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(54) ALIGNMENT APPARATUS

(71) We, KASPER INSTRUMENTS, a corporation organised and existing under the laws of the state of California, United States of America, of 500, Ellis Street, Mountain View, California 94040, United States of America, do hereby declare the invention for which we pray that a Patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to alignment apparatus, e.g., to apparatus for aligning a semiconductor wafer with a photomask and exposing a photo-sensitive surface of the aligned wafer through the mask.

In most conventional optical alignment and exposure instruments for transferring a geometric pattern on a photomask to a semiconductor wafer, a photosensitive surface of the wafer and an adjacent pattern-bearing surface of the mask are initially brought into intimate contact to establish parallel plane alignment therebetween. The wafer and mask are then separated to permit out of contact alignment of a pattern on the wafer with the pattern on the mask. After this pattern alignment operation, however, the photosensitive surface of the wafer and the pattern-bearing surface of the mask are again brought into intimate contact and so maintained during exposure of the photosensitive surface of the wafer through the mask. Optical alignment and exposure instruments of this type are shown and described, for example, in U.S. Patent 3,192,844 issued July 6, 1965 to Peter R. Szasz et al and in U.S. Patent 3,220,231 issued November 30, 1965 to James A Evans et al. The mechanical abrasion inevitably produced between the wafer and the mask in such optical alignment and exposure instruments may damage the photo-

sensitive surface of the wafer and the pattern-bearing surface of the mask. Damaged or scratched areas on the pattern-bearing surface of the mask are especially undesirable since they will be reproduced on all wafers with which the mask is subsequently used.

Accordingly, it is the object of this invention to provide improved alignment apparatus.

The present invention provides alignment apparatus for use in aligning a workpiece with respect to a mask, said alignment apparatus comprising a workpiece chuck for holding the workpiece, and a mask holder for holding the mask, the workpiece chuck or the mask holder including spacing means for orienting a first surface of the workpiece held by the workpiece chuck and an adjacent first surface of the mask held by the mask holder in substantially parallel planes spaced a finite distance apart without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder and without moving the mask held by the mask holder.

In an apparatus as set forth in the last preceding paragraph preferably the workpiece chuck includes the spacing means.

In an apparatus as set forth in the last preceding paragraph preferably the spacing means is supported by the workpiece chuck around the workpiece bearing surface thereof for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder.

In an apparatus as set forth in the last

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preceding paragraph but one preferably the workpiece chuck is supported for pivotal movement to orient the adjacent first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes and for movement between a retracted position at which the workpiece can be loaded onto and unloaded from the workpiece chuck and an extended position closer to the mask holder at which position the spacing means can be employed for pivoting the workpiece chuck to orient the first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder.

In an apparatus as set forth in the last preceding paragraph preferably the workpiece chuck is supported beneath the mask holder for retractable movement toward the mask holder, optical means is provided for viewing the mask and the workpiece held by the mask holder and the workpiece chuck, respectively, alignment means is provided for relatively moving the workpiece chuck and the mask holder to bring a pattern on the workpiece held by the workpiece chuck into alignment with a pattern on the mask held by the mask holder, and exposure means is provided for exposing a photosensitive film on the first surface of the workpiece held by the workpiece chuck through the mask held by the mask holder while the workpiece chuck is positioned between its extended position and a position at which the first surface of the workpiece held by the workpiece chuck contacts the adjacent first surface of the mask held by the mask holder.

In an apparatus as set forth in the last preceding paragraph or the last preceding paragraph but one preferably the spacing means is supported by the workpiece chuck around the workpiece bearing surface thereof, and the workpiece chuck is adapted to permit relative movement between the spacing means and the workpiece bearing surface of the workpiece chuck so that the spacing means can be positioned closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder.

An apparatus as set forth in the last preceding paragraph preferably comprises calibrating means for spacing a first surface of the spacing means and the first surface of the workpiece held by the workpiece chuck a finite distance apart in substantially parallel planes with the first surface of the spacing means being spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder.

In an apparatus as set forth in the last pre-

ceding paragraph preferably the calibrating means is movable to an operative position between the workpiece chuck and the mask holder and an inoperative position retracted from between the workpiece chuck and the mask holder, and the calibrating means is operable in its operative position for spacing the first surfaces of the spacing means and the workpiece held by the workpiece chuck the finite distance apart in substantially parallel planes when the workpiece chuck is moved to an intermediate position between its retracted and extended positions.

In an apparatus as set forth in the last preceding paragraph preferably the spacing means is supported by the workpiece chuck for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder, the spacing means can be moved to its extended position and releasably locked in place relative to the workpiece chuck when the first surfaces of the spacing means and the workpiece held by the workpiece chuck are spaced the finite distance apart in substantially parallel planes by the calibrating means, the workpiece chuck can then be moved from its intermediate position towards its retracted position to permit movement of the calibrating means to its inoperative position, the workpiece chuck can thereupon be moved to its extended position at which the spacing means is operable for pivoting the workpiece chuck to orient the first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes spaced the finite distance apart without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder, and the spacing means can then be released and moved to its retracted position to permit out of contact alignment of a pattern on the first surface of the workpiece held by the workpiece chuck with a pattern on the first surface of the mask held by the mask holder.

In an apparatus as set forth in any one of the last three preceding paragraphs preferably the calibrating means comprises first means for abutment with a peripheral portion of the first surface of the workpiece held by the workpiece chuck in a first reference plane when the workpiece chuck is moved to its intermediate position, and second means for abutment with the first surface of the spacing means in a substantially parallel second reference plane when the workpiece chuck is moved to its intermediate position and the first surface of the spacing means is positioned closer, by the finite distance, than the first

surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder, the first and second reference planes being spaced the finite distance apart with the second reference plane being spaced closer than the first reference plane to the first surface of the mask held by the mask holder.

10 In an apparatus as set forth in the last preceding paragraph preferably the first and second means of the calibrating means are operable for spacing apart the first surfaces of the spacing means and the workpiece held by the workpiece chuck by a finite distance

15 in the range from .0002 to .002 of an inch.

20 Preferably at least one of the first and second means of the calibrating means is adjustable for varying the finite distance by which the calibrating means spaces apart the first surfaces of the spacing means and the workpiece held by the workpiece chuck.

25 The first means may comprise an annular step having a plane surface for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, and the second means may comprise a parallel plane surface positioned around this annular step and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane. Alternatively the first means may comprise a plurality of spaced pins for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, and the second means may comprise a plane surface positioned around these pins and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane. As a further alternative the first means may comprise an air cushion for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, and the second means may comprise a plane surface positioned around this air cushion and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane. As yet another alternative the first means may comprise a first air cushion for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, the second means may comprise a second air cushion positioned around this first air cushion and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane, and means may be provided for adjusting the offset between these first and second air cushions and providing an output indication of the finite distance by which the calibrating means spaces apart the first surfaces of the spacing

means and the workpiece held by the workpiece chuck. 65

According to one of the preferred embodiments of the present invention at least one of the first and second means includes a plurality of spaced air jets for providing an air cushion for abutment with the first surface of the workpiece held by the workpiece chuck or the first surface of the spacing means in the first or second reference plane. 70

75 Preferably the spacing means include a hollow locking ring structure supported by the workpiece chuck for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder, the locking ring structure having an inwardly curved bottom wall that can be forced outward to expand the locking ring structure into locking engagement with the workpiece chuck when the locking ring structure is moved to its extended position. 80

85 (Preferably the locking ring structure comprises a hollow generally U-shaped locking ring with its side and inwardly curved bottom walls being slotted to make them expandable, with an annular inflatable tube contained therein for forcing its inwardly curved bottom wall outward to expand its side walls into locking engagement with a peripheral portion of the workpiece chuck, and with a ring attached to the top thereof and provided with a plane first surface for abutment upon a marginal portion of the first surface of the mask when the locking ring structure and the workpiece chuck are moved to their extended positions, and wherein the spacing means further includes an annular inflatable seal attached to a bottom wall of the peripheral portion of the workpiece chuck and to the inwardly curved bottom wall of the locking ring for moving the locking ring structure between its retracted and extended positions. 90

95 Preferably the locking ring structure is supported for pivotal movement to permit face-to-face abutment of the first surface of the locking ring structure and a reference surface making a slight angle relative to the workpiece bearing surface of the workpiece chuck. 100

105 In an apparatus as set forth in the last preceding paragraph but eleven preferably the spacing means comprises a spacing structure supported by a peripheral portion of the workpiece chuck for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the 110

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workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder, and the spacing structure is provided with a stop portion for engaging a stop portion of the peripheral portion of the workpiece chuck to limit the distance the spacing structure may be moved between its retracted and extended positions.

Preferably the spacing structure comprises a spacing ring with a plane first surface for abutment upon a marginal portion of the first surface of the mask held by the mask holder when the spacing structure and the workpiece chuck are moved to their extended positions, the stop portion of the spacing structure comprises an annular stop portion of the spacing ring positioned for abutment with the stop portion of the peripheral portion of the workpiece chuck when the spacing ring is in its extended position, and the peripheral portion of the workpiece chuck includes means for moving the spacing ring between its retracted and extended positions. More preferably the stop portions of the spacing ring and the peripheral portion of the workpiece chuck limit movement of the spacing ring between its retracted and extended positions to a distance in the range from .0002 to .002 of an inch. An apparatus according to the present invention preferably includes drive means for retractably moving the workpiece chuck toward the mask holder. Preferably the drive means includes a first piston for moving the workpiece chuck between its retracted and extended positions, and a second piston for moving the workpiece chuck between its extended position and a position still closer to the first surface of the mask held by the mask holder. More preferably the workpiece chuck is pivotally supported by the second piston, the second piston is coaxially supported by the first piston and is provided with first stop means for engaging a stop portion of the first piston to limit the distance the workpiece chuck may be moved toward the mask holder by the second piston, the first piston is operable for moving both the second piston and the workpiece chuck between the retracted and extended positions of the workpiece chuck, releasable locking means is provided for locking the first piston in whatever vertical position it may be in, and the first and second pistons include stop means for preventing the workpiece chuck from being moved further than its retracted position away from the mask holder. Still more preferably the first stop means of the second piston is adjustable to permit movement of the workpiece chuck to any position from its extended position to a position still closer to the mask holder when the workpiece chuck is moved to its extended position by the first piston.

There now follows a detailed description which is to be read with reference to the accompanying drawings of an apparatus

according to the present invention; it is to be clearly understood that this apparatus has been selected for description to illustrate the invention by way of example and not by way of limitation.

In the drawings:—

Figure 1 is a half-sectional side view of an optical alignment apparatus according to the present invention, when the chuck is in the initial wafer loading and unloading position;

Figure 2 is a cross-sectional view of the locking ring structure employed in the chuck of Figure 1;

Figure 3 is a cutaway perspective view of the locking ring employed in the locking ring structure of Figures 1 and 2;

Figures 4A and 4B, 5A and 5B, 6A and 6B, and 7A and 7B are top and half-sectional side views of different calibrators that may be employed in the apparatus of Figure 1;

Figure 8 is a simplified representation of the chuck and calibrator of Figure 1, as viewed in a plane orthogonal to that of Figure 1, when the chuck is in the calibration position;

Figure 9 is a simplified representation of the optical alignment apparatus of Figure 1, as viewed in a plane orthogonal to that of Figure 1, when the chuck is in the alignment position;

Figure 10 is a simplified representation of the optical alignment apparatus of Figure 1, as viewed in a plane orthogonal to that of Figure 1, when the chuck is in the exposure position; and

Figures 11 and 12 are half-sectional side views of another chuck that may be employed in the optical alignment apparatus of Figure 1, when the chuck is in the wafer loading and unloading and the alignment positions, respectively.

Referring now to Figure 1, there is shown an optical alignment apparatus 10, which, except as differently set forth herein, may be constructed and operated, for example, in the same manner as the apparatus shown and described in detail in U.S. Patent Specification No. 3,490,846 entitled OPTICAL ALIGNMENT AND EXPOSURE APPARATUS. The optical alignment apparatus 10 includes a mask holder 12 pivotally mounted on a pin 14 extending between a pair of spaced blocks 16 (only one shown) secured to a top plate 18. The mask holder 12 may therefore be pivoted about the axis of the pin 14 between a raised mask loading and unloading position and a lowered operative position when the optical unit 20 (see Figure 10) of the system is raised, as described in connection with Figure 3 of U.S. Patent Specification NO. 3,490,846.

Locating lugs 21 extend from the bottom of the mask holder 12 for locating a photo-mask 22, which is made of glass or some other transparent material with a desired geometric pattern formed on its lower surface, at an aperture 24 extending through the mask

holder. The mask 22 is held in place on the mask holder 12 by drawing a vacuum through a groove 26 formed in the lower surface of the mask holder 12 around the aperture 24 and covered by the mask. This is accomplished by connecting the groove 26 through a passageway in the mask holder, a flexible tube 28, and a first normally open solenoid-operated valve to a vacuum source. As shown and described in connection with Figure 11 of U.S. Patent Specification No. 3,490,846, the first normally open solenoid-operated valve may be actuated to interrupt the vacuum connection to the groove 26, and thereby release the mask 22 from the mask holder 12, by a microswitch that is activated by the mask holder in the raised mask loading and unloading position.

A pair of concentric resilient seal rings 30 are positioned in grooves formed in the lower surface of the mask holder 12 around the groove 26. In the lowered operative position of the mask holder 12, these seal rings sealingly engage the upper surface of the top plate 18. The mask holder 12 may therefore be urged into tight engagement with the top plate 18 by drawing a vacuum between the seal rings 30. This is accomplished by connecting the area between the seal rings 30 through a passageway 32 in the mask holder, a flexible tube 34, a passageway 35 in the top plate 18, and a second normally open solenoid-operated valve to the vacuum source. The second normally open solenoid-operated valve may be actuated to interrupt the vacuum connection between the seal rings 30, and thereby release the mask holder 12 from the top plate 18, by another microswitch that is activated when the optical unit 20 (see Figure 10) of the system is raised so that the mask holder 12 may be pivoted to the raised mask loading and unloading position.

The top plate 18 on which the mask holder 12 is mounted is attached by screws 36 to posts 38, which are in turn secured by screws 40 to a horizontally movable platform 42. This platform is horizontally reciprocally mounted by bearing supports 44 on an intermediate plate 46, which itself is horizontally reciprocally mounted by bearing supports 48 on a stationary base plate 50. The bearing supports 44 and 48 are oriented at right angles to one another so that the platform 42 and the intermediate plate 46 may be driven by a hand-operated lever arrangement, as described in connection with Figures 11 and 12 of U.S. Patent Specification No. 3,490,846, to move the top plate 18 and, hence, the mask holder 12 in any horizontal direction relative to a stationary base plate 50.

The apparatus 10 also includes a vacuum chuck 52 for supporting a semiconductor wafer 54 to be aligned with the mask 22. The vacuum chuck 52 is positioned beneath the mask holder 12 and is supported by a generally annular-shaped chuck holder 55 on another

horizontally movable platform 56. This platform is horizontally reciprocally mounted by bearing supports 58 on another intermediate plate 60, which itself is horizontally reciprocally mounted by bearing supports 62 on the platform 42. The bearing supports 58 and 62 are oriented at right angles to one another so that the platform 56 and the intermediate plate 60 may be driven by a hand-operated lever arrangement, as described in connection with Figures 11 and 13-14 of U.S. Patent Specification No. 3,490,846, to move the chuck holder 55 and, hence, the vacuum chuck 52 in any horizontal direction relative to the platform 42 and the mask holder 12 mounted thereon. This permits horizontal movement of the wafer 54 relative to the mask 22 to align a pattern on the upper surface of the wafer with the pattern on the lower surface of the mask.

Releasable locking apparatus 63, like that described in connection with Figure 11 of U.S. Patent Specification No. 3,490,846, normally locks the platform 42 against movement relative to the stationary base plate 50 to facilitate alignment of the pattern on the upper surface of the wafer 54 with the pattern on the lower surface of the mask 22. This releasable locking apparatus comprises a cylinder 64 with an open bottom resting upon the stationary base plate 50 and with a sleeve 66 extending upwardly through an enlarged clearance hole 68 in the intermediate plate 46 and into a hole 70 in the platform 42. The sleeve 66 is provided with longitudinally extending slots 72 so that it may be expanded outward into tight engagement with the walls of the hole 70 by a sleeve expanding head 74 attached to a piston 76 vertically reciprocally mounted within the cylinder. A peripheral seal ring 78 provides slidable fluid-tight engagement between the cylinder 64 and the piston 76. Thus, a vacuum may be drawn within the cylinder 64 between the lower surface of the piston 76 and the upper surface of the stationary base plate 50 to urge the cylinder into locking engagement with the stationary base plate and move the piston and the attached head 74 downward, thereby expanding the sleeve 66 into locking engagement with the platform 42. This is accomplished by connecting the cylinder 64 below the piston 76 through a passageway 80 in the piston, a flexible tube 82 extending through an opening 84 in the sleeve 66 of the cylinder, and a third normally open control valve to the vacuum source. As explained in connection with Figure 11 of U.S. Patent Specification No. 3,490,846, the third normally open control valve may be actuated by the operator to vent the tube 82 to the atmosphere and thereby release the cylinder 64 from locking engagement with the stationary base plate 50 and the platform 42. This permits movement of the mask holder 12 and the vacuum chuck 52

together as a unit relative to the stationary base plate 50 so that the mask 22 and the wafer 54 may be brought into the optical field of a microscope of the optical unit 20 (see Figure 10) without moving the ocular lens system 85 of the microscope.

In order to further facilitate alignment of the pattern on the upper surface of the wafer 54 with the pattern on the lower surface of the mask 22, the vacuum chuck 52 is also made horizontally adjustable in a rotary direction about a vertical axis. This is accomplished in the same manner as described in connection with Figures 11 and 15 of U.S. Patent Specification No. 3,490,846 by providing the platform 56 with an aperture 86 for receiving the chuck holder 55 and with a radial flange 88 positioned at the lower end of this aperture for rotatably supporting the chuck holder. A plate 92 with an aperture 94 positioned in axial alignment with the aperture 86 is secured to the top of the platform 56 by screws 96. The plate 92 and the flange 88 form an annular channel within which an outwardly directed radial flange 100 of the chuck holder 55 is supported between thrust bearings 102 to rotatably support the chuck holder on the platform 56. The chuck holder 55 is maintained in axial alignment with the aperture 86 by three roller bearings (only one shown) mounted on the platform 56 at spaced positions around the radial flange 88. One of these roller bearings 104 is carried by a radially slidable block 106 that is resiliently biased by a spring 108 toward the chuck holder 55 to urge the roller bearing 104 into engagement with the chuck holder which, in turn, is urged into engagement with the other two roller bearings. A ball 110 is carried at the end of a pin 112 extending from the flange 100 of the chuck holder 55 so that fine and coarse rotatable adjustment of the chuck holder and, hence, of the vacuum chuck 52 may be accomplished by engagement of the ball 110 between a pair of operator-controlled adjustably positionable push rods in the same manner as described in connection with Figure 15 of U.S. Patent Specification No. 3,490,846.

The chuck holder 55 comprises an annular upper part 55a with the radial flange 100, an annular intermediate part 55b with an outwardly directed radial flange positioned at its upper end and secured to the upper part 55a by screws 114, and an annular lower part 55c attached to the intermediate part 55b by screws 116. The lower part 55c has a cylindrical wall 118 that extends upward through the intermediate and upper parts 55b and 55a at a spaced distance therefrom. A first piston 120 for supporting the vacuum chuck 52 and driving it upward toward the mask holder 12 is vertically reciprocally supported at the upper end of the cylindrical wall 118. This piston comprises a hollow cylindrical part 120a coaxially positioned within the cylindrical wall

118 at a spaced distance therefrom and provided with an outwardly directed radial flange that is positioned above the upper end of the cylindrical wall 118 and secured by screws 122 to a sleeve-like part 120b telescopically surrounding the cylindrical wall 118.

The first piston 120 and, hence, the vacuum chuck 52 are raised by application of fluid pressure to an annular chamber 124 formed by an inwardly directed radial flange positioned at the upper end of the intermediate part 55b of the chuck holder and provided with a peripheral seal ring 126 for providing slidable fluid-tight engagement of the sleeve-like part 120b between this flange and the cylindrical wall 118. Fluid pressure is applied to the chamber 124 from a source of fluid pressure, such as compressed air, through a fourth control valve when opened by the operator, a flexible tube 128, and a fitting that extends through the intermediate part 55b of the chuck holder. The first piston 120 and, hence, the vacuum chuck 52 are lowered under the action of gravity by actuating this fourth control valve to disconnect the tube 128 from the source of fluid pressure and vent it instead to the atmosphere. The fourth control valve may also be actuated to connect the tube 128 to the source of vacuum and thereby facilitate the lowering of the first piston 120 and the vacuum chuck 52. One or more set screws 130 extend through the upper end of the first piston 120 and abut upon the upper end face of the cylindrical wall 118 to prevent the first piston 120 and the vacuum chuck 52 from travelling downward beyond a lowered wafer loading and unloading position at which the upper surface of the vacuum chuck lies in the same plane as a top plate 131. A pin 132 also extends through one side of the sleeve-like part 120b of the first piston and protrudes into an adjoining longitudinally extending groove 134 in the cylindrical wall 118 of the chuck holder to prevent rotation of the first piston 120 and the vacuum chuck 52 relative to the chuck holder as the first piston and vacuum chuck are raised and lowered.

The sleeve-like part 120b of the first piston is surrounded by a locking device 136, like that described in connection with Figure 16 of U.S. Patent Specification No. 3,490,846, for releasably locking the first piston and, hence, the vacuum chuck 52 in any vertical position to which they may be raised. The locking device 136 comprises a locking ring 138 coaxially positioned around the sleeve-like part 120b, two or more locking ring sections 140 coaxially positioned around the sleeve-like part 120b and within an annular groove 142 in the inner wall of the locking ring 138, and a resilient inflatable tube 144 seated within the groove 142 between a V-shaped bottom surface thereof and a V-shaped groove formed in the outer wall of the locking ring sections 140. The inflatable tube 144 is connected through a

flexible tube 146 and a fifth control valve to the source of fluid pressure. Thus, when the fifth control valve is opened by the operator, the tube 144 is inflated and the locking ring sections 140 are urged radially inward into clamping engagement with the sleeve-like part 120b of the first piston, thereby locking the ring 138 to the first piston. This locks the first piston 120 and the vacuum chuck 52 in whatever vertical position they are then in because the locking ring 138 is fixedly engaged between an inwardly directed radial flange 148 of the upper part 55a of the chuck holder and an externally-threaded stop ring 150 screwed into an internally-threaded lower portion of the upper part 55a. The first piston 120 may be released by actuating the fifth control valve to vent the tube 146 to the atmosphere, thereby deflating the tube 144 and permitting vertical sliding movement of the first piston relative to the locking device 136.

A ring gear 152 is attached to an inwardly offset lower portion of the stop ring 150 and engaged by a spur gear 153 affixed to a rotatably mounted shaft 154. The shaft 154 is coupled through bevel gears 156 and 158 to another shaft 160 that extends out of the front of the instrument. Thus, by turning the shaft 160 the operator may unscrew the stop ring 150 by an amount sufficient to permit vertical travel of the locking device 136 between the stop ring 150 and the flange 148 of the chuck holder. The apparatus 10 may therefore be operated as described in connection with Figure 16 of U.S. Patent Specification No. 3,490,846, since there is sufficient frictional engagement between the locking ring sections 140 of the locking device 136 and the sleeve-like part 120b of the first piston to prevent the locking device from sliding downwardly along the first piston under the force of gravity once it is moved upward with the first piston into abutment upon the flange 148 of the chuck holder. During operation of the apparatus 10 in the out of contact mode of the present invention, however, the stop ring 150 is screwed into the lower portion of the part 55a of the chuck holder until the locking device 136 is fixedly positioned between and in abutment with the stop ring 150 and the flange 148.

A second piston 162 for supporting the vacuum chuck 52 and driving it upward toward the mask holder 12 is vertically reciprocally mounted within the first piston 120. The second piston 162 comprises a hollow cylindrical part 162a telescopically positioned within and in fluid-tight slidable abutment with the cylindrical part 120a of the first piston. The cylindrical part 162a is provided with an outwardly directed radial flange at its upper end to prevent the second piston 162 and the vacuum chuck 52 from travelling downward beyond the lowered wafer loading and unloading position at which the upper surfaces of the first and second pistons lie in the same

plane and the upper surface of the vacuum chuck lies in the same plane as the top plate 131. When the second piston 162 is in this lowered position, the outwardly directed radial flange of the cylindrical part 162a rests upon an annular ridge formed along an offset inner peripheral portion 164 of the first piston 120. This annular ridge serves to prevent any dust particles, which might otherwise collect on the uppermost surface of the offset portion 164 when the second piston 162 is raised, from interfering with return of the second piston to its lowered position.

The second piston 162 is raised by application of fluid pressure to a cylindrical chamber 166 formed between an end wall 162b positioned toward the upper end of the cylindrical part 122a and an internally-threaded cap 168 screwed onto an externally-threaded lower end portion of the cylindrical wall 120a of the first piston. Fluid pressure is applied to the chamber 166 through a sixth control valve when opened by the operator, a flexible tube 172, and a fitting that extends through the cap 168. The amount the second piston 162 may be raised and, hence, the amount the vacuum chuck 52 may be raised by the second piston is limited by abutment of an externally-threaded annular stop ring 176, which is screwed into an internally-threaded lower end portion of the cylindrical part 162a of the second piston, upon an offset lower portion 180 of the cylindrical part 120a of the first piston. The stop ring 176 may be screwed further into or out of the threaded lower end portion of the cylindrical part 162a to decrease or increase, respectively, the amount the vacuum chuck 52 is raised by the second piston 162 and may even be screwed into fixed abutment upon the offset lower portion 180 of the cylindrical part 120 to prevent the vacuum chuck from being raised at all by the second piston. The second piston 162 and, hence, the vacuum chuck 52 are lowered under the action of gravity by actuating the sixth control valve to disconnect the tube 172 from the source of fluid pressure and instead vent it to the atmosphere. The sixth control valve may also be actuated to connect the tube 172 to the source of vacuum and thereby facilitate the lowering of the second piston 162 and the vacuum chuck 52.

As described in connection with Figure 16 of U.S. Patent Specification No. 3,490,846, the vacuum chuck 52 includes a chuck plate 182 with a central downwardly-extending stem secured to a bearing member 186, which is in the form of a section of a sphere. The bearing member 186 is seated on a conically-shaped inner peripheral part of the upper end portion of the cylindrical part 162a so that the center of radius of the bearing member 186 is located at substantially the center of a perforated top plate, 188 concentrically mounted on the upper surface of the chuck plate 182

and so that clearance space is provided between the chuck plate 182 and an annular ridge 190 formed on the upper surface of the first piston 120. The vacuum chuck 52 may therefore pivot about its vertical axis in any horizontal direction as required for parallel plane alignment of the adjacent surfaces of the wafer 54 and the mask 22.

A plurality of interconnected radial grooves 192 formed in the upper surface of the chuck plate 182 are covered by the perforated top plate 188. These grooves communicate with an axial bore 194 longitudinally extending through the stem of the chuck plate 182. The end wall 162b is also provided with an axial bore that communicates with the bore 194 and that is connected through a fitting extending through the end wall 162b, a flexible tube 198, another fitting extending through the cap 168, another flexible tube 202, and a seventh control valve to the source of vacuum. Thus, once a wafer 54 is loaded onto the vacuum chuck 52, it may be firmly held in place on the perforated top plate 188 by opening the seventh control valve so that a vacuum is drawn through the tube 202. The vacuum drawn through the tube 202 also increases the frictional engagement between the bearing member 186 and the conically-shaped inner peripheral portion of the cylindrical part 162a. This frictional engagement is sufficient to maintain the vacuum chuck 52 in whatever position it may be pivoted to during parallel plane alignment of the adjacent surfaces of the wafer 54 and the mask 22.

When a wafer 54 is to be loaded onto or unloaded from the vacuum chuck 52, the seventh control valve is actuated to vent the tube 202 to the atmosphere and thereby permit sliding movement of the wafer across the perforated top plate 188 of the vacuum chuck. A wafer 54 may be loaded onto and unloaded from the perforated top plate 188 of the vacuum chuck 52 by moving the wafer along the top plate 188 when the vacuum chuck is in its wafer loading and unloading position. This may be accomplished by employing a wafer loading and unloading mechanism like that described in connection with Figures 17-23 of U.S. Patent Specification No. 3,490,846. The wafer loading and unloading mechanism is rendered inoperative once the vacuum chuck 52 is raised and is rendered operative again by a microswitch that is activated for this purpose by a peripheral flange 206 of the chuck plate 182 when the vacuum chuck is returned to its wafer loading and unloading position.

An annular locking ring structure 208 is vertically reciprocally mounted within a generally U-shaped peripheral portion 210 of the chuck plate 182 around the perforated top plate 188. As shown in Figures 1-3, the locking ring structure 208 includes a locking ring 212 with a generally U-shaped cross-

section as best shown in Figure 2, and with its side and bottom walls slotted, as best shown in Figure 3, so that they may be expanded outward by a resilient inflatable tube 214 contained therein. The bottom wall 212a of this locking ring is curved inward so that outward expansion of the bottom wall 212a also forces the side walls of the locking ring outward with a substantially greater force than that exerted by the inflatable tube 214. The bottom wall 212a therefore serves, in effect, as a force amplifier for converting the downwardly directed force exerted thereon by the inflatable tube 214 into a substantially greater outwardly directed force upon the side walls of the locking ring 212. The resultant outward expansion of the side walls of the locking ring 212 by the inflatable tube 214 and especially by outward expansion of the inwardly curved bottom wall 212a clamps the locking ring in tight locking engagement with the peripheral portion 210 of the chuck plate 182. The inflatable tube 214 is connected through a flexible tube 216, which extends through an opening in one side wall of the locking ring 212 and through a slot 217 in the adjoining portion of the chuck plate 182, and an eighth control valve to the source of fluid pressure. Thus, when the operator opens the eighth control valve, the tube 214 is inflated and the side walls of the locking ring 212 are expanded outward into tight locking engagement with the peripheral portion 210 of the chuck plate 182, thereby locking the locking ring structure 208 in whatever vertical position it is then in. The locking ring structure 208 may be released by actuating the eighth control valve to vent the tube 216 to the atmosphere, thereby deflating the tube 214 and permitting vertical sliding movement of the locking ring structure relative to the chuck plate 182.

Inwardly directed flanges 212b at the upper end of the locking ring 212 are captivated between two rings 218 and 220 positioned on opposite sides of these flanges and secured together in abutment therewith by screws 222. A portion of the upper ring 218 abuts upon an offset portion 224 of the chuck plate 182 to prevent the locking ring structure 208 from travelling downward beyond a lowered inoperative position at which the upper surfaces of the ring 218, the chuck plate 182, and the perforated top plate 188 lie in the same plane. The locking ring structure 208 may be raised above the upper surface of a wafer 54 supported on the vacuum chuck 52 by applying fluid pressure to the lower side of a resilient inflatable seal 226, which is captivated at the bottom of the peripheral portion 210 of the chuck plate by a plurality of retaining elements 228 secured to the bottom of the peripheral portion 210 by screws 230. Fluid pressure is applied from the source of fluid pressure to the lower side of the inflatable seal 226 through a ninth control valve

when opened by the operator, a flexible tube 232, and a passageway 234 that communicates with the lower side of the inflatable seal 226 between a pair of adjacent retaining elements 228. The upper side of the seal 226 is attached to the bottom wall of the locking ring 212 around the periphery thereof, as indicated at 236, so that the locking ring structure 208 may be lowered by actuating the ninth control valve to disconnect the tube 232 from the source of fluid pressure and vent it instead to the atmosphere or connect it to the source of vacuum. Sufficient clearance is provided between the locking ring structure 208 and the adjacent wall of the peripheral portion 210 of the chuck plate 182 so that the locking ring structure may pivot slightly when driven upward into abutment upon a reference surface making a slight angle with respect to the wafer bearing surface of the vacuum chuck 52. This insures face-to-face abutment of the upper surface of the ring 218 and, hence, of the locking ring structure 208 with the reference surface.

The optical alignment apparatus 10 also includes a calibrator 238 for spacing the upper surface of the locking ring structure 208 a selected distance x of, for example, .0002 to .002 of an inch above the upper surface of a wafer 54 supported on the vacuum chuck 52. The calibrator 238 comprises a square plate with a spacing structure 240 positioned on its lower surface for abutment with a peripheral portion of the upper surface of the wafer 54 in a first reference plane and surrounded by a reference surface 242 inwardly offset by the selected distance x for abutment with the upper surface of the locking ring structure 208 in a parallel second reference plane spaced the selected distance x above the first reference plane.

The spacing structure 240 of the calibrator comprises a fixed annular step the surface of which is parallel to and spaced the selected distance x from the reference surface 242. Alternatively, however, the spacing structure 240 can comprise an adjustable annular step provided by screwing an externally-threaded ring 244 into a central internally-threaded aperture 246 of the calibrator plate 238 as shown in Figures 4A and 4B; a plurality of pins 248 fixedly mounted at equally spaced positions around a central aperture 249 of the calibrator plate 238 and spaced the selected distance x from the reference surface 242 as shown in Figures 5A and 5B; a plurality of pins 250 embedded in an externally-threaded ring 251 and adjustably mounted by screwing the externally-threaded ring 251 into an internally-threaded central aperture 252 of the calibrator plate 238 as shown in Figures 6A and 6B; or an adjustable air cushion 254 provided by a plurality of spacing air jets 256 located at equally spaced positions around a

central aperture 258 of the calibrator plate 238 and connected by a passageway 260 and a control valve to a source of air pressure as shown in Figures 7A and 7B. One advantage of employing the adjustable annular step 244 of Figures 4A and 4B, the adjustably-mounted pins 250 of Figures 6A and 6B, or the adjustable air cushion 254 provided by the spacing air jets 256 of Figures 7A and 7B as the spacing structure is that they all permit the operator to change the selected distance x by which the calibrator 238 spaces the upper surface of the locking ring structure 208 above the upper surface of the wafer 54 without the necessity of changing calibrators.

The reference surface 242 of the calibrator 238 may also be made adjustable in lieu of, or in addition to, making the spacing structure 240 adjustable. For example, a plurality of reference air jets may be located at equally spaced positions around the surface 242 of the calibrator shown in Figures 7A and 7B to provide an adjustable reference air cushion for abutment with the upper surface of the locking ring structure 208 in the second reference plane. The air pressure applied to these air jets and, hence, this reference air cushion may then be adjusted to vary the selected distance x by which the calibrator 238 spaces the upper surface of the locking ring structure 208 above the upper surface of the wafer 54. Moreover, these reference air jets and the spacing air jets 256 may be connected to differential gauges for providing a readout of the selected distance x by which the calibrator 238 spaces the upper surface of locking ring structure 208 above the upper surface of the wafer 54.

The calibrator 238 is supported for horizontal reciprocal movement between the mask holder 12 and the vacuum chuck 52 by a pair of guide rails 261 fixedly mounted on the top plate 131. A piston rod 262 attached to a bifurcated bracket formed on the back end of the calibrator 238 is driven by an operator-controlled fluid cylinder for moving the calibrator along the guide rails 261 between an inoperative position completely retracted from the vertical path traversed by the vacuum chuck 52 when it is elevated toward the mask holder 12 and an operative position directly in this path and substantially in vertical alignment with the vacuum chuck and mask holder.

In the operation of the apparatus 10, a mask 22 is loaded onto the mask holder 12 while the mask holder is in its raised mask loading and unloading position and is firmly held in place thereon by drawing vacuum through the tube 28. The mask holder 12 is then pivoted to its lowered operative position and firmly held in place upon the top plate 18 by drawing vacuum through the tube 34. A wafer 54 is loaded onto the vacuum chuck 52 while the vacuum chuck is in its lowered wafer loading and un-

loading position and is firmly held in place thereon by drawing vacuum through the tube 202.

5 Following these loading operations, the calibrator 238 is moved into its operative position between the vacuum chuck 52 and the mask holder 12, if it is not already in that position. The vacuum chuck 52 is then driven upward by the first piston 120, which is in turn
10 driven upward by applying fluid pressure to the chamber 124 through the tube 128, to position a peripheral portion of the upper surface of the wafer 54 in face-to-face abutment upon the spacing structure 240 of the calibrator 238 in the first reference plane as shown in
15 Figure 8. This pivots the vacuum chuck 52 as required to establish parallel plane alignment between the upper surface of the wafer 54, the adjoining surface of the spacing structure 240, and the reference surface 242 of the cali-
20 brator. The locking ring structure 208 of the vacuum chuck is driven further upward by applying fluid pressure to the lower side of the inflatable seal 226 through the tube 232 to position the upper surface of the locking ring
25 structure in abutment upon the reference surface 242 of the calibrator in the parallel second reference plane as further shown in Figure 8. This spaces the upper surface of the
30 locking ring structure 208 the selected distance x above the upper surface of the wafer 54 and pivots the locking ring structure 208 as required, if, for example, the wafer is wedge-shaped, to establish parallel plane alignment
35 of these surfaces. The locking ring structure 208 is then locked in this vertical position by applying fluid pressure to the inflatable tube 214 through the tube 216.

40 Following this calibration operation, the vacuum chuck 52 is lowered to its initial wafer loading and unloading position or any intermediate position at which the calibrator 238 may be retracted from between the vacuum
45 chuck 52 and the mask holder 12. This is accomplished by venting the tube 128 to the atmosphere or by drawing a vacuum there-through to lower the first piston 120. The calibrator 238 is then retracted to its inoperative
50 position out of the vertical path between the vacuum chuck 52 and the mask holder 12. At this point the vacuum chuck 52 is driven upward again by the first piston 120, which is in turn driven upward by again applying fluid
55 pressure to the chamber 124 through the tube 128, to position the upper surface of the locking ring structure 208 in abutment upon a marginal unused portion of the lower surface of the mask 22 as shown in Figure 9. This again
60 pivots the vacuum chuck 52 as required to establish parallel plane alignment of the upper surface of the wafer 54 and the lower surface of the mask 22 and spaces these surfaces apart by the selected distance x without bringing the wafer into contact with the mask. The
65 vacuum chuck 52 is then locked in this vertical

position by applying fluid pressure to the inflatable tube 144 through the tube 146 to lock the first piston 120 vertically in place.

70 Following this parallel plane alignment operation, the locking ring structure 208 of the vacuum chuck 52 is released by venting the tube 216 to the atmosphere and is returned to its initial position by venting the tube 232 to the atmosphere or by drawing a vacuum there-through. A pattern on the upper surface
75 of the wafer 54 may then be aligned with a corresponding pattern on the adjacent parallel lower surface of the mask 22 while the wafer and the mask are out of contact. This is accomplished with the aid of an optical unit
80 20 (see Figure 10), like that described in detail in connection with Figures 1-10 of U.S. Patent Specification No. 3,490,846, by rotating a turret 264 of the optical unit to position a single field row and column or a split-field ob-
85 jective lens system 266 or 268, respectively, in operative alignment with the stationary ocular lens system 85 of the microscope and by then horizontally moving the vacuum chuck 52 relative to the mask holder 12 while viewing
90 the orientation of the patterns on the mask 22 and the wafer 54 through the aligned ocular and objective lens systems of the microscope.

95 After this pattern alignment operation, a photosensitive film on the upper surface of the wafer 54 is exposed through the mask 22 by rotating the turret 264 of the optical unit 20 to position a mirror for directing a beam 270 of ultraviolet light onto the mask as shown in
100 Figure 10. This exposure operation may be performed while the wafer 54 is in its alignment position. For greater resolution, however, the vacuum chuck 52 may first be driven upward by the second piston 162, which is in turn driven upward by applying fluid pressure
105 to the chamber 166 through the tube 172, to position the wafer 54 in an elevated position closer to the mask 22 as shown in Figure 10. The wafer 54 may, if desired, be elevated to any position for exposure by adjusting the
110 setting of the stop ring 176 of the second piston.

115 Following the exposure operation, the first piston 120 is released and the vacuum chuck 52 returned to its initial wafer loading and unloading position by venting the tube 146 to the atmosphere to release the first piston 120 and by then venting the tubes 128 and 172 to the atmosphere or by drawing a vacuum there-through to lower the first and second pistons.
120 Once the vacuum chuck 52 is returned to its wafer loading and unloading position, the tube 202 is also vented to the atmosphere so that the wafer 54 may be unloaded from the vacuum chuck and replaced by the next wafer
125 to be aligned with and exposed through the mask 22.

Referring now to Figures 11 and 12, there is shown another vacuum chuck 280 that may be employed in the apparatus 10 of Figure 1
130

in lieu of the calibrator 238 and the vacuum chuck 52 described above. The vacuum chuck 280 is best employed with wafers 54 having substantially parallel upper and lower surfaces. Those parts of the vacuum chuck 280 which are similar or identical to corresponding parts of the vacuum chuck 52 and which have therefore already been described in detail above are represented by the same reference numerals used in connection with Figure 1.

The vacuum chuck 280 includes a spacing ring 282 vertically reciprocally mounted within a generally U-shaped peripheral portion 210 of the chuck plate 182 around the perforated top plate 188. The spacing ring 282 may be raised above the upper surface of a wafer 54 supported on the perforated top plate 188 of the vacuum chuck 280 by applying fluid pressure to the bottom of the spacing ring. Fluid pressure is applied from the source of fluid pressure to the bottom of the spacing ring 282 through a control valve when opened by the operator, a flexible tube 284, and a passageway 286 that communicates with the bottom of the spacing ring. An inwardly-directed annular flange 288 of the spacing ring 282 abuts upon an adjacent stop portion 290 of the peripheral portion 210 of the chuck plate to prevent the spacing ring 282 from travelling upward more than a selected distance x above the upper surface of the wafer 54 as shown in Figure 12. The spacing ring 282 may be lowered under the action of gravity by actuating the control valve for the tube 284 to disconnect the tube 284 from the source of fluid pressure and instead vent it to the atmosphere. This control valve may also be actuated to connect the tube 284 to the source of vacuum and thereby facilitate the lowering of the spacing ring 282. A pair of annular ridges 292 concentrically formed on the bottom of the spacing ring 282 abut upon the bottom of the peripheral portion 210 of the chuck plate 182 to prevent the spacing ring 282 from travelling downward beyond a lowered inoperative position at which the upper surfaces of the spacing ring 282, the chuck plate 182, and the perforated top plate 188 lie in the same horizontal plane. The annular ridges 292 serve to prevent any dust particles, which may collect on the bottom of the peripheral portion 210, from interfering with return of the spacing ring 282 to its lowered inoperative position.

The outer side and bottom walls of the peripheral portion 210 of the chuck plate comprise a generally L-shaped annular ring internally threaded along the inner peripheral surface of the bottom wall and screwed into an externally threaded lower portion 294 of the inner side wall of the peripheral portion 210. This facilitates the assembly of the vacuum chuck 280 and permits the use of the different spacing rings 282 in the same vacuum chuck to alter the selected distance x .

In operation, the spacing ring 282 of the vacuum chuck 280 is driven upward the selected distance x above the upper surface of the wafer 54 as determined by abutment of the flange 288 of the spacing ring upon the stop portion 290 of the chuck plate. This is accomplished by application of fluid pressure to the tube 284. The vacuum chuck 280 is then driven upward by the first piston 120, as described above, to position the spacing ring 282 in face-to-face abutment upon a marginal unused portion of the lower surface of the mask 22 as shown in Figure 12. This pivots the vacuum chuck 280 as required to establish parallel plane alignment of the upper surface of the wafer 54 and the adjacent lower surface of the mask 22 and spaces these surfaces apart by the selected distance x without bringing the wafer into contact with the mask. The vacuum chuck 280 is then locked in this vertical position by locking the first piston 120 vertically in place as described above. Following this parallel plane alignment operation, the spacing ring 282 of the vacuum chuck is returned to its initial inoperative position by venting the tube 284 to the atmosphere or by drawing a vacuum therethrough. The pattern alignment and exposure operations may then be performed in the same manner as described above.

The vacuum chuck 280 may also employ a spacing structure other than a fixed spacing ring 288. For example, it may employ an adjustable spacing ring provided by replacing the inwardly directed flange 288 of the spacing ring 282 with an externally-threaded stop ring that is adjustably screwed into an internally-threaded lower portion of the spacing ring. Alternatively, it may employ air jets to provide an adjustable air cushion for abutment with a marginal portion of the mask 22 in a plane parallel to and spaced a selected distance x above the upper surface of the wafer 54. In this case, the operator may alter the selected distance x by adjusting the air pressure applied to the air jets.

As indicated above, the operator may turn the shaft 160 to unscrew the stop ring 150 by an amount sufficient to permit operation of the apparatus 10 as described in connection with Figure 16 of U.S. Patent Specification No. 3,490,846. In this mode of operation a wafer 54 is brought into contact with a mask 22 to establish parallel plane alignment of the adjacent surfaces of the wafer and the mask, is then separated from the mask to permit out of contact alignment of a pattern on the wafer with a pattern on the mask, and is thereafter again brought into contact with the mask to permit exposure of a photosensitive film on the wafer through the mask. The wafer may be driven into contact with the mask both for parallel plane alignment and exposure by employing the first or main piston 120 in the same manner as described in connection with Figure 16 of U.S. Patent Specification 3,490,846. In

the apparatus 10, however, the first or main piston 120 may be employed to drive the wafer into proximity with the mask and the second or auxiliary piston 162 employed to drive the wafer into actual contact with the mask more gently than can be achieved by employing the larger first or main piston. Alternatively, the first or main piston 120 may be employed to drive the wafer into contact with the mask for parallel plane alignment and, after out of contact pattern alignment, the second or auxiliary piston 162 employed for driving the wafer to any position from its pattern alignment position to the position of contact with the mask for exposure. In either case the second or auxiliary piston 162 permits a reduction in the number and/or force of the contacts between the wafer and the mask.

WHAT WE CLAIM IS:—

1. Alignment apparatus for use in aligning a workpiece with respect to a mask, said alignment apparatus comprising a workpiece chuck for holding the workpiece, and a mask holder for holding the mask, the workpiece chuck or the mask holder including spacing means for orienting a first surface of the workpiece held by the workpiece chuck and an adjacent first surface of the mask held by the mask holder in substantially parallel planes spaced a finite distance apart without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder and without moving the mask held by the mask holder.

2. Apparatus according to claim 1 wherein the workpiece chuck includes the spacing means.

3. Apparatus according to claim 2 wherein the spacing means is supported by the workpiece chuck around the workpiece bearing surface thereof for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder.

4. Apparatus according to claim 2 wherein the workpiece chuck is supported for pivotal movement to orient the adjacent first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes and for movement between a retracted position at which the workpiece can be loaded onto and unloaded from the workpiece chuck and an extended position closer to the mask holder at which position the spacing means can be employed for pivoting the workpiece chuck to orient the first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder.

5. Apparatus according to claim 4 wherein the workpiece chuck is supported beneath the mask holder for retractable movement toward the mask holder, optical means is provided for viewing the mask and the workpiece held by the mask holder and the workpiece chuck, respectively, alignment means is provided for relatively moving the workpiece chuck and the mask holder to bring a pattern on the workpiece held by the workpiece chuck into alignment with a pattern on the mask held by the mask holder, and exposure means is provided for exposing a photosensitive film on the first surface of the workpiece held by the workpiece chuck through the mask held by the mask holder while the workpiece chuck is positioned between its extended position and a position at which the first surface of the workpiece held by the workpiece chuck contacts the adjacent first surface of the mask held by the mask holder.

6. Apparatus according to either one of claims 4 and 5 wherein the spacing means is supported by the workpiece chuck around the workpiece bearing surface thereof, and the workpiece chuck is adapted to permit relative movement between the spacing means and the workpiece bearing surface of the workpiece chuck so that the spacing means can be positioned closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder.

7. Apparatus according to claim 6 further comprising calibrating means for spacing a first surface of the spacing means and the first surface of the workpiece held by the workpiece chuck a finite distance apart in substantially parallel planes with the first surface of the spacing means being spaced closer than the first surface of the workpiece held by the mask holder.

8. Apparatus according to claim 7 wherein the calibrating means is movable to an operative position between the workpiece chuck and the mask holder and an inoperative position retracted from between the workpiece chuck and the mask holder, and the calibrating means is operable in its operative position for spacing the first surfaces of the spacing means and the workpiece held by the workpiece chuck the finite distance apart in substantially parallel planes when the workpiece chuck is moved to an intermediate position between its retracted and extended positions.

9. Apparatus according to claim 8 wherein the spacing means is supported by the workpiece chuck for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the



the apparatus 10, however, the first or main piston 120 may be employed to drive the wafer into proximity with the mask and the second or auxiliary piston 162 employed to drive the wafer into actual contact with the mask more gently than can be achieved by employing the larger first or main piston. Alternatively, the first or main piston 120 may be employed to drive the wafer into contact with the mask for parallel plane alignment and, after out of contact pattern alignment, the second or auxiliary piston 162 employed for driving the wafer to any position from its pattern alignment position to the position of contact with the mask for exposure. In either case the second or auxiliary piston 162 permits a reduction in the number and/or force of the contacts between the wafer and the mask.

WHAT WE CLAIM IS:—

1. Alignment apparatus for use in aligning a workpiece with respect to a mask, said alignment apparatus comprising a workpiece chuck for holding the workpiece, and a mask holder for holding the mask, the workpiece chuck or the mask holder including spacing means for orienting a first surface of the workpiece held by the workpiece chuck and an adjacent first surface of the mask held by the mask holder in substantially parallel planes spaced a finite distance apart without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder and without moving the mask held by the mask holder.

2. Apparatus according to claim 1 wherein the workpiece chuck includes the spacing means.

3. Apparatus according to claim 2 wherein the spacing means is supported by the workpiece chuck around the workpiece bearing surface thereof for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder.

4. Apparatus according to claim 2 wherein the workpiece chuck is supported for pivotal movement to orient the adjacent first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes and for movement between a retracted position at which the workpiece can be loaded onto and unloaded from the workpiece chuck and an extended position closer to the mask holder at which position the spacing means can be employed for pivoting the workpiece chuck to orient the first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder.

5. Apparatus according to claim 4 wherein the workpiece chuck is supported beneath the mask holder for retractable movement toward the mask holder, optical means is provided for viewing the mask and the workpiece held by the mask holder and the workpiece chuck, respectively, alignment means is provided for relatively moving the workpiece chuck and the mask holder to bring a pattern on the workpiece held by the workpiece chuck into alignment with a pattern on the mask held by the mask holder, and exposure means is provided for exposing a photosensitive film on the first surface of the workpiece held by the workpiece chuck through the mask held by the mask holder while the workpiece chuck is positioned between its extended position and a position at which the first surface of the workpiece held by the workpiece chuck contacts the adjacent first surface of the mask held by the mask holder.

6. Apparatus according to either one of claims 4 and 5 wherein the spacing means is supported by the workpiece chuck around the workpiece bearing surface thereof, and the workpiece chuck is adapted to permit relative movement between the spacing means and the workpiece bearing surface of the workpiece chuck so that the spacing means can be positioned closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder.

7. Apparatus according to claim 6 further comprising calibrating means for spacing a first surface of the spacing means and the first surface of the workpiece held by the workpiece chuck a finite distance apart in substantially parallel planes with the first surface of the spacing means being spaced closer than the first surface of the workpiece held by the mask holder.

8. Apparatus according to claim 7 wherein the calibrating means is movable to an operative position between the workpiece chuck and the mask holder and an inoperative position retracted from between the workpiece chuck and the mask holder, and the calibrating means is operable in its operative position for spacing the first surfaces of the spacing means and the workpiece held by the workpiece chuck the finite distance apart in substantially parallel planes when the workpiece chuck is moved to an intermediate position between its retracted and extended positions.

9. Apparatus according to claim 8 wherein the spacing means is supported by the workpiece chuck for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the



mask holder, the spacing means can be moved to its extended position and releasably locked in place relative to the workpiece chuck when the first surfaces of the spacing means and the workpiece held by the workpiece chuck are spaced the finite distance apart in substantially parallel planes by the calibrating means, the workpiece chuck can then be moved from its intermediate position toward its retracted position to permit movement of the calibrating means to its inoperative position, the workpiece chuck can thereupon be moved to its extended position at which the spacing means is operable for pivoting the workpiece chuck to orient the first surfaces of the workpiece and the mask held by the workpiece chuck and the mask holder, respectively, in substantially parallel planes spaced the finite distance apart without bringing the workpiece held by the workpiece chuck into contact with the mask held by the mask holder, and the spacing means can then be released and moved to its retracted position to permit out of contact alignment of a pattern on the first surface of the workpiece held by the workpiece chuck with a pattern on the first surface of the mask held by the mask holder.

10. Apparatus according to any one of claims 7, 8 and 9 wherein the calibrating means comprises first means for abutment with a peripheral portion of the first surface of the workpiece held by the workpiece chuck in a first reference plane when the workpiece chuck is moved to its intermediate position, and second means for abutment with the first surface of the spacing means in a substantially parallel second reference plane when the workpiece chuck is moved to its intermediate position and the first surface of the spacing means is positioned closer, by the finite distance, than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder, the first and second reference planes being spaced the finite distance apart with the second reference plane being spaced closer than the first reference plane to the first surface of the mask held by the mask holder.

11. Apparatus according to claim 10 wherein the first and second means of the calibrating means are operable for spacing apart the first surfaces of the spacing means and the workpiece held by the workpiece chuck by a finite distance in the range from 0.0002 to .002 of an inch.

12. Apparatus according to either one of claims 10 and 11 wherein at least one of the first and second means of the calibrating means is adjustable for varying the finite distance by which the calibrating means spaces apart the first surfaces of the spacing means and the workpiece held by the workpiece chuck.

13. Apparatus according to any one of claims 10, 11 and 12 wherein the first means com-

prises an annular step having a plane surface for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, and the second means comprises a parallel plane surface positioned around this annular step and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane.

14. Apparatus according to any one of claims 10, 11 and 12 wherein the first means comprises a plurality of spaced pins for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, and the second means comprises a plane surface positioned around these pins and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane.

15. Apparatus according to any one of claims 10, 11 and 12 wherein the first means comprises an air cushion for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, and the second means comprises a plane surface positioned around this air cushion and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane.

16. Apparatus according to any one of claims 10 and 11 wherein the first means comprises a first air cushion for abutment with the peripheral portion of the first surface of the workpiece held by the workpiece chuck in the first reference plane, the second means comprises a second air cushion positioned around this first air cushion and inwardly offset by the finite distance for abutment with the first surface of the spacing means in the second reference plane, and means is provided for adjusting the offset between these first and second air cushions and providing an output indication of the finite distance by which the calibrating means spaces apart the first surfaces of the spacing means and the workpiece held by the workpiece chuck.

17. Apparatus according to any one of claims 10, 11 and 12 wherein at least one of the first and second means includes a plurality of spaced air jets for providing an air cushion for abutment with the first surface of the workpiece held by the workpiece chuck or the first surface of the spacing means in the first or second reference plane.

18. Apparatus according to any of claims 4 to 17 wherein the spacing means includes a hollow locking ring structure supported by the workpiece chuck for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position



spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder, the locking ring structure having an inwardly curved bottom wall that can be forced outward to expand the locking ring structure into locking engagement with the workpiece chuck when the locking ring structure is moved to its extended position.

19. Apparatus according to claim 18 wherein the locking ring structure comprises a hollow generally U-shaped locking ring with its side and inwardly curved bottom walls being slotted to make them expandable, with an annular inflatable tube contained therein for forcing its inwardly curved bottom wall outward to expand its side walls into locking engagement with a peripheral portion of the workpiece chuck, and with a ring attached to the top thereof and provided with a plane first surface for abutment upon a marginal portion of the first surface of the mask when the locking ring structure and the workpiece chuck are moved to their extended positions, and wherein the spacing means further includes an annular inflatable seal attached to a bottom wall of the peripheral portion of the workpiece chuck and to the inwardly curved bottom wall of the locking ring for moving the locking ring structure between its retracted and extended positions.

20. Apparatus according to claim 19 wherein the locking ring structure is supported for pivotal movement to permit face-to-face abutment of the first surface of the locking ring structure and a reference surface making a slight angle relative to the workpiece bearing surface of the workpiece chuck.

21. Apparatus according to claim 6 wherein the spacing means comprises a spacing structure supported by a peripheral portion of the workpiece chuck for movement between a retracted position spaced at least as far as the workpiece bearing surface of the workpiece chuck from the first surface of the mask held by the mask holder and an extended position spaced closer than the first surface of the workpiece held by the workpiece chuck to the first surface of the mask held by the mask holder, and the spacing structure is provided with a stop portion for engaging a stop portion of the peripheral portion of the workpiece chuck to limit the distance the spacing structure may be moved between its retracted and extended positions.

22. Apparatus according to claim 21 wherein the spacing structure comprises a spacing ring with a plane first surface for abutment upon a marginal portion of the first surface of the mask held by the mask holder when the

spacing structure and the workpiece chuck are moved to their extended positions, the stop portion of the spacing structure comprises an annular stop portion of the spacing ring positioned for abutment with the stop portion of the peripheral portion of the workpiece chuck when the spacing ring is in its extended position, and the peripheral portion of the workpiece chuck includes means for moving the spacing ring between its retracted and extended positions.

23. Apparatus according to claim 22 wherein the stop portions of the spacing ring and the peripheral portion of the workpiece chuck limit movement of the spacing ring between its retracted and extended positions to a distance in the range from .0002 to .002 of an inch.

24. Apparatus according to any of the preceding claims 4 to 23 including drive means for retractably moving the workpiece chuck toward the mask holder.

25. Apparatus according to claim 24 wherein the drive means includes a first piston for moving the workpiece chuck between its retracted and extended positions, and a second piston for moving the workpiece chuck between its extended position and a position still closer to the first surface of the mask held by the mask holder.

26. Apparatus according to claim 25 wherein the workpiece chuck is pivotally supported by the second piston, the second piston is coaxially supported by the first piston and is provided with first stop means for engaging a stop portion of the first piston to limit the distance the workpiece chuck may be moved toward the mask holder by the second piston, the first piston is operable for moving both the second piston and the workpiece chuck between the retracted and extended positions of the workpiece chuck, releasable locking means is provided for locking the first piston in whatever vertical position it may be in, and the first and second pistons include second stop means for preventing the workpiece chuck from being moved further than its retracted position away from the mask holder.

27. Apparatus according to claim 26 wherein the first stop means of the second piston is adjustable to permit movement of the workpiece chuck to any position from its extended position to a position still closer to the mask holder when the workpiece chuck is moved to its extended position by the first piston.

28. Alignment apparatus according to claim 1 substantially as hereinbefore described with reference to Figures 1 to 10, or Figures 1 to 10 as modified by Figures 11 and 12, of the accompanying drawings.



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