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(54) OPTICAL ALIGNMENT AND CONTACT PRINTING SYSTEM WITH IMPROVED CHUCK ASSEMBLY

(71) We, KASPER INSTRUMENTS INC., 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 generally to apparatus for aligning a semiconductor wafer and a photomask and transferring a geometric pattern on the mask to the wafer by contact printing. More particularly, this invention relates to improved chuck assemblies for use in such apparatus to position and maintain a photosensitive film bearing surface of the wafer in contact with a pattern bearing surface of the mask while the photosensitive film is exposed through the mask.

In many conventional optical alignment and contact printing systems the photosensitive film bearing surface of the wafer is driven into abutment upon the pattern bearing surface of the mask and so maintained during the contact printing operation by applying fluid pressure to the chuck assembly on which the wafer is supported and, in some cases, by additionally applying fluid pressure to the chuck assembly on which the wafer is supported and, in some cases, by additionally applying fluid pressure to the lower surface of the wafer itself. This type of pressure contact tends to bow the mask and thereby impair the alignment of the mask and wafer achieved during a previous pattern alignment operation. Moreover, if dust or other particles happen to be situated between the chuck assembly and the wafer supported thereon, the application of fluid drive pressure to the chuck assembly during the contact printing operation may also force the wafer against the mask with an uneven pressure across the mask. This impairs the resolution with which a pattern

may be transferred from the mask to the wafer. The foregoing problems associated with conventional pressure contact chuck assemblies are especially serious in the case of large wafers having a diameter of three or more inches.

Some chuck assemblies have been developed for preventing mask bowing by permitting evacuation of the region between the chuck assembly and the mask, but they have typically not eliminated the problem of uneven contact pressure across the mask when dust or other particles happen to be situated between the chuck assembly and the wafer supported thereon. Furthermore, they have typically included structures fixedly projecting above the wafer bearing surface of the chuck assembly and thereby interfering with loading and unloading of the wafer in the plane of the wafer bearing surface of the chuck assembly. Such chuck assemblies require an elaborate and expensive loading mechanism typically incapable of properly loading wafers not previously carefully aligned for the loading mechanism by hand or another mechanism.

It is an object of the present invention to provide improved apparatus for use in optically aligning a first element with respect to a second element and for clamping the first and second elements together after they are aligned.

The present invention provides apparatus for use in optically aligning a first element with respect to a second element and for clamping the first and second elements together after they are aligned, said apparatus comprising first means for holding a first element on an element bearing surface of the first means; second means for holding a second element; one of said first and second means being movable relative to the other; third means for relatively moving the first and second means in substantially parallel planes to align the first element with respect to the second element; fourth means normally retracted from the element bearing surface of the first means and operable for

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sealingly engaging both the first means and one of the second means and the second element around the first element; and fifth means for at least partially evacuating a region enclosed between the first means, the second element, and the fourth means to clamp the first and second elements together after they are aligned.

Preferably said fourth means is supported by one of the first and second means and is normally retracted from the element bearing surface of the first means to permit the first element to be loaded onto and unloaded from the first means along the element bearing surface thereof.

Preferably an apparatus according to the present invention further comprises sixth means normally retracted from the element bearing surface of the first means and operable for sealingly engaging both the first means and a peripheral portion of the first element; said fifth means being operable for at least partially evacuating a region enclosed between the fourth means, the sixth means, a portion of the first means between the fourth and sixth means, the first element, and the second element to clamp the first and second elements together after they are aligned. Preferably the fourth and sixth means are supported by one of the first and second means and are normally retracted from the element bearing surface of the first means to permit the first element to be loaded onto and unloaded from the first means along the element bearing surface thereof.

In an apparatus according to the present invention, preferably the first means comprises a chuck for holding a workpiece comprising the first element on a plane workpiece bearing surface of the chuck; the second means comprises a holder for holding a mask comprising the second element; the first means further comprises drive means for supporting the chuck and for moving the chuck between a first position away from the holder and a second position closer to the holder; the fourth means comprises a first seal supported by one of the chuck and the drive means around the workpiece, but normally retracted from the plane of the workpiece bearing surface of the chuck; the first seal is operable for sealingly engaging both said one of the chuck and the drive means and one of the holder and the mask around the workpiece when the chuck is in the second position; the fifth means comprises a conduit communicating with the region enclosed between the chuck, the mask, and the first seal when it sealingly engages both said one of the chuck and drive means and said one of the holder and mask around the workpiece; and the fifth means further comprises evacuating means coupled to the conduit for at least partially evacuating this

region to clamp the workpiece and the mask together.

An apparatus as set forth in the last preceding paragraph may further comprise a workpiece loading-and-unloading platform lying in substantially the same plane as the workpiece bearing surface of the chuck when the chuck is in the first position; the first seal normally being retracted from the plane of the workpiece bearing surface of the chuck to permit the workpiece to be loaded onto and unloaded from the chuck along and parallel to the plane of the workpiece loading-and-unloading platform and the workpiece bearing surface of the chuck when the chuck is in the first position.

In an apparatus as set forth in the last preceding paragraph or the last preceding paragraph but one preferably the first seal comprises a first inflatable seal ring supported by the chuck around the workpiece; and means is provided for inflating the first seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position; the evacuating means being operable for at least partially evacuating the region enclosed between the chuck, the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, and the mask to clamp the workpiece and the mask together.

In an apparatus as set forth in the last preceding paragraph but one or the last preceding paragraph but two preferably the first seal comprises a first inflatable seal ring supported by the drive means around the workpiece; and means is provided for inflating the first inflatable seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position. Preferably the apparatus further comprises coupling means for preventing relative movement between the chuck and the drive means except by a limited amount along a common vertical axis; and sealing means supported by one of the chuck and the drive means for slidably sealingly engaging the other of the chuck and the drive means; the evacuating means being operable for at least partially evacuating a region enclosed between the drive means, the sealing means, the chuck, the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, and the mask to clamp the workpiece and the mask together. Preferably the chuck comprises a first member for holding the workpiece on a plane workpiece bearing surface of the first member; the chuck further comprises a second member for supporting the first member; the coupling means comprises means for clamping the first and second members together; the coupling means further comprises one or more spring elements attached to both the second member and the drive means for

preventing relative movement therebetween except by a limited amount along the common vertical axis; and the sealing means comprises a seal ring supported by the first member for slidably sealingly engaging the drive means.

An apparatus as set forth in the last preceding paragraph but three may further comprise a second seal supported by the chuck, but normally retracted from the plane of the workpiece bearing surface of the chuck; the second seal being operable for sealingly engaging both the chuck and a peripheral portion of the workpiece when the chuck is in the second position; the conduit communicating with the region enclosed between the first seal when it sealingly engages both said one of the chuck and the drive means and said one of the holder and the mask, the second seal when it sealingly engages both the chuck and the peripheral portion of the workpiece, a portion of the chuck between the first and second seals, the workpiece, and the mask to clamp the workpiece and the mask together; and the evacuating means is operable for at least partially evacuating this region to clamp the workpiece and the mask together.

An apparatus as set forth in the last preceding paragraph may further comprise a workpiece loading and unloading platform lying in substantially the same plane as the workpiece bearing surface of the chuck when the chuck is in the first position; the first and second seals normally being retracted from the plane of the workpiece bearing surface of the chuck to permit the workpiece to be loaded onto and unloaded from the chuck along and parallel to the plane of the workpiece loading and unloading platform and the workpiece bearing surface of the chuck when the chuck is in the first position.

In an apparatus as set forth in the last preceding paragraph or the last preceding paragraph but one preferably the first seal comprises a first inflatable seal ring supported by the chuck around the workpiece; the second seal comprises a second inflatable seal ring supported by the chuck within the first inflatable seal ring and adjacent to the peripheral portion of the workpiece; the apparatus further comprises inflating means for inflating the first inflatable seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position and for inflating the second inflatable seal ring to sealingly engage the peripheral portion of the workpiece when the chuck is in the second position; and the evacuating means is operable for at least partially evacuating a region enclosed between the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, the second inflatable seal ring when it

is inflated to sealingly engage the peripheral portion of the workpiece, a portion of the chuck between the first and second inflatable seal rings, the workpiece, and the mask to clamp the workpiece and the mask together.

In an apparatus as set forth in the last preceding paragraph but one or the last preceding paragraph but two preferably the first seal comprises a first inflatable seal ring supported by the drive means around the workpiece; the second seal comprises a second inflatable seal ring supported by the chuck within the first inflatable seal ring and adjacent to the peripheral portion of the workpiece; and the apparatus further comprises inflating means for inflating the first inflatable seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position and for inflating the second inflatable seal ring to sealingly engage the peripheral portion of the workpiece when the chuck is in the second position. Preferably the apparatus further comprises coupling means for preventing relative movement between the chuck and the drive means except by a limited amount along a common vertical axis; and sealing means supported by one of the chuck and drive means for slidably sealingly engaging the other of the chuck and drive means; the evacuating means being operable for at least partially evacuating a region enclosed between the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, the second inflatable seal ring when it is inflated to sealingly engage the peripheral portion of the workpiece; a portion of the drive means and the chuck between the first and second inflatable seal rings, the sealing means, the workpiece, and the mask to clamp the workpiece and the mask together. Preferably the chuck comprises a first member for holding the workpiece on a plane workpiece bearing surface of the first member; the chuck further comprises a second member for supporting the first member; the coupling means comprises means for clamping the first and second members together; the coupling means further comprises one or more spring elements attached to both the second member and the drive means for preventing relative movement therebetween except by a limited amount along the common vertical axis; and the sealing means comprises a seal ring supported by the first member for slidably sealingly engaging the drive means.

An apparatus as set forth in the last preceding paragraph but seven or any preceding paragraph following that paragraph may further comprise a base; the holder being mounted on the base; the drive means being mounted on the base under the holder for vertical movement relative to the holder, the chuck being supported by the drive means

under the holder for pivotal movement to orient a first surface of the workpiece and an adjacent first surface of the mask in substantially parallel planes and for vertical movement between the first position at which the workpiece is separated from the mask and the second position at which the first surface of the workpiece and the adjacent first surface of the mask are positioned in contact; the third means being operable for relatively moving the chuck and the holder in substantially parallel planes when the chuck is in a third position between the first and second positions to align the workpiece with respect to the mask; optical means for viewing the workpiece and the mask held by the chuck and the holder, respectively, while the workpiece and the mask are being aligned; and exposure means for exposing a photosensitive film on the first surface of the workpiece through the mask after the workpiece and the mask are aligned and while they are clamped together.

In an apparatus as set forth in the last preceding paragraph but eight or any preceding paragraph following that paragraph preferably the chuck is a wafer chuck for holding a semiconductive wafer comprising the workpiece on a plane workpiece bearing surface of the wafer chuck; and the holder is arranged to hold the mask.

There now follows a detailed description which is to be read with reference to the accompanying drawings of several apparatuses according to the invention. Each of these apparatuses is an optical alignment and contact printing apparatus and 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 and contact printing apparatus according to the present invention showing a chuck assembly thereof in its initial wafer loading and unloading position;

Figures 2 and 3 are cross-sectional views of one of the inflatable seal rings employed in the chuck assembly of the apparatus of Figure 1;

Figure 4 is a simplified representation of the optical alignment and contact printing apparatus of Figure 1, as viewed in a plane orthogonal to that of Figure 1, when the chuck assembly is in its contact printing position;

Figure 5 is a half-sectional side view of another chuck assembly of an apparatus according to the present invention when the chuck assembly is in its initial wafer loading and unloading position;

Figure 6 is a simplified representation of the chuck assembly of Figure 5 when it is in its contact printing position; and

Figures 7 and 8 are half-sectional side

views of further chuck assemblies and apparatuses according to this invention.

Referring to Figure 1, there is shown an optical alignment and contact printing apparatus 10 which, except as differently set forth herein, may be constructed and operated, for example, in the same manner as the apparatus disclosed in US Patent Specification No. 3,490,846. The optical alignment and contact printing apparatus 10 includes a mask holder 12 pivotally mounted on a pin 14 extending between a pair of spaced blocks 16 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 an optical unit 20 (see Figure 4) of the system is raised, as described in connection with Figure 3 of U.S. Patent 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 an annular 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 to a source of vacuum 27 (see Figure 4) through a passageway in the mask holder, a flexible tube 28, a passageway in top plate 18, and a first normally open solenoid-operated valve. As shown and described in connection with Figure 11 of U.S. Patent 3,490,846, the first normally open solenoid-operated valve may be actuated to interrupt the vacuum connection to the groove 26, thereby releasing 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 mounted 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 region between the seal rings 30 to the source of vacuum 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. The second normally open solenoid-operated valve may be actuated to interrupt the vacuum connection between the seal rings 30, thereby releasing

the mask holder 12 from the top plate 18, by another microswitch that is activated when the optical unit 20 (see Figure 4) of the system is raised.

5 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 3,490,846, to move the top plate 18 and, hence, the mask holder 12 in any horizontal direction relative to the stationary base plate 50.

25 The optical alignment and contact printing 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 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 key pattern on the upper surface of the wafer with a corresponding key pattern on the lower surface of the mask.

50 A releasable locking apparatus 63, similar to that described in connection with Figure 11 of U. S. Patent 3,490,846, normally locks the platform 42 against movement relative to the stationary base plate 50 to facilitate alignment of the key pattern on the upper surface of the wafer 54 with the corresponding key 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 outwardly into tight engagement with the walls of the hole 70 by a sleeve expanding head 74 attached by a screw 75 to a piston 76 vertically reciprocally mounted within the cylinder. A peripheral seal ring 78 mounted in an annular lower portion of the piston 76 provides slidable fluid-tight engagement between the cylinder and the piston. The region enclosed between the lower surface of the piston 76 and the upper surface of the stationary base plate 50 by the cylinder 64 may therefore be evacuated to urge the cylinder into locking engagement with the stationary base plate and move the piston and the attached head 74 downwardly thereby expanding the sleeve 66 into locking engagement with the platform 42. This is accomplished by connecting the enclosed region to the source of vacuum 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. As explained in connection with Figure 11 of U.S. Patent 3,490,846, the third normally open control valve may be actuated 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 4) without moving the ocular lens system 85 of the microscope.

105 In order to further facilitate alignment of the key pattern on the upper surface of the wafer 54 with the corresponding key pattern on the lower surface of the mask 22, the vacuum chuck 52 is also made horizontally adjustable in a rotary direction about its vertical axis. This is accomplished in the same manner as described in connection with Figures 11 and 15 of U.S. Patent 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 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, 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 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 113 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 upwards through the intermediate and upper parts 55b and 55a at a spaced distance therefrom. A piston 120 for supporting the vacuum chuck 52 and moving it between a lowered wafer loading and unloading position shown in Figure 1 and a raised parallel plane alignment and contact printing position shown in Figure 4 is vertically reciprocally supported at the upper end of the cylindrical wall 118. This piston comprises a hollow cylindrical part 120a for receiving and coaxially supporting the vacuum chuck 52 at the upper end of the cylindrical wall 118. It also comprises a sleeve-like part 120b telescopically surrounding the cylindrical wall 118 and coaxially secured to the cylindrical piston part 120a by screws 122. The lower portion of the sleeve-like piston part 120b is received within an annular chamber 124 formed between the intermediate and lower parts 55b and 55c of the chuck holder by an inwardly directed radial flange 125 positioned at the upper end of the intermediate part 55b. A peripheral seal ring 126 mounted in the flange 125 provides slidable fluid-tight engagement between the sleeve-like piston part 120b and the mouth of the chamber 124.

The piston 120 and, hence, the vacuum chuck 52 are raised toward the mask holder 12 by applying fluid pressure to the chamber 124 through a flexible tube 127 and a fitting 128 extending through the intermediate part 55b of the chuck holder. This is accomplished by actuating a fourth control valve 129 to connect the tube 127 and, therefore, the chamber 124 to a source of fluid pressure 135 (see Figure 4) such as compressed air or nitrogen. The piston 120 and the vacuum

chuck 52 are lowered under the action of gravity by actuating the fourth control valve 129 to disconnect the tube 127 from the source of fluid pressure and vent it instead to the atmosphere thereby interrupting the fluid pressure connection to the chamber 124. The fourth control valve may also be actuated to connect the tube 127 to the source of vacuum and thereby facilitate the lowering of the piston 120 and the vacuum chuck 52. An annular portion 130 of the piston part 120a abuts upon the upper end of the cylindrical wall 118 to prevent the piston 120 and the vacuum chuck 52 from travelling downward beyond the lowered wafer loading and unloading position at which the upper surface of the vacuum chuck and the upper surface of the piston (i.e. the upper surface of a peripheral portion 131 of the piston part 120a) lie in the same plane as the upper surface of a top plate 132. A pin 133 also extends through one side of the sleeve-like piston part 120b and protrudes into an adjoining longitudinally extending groove 134 in the cylindrical wall 118 of the chuck holder to prevent rotation of the piston 120 and the vacuum chuck 52 relative to the chuck holder as the piston and the vacuum chuck are raised and lowered.

The piston 120 is surrounded by a locking device 136, similar to that described in connection with Figure 16 of U.S. Patent 3,490,846, for being raised a finite distance with the piston and for thereafter being releasably secured to the piston. The locking device 136 comprises a locking ring 138 coaxially positioned around the sleeve-like piston-part 120b, two or more locking ring sections 140 coaxially positioned around the sleeve-like piston 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 locking device 136 is locked to the piston 120 by inflating the tube 144 and thereby urging the locking ring sections 140 radially inward into clamping engagement with the sleeve-like piston part 120b. The tube 144 is inflated by applying fluid pressure thereto through a flexible tube 146 passing through an aperture in the locking ring 138 of the locking device. This is accomplished by actuating a fifth control valve 147 to connect the tube 146 and, therefore, the inflatable tube 144 to the source of fluid pressure. The locking ring 138 may be released from locking engagement with the piston 120 by actuating the fifth control valve 147 to disconnect the tube 146 from the source of fluid pressure and vent it instead to the atmosphere thereby deflating the tube 144 and permitting vertical sliding movement of the

locking device 136 relative to the piston. Sufficient frictional engagement is provided between the locking ring sections 140 of the locking device 136 and the sleeve-like part 120b of the piston by the tube 144 when deflated to permit upward vertical travel of the locking device with the piston and to prevent the locking device from sliding downwardly along the piston under the force of gravity.

Upward vertical movement of the locking device 136 is limited by a first stop comprising an inwardly directed radial flange 148 of the upper part 55a of the chuck holder. Similarly, downward vertical movement of the locking device is limited by an adjustable second stop comprising an externally-threaded stop ring 150 screwed into an internally-threaded lower portion of the upper part 55a. 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 the front of the instrument. Thus, by turning the shaft 160 the operator may adjust the vertical separation between the stop ring 150 and the flange 148 of the chuck holder.

As described in connection with Figure 16 of U.S. Patent 3,490,846, the vacuum chuck 52 includes a circular chuck plate 182 with a central downwardly-extending stem 187 secured to a bearing member 186, which is in the form of a section of a sphere. The bearing member 186 is seated in a central conically-recessed portion 188 of the cylindrical piston part 120a so that the centre of radius of the bearing member 186 is located at substantially the centre of a perforated circular top plate 189 concentrically mounted on a central recessed portion of the upper surface of the chuck plate 182, so that clearance space is provided between the chuck plate 182 and the rest of the cylindrical piston part 120a, and so that the upper surface of the chuck plate 182 and the perforated top plate 189 lies in substantially the same plane as the upper surface of the peripheral portion 131 of the cylindrical piston part 120a. 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.

The perforated top plate 189 covers a plurality of interconnected radial grooves 192 formed in the central recessed portion of the upper surface of the chuck plate 182. These grooves communicate with an axial bore 194 longitudinally extending through the stem 187 of the chuck plate. The axial bore 194 in turn communicates with a fitting 195 axially extending through the central

conically-recessed portion 188 of the cylindrical piston part 120a and communicating with a flexible tube 196. A wafer 54 is positioned on the upper surface of the vacuum chuck 52 over the perforated top plate 189 and may therefore be firmly held in place on the vacuum chuck by drawing a vacuum through the perforated top plate 189, the radial grooves 192, the axial bore 194, the fitting 195, and the tube 196. This vacuum is drawn by actuating a sixth control valve 197 to connect the tube 196 to the source of vacuum. The vacuum drawn through the tube 196 also increases the frictional engagement between the bearing member 186 and the central conically-recessed portion 188 of the cylindrical piston part 120a. 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 and to clamp the vacuum chuck 52 and the piston 120 together.

When a wafer 54 is to be loaded or unloaded from the vacuum chuck 52, the sixth control valve 197 is actuated to disconnect the tube 196 from the source of vacuum and vent it instead to the atmosphere thereby permitting sliding movement of the wafer across the upper surface of the vacuum chuck. A wafer 54 may then be loaded onto and unloaded from the vacuum chuck 52 by simply moving the wafer along the upper surface of the top plate 132 and the adjoining upper surfaces of the vacuum chuck and the peripheral portion 131 of the piston 120 when the vacuum chuck is in the lowered wafer loading and unloading position. This may be accomplished by employing a wafer loading and unloading mechanism similar to that described in connection with Figures 17-23 of the drawings accompanying U.S. Patent Specification No. 3,490,846 or that shown and described in U.S. Patent Specification No. 3,700,567. The wafer loading and unloading mechanism is rendered operative by a microswitch activated for this purpose by a peripheral flange 198 of the cylindrical piston part 120a when the vacuum chuck is lowered to the wafer loading and unloading position and is rendered inoperative once the vacuum chuck is raised from the wafer loading and unloading position.

A first inflatable seal ring 200 is fixedly mounted in an annular channel 202 formed in the wafer bearing upper surface of the chuck plate 182 around the perforated top plate 189 and the wafer 54 supported thereon. As shown in detail in Figures 2 and 3, the inflatable seal ring 200 comprises an inverted generally U-shaped rubber annulus with a pair of oppositely facing shoulders 204 around its lower inner edges and with an inwardly curved upper end having a tri-

angular inner ridge 206 and a larger triangular outer ridge 208. The seal ring 200 is held in fluid-tight engagement with the walls of the channel 202 of the chuck plate by a generally U-shaped annular retainer 210. This retainer is provided with a pair of oppositely facing channels 214 around the outer walls thereof for receiving and snugly engaging the shoulders 204 of the seal ring and is further provided with inwardly curved upper edges 212 for supporting the inwardly curved upper end of the seal ring 200 when the seal ring is deflated. The retainer is secured to the bottom of the channel 202 by a plurality of symmetrically spaced screws 216 (see Figure 2), and is additionally provided with a passageway 218 extending through a lower end portion 220 of the retainer and communicating with another passageway 222 extending through the lower portion of the chuck plate 182 (see Figure 3).

The first seal ring 200 is normally deflated and retracted from the wafer bearing upper surface of the chuck plate 182 so as not to interfere with wafer loading and unloading in the plane of this wafer bearing surface when the vacuum chuck 52 is in the lowered wafer loading and unloading position. However, it may be inflated to project above the upper surface of the wafer 54 and to sealingly engage an unused marginal portion of the lower surface of the mask 22 when the vacuum chuck 52 is in the raised contact printing position. The first seal ring 200 is inflated by applying fluid pressure to the interior of the seal ring retainer 210 through the passageway 218 in the lower end portion of the seal ring retainer 210, the passageway 222 in the chuck plate 182, and a flexible tube 223 passing through a circular aperture 224 in the cylindrical piston part 120a. This is accomplished by actuating a seventh control valve 225 to connect the tube 223 to the source of fluid pressure.

A passageway 226 extends through the chuck plate 182 and communicates with the upper surface of the chuck plate between the first seal ring 200 and both the perforated top plate 189 and the wafer 54 supported thereon. This passageway is connected to a flexible tube 227 passing through another circular aperture 228 symmetrically positioned in the cylindrical piston part 120a opposite the circular aperture 224. Thus, when the first seal ring 200 is inflated to sealingly engage the lower surface of the mask 22, the region enclosed between the lower surface of the mask and the upper surface of the vacuum chuck by first seal ring may be evacuated through the passageway 226 and the tube 227 to clamp the vacuum chuck and the wafer to the mask. This is accomplished by actuating an eighth control valve

229 to connect the tube 227 to the source of vacuum.

The vacuum chuck 52 and the wafer 54 may be unclamped from the mask 22 by breaking the seal between the first seal ring 200 and the mask and by deflating the first seal ring and returning it to its normal retracted position. This is accomplished by actuating the seventh and eighth control valves 225 and 229 to disconnect the tubes 223 and 227 from the sources of fluid pressure and vacuum respectively, and vent them instead to the atmosphere. The seventh control valve 225 may also be actuated to connect the tube 223 to the source of vacuum and thereby facilitate breaking the seal between the first seal ring and the mask and returning the first seal ring to its normal retracted position.

In the operation of the optical alignment and contact printing apparatus 10, a mask 22 is loaded onto the mask holder 12 while the optical unit 20 (see Figure 4) of the apparatus is raised and the mask holder is in its raised mask loading and unloading position. The mask is firmly held in place on the mask holder 12 by drawing a vacuum through the first normally open solenoid-operated valve and, hence the groove 26. The mask holder 12 and the optical unit 20 are then both pivoted to their lowered operative positions. The mask holder is firmly held in its lowered operative position upon the top plate 18 by drawing a vacuum through the second normally open solenoid-operated valve and, hence, the region between the seal rings 30. Either before or after this mask loading operation, a wafer 54 is loaded onto the vacuum chuck 52 while the vacuum chuck is in its lowered wafer loading and unloading position. The wafer is firmly held in place on the vacuum chuck 52 by actuating the sixth control valve 197 to connect the tube 196 to the source of vacuum, thereby applying a vacuum to the lower surface of the wafer through the perforated top plate 189.

Following these mask and wafer loading operations, the piston 120 and, hence, the vacuum chuck 52 are driven upward toward the mask holder 12 by actuating the fourth control valve 129 to connect the tube 127 to the source of fluid pressure thereby applying fluid pressure to the chamber 124, and, hence, to the piston. This positions the upper surface of the wafer 54 in abutment upon the lower surface of the mask 22 and thereby pivots the vacuum chuck 52 as required to establish parallel plane alignment of these adjacent surfaces. It also positions the locking device 136, which frictionally engages the piston 120 as described above, in abutment upon the flange 148 of the chuck holder 55. The locking device 136 is then locked to the piston 120 by actuating the fifth control valve

147 to connect the tube 146 to the source of fluid pressure thereby inflating the tube 144 and urging the locking ring sections 140 of the locking device into clamping engagement with the piston. The piston 120 and, hence, the vacuum chuck 52 are then lowered to an intermediate pattern alignment position between the raised parallel plane alignment and the lowered wafer loading and unloading positions by actuating the fourth control valve 129 to disconnect the tube 127 from the source of fluid pressure and vent it instead to the atmosphere or connect it to the source of vacuum. Downward movement of the piston 120 and the vacuum chuck 52 to the intermediate pattern alignment position is stopped by abutment of the locking device 136 upon the adjustable stop ring 150.

Since the locking device 136 is clamped to the piston 120 only after being raised into abutment upon the flange 148 of the chuck holder and only after the wafer 54 is raised into abutment with the mask 22, the separation achieved between the upper surface of the wafer and the lower surface of the mask by downward movement of the piston and the vacuum chuck to the intermediate pattern alignment position is the same for wafers of different thickness. Although the setting of the adjustable stop ring 150 may be altered to adjust the separation achieved between the upper surface of the wafer 54 and the lower surface of the mask 22 by downward movement of the piston and vacuum chuck to the intermediate pattern alignment position, the adjustable stop ring is typically set to provide a separation of, for example, .0002 to .002 of an inch and is not thereafter changed from wafer to wafer.

Once the piston 120 and the vacuum chuck 52 are lowered to the intermediate pattern alignment position, a key pattern on the upper surface of the wafer 54 may be aligned with a corresponding key pattern on the adjacent parallel lower surface of the mask 22. This is accomplished with the aid of the optical unit 20 (see Figure 4), which may be of the same type as that described in detail in connection with Figures 1—10 of U.S. Patent 3,490,846, by rotating a turret 230 of the optical unit to position a single field row and column or a split-field objective lens system 232 or 234, 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 the orientation of the key patterns on the mask 22 and the wafer 54 through the aligned ocular and objective lens systems of the microscope.

After completing these parallel plane and pattern alignment operations, the piston 120 and the vacuum chuck 52 are returned to

the raised position by once again actuating the fourth control valve 129 to connect the tube 127 and, hence, the chamber 124 to the source of fluid pressure. This again positions the upper surface of the wafer 54 in abutment upon the lower surface of the mask 22 in preparation for contact printing. As shown in Figure 4, the first seal ring 200 is then inflated to sealingly engage an unused marginal portion of the lower surface of the mask 22 by actuating the seventh control valve 225 to connect the tube 223 to the source of fluid pressure 135 thereby applying fluid pressure to the interior of the seal ring retainer 210 and, hence, to the first seal ring itself. The region enclosed (as indicated by dashed line A) between the mask 22, the first seal ring 200, and the vacuum chuck 52 is thereupon evacuated by actuating the eighth control valve 229 to connect the tube 227 and, hence, the enclosed region to the source of vacuum 27. This clamps the vacuum chuck 52, the wafer 54 supported thereon, and the mask 22 together thereby holding the mask and the wafer in intimate contact for contact printing. If desired, the fourth control valve 129 may thereupon be actuated to disconnect the tube 127 and, hence, the chamber 124 from the source of fluid pressure 135 and vent them instead to the atmosphere. This removes the fluid drive pressure from the piston 120 and the vacuum chuck 52 thereby equalizing the pressure applied to the mask 22 and the wafer 54 as indicated by the arrows 236 (these arrows represent atmospheric pressure). Even when the fluid drive pressure is removed from the piston 120 and the vacuum chuck 52, they both remain in the raised contact printing position with the vacuum chuck clamped to the mask and the piston clamped to the vacuum chuck as long as fluid pressure continues to be applied through the tube 223 and vacuum continues to be drawn through the tubes 227 and 196. In any case, once the wafer 54 and the mask 22 are clamped together, contact printing is achieved by rotating the turret 230 of the optical unit 20 to position a mirror for directing a beam of ultraviolet light 240 onto the mask and to thereby expose a photosensitive film on the upper surface of the wafer through a pattern on the lower surface of the mask.

Following this contact printing surface operation, the vacuum chuck 52 and the wafer 54 supported thereon are unclamped from the mask 22 by actuating the seventh and eighth control valves 225 and 229 to disconnect the tubes 223 and 227 from the sources of fluid pressure and vacuum 135 and 27, respectively, and vent them instead to the atmosphere. The locking device 136 is then unclamped from the piston 120 by actuating the fifth control valve 147 to disconnect the tube 146 from the source of fluid

pressure 135 and vent it instead to the atmosphere. The piston 120 and the vacuum chuck 52 are thereupon returned to the lowered wafer loading and unloading position by similarly actuating the fourth control valve 129 to disconnect the tube 127 from the source of fluid pressure 135 and vent it to the atmosphere, if this has not already been done, or connect it to the source of vacuum 27. Once the vacuum chuck 52 is returned to its lowered wafer loading and unloading position, the vacuum applied to the lower surface of the wafer 54 is removed by actuating the sixth control valve 197 to disconnect the tube 196 from the source of vacuum 27 and vent it instead to the atmosphere. The wafer 54 may then be unloaded from the vacuum chuck 52 and be replaced by the next wafer to be aligned with and exposed through the mask 22.

Referring to Figure 5, there is shown another vacuum chuck 242 for use in an apparatus according to this invention. The vacuum chuck 242 can be employed in the optical alignment and contact printing apparatus 10 of Figure 1 in place of vacuum chuck 52. It includes all the parts of the vacuum chuck 52, and as these parts have already been described above with the aid of Figures 1—3, they are therefore represented in Figure 5 by the same reference numerals used for them in Figures 1—3. In addition, the vacuum chuck 242 includes a second inflatable seal ring 244 fixedly mounted in an annular channel 246 formed in the wafer bearing upper surface of the chuck plate 182 around the perforated top plate 189 and beneath a peripheral portion of the lower surface of the wafer 54. The second inflatable seal ring 244 is of the same type and is held in place by a retainer 248 in the same manner as the first inflatable seal ring 200. It is also normally deflated and retracted from the wafer bearing upper surface of the chuck plate 182, like the first inflatable seal ring 200, so as not to interfere with wafer loading and unloading in the plane of this wafer bearing surface when the vacuum chuck is in the lowered wafer loading and unloading position.

As shown in Figure 6, when the vacuum chuck 242 is driven upward to the raised position by the piston 120 in preparation for contact printing, the first and second seal rings 200 and 244 are inflated to sealingly engage an unused marginal portion of the lower surface of the mask 22 and a concentric peripheral portion of the lower surface of the wafer 54, respectively. The first and second seal rings 200 and 244 are inflated by applying fluid pressure through a modified passageway 222 extending through the lower portion of the chuck plate 182 and communicating with the interiors of both the first and second seal ring retainers 210 and

248 and with the flexible tube 223. This is accomplished by actuating the seventh control valve 225 to connect the tube 223 to the source of fluid pressure. The region enclosed (as indicated by dashed line B) between the mask 22, the first seal ring 200, the portion of the vacuum chuck 242 between the first and second seal rings 200 and 244, the second seal ring 244, and the wafer 54 is thereupon evacuated. This is accomplished by actuating the eighth control valve 229 to connect the tube 227 and, hence, the passageway 226, which communicates with the upper surface of the chuck plate 182 between the first and second seal rings 200 and 244 and between the first seal ring 200 and both the perforated top plate 189 and the wafer 54, to the source of vacuum. Evacuation of the enclosed region B clamps the vacuum chuck 242, the wafer 54, and the mask 22 together thereby holding the mask and the wafer in intimate contact for contact printing. If desired, the fourth and sixth control valves 129 and 197 may then be actuated to disconnect the tubes 127 and 196 from the sources of fluid pressure and vacuum, respectively, and vent them instead to the atmosphere thereby removing both the fluid drive pressure applied to the piston 120 and, hence, the vacuum chuck 242 and the vacuum applied to the lower surface of the wafer 54. This equalizes the pressure applied to the upper surface of the mask 22 and the lower surface of the wafer 54 as indicated by arrows 250 (representing atmospheric pressure) and prevents dust or other particles that may be situated on the wafer bearing upper surface of the vacuum chuck 242 from causing uneven contact pressure between these adjacent surfaces of the wafer and the mask. When both the fluid drive pressure applied to the piston 120 and the vacuum applied to the lower surface of the wafer 54 are removed, the piston travels downward until the locking device 136, which is clamped to the piston by application of fluid pressure to the tube 146, abuts upon the adjustable stop ring 150. However, the vacuum chuck 242 remains clamped to the mask 22 in the raised contact printing position as long as fluid pressure continues to be applied through the tube 223 and vacuum continues to be drawn through the tube 227.

Once the contact printing operation is finished, the piston 120 is driven upward into supporting engagement with the vacuum chuck 242 by actuating the fourth control valve 129 to connect the tube 127 to the source of fluid pressure. Concomitantly, vacuum is again applied to the lower surface of the wafer 54 by actuating the sixth control valve 197 to connect the tube 196 to the source of vacuum. The vacuum chuck 242 and the wafer 54 supported thereon are then

unclamped from the mask 22 by actuating the seventh and eighth control valves 225 and 229 to disconnect the tubes 223 and 227 from the sources of fluid pressure and vacuum, respectively, and vent them instead to the atmosphere. The locking device 136 is thereupon unclamped from the piston 120 by actuating the fifth control valve 147 to disconnect the tube 146 from the source of fluid pressure and vent it instead to the atmosphere. The vacuum chuck 242 is then returned to its initial wafer loading and unloading position by similarly actuating the fourth control valve 129 to once again disconnect the tube 127 from the source of fluid pressure and vent it to the atmosphere or connect it to the source of vacuum.

The separation achieved between the vacuum chuck 242 and the piston 120 when the tubes 127 and 196 are vented to the atmosphere to equalize the pressure applied to the upper surface of the mask 22 and the lower surface of the wafer 54 is normally limited to only .002 or less of an inch by abutment of the locking device 136, which is then clamped to the piston, upon the adjustable locking ring 150. Thus, once the contact printing operation is finished and vacuum is again applied to the lower surface of the wafer 54, the vacuum chuck 242 may simply be unclamped from the mask 22 and permitted to drop back into engagement with the piston 120 in lieu of driving the piston upward into engagement with the vacuum chuck. The vacuum chuck 242 may then be returned to the lowered wafer loading and unloading position by unclamping the locking device 136 from the piston 120 and venting the tube 127 to the atmosphere or drawing a vacuum therethrough.

The vacuum chuck 242 may be modified so that each of the first and second seal rings 200 and 244 is inflated by application of fluid pressure from the source of fluid pressure through a separate control valve, a separate flexible tube 223 passing through one of the apertures 224 or 228 in the cylindrical piston part 120a and a separate passageway 222 extending through the lower portion of the chuck plate 182 and communicating with the interior of the corresponding seal ring retainer 210 or 246. When so modified, the vacuum chuck 242 may also be operated in the same manner as the vacuum chuck 52 if the operator so desires.

Referring to Figure 7, there is shown another vacuum chuck 252 for use in an apparatus according to this invention. The vacuum chuck 252 may also be employed in the optical alignment and contact printing apparatus 10 of Figure 1 in place of the vacuum chuck 52. It includes a circular chuck plate 254 coaxially supported by a cylindrical part 256 which is in turn coaxially supported within a modified cylindri-

cal piston part 120a. The chuck plate 254 is provided with a central downwardly-extending stem 258 secured to a bearing member 260, with a plurality of interconnected radial grooves 262 formed in the upper surface of the chuck plate and covered by a concentric perforated circular top plate 264, with an axial bore 266 longitudinally extending through the stem 258 and communicating with the radial grooves 262, and with a seal ring 267 fixedly mounted around a peripheral portion 268 of the chuck plate and in slidable fluid-tight engagement with the inner wall of the peripheral portion 131 of the modified piston part 120a.

The bearing member 260 comprises a section of a sphere seated in a central conically-recessed portion 269 of the cylindrical part 256 so that the centre of radius of the bearing member is located at the centre of the perforated top plate 264, so that clearance space is provided between the chuck plate 254 and the rest of the cylindrical part 256 and between the chuck plate 254 and the modified piston part 120a, and so that the upper surface of the vacuum chuck 252 lies in substantially the same plane as the upper surface of the peripheral portion 131 of the modified piston part 120a and the upper surface of the top plate 132 when the vacuum chuck 252 is in the lowered, wafer loading and unloading position. This permits the vacuum chuck 252 to pivot about its vertical axis in any horizontal direction as required for parallel plane alignment and facilitates loading and unloading of the wafer 54.

Once loaded onto the vacuum chuck 252, the wafer 54 is held in place thereon by drawing a vacuum through the perforated top plate 264, the radial grooves 262 and the axial bore 266 in the chuck plate 254, an axial bore 270 extending through the cylindrical part 256, a fitting 272, and a flexible tube 274. This is accomplished by actuating the sixth control valve 197 to connect the tube 274 to the source of vacuum. The vacuum drawn through the tube 274 also increases the frictional engagement between the bearing member 260 and the central conically-recessed portion 269 of the cylindrical part 256. This frictional engagement is sufficient to maintain the vacuum chuck 252 in whatever position it may be pivoted to during parallel plane alignment of the adjacent surfaces of the wafer 54 and the mask 22 and to clamp the vacuum chuck 252 and the cylindrical part 256 together.

The cylindrical part 256 and, hence, the vacuum chuck 252 are supported upon the piston 120 by abutment of an annular upper portion 276 of the cylindrical part 256 upon an upper portion 278 of the modified piston part 120a. In addition, the cylindrical part 256 is mechanically coupled to the piston 120

by a plurality of flat springs 280 symmetrically attached between the upper portion 276 of the cylindrical part 256 and the upper portion 278 of the modified piston part 120a and by a plurality of flat springs 282 symmetrically attached between a lower end 284 of the cylindrical part 256 and an annular lower portion 286 of the modified piston part 120a. The flat springs 280 and 282 prevent relative movement between the cylindrical part 256 and the modified piston part 120a except by a limited amount of about .002 or less of an inch along a common vertical axis 288.

A first inflatable seal ring 290 of the same type as the seal rings 200 and 244 described above in connection with Figures 1-6 is fixedly mounted in an annular channel 292 formed in the peripheral portion 131 of the modified piston part 120a around the chuck plate 254. The first inflatable seal ring 290 is held in place by a retainer 294 in the same manner as described above in connection with the inflatable seal rings 200 and 244 and is also normally deflated and retracted from the plane of the wafer bearing upper surface of the vacuum chuck 252 so as not to interfere with wafer loading and unloading in the plane of this wafer bearing surface.

When the vacuum chuck 252 is driven upward to the raised parallel plane alignment and contact printing position by the piston 120 in preparation for contact printing, the first seal ring 290 is inflated to sealingly engage an unused marginal portion of the mask 22. The seal ring 290 is inflated by applying fluid pressure to the interior of the seal ring retainer 294 through a passageway 296 extending through the upper portion 278 of the modified piston part 120a and communicating with the interior of the seal ring retainer 294 and with a flexible tube 298 passing through a circular aperture 300 in the lower portion 286 of the modified piston part 120a. This is accomplished by actuating the seventh control valve 225 to connect the tube 298 to the source of fluid pressure. The region enclosed between the mask 22, the seal ring 290, the peripheral portion 131 of the modified piston part 120a, the seal ring 267, and the vacuum chuck 252 is then evacuated. The enclosed region is evacuated through a passageway 302 extending through the chuck plate 254, communicating with the upper surface of the chuck plate between the outer periphery of the chuck plate and both the perforated top plate 264 and the wafer 54 supported thereon, and communicating with a flexible tube 304 passing through circular apertures 306 in the upper and lower portions 278 and 286 respectively of modified piston part 120a and passing through a slot 308 in the cylindrical wall 118 of the chuck holder. This is accomplished by actuating

the eighth control valve 229 to connect the tube 304 to the source of fluid pressure. Evacuation of the enclosed region clamps the vacuum chuck 252, the wafer 54 supported thereon, and the mask 22 together thereby holding the mask and the wafer in intimate contact for contact printing.

Once the vacuum chuck 252, the wafer 54, and the mask 22 are clamped together, the tube 127 and, hence, the chamber 124 may be vented to the atmosphere to remove the fluid drive pressure from the piston 120 and the vacuum chuck 252 thereby equalizing the pressure applied to the mask 22 and the wafer 54. As long as fluid pressure continues to be applied through the tube 298 and vacuum continues to be drawn through the tubes 304 and 274, the vacuum chuck 252 and the cylindrical part 256 will remain in the raised contact printing position with the vacuum chuck 252 and the wafer 54 supported thereon clamped to the mask 22 and with the cylindrical part 256 clamped to the vacuum chuck 252. The flat springs 280 and 282 attached between the cylindrical part 256 and the modified piston part 120a will prevent the piston 120 from travelling downward to the intermediate pattern alignment position.

When the contact printing operation is finished the vacuum chuck 252 and the wafer 54 supported thereon are returned to the lowered wafer loading and unloading position by actuating the seventh and eighth control valves 225 and 229 to vent the tubes 298 and 304 to the atmosphere thereby unclamping the vacuum chuck 252 and the wafer 54 supported thereon from the mask 22, by actuating the fifth control valve 147 to vent the tube 146 to the atmosphere thereby unclamping the locking device 136 from the piston 120, and by actuating the fourth control valve 129 to vent the tube 127 to the atmosphere (if not already done) or connect it to the source of vacuum thereby lowering the piston 120 and, hence, the vacuum chuck 252 and the wafer 54 supported thereon. Once the vacuum chuck 252 and the wafer 54 supported thereon are returned to the lowered wafer loading and unloading position, the sixth control valve 197 is actuated to vent the tube 274 to the atmosphere and thereby permit sliding movement of the wafer across the upper surface of the vacuum chuck.

Referring now to Figure 8, there is shown another vacuum chuck 312 for use in an apparatus according to this invention. The vacuum chuck 312 may be employed in the optical alignment and contact printing apparatus 10 of Figure 1 in place of the vacuum chuck 52. In addition to the parts described above in connection with the vacuum chuck 252 of Figure 7 and therefore represented in Figure 8 by the same reference

numerals used for them in Figure 7, the vacuum chuck 312 includes a second inflatable seal ring 314 of the same type as the first inflatable seal ring 290. The second inflatable seal ring 314 is fixedly mounted in an annular channel 316 formed in the wafer bearing upper surface of the peripheral portion 268 of the chuck plate 254 around the perforated top plate 264 and beneath a peripheral portion of the lower surface of the wafer 54. It is held in place by a retainer 318 in the same manner as the first inflatable seal ring 290 and is also normally deflated and retracted from the wafer bearing upper surface of the chuck plate 254 so as not to interfere with wafer loading and unloading in the plane of this wafer bearing surface when the vacuum chuck 312 is in the lowered wafer loading and unloading position.

When the vacuum chuck 312 and the wafer 54 supported thereon are driven upward to the raised parallel plane alignment and contact printing position by the piston 120 in preparation for contact printing, the first inflatable seal ring 290 is inflated to sealingly engage an unused marginal portion of the lower surface of the mask 22 in the same manner as described above in connection with the vacuum chuck 252 of Figure 7. Concomitantly, the second inflatable seal ring 314 is inflated to sealingly engage a concentric peripheral portion of the lower surface of the wafer 54 by applying fluid pressure through a passageway 320 formed in the peripheral portion 268 of the chuck plate 254 and communicating with the interior of the seal ring retainer 318 and with a flexible tube 322 passing through the apertures 306 in the upper and lower portions 278 and 286 of the modified piston part 120a and the slot 308 in the cylindrical wall 118 of the chuck holder. This is accomplished by actuating a ninth control valve 324 to connect the tube 322 to the source of fluid pressure. The region enclosed between the mask 22, the first inflatable seal ring 290, the peripheral portion 131 of the modified piston part 120a, the seal ring 267, the portion of the vacuum chuck 312 between the seal rings 267 and 314, the second inflatable seal ring 314, and the wafer 54 is thereupon evacuated. This is accomplished by actuating the eighth control valve 229 to connect the tube 304 and, hence, the enclosed region to the source of vacuum. Evacuation of the enclosed region clamps the vacuum chuck 312, the wafer 54 supported thereon, and the mask 22 together thereby holding the mask and the wafer in intimate contact for contact printing.

Once the vacuum chuck 312, the wafer 54, and the mask 22 are clamped together, the fourth and sixth control valves 129 and 197 may be actuated to vent the tubes 127 and 196 to the atmosphere thereby removing

both the fluid drive pressure applied to the piston 120, and hence, the vacuum chuck 312 and the vacuum applied to the lower surface of the wafer 54. This equalizes the pressure applied to the upper surface of the mask 22 and the lower surface of the wafer 54. When both the fluid drive pressure applied to the piston 120 and the vacuum applied to the lower surface of the wafer 54 are removed, the piston 120 and the cylindrical part 256 both travel downward to the intermediate pattern alignment position where the locking device 136 which is then clamped to the piston by application of fluid pressure to the tube 146, abuts upon the adjustable stop ring 150. However, the vacuum chuck 312 and the wafer 54 supported thereon remain clamped to the mask 22 in the raised contact printing position as long as fluid pressure continues to be applied through the tubes 298 and 322 and vacuum continues to be drawn through the tube 304. Once the contact printing operation is finished, the vacuum chuck 312 and the wafer 54 may be unclamped from the mask 22 and returned to the lowered wafer loading and unloading position in the same manner as described above in connection with the vacuum chuck 242 of Figures 5 and 6.

WHAT WE CLAIM IS:—

1. Apparatus for use in optically aligning a first element with respect to a second element and for clamping the first and second elements together after they are aligned, said apparatus comprising first means for holding the first element on an element bearing surface of the first means; second means for holding the second element; one of said first and second means being movable relative to the other; third means for relatively moving the first and second means in substantially parallel planes to align the first element with respect to the second element; fourth means normally retracted from the element bearing surface of the first means and operable for sealingly engaging both the first means and one of the second means and the second element around the first element; and fifth means for at least partially evacuating a region enclosed between the first means, the second element, and the fourth means to clamp the first and second elements together after they are aligned.

2. Apparatus according to claim 1 wherein said fourth means is supported by one of the first and second means and is normally retracted from the element bearing surface of the first means to permit the first element to be loaded onto and unloaded from the first means along the element bearing surface thereof.

3. Apparatus according to either one of claims 1 and 2 and further comprising sixth means normally retracted from the element bearing surface of the first means and oper-



numerals used for them in Figure 7, the vacuum chuck 312 includes a second inflatable seal ring 314 of the same type as the first inflatable seal ring 290. The second inflatable seal ring 314 is fixedly mounted in an annular channel 316 formed in the wafer bearing upper surface of the peripheral portion 268 of the chuck plate 254 around the perforated top plate 264 and beneath a peripheral portion of the lower surface of the wafer 54. It is held in place by a retainer 318 in the same manner as the first inflatable seal ring 290 and is also normally deflated and retracted from the wafer bearing upper surface of the chuck plate 254 so as not to interfere with wafer loading and unloading in the plane of this wafer bearing surface when the vacuum chuck 312 is in the lowered wafer loading and unloading position.

When the vacuum chuck 312 and the wafer 54 supported thereon are driven upward to the raised parallel plane alignment and contact printing position by the piston 120 in preparation for contact printing, the first inflatable seal ring 290 is inflated to sealingly engage an unused marginal portion of the lower surface of the mask 22 in the same manner as described above in connection with the vacuum chuck 252 of Figure 7. Concomitantly, the second inflatable seal ring 314 is inflated to sealingly engage a concentric peripheral portion of the lower surface of the wafer 54 by applying fluid pressure through a passageway 320 formed in the peripheral portion 268 of the chuck plate 254 and communicating with the interior of the seal ring retainer 318 and with a flexible tube 322 passing through the apertures 306 in the upper and lower portions 278 and 286 of the modified piston part 120a and the slot 308 in the cylindrical wall 118 of the chuck holder. This is accomplished by actuating a ninth control valve 324 to connect the tube 322 to the source of fluid pressure. The region enclosed between the mask 22, the first inflatable seal ring 290, the peripheral portion 131 of the modified piston part 120a, the seal ring 267, the portion of the vacuum chuck 312 between the seal rings 267 and 314, the second inflatable seal ring 314, and the wafer 54 is thereupon evacuated. This is accomplished by actuating the eighth control valve 229 to connect the tube 304 and, hence, the enclosed region to the source of vacuum. Evacuation of the enclosed region clamps the vacuum chuck 312, the wafer 54 supported thereon, and the mask 22 together thereby holding the mask and the wafer in intimate contact for contact printing.

Once the vacuum chuck 312, the wafer 54, and the mask 22 are clamped together, the fourth and sixth control valves 129 and 197 may be actuated to vent the tubes 127 and 196 to the atmosphere thereby removing

both the fluid drive pressure applied to the piston 120, and hence, the vacuum chuck 312 and the vacuum applied to the lower surface of the wafer 54. This equalizes the pressure applied to the upper surface of the mask 22 and the lower surface of the wafer 54. When both the fluid drive pressure applied to the piston 120 and the vacuum applied to the lower surface of the wafer 54 are removed, the piston 120 and the cylindrical part 256 both travel downward to the intermediate pattern alignment position where the locking device 136 which is then clamped to the piston by application of fluid pressure to the tube 146, abuts upon the adjustable stop ring 150. However, the vacuum chuck 312 and the wafer 54 supported thereon remain clamped to the mask 22 in the raised contact printing position as long as fluid pressure continues to be applied through the tubes 298 and 322 and vacuum continues to be drawn through the tube 304. Once the contact printing operation is finished, the vacuum chuck 312 and the wafer 54 may be unclamped from the mask 22 and returned to the lowered wafer loading and unloading position in the same manner as described above in connection with the vacuum chuck 242 of Figures 5 and 6.

WHAT WE CLAIM IS:—

1. Apparatus for use in optically aligning a first element with respect to a second element and for clamping the first and second elements together after they are aligned, said apparatus comprising first means for holding the first element on an element bearing surface of the first means; second means for holding the second element; one of said first and second means being movable relative to the other; third means for relatively moving the first and second means in substantially parallel planes to align the first element with respect to the second element; fourth means normally retracted from the element bearing surface of the first means and operable for sealingly engaging both the first means and one of the second means and the second element around the first element; and fifth means for at least partially evacuating a region enclosed between the first means, the second element, and the fourth means to clamp the first and second elements together after they are aligned.

2. Apparatus according to claim 1 wherein said fourth means is supported by one of the first and second means and is normally retracted from the element bearing surface of the first means to permit the first element to be loaded onto and unloaded from the first means along the element bearing surface thereof.

3. Apparatus according to either one of claims 1 and 2 and further comprising sixth means normally retracted from the element bearing surface of the first means and oper-



able for sealingly engaging both the first means and a peripheral portion of the first element; said fifth means being operable for at least partially evacuating a region enclosed between the fourth means, the sixth means, a portion of the first means between the fourth and sixth means, the first element, and the second element to clamp the first and second elements together after they are aligned.

4. Apparatus as in claim 3 wherein the fourth and sixth means are supported by one of the first and second means and are normally retracted from the element bearing surface of the first means to permit the first element to be loaded onto and unloaded from the first means along the element bearing surface thereof.

5. Apparatus as in claim 1 wherein the first means comprises a chuck for holding a workpiece comprising the first element on a plane workpiece bearing surface of the chuck; the second means comprises a holder for holding a mask comprising the second element; the first means further comprises drive means for supporting the chuck and for moving the chuck between a first position away from the holder and a second position closer to the holder; the fourth means comprises a first seal supported by one of the chuck and the drive means around the workpiece, but normally retracted from the plane of the workpiece bearing surface of the chuck; the first seal is operable for sealingly engaging both said one of the chuck and the drive means and one of the holder and the mask around the workpiece when the chuck is in the second position; the fifth means comprises a conduit communicating with the region enclosed between the chuck, the mask, and the first seal when it sealingly engages both said one of the chuck and the drive means and said one of the holder and mask around the workpiece; and the fifth means further comprises evacuating means coupled to the conduit for at least partially evacuating this region to clamp the workpiece and the mask together.

6. Apparatus according to claim 5 and further comprising a workpiece loading-and-unloading platform lying in substantially the same plane as the workpiece bearing surface of the chuck when the chuck is in the first position; the first seal normally being retracted from the plane of the workpiece bearing surface of the chuck to permit the workpiece to be loaded onto and unloaded from the chuck along and parallel to the plane of the workpiece loading-and-unloading platform and the workpiece bearing surface of the chuck when the chuck is in the first position.

7. Apparatus according to either one of claims 5 and 6 wherein the first seal comprises a first inflatable seal ring supported

by the chuck around the workpiece; means is provided for inflating the first inflatable seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position; and the evacuating means is operable for at least partially evacuating the region enclosed between the chuck, the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, and the mask to clamp the workpiece and the mask together.

8. Apparatus according to either one of claims 5 and 6 wherein the first seal comprises a first inflatable seal ring supported by the drive means around the workpiece; and inflating means is provided for inflating the first inflatable seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position.

9. Apparatus according to claim 8 and further comprising coupling means for preventing relative movement between the chuck and the drive means except by a limited amount along a common vertical axis; and sealing means supported by one of the chuck and the drive means for slidably sealingly engaging the other of the chuck and the drive means; the evacuating means being operable for at least partially evacuating a region enclosed between the drive means, the sealing means, the chuck, the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, and the mask to clamp the workpiece and the mask together.

10. Apparatus according to claim 9 wherein the chuck comprises a first member for holding the workpiece on a plane workpiece bearing surface of the first member; the chuck further comprises a second member for supporting the first member; the coupling means comprises means for clamping the first and second members together; the coupling means further comprises one or more spring elements attached to both the second member and the drive means for preventing relative movement therebetween except by a limited amount along the common vertical axis; and the sealing means comprises a seal ring supported by the first member for slidably sealingly engaging the drive means.

11. Apparatus according to claim 5 and further comprising a second seal supported by the chuck, but normally retracted from the plane of the workpiece bearing surface of the chuck; the second seal being operable for sealingly engaging both the chuck and a peripheral portion of the workpiece when the chuck is in the second position; the conduit communicating with the region enclosed between the first seal when it sealingly engages both said one of the chuck and the drive means and said one of the holder and the mask, the second seal when it sealingly en-



gages both the chuck and the peripheral portion of the workpiece, a portion of the chuck between the first and second seals, the workpiece and the mask to clamp the workpiece and the mask together; and the evacuating means is operable for at least partially evacuating this region to clamp the workpiece and the mask together.

12. Apparatus according to claim 11 and further comprising a workpiece loading and unloading platform lying in substantially the same plane as the workpiece bearing surface of the chuck when the chuck is in the first position; the first and second seals normally being retracted from the plane of the workpiece bearing surface of the chuck to permit the workpiece to be loaded onto and unloaded from the chuck along and parallel to the plane of the workpiece loading and unloading platform and the workpiece bearing surface of the chuck when the chuck is in the first position.

13. Apparatus according to either one of claims 11 and 12 wherein the first seal comprises a first inflatable seal ring supported by the chuck around the workpiece; the second seal comprises a second inflatable seal ring supported by the chuck within the first inflatable seal ring and adjacent to the peripheral portion of the workpiece; and the apparatus further comprises inflating means for inflating the first inflatable seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position and for inflating the second inflatable seal ring to sealingly engage the peripheral portion of the workpiece when the chuck is in the second position; and the evacuating means is operable for at least partially evacuating a region enclosed between the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, the second inflatable seal ring when it is inflated to sealingly engage the peripheral portion of the workpiece, a portion of the chuck between the first and second inflatable seal rings, the workpiece, and the mask to clamp the workpiece and the mask together.

14. Apparatus according to either one of claims 11 and 12 wherein the first seal comprises a first inflatable seal ring supported by the drive means around the workpiece; the second seal comprises a second inflatable seal ring supported by the chuck within the first inflatable seal ring and adjacent to the peripheral portion of the workpiece; and the apparatus further comprises inflating means for inflating the first inflatable seal ring to sealingly engage a marginal portion of the mask when the chuck is in the second position and for inflating the second inflatable seal ring to sealingly engage the peripheral portion of the workpiece when the chuck is in the second position.

15. Apparatus according to claim 14 and further comprising coupling means for preventing relative movement between the chuck and the drive means except by a limited amount along a common axis; and sealing means supported by one of the chuck and drive means for slidably sealingly engaging the other of the chuck and drive means; said evacuating means being operable for at least partially evacuating a region enclosed between the first inflatable seal ring when it is inflated to sealingly engage the marginal portion of the mask, the second inflatable seal ring when it is inflated to sealingly engage the peripheral portion of the workpiece, a portion of the drive means and the chuck between the first and second inflatable seal rings, the sealing means, the workpiece, and the mask to clamp the workpiece and the mask together.

16. Apparatus according to claim 15 wherein the chuck comprises a first member for holding the workpiece on a plane workpiece bearing surface of the first member; the chuck further comprises a second member for supporting the first member; the coupling means comprises means for clamping the first and second members together, the coupling means further comprises one or more spring elements attached to both the second member and the drive means for preventing relative movement therebetween except by a limited amount along the common vertical axis; and the sealing means comprises a seal ring supported by the first member for slidably sealingly engaging the drive means.

17. Apparatus according to any one of claims 5 to 16 wherein and further comprising a base; the holder being mounted on the base; the drive means being mounted on the base under the holder for vertical movement relative to the holder; the chuck being supported by the drive means under the holder for pivotal movement to orient a first surface of the workpiece and an adjacent first surface of the mask in substantially parallel planes and for vertical movement between the first position at which the workpiece is separated from the mask and the second position at which the first surface of the workpiece and the adjacent first surface of the mask are positioned in contact; the third means being operable for relatively moving the chuck and the holder in substantially parallel planes when the chuck is in a third position between the first and second positions to align the workpiece with respect to the mask; optical means for viewing the workpiece and the mask held by the chuck and the holder, respectively, while the workpiece and the mask are being aligned; and exposure means for exposing a photo-sensitive film on the first surface of the workpiece through the mask after the workpiece



and the mask are aligned and while they are clamped together.

18. Apparatus according to any one of claims 5 to 17 wherein the chuck is a wafer chuck for holding a semiconductor wafer comprising the workpiece on a plane workpiece bearing surface of the wafer chuck; and said holder is arranged to hold the mask.

- 10 19. Apparatus for use in aligning a first

element with respect to a second element and for clamping the first and second elements together after they are aligned, substantially as hereinbefore described with reference to the accompanying drawings.

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