the wafer relative to the robotic arm using the sensor data and position data from the robotic arm.

15. The method of claim 14 wherein the plurality of sensors include optical sensors.

16. The method of claim 15 wherein the plurality of sensors include light emitting diodes.

17. The method of claim 15 wherein the plurality of sensors include auto focusing photodiode detectors.

18. The method of claim 14 wherein determining a location includes applying a Kalman Filter to the position data from the robotic arm.

19. The method of claim 18 further comprising updating the Kalman Filter based upon the sensor data.

20. The method of claim 14 wherein the wafer is substantially circular.

21. The method of claim 14 wherein the wafer includes an alignment notch.

22. The method of claim 14 wherein the plurality of sensors include at least one detector positioned opposite a light emitting diode such that a light path from the light emitting diode to the light detector includes a predetermined position within the interior.

23. The method of claim 14 wherein the plurality of sensors include at least one detector positioned such that light from a light emitting diode, when reflected off of the wafer at a predetermined location, is detected by the detector.
24. The method of claim 14 wherein retracting includes retracting in a linear motion.
25. The method of claim 14 wherein extending includes extending in a linear motion.
26. The method of claim 14 wherein rotating includes rotating about a center axis of the robotic arm.
27. The method of claim 14 wherein detecting the presence of the wafer includes detecting a first transition from absence to presence of the wafer at one of the plurality of sensors and detecting a second transition from presence to absence of the wafer at the one of the plurality of sensors, wherein a path of the wafer from the first transition to the second transition is non-linear.
28. The method of claim 27 wherein the path includes at least on arc resulting from a rotation of the wafer.
29. A device for handling a wafer comprising:
an interior accessible through a plurality of entrances; and
a plurality of sensors consisting of two sensors for each one of the plurality of entrances, each sensor capable of detecting a presence of a wafer at a predetermined location within the interior, wherein the plurality of sensors are arranged so that at least two of the plurality of sensors detect the wafer for any position of the wafer entirely within the interior.
30. The device of claim 29 wherein the plurality of entrances includes four entrances.

31. The device of claim 29 wherein the plurality of entrances includes seven entrances.
32. The device of claim 29 wherein the plurality of entrances includes eight entrances.
33. The device of claim 29 wherein the plurality of sensors include optical sensors.
34. The device of claim 33 wherein the plurality of sensors include at least one light emitting diode.
35. The device of claim 29 further comprising a robotic arm having a center axis within the interior, the robotic arm including an end effector for handling wafers.
36. A device for handling a wafer comprising:
an interior accessible through a plurality of entrances; and
a plurality of sensors consisting of two sensors for each one of the plurality of entrances, each sensor capable of detecting a presence of a wafer at a predetermined location within the interior, wherein the plurality of sensors are arranged so that a first pair of sensors detect a wafer entering linearly through each one of the plurality of entrances and a second pair of sensors are positioned substantially immediately outside the maximum diameter of the wafer entering linearly through each one of the plurality of entrances, and wherein each one of the plurality of entrances shares one of the first pair of sensors and the second pair of sensors with each neighboring one of the plurality of entrances.
37. The device of claim 36 wherein the plurality of entrances includes four entrances.
38. The device of claim 36 wherein the plurality of entrances includes seven entrances.

39. The device of claim 36 wherein the plurality of entrances includes eight entrances.
40. The device of claim 36 wherein the plurality of sensors include optical sensors.
41. The device of claim 40 wherein the plurality of sensors include at least one light emitting diode.
42. The device of claim 36 further comprising a robotic arm having a center axis within the interior, the robotic arm including an end effector for handling wafers.
43. A device for handling a wafer comprising:
an interior accessible through four entrances; and
eight sensors, each capable of detecting a presence of a wafer at a predetermined location within the interior, the sensors arranged into two square arrays centered about a center of the interior, sized such that a first one of the square arrays is smaller than a second one of the square arrays and oriented so that a group of four of the sensors at opposing vertices of the two square arrays are collinear.
44. The device of claim 43 wherein the eight sensors include optical sensors.
45. The device of claim 44 wherein the eight sensors include at least one light emitting diode.
46. The device of claim 43 further comprising a robotic arm having a center axis within the interior, the robotic arm including an end effector for handling wafers.
47. A device comprising:
a robotic arm for handling a wafer, the robotic arm including one or more encoders that provide encoder data identifying a position of one or more components of the robotic arm; and

a processor adapted to apply an extended Kalman Filter to the encoder data to estimate a position of the wafer.

48. The device of claim 47 wherein the position includes a wafer center.

49. The device of claim 47 wherein the position includes a wafer radius.

50. The device of claim 47 wherein the position is determined with reference to an end effector of the robotic arm.

51. The device of claim 47 wherein the position is determined with reference to a center axis of the robotic arm.

52. The device of claim 47 wherein the processor recalculates the position each time new encoder data is received.

53. The device of claim 52 wherein new encoder data is received at substantially 2 kHz.

54. The device of claim 47 wherein the processor is adapted to update one or more equations of the Kalman Filter using transition data from one or more sensors that detect the presence of a wafer at one or more predetermined locations within a robotic wafer handler.

55. A method comprising:

disposing a plurality of sensors within an interior of a wafer handling device, each one of the plurality of sensors capable of detecting a transition between presence and absence of a wafer at a predetermined location within the interior;

handling a wafer with a robotic arm, the robotic arm including one or more encoders that provide encoder data identifying a position of one or more components of the robotic arm; and

applying the encoder data to an extended Kalman Filter to provide an estimated position of the wafer.

56. The method of claim 55 further comprising:
detecting a transition at one of the plurality of sensor to provide an actual position of the wafer;
determining an error between the actual position and the estimated position; and
updating one or more variables for the extended Kalman Filter based upon the error.

57. The method of claim 56 wherein applying the encoder data includes calculating a wafer position every 0.5 milliseconds.

58. The method of claim 55 wherein the estimated position of the wafer includes a center of the wafer.

59. The method of claim 55 wherein the estimated position of the wafer includes a radius of the wafer.

60. A device comprising:
an interior chamber having a plurality of entrances shaped and sized for passage of at least one wafer;
a contact image sensor positioned to scan a wafer within the interior;
a robot within the interior including an end effector for handling the wafer, the robot configured to move the wafer within a measurement volume of the contact image sensor thereby obtaining an image of at least a portion of the wafer; and
a processor configured to process the image and determine a center of the wafer.

61. The device of claim 60 wherein the robot moves the wafer linearly through the measurement volume of the contact image sensor.

62. The device of claim 61 wherein the contact image sensor is oriented normal to a path of the wafer.
63. The device of claim 61 wherein the contact image sensor is oriented at a forty-five degree angle to a path of the wafer.
64. The device of claim 60 wherein the robot moves the wafer in a curved path through the measurement volume of the contact image sensor.
65. The device of claim 60 wherein the robot moves the wafer in a discontinuous path through the measurement volume of the contact image sensor.
66. The device of claim 60 wherein the robot rotates the wafer within the measurement volume of the contact image sensor.
67. The device of claim 66 wherein the robot is adapted to lift the wafer into the measurement volume of the contact image sensor.
68. The device of claim 66 wherein the robot includes a rotating chuck on an end effector adapted to rotate the wafer.
69. The device of claim 68 wherein the rotating chuck rotates between one-hundred eighty degrees and three-hundred sixty degrees.
70. The device of claim 66 further comprising a rotating chuck adapted to lift the wafer from the end effector into the measurement volume of the contact image sensor.
71. The device of claim 60 wherein the contact image sensor is at least 300 mm in length.

72. The device of claim 60 wherein the contact image sensor has a length exceeding a diameter of the wafer.
73. The device of claim 60 wherein the contact image sensor is positioned at one of the plurality of entrances to the interior.
74. The device of claim 73 further comprising a plurality of contact image sensors, each one of the plurality of contact image sensors placed at one of the plurality of entrances to the interior.
75. The device of claim 60 wherein the contact image sensor is placed to intersect a center of the interior.
76. The device of claim 60 further comprising a second contact image sensor, wherein the contact image sensor and the second contact image sensor are positioned collinearly.
77. The device of claim 76 wherein the contact image sensor and the second contact image sensor are positioned at one of the plurality of entrances to the interior.
78. The device of claim 77 further comprising a plurality of pairs of collinear contact image sensors positioned at each one of the plurality of entrances to the interior.
79. The device of claim 76 further comprising a second pair of collinear contact image sensors, wherein the second pair of collinear contact image sensors are positioned to intersect a center of the interior.
80. The device of claim 60 wherein the plurality of entrances includes four entrances.
81. The device of claim 60 wherein the plurality of entrances includes eight entrances.

82. The device of claim 60 wherein the processor is further configured to identify an alignment notch on the wafer.

83. The device of claim 60 wherein the processor is further configured to determine a radius of the wafer.

84. A method comprising:
positioning a contact image sensor to capture image data from the interior of a robotic wafer handler;
passing at least a portion of a wafer by the contact image sensor to acquire an image; and
determining a center of the wafer based upon the image.

85. The method of claim 84 wherein passing at least a portion of the wafer by the contact image sensor includes passing the wafer linearly through a measurement volume of the contact image sensor.

86. A device comprising:
a robotic arm within a robot chamber, the robotic arm including an end effector adapted to handle a wafer; and
a linear array of charge-coupled devices within the interior of the robot chamber, the linear array positioned to acquire image data from a measurement volume in one or more predetermined locations within the robot chamber.

87. The device of claim 86 further comprising an external illumination source that illuminates the linear array.

88. The device of claim 86 further comprising a wireless power coupling that inductively powers the linear array.

89. The device of claim 86 further comprising a wireless transceiver for exchanging data wirelessly with the linear array.
90. The device of claim 89 wherein the wireless transceiver is positioned outside the robotic chamber.
91. The device of claim 89 wherein the data includes the image data.
92. The device of claim 86 wherein the linear array is a 1 by n array of charge-coupled devices.
93. The device of claim 86 wherein the linear array includes a two dimensional array of charge-coupled devices.
94. The device of claim 86 further comprising a plurality of linear arrays each capturing image data at a different location within the interior.
95. The device of claim 86 wherein the robotic arm includes a chuck on the end effector adapted to rotate the wafer within the measurement volume of the linear array.
96. The device of claim 95 wherein the robotic arm is adapted to lift the wafer into the measurement volume of the linear array.
97. The device of claim 95 wherein the chuck rotates between one-hundred eighty degrees and three-hundred sixty degrees.
98. The device of claim 86 further comprising a rotating chuck adapted to lift the wafer from the end effector into the measurement volume of the linear array.
99. The device of claim 86 further comprising a processor configured to determine a center of the wafer using the image data.

100. The device of claim 86 further comprising a processor configured to determine a radius of the wafer using the image data.

101. The device of claim 86 further comprising a processor configured to identify an alignment notch on the wafer using the image data.

102. A device comprising:

a robotic arm within a robot chamber, the robotic arm including an end effector adapted to handle a wafer; and

a linear array of charge-coupled devices on the end effector positioned to capture edge data from a wafer resting on the end effector.

103. The device of claim 102 further comprising an external illumination source that illuminates the linear array.

104. The device of claim 102 further comprising a wireless power coupling that inductively powers the linear array.

105. The device of claim 102 further comprising a wireless transceiver for exchanging data wirelessly with the linear array.

106. The device of claim 105 wherein the wireless transceiver is positioned outside the robotic chamber.

107. The device of claim 102 wherein the linear array is a 1 by n array of charge-coupled devices.

108. The device of claim 102 wherein the linear array includes a two dimensional array of charge-coupled devices.

109. The device of claim 102 wherein the robotic arm includes a chuck on the end effector adapted to rotate the wafer within the measurement volume of the linear array.

110. The device of claim 102 further comprising a rotating chuck adapted to lift the wafer from the end effector and rotate the wafer within the measurement volume of the linear array.

111. The device of claim 102 further comprising a processor configured to determine a center of the wafer using the edge data.

112. The device of claim 102 further comprising a processor configured to determine a radius of the wafer using the edge data.

113. The device of claim 102 further comprising a plurality of linear arrays positioned to capture edge data from a number of locations on a surface of the end effector.

What is claimed is:

1. A device for handling a substantially circular wafer, the device comprising:
 - an interior accessible through a plurality of entrances;
 - a plurality of sensors, each sensor capable of detecting a presence of the substantially circular wafer, at a predetermined location within the interior, wherein the plurality of sensors are arranged so that no more than two sensors of the plurality of sensors are provided for each entrance and at least two of the plurality of sensors detect the wafer for any position of the wafer entirely within the interior; and
 - at least another sensor is positioned outside a diameter of the wafer to immediately detect rotational movement of the wafer.
2. The device of claim 1, wherein the plurality of entrances includes four entrances, seven entrances or eight entrances.
3. The device of claim 1, wherein the plurality of sensors includes optical sensors.
4. The device of claim 3, wherein the plurality of sensors includes at least one light emitting diode.
5. The device of claim 1, further comprising a robotic arm having a center axis within the interior, the robotic arm including an end effector for handling wafers.
6. A device for handling a substantially circular wafer, the device comprising:
 - an interior accessible through a plurality of entrances;
 - a plurality of sensors, each sensor capable of detecting a presence of the substantially circular wafer, at a predetermined location within the interior, wherein the plurality of sensors are arranged so that no more than two sensors of the plurality of sensors are provided for each entrance and at least two of the plurality of sensors detect the wafer for any position of the wafer entirely within the interior; and
 - at least another sensor is positioned outside a diameter of the wafer to immediately detect rotational movement of the wafer;
 - wherein a first one of the two sensors is positioned to detect the wafer when the wafer has passed entirely into the interior through one of the plurality of entrances, and a second one of the two sensors is positioned immediately outside a diameter of the wafer when the wafer has passed entirely into the interior through one of the plurality of entrances.
7. The device of claim 6, wherein the plurality of entrances includes four entrances, seven entrances or eight entrances.
8. The device of claim 6, wherein the plurality of sensors includes optical sensors.
9. The device of claim 8, wherein the plurality of sensors includes at least one light emitting diode.
10. The device of claim 6, further comprising a robotic arm having a center axis within the interior, the robotic arm including an end effector for handling wafers.