

[54] **APPARATUS AND METHOD FOR HANDLING AND TREATING ARTICLES**

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[51] Int. Cl. B65g 51/02, B65g 60/00

[58] Field of Search 302/29, 31, 2, 11; 221/81, 221/236, 278, 88; 271/74; 198/19, 20; 214/16.4 R, 1 BT

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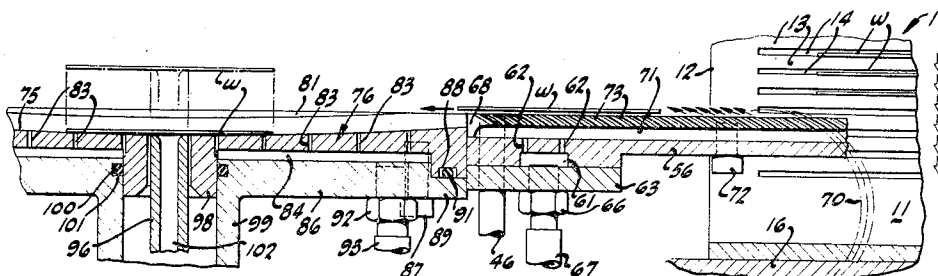
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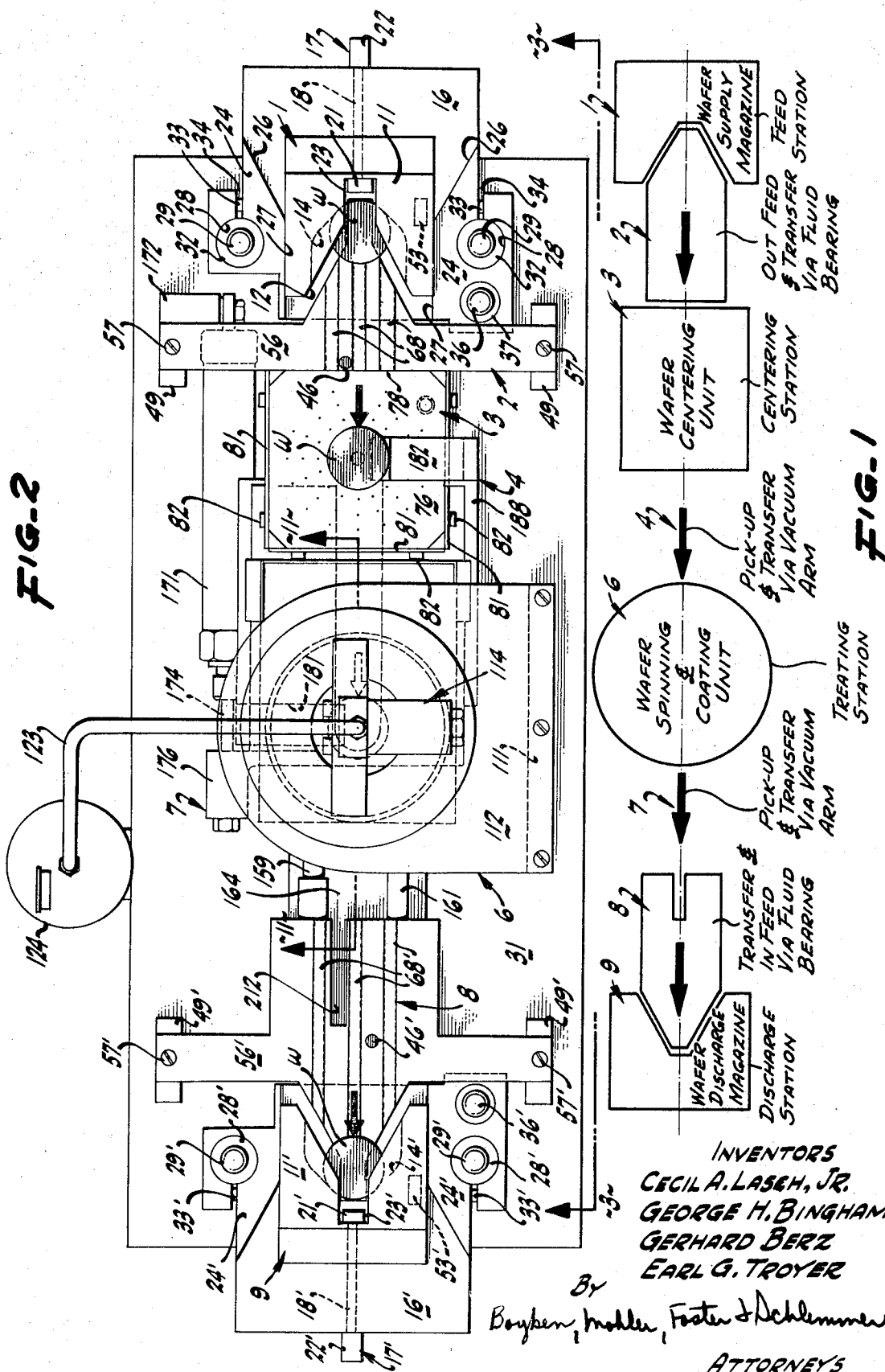
[57] **ABSTRACT**

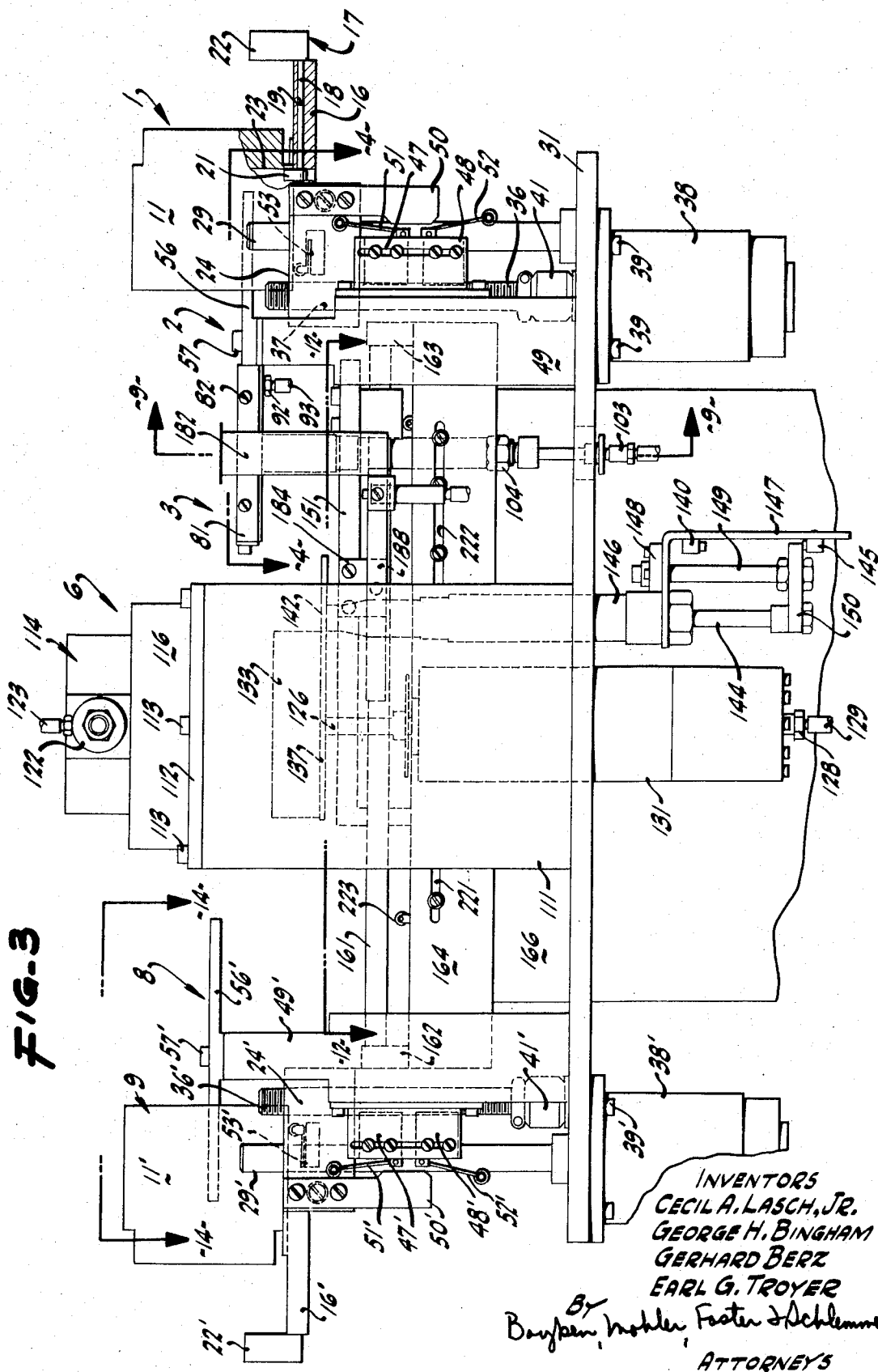
Improved apparatus and method for transporting articles and for centering articles in sequence by means of fluid-bearing devices. The apparatus and method disclosed have particular utility in the handling and treatment of fragile articles, such as silicon wafers, but their utility is not restricted to such use. After centering, the articles are transferred by vacuum means to a spinning unit at which the articles are treated, as by coating the same with a liquid product, such as a photoresist material. Transfer from the spinning unit is by vacuum means.

In a substantially continuous procedure, articles to be treated are withdrawn in sequence from a supply magazine by fluid-bearing structure, moved through the centering and treating steps, and deposited in a discharge magazine by fluid-bearing structure without manual handling during the procedure. The fluid-bearing structure of an alternative embodiment is provided with bidirectional capability.

52 Claims, 20 Drawing Figures







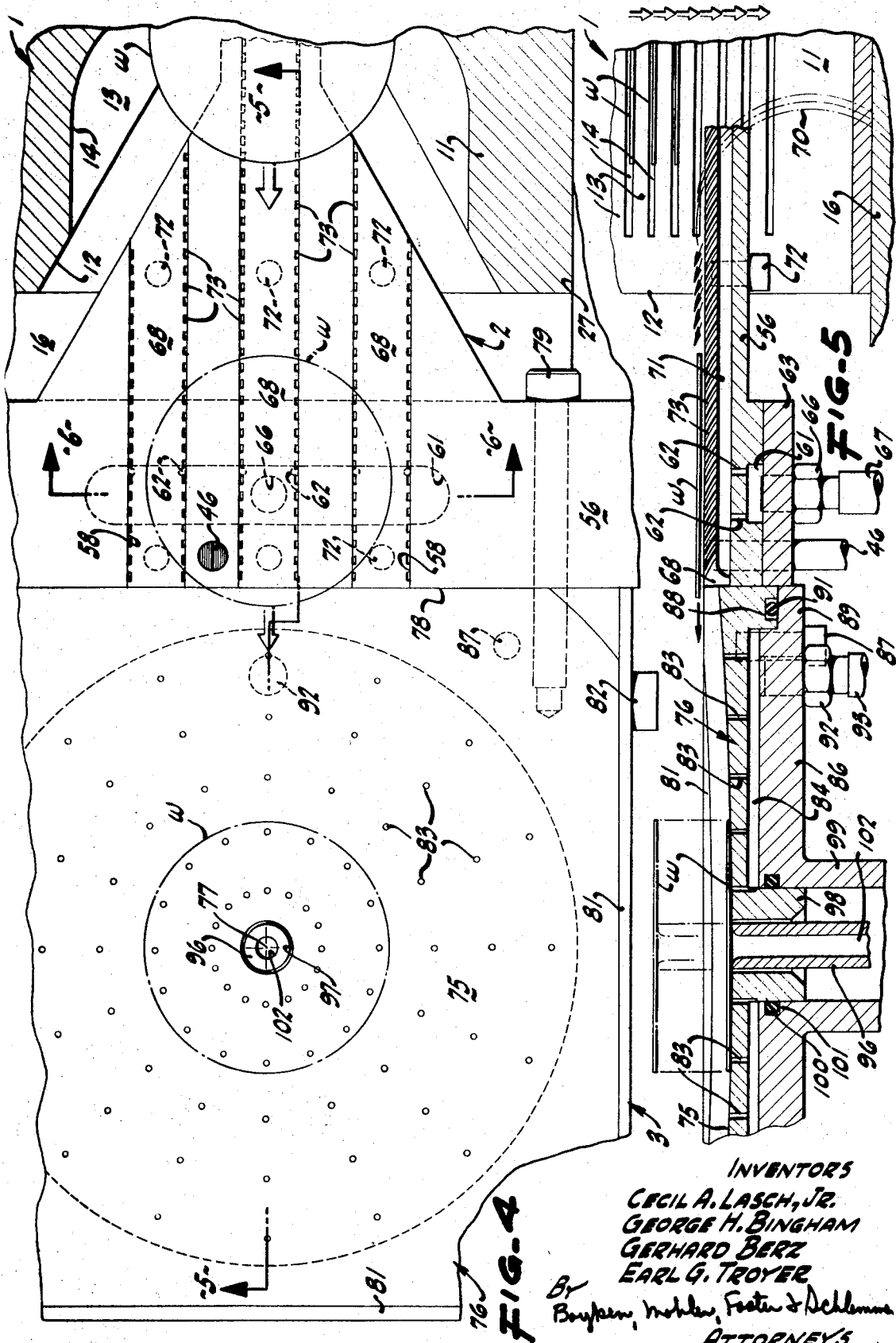


FIG. 4

FIG. 5

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FIG. 6

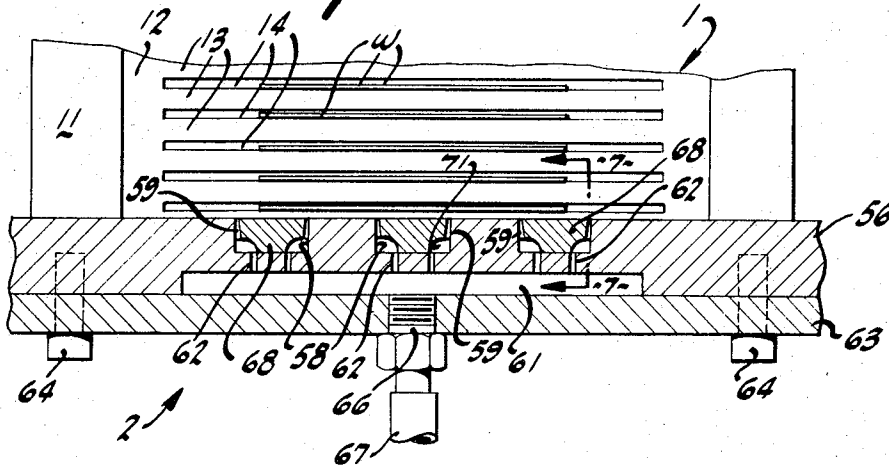


FIG. 9

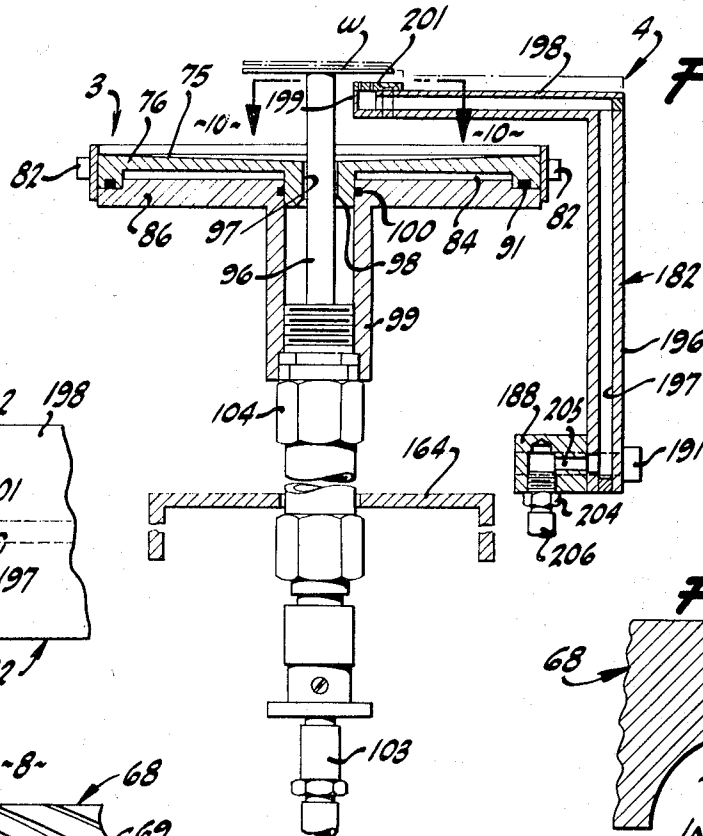


FIG. 10

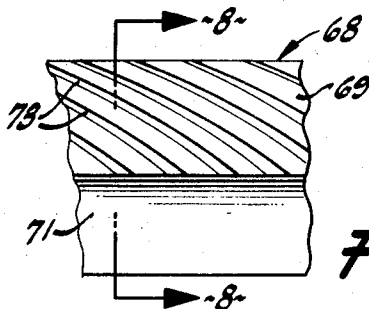
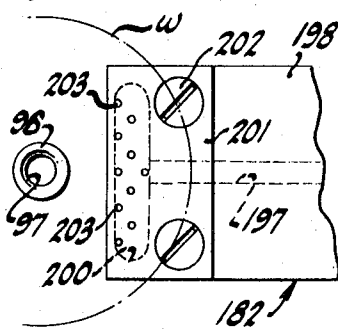
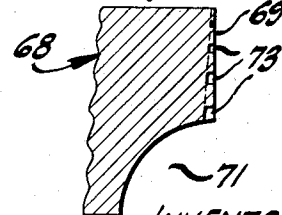


FIG. 7

FIG. 8



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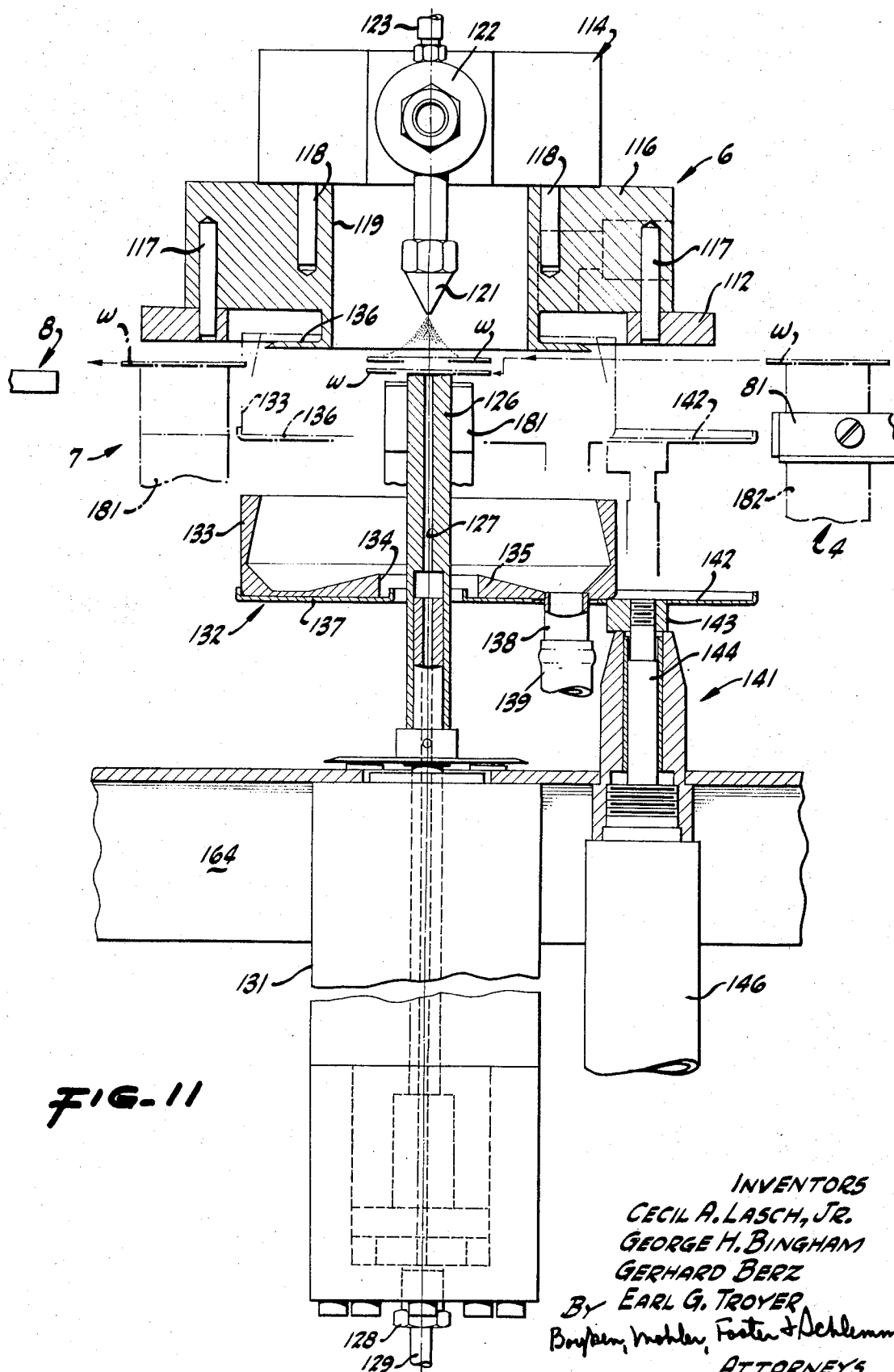


FIG. 11

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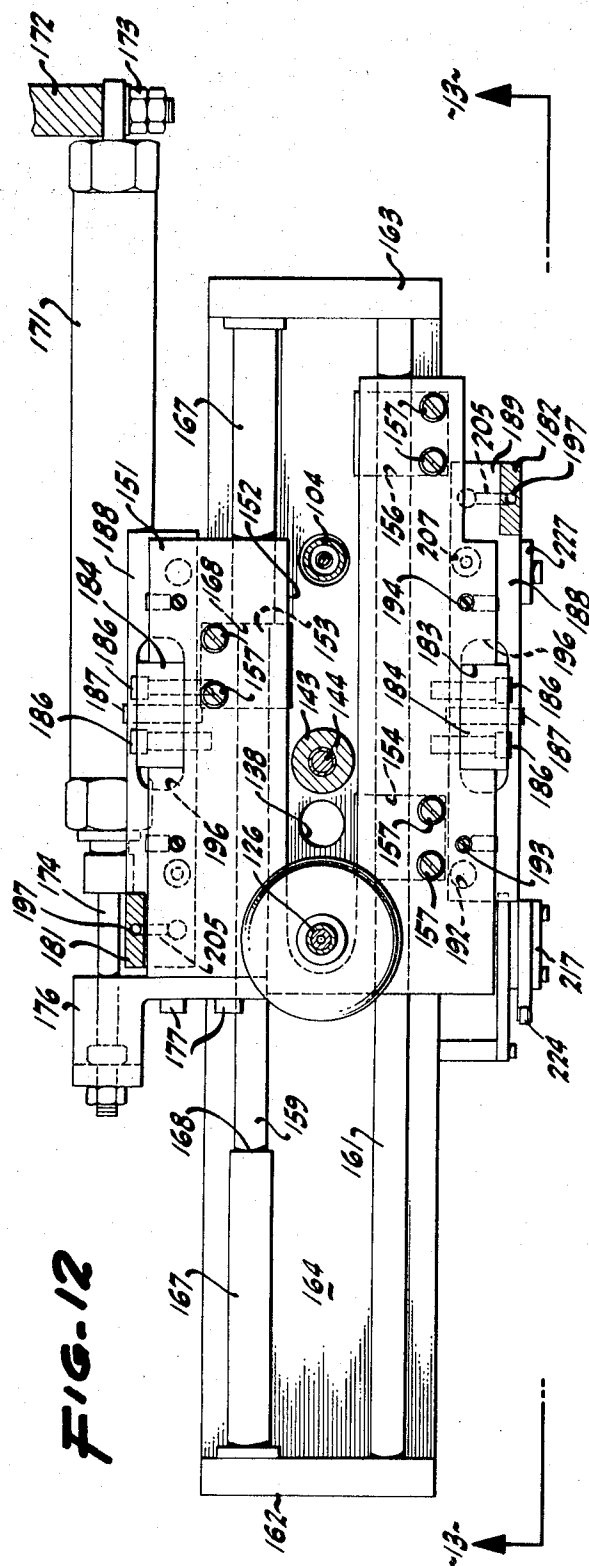


FIG-12

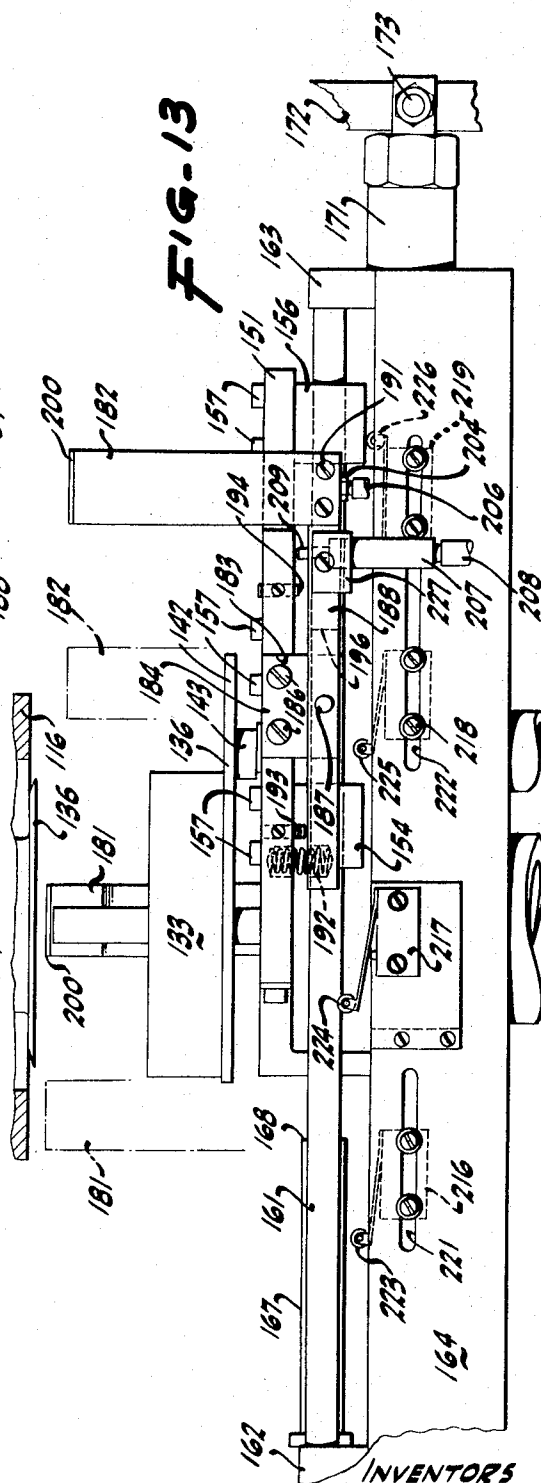


FIG-13

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FIG. 16

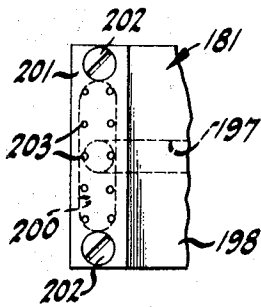


FIG. 14

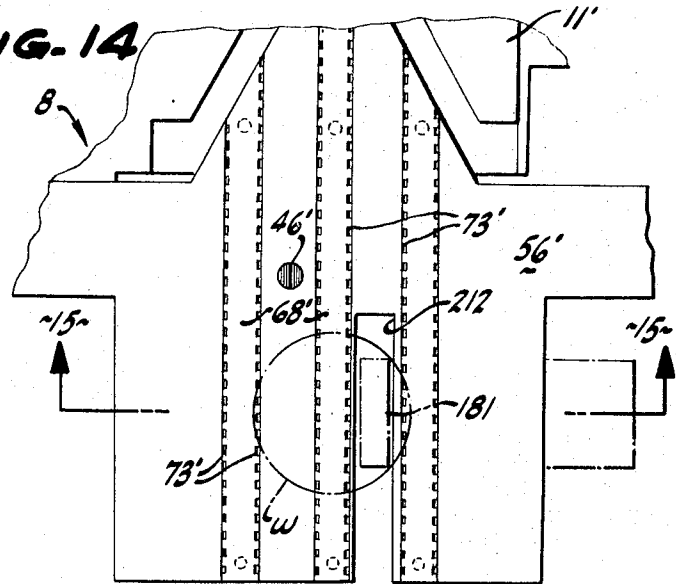


FIG. 19

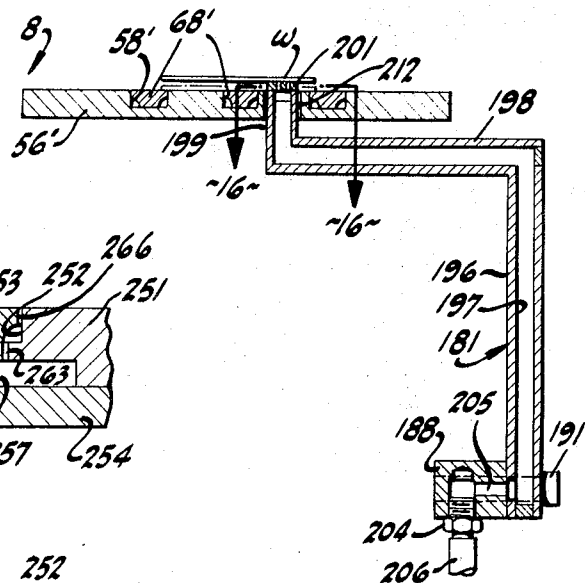
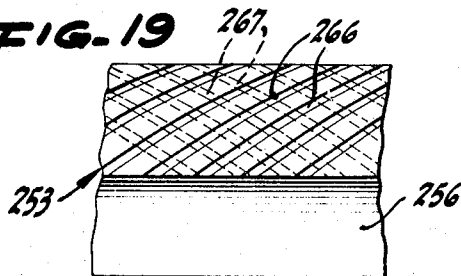


FIG. 18

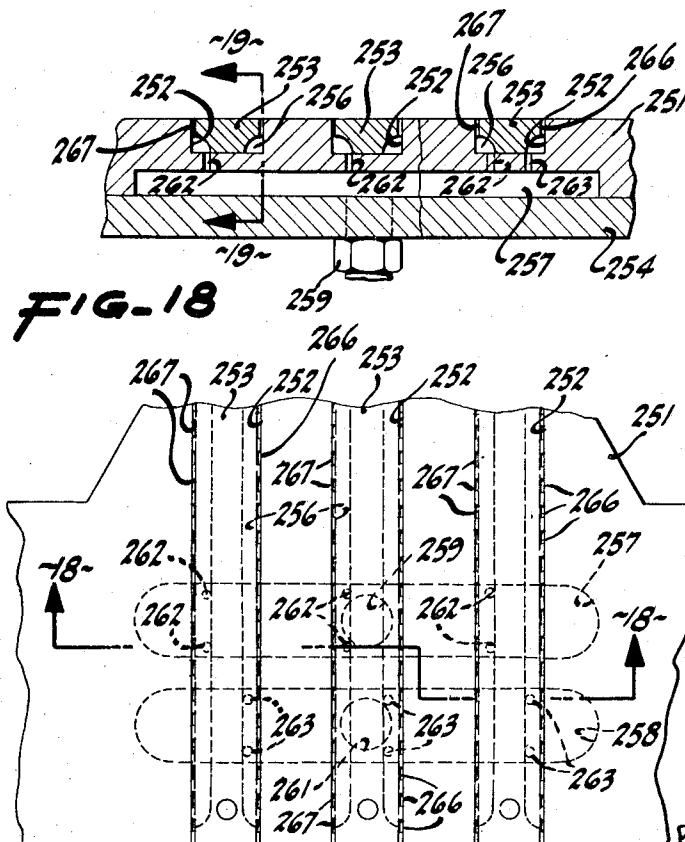


FIG. 17

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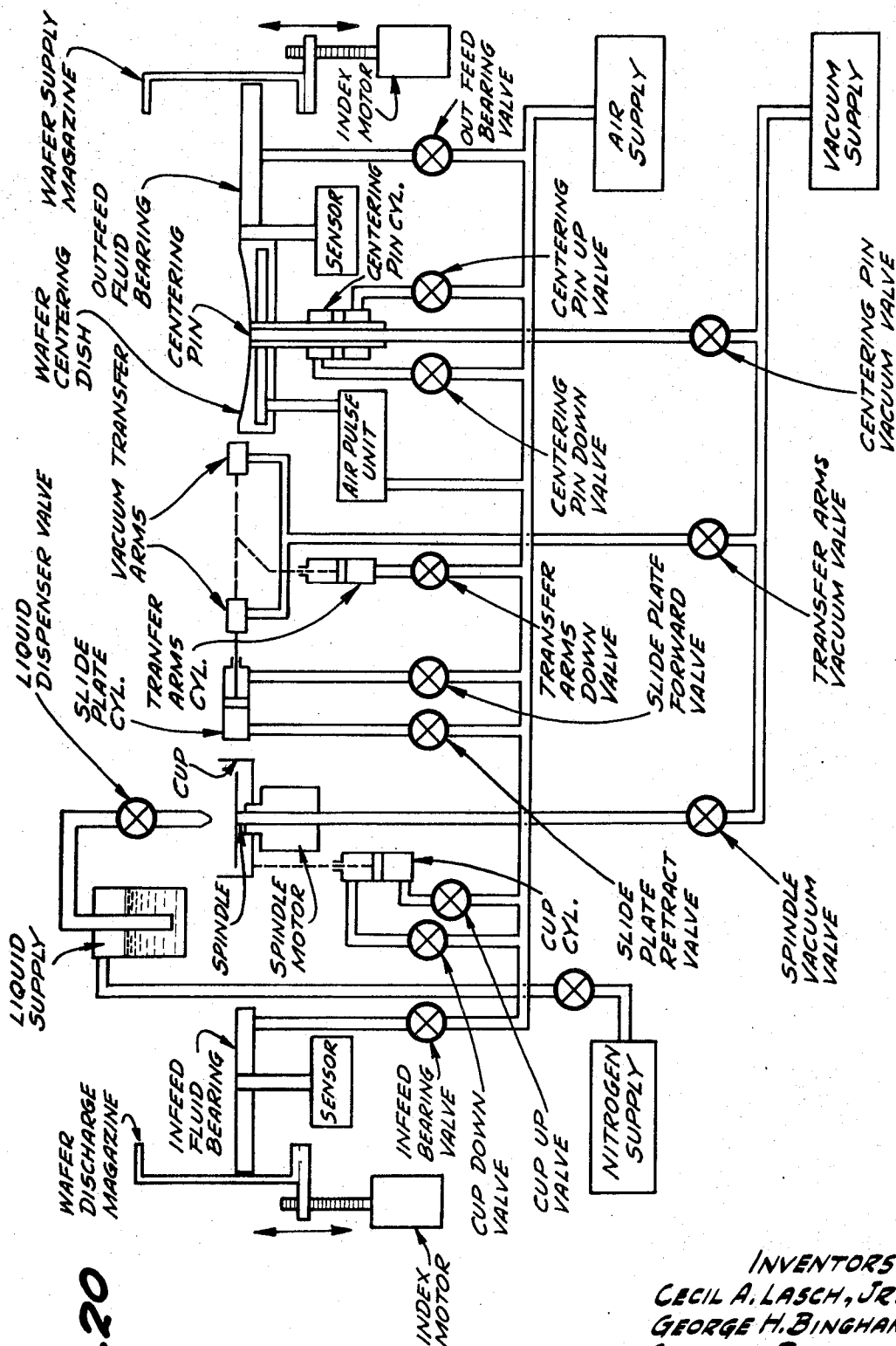


FIG. 20

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APPARATUS AND METHOD FOR HANDLING AND TREATING ARTICLES

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an apparatus and method for handling articles, particularly articles of a fragile nature. More particularly, this invention in the embodiment disclosed herein relates to apparatus and method for handling and treating fragile articles, such as silicon wafers commonly used in the electronics industry in the manufacture of integrated circuits, transistors and the like, between predetermined locations at which various operations are performed thereon in sequence.

Still more particularly, this invention relates to improved fluid-bearing means, of the pneumatic type, for transporting articles and, when such means is incorporated into an integrated apparatus, for centering such articles to facilitate subsequent treatment thereof. In an alternative embodiment, such fluid-bearing means includes bidirectional capability to permit selective movement of the articles in two directions relative to a predetermined location.

This invention furthermore relates to improved supply magazine and discharge magazine structure from which, and into which, articles may be automatically unloaded and loaded by fluid bearing means associated therewith. Magazine indexing means is provided in conjunction with the out-feed and in-feed fluid-bearing structures.

This invention also relates to an improved mechanism for coating articles, such as fragile silicon wafers, with a fluid material, such as a photoresist material known and heretofore used in the electronics industry in the manufacture of components above noted.

In its broader aspects, this invention relates to means and procedures for handling articles of various types by means of improved fluid-bearing structures for performing various functions on such articles, such as for moving the same from one point to another or for centering the same in preparation for subsequent treating operations.

In its more specific aspects, this invention relates to improved fluid-bearing wafer transporting means and fluid-bearing wafer centering means, combined with wafer supply magazine and discharge magazine structures which are automatically indexed to permit out-feed and in-feed therefrom, coupled with vacuum transfer mechanisms and a wafer coating unit to provide an integrated wafer handling and coating apparatus and procedure.

Description of The Prior Art

In the electronics industry, mechanisms for applying a liquid coating, such as a photoresist material, to an article, such as a silicon wafer, have been generally known heretofore. However, with prior known coating procedures, articles to be treated generally have required manual handling, normally by using vacuum pickup devices or tweezers, usually in a one-at-a-time procedure. Heretofore, so far as is known, a spinning and coating mechanism has not been incorporated as an integral part of an overall apparatus for the handling and coating of articles, such as silicon wafers, without requiring any manual intermediate handling thereof.

The apparatus and method of this invention have been devised to incorporate into a single integrated apparatus those handling and treating procedures heretofore accomplished manually, thereby eliminating intermediate manual handling to facilitate manufacture of articles, such as electronic components, and thereby speed up their manufacture and reduce their unit cost.

Fluid-bearing devices of various types have been generally known heretofore, and the following U.S. Pats. Nos. disclose devices which are exemplary of the prior art: Hazel 2,778,691 dated Jan. 22, 1957; Cole 3,103,388 dated Sept. 10, 1963; and Coville 3,318,640 dated May 9, 1967. Prior known fluid-bearing structures of the type exemplified by these patents, however, do not contemplate or disclose the improved bearing features disclosed hereinafter.

Furthermore, while fragile articles, such as silicon wafers, have been transported in groups in magazines to protect such articles prior to or after treatment thereof, heretofore, loading and unloading of such magazines has been manually effected, such as by vacuum, tweezers or other suitable devices. So far as is known, the novel arrangement disclosed herein of employing fluid-bearing means to automatically unload or load articles, such as silicon wafers, into supply or discharge magazines has been unknown. The savings and convenience of such a handling procedure is very important in a fragile article-handling operation because of the virtual elimination of the danger of breakage of such articles which has been frequently encountered in prior manual handling operations.

Furthermore, with heretofore known procedures for treating silicon wafers in the electronics industry to coat the same with a photoresist material or the like, manual operations have been employed to place the articles on the spindle of a spinning device. Such manual operations required a value judgment as to whether the articles were properly centered on the spindle prior to rotation of the same. Such judgment frequently was inaccurate, because of understandable human error, thereby resulting in nonuniform coating or breakage. The present invention includes fluid-bearing means for automatically centering articles prior to their being placed on a rotating spindle so that proper article positioning is assured.

The numerous advantageous features of this invention are incorporated into a compact table-top supported machine in the embodiment illustrated. However, it should be understood that the respective inventive features disclosed herein also have applicability and utility independently of each other and in other handling and treating environments apart from the exemplary wafer-handling procedure disclosed herein.

SUMMARY OF THE INVENTION

The present invention relates to an apparatus and method for handling and treating articles. The invention as specifically disclosed herein relates to an apparatus and method for transporting fragile articles, such as silicon wafers, from one location to another during processing of such articles. Still more particularly, this invention relates to an apparatus and method in which articles, such as silicon wafers, are automatically fed from a supply source, such as from a supply magazine, and transported to a centering device; after centering, the articles are transported to a treating unit where the same are treated, such as by coating the same with a fluid material, such as a photoresist material; following such treatment, the articles are transported from the treating unit and are discharged, such as by loading the same automatically into a discharge magazine. All such operations are effected in sequence without requiring any intermediate manual handling.

In the apparatus illustrated herein, the various novel aspects of this invention are incorporated into a single machine capable of handling articles of varying sizes without requiring adjustment or modifications of the machine components. Silicon wafers commonly employed in the electronics industry for numerous known purposes are typical of the variable size articles which may be handled with the apparatus disclosed. However, utilization of the various novel features of this invention in other fields of endeavor is contemplated within the scope of this invention.

Specifically, novel improved fluid-bearing means preferably are used to transport articles in this invention, as well as to center such articles when centering is required in a given treating procedure. The utilization of improved fluid-bearing track structure to withdraw articles in sequence from a source of supply, such as a supply magazine, or to insert such articles into a discharge station, such as a discharge magazine, without manual handling is an important feature of this invention and has applicability in areas other than wafer handling. In conjunction with such magazine out-feed or in-feed procedures, magazine indexing mechanisms are provided.

The air-bearing centering unit, and the air-bearing track structure disclosed herein, are provided by structures which,

respectively, insure proper centering of articles of widely varying types and sizes fed thereto in sequence, and effective transportation of such articles relative to a reference location, either in a single directional or in a bidirectional relationship.

From the foregoing, it should be understood that objects of this invention include: the provision of improved fluid-bearing means for handling articles of various types and varied sizes; the provisions of improved fluid-bearing means particularly well suited for handling fragile articles, such as silicon wafers; the provision of means for centering articles of various types and varied sizes by utilizing fluid-bearing structure to effect centering; the provisions of improved treating means for coating articles, such as silicon wafers, and transfer mechanisms for introducing into and removing articles from such treating means; the provision, in combination, of fluid-bearing means for removing articles from or introducing articles into magazines or other reference stations; the provision of an improved mechanism for automatically indexing supply or discharge magazines to permit article movement relative thereto; the provision of an overall apparatus and method for automatically transferring articles, such as silicon wafers, through a series of steps without intermediate manually handling thereof; and the provision of an apparatus and method for handling and treating in sequence a series of articles, such as silicon wafers, to withdraw the same from a supply magazine or other source of supply, center the same, place the same on a spinning unit on which the same are coated with a material such as a photoresist material, to remove the articles from the spinning unit, and to insert the same into a discharge magazine.

These and other objects of the overall combination and sub-combinations of novel features disclosed herein will become apparent from a study of the following detailed disclosure in which reference is directed to the attached drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic flow diagram of the handling and treating procedure effected by the subject apparatus.

FIG. 2 is a plan view of the apparatus.

FIG. 3 is a side elevational view of the apparatus taken in the plane of line 3—3 of FIG. 2.

FIG. 4 is a partial plan view of the centering unit and out-feed fluid-bearing track structure taken in the plane of line 5—5 of FIG. 4.

FIG. 6 is a vertical sectional view through the out-feed fluid-bearing track structure taken in the plane of line 6—6 of FIG. 4.

FIG. 7 is a vertical sectional view through the track structure taken in the plane of line 7—7 of FIG. 6.

FIG. 8 is a vertical sectional view through a bar of the track structure taken in the plane of line 8—8 of FIG. 7.

FIG. 9 is a vertical sectional view through the centering unit taken in the plane line 9—9 of FIG. 3.

FIG. 10 is a partial plan view through the apparatus taken in the plane of line 10—10 of FIG. 9.

FIG. 11 is a vertical sectional view through the spinning unit of the apparatus taken in the plane of line 11—11 of FIG. 2.

FIG. 12 is a horizontal sectional view through a portion of the apparatus taken in the plane of line 12—12 of FIG. 3.

FIG. 13 is a side elevational view of that portion of the apparatus shown in FIG. 12 taken in the plane of line 13—13 of FIG. 12.

FIG. 14 is a partial plan view of the infeed fluid-bearing track structure taken in the plane of line 14—14 of FIG. 3.

FIG. 15 is a vertical sectional view through the infeed track structure taken in the plane of line 15—15 of FIG. 14.

FIG. 16 is a horizontal sectional view through the infeed track structure taken in the plane of line 16—16 of FIG. 15.

FIG. 17 is a plan view of an alternative fluid-bearing track structure having bidirectional capability.

FIG. 18 is a vertical sectional view through the alternative embodiment of FIG. 17 taken in the plane of the line 18—18 of FIG. 17.

FIG. 19 is a vertical sectional view through the alternative embodiment of FIG. 17 taken in the plane of line 19—19 of FIG. 18.

FIG. 20 is a schematic view of the valve control arrangement employed with the preferred embodiment of the apparatus illustrated.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As noted previously, the apparatus and method of this invention are disclosed herein with particular reference to the handling, transporting, and treatment of articles, such as thin, fragile silicon wafers of the type widely used in the electronics industry. However, it should be understood that use of the novel combination and subcombination invention is not restricted to the particular exemplary showing contained herein but that such features are readily adaptable for use in other fields in the handling, transporting or treating of various and varied articles. It should also be understood that the various features of this invention, while highly effective when combined to provide an integrated apparatus such as that described, have applicability independently of each other in the handling and treatment of articles as disclosed herein as well as others.

SUMMARY OF OPERATION

Referring first to the schematic showing of FIG. 1, the sequence of treatment of a series of articles, such as the exemplarily thin silicon wafers in preparation of the same for subsequent use and transformation into integrated circuits, transistors, and the like, will be described. A quantity of such wafers (each designated W in the drawings) numbering 20 or more, have been previously positioned in a supply magazine 1 in any known fashion. The wafer filled magazine 1 is manually or otherwise positioned at a feed station at which the magazine is vertically indexed in step fashion to present individual wafers sequentially at an out-feed position. Wafer withdrawing out-feed and transfer means, generally designated 2, in the form of a fluid-bearing track structure, preferably of the pneumatic type, removes individual wafers in sequence from the supply magazine and transfers the same to a centering unit, generally designated 3, positioned at an adjacent centering station. The centering unit comprises fluid-bearing structure, preferably of the pneumatic type, in which the wafers presented thereto in sequence have their centers located and oriented in a predetermined position, such position being maintained positively by pickup and transfer means, generally designated 4, during transfer of the wafers from the centering station.

The transfer means 4, preferably of the vacuum arm type, picks up and transports the wafers in sequence from the centering station to an adjacent treating station. At the latter station, a treating operation is performed on each successive wafer by a spinning and coating unit, designated 6. Such treating operation in the disclosed embodiment comprises a coating step performed by spinning each wafer as a measured quantity of fluid material, such as a photoresist liquid, is applied thereto and spread thereover by centrifugal force during spinning.

Following such coating, the wafers are picked up in sequence and transported by second pickup and transfer means, generally designated 7, which also preferably is of the vacuum arm type, toward a wafer discharge station. Such transfer means places the wafers in sequence on other transfer and infeed means, generally designated 8, provided adjacent the discharge station. The infeed means, in the form of a fluid-bearing track structure, preferably of the pneumatic type, moves the wafers in sequence to the discharge station.

At the discharge station, a discharge magazine 9 is positioned to receive the coated wafers therein for subsequent transfer as a group (manually or otherwise) to other treating stations during their subsequent transformation into electronics components. The discharge magazine is vertically indexed in step fashion to receive individual wafers presented

thereto in sequence by the infeed fluid-bearing track structure 8.

Upon emptying of all untreated wafers from the supply magazine 1 and filling of the discharge magazine 9 with treated wafers, new supply and discharge magazines are positioned in the apparatus and the cycle of operations described is repeated.

Details of the various cooperating components and units of the apparatus will now be described.

WAFER SUPPLY MAGAZINE STRUCTURE AND INDEXING MEANS

Reference is directed to FIGS. 1 through 6 for an illustration of the components of the apparatus employed at the wafer feed station. As mentioned previously, at such station is provided a wafer supply magazine 1 in which are positioned a plurality of wafers, the number of which is determined by the magazine's size, which may be varied to meet particular needs. In the illustrated embodiment, the magazine has space provided therein to receive 20 wafers vertically spaced one above the other.

The supply magazine comprises a body 11 formed of suitable plastic, such as nylon or Teflon, having a generally U-shaped configuration in horizontal cross section as best seen in FIG. 2. The magazine body is provided with a generally Y-shaped cutout portion 12, through which wafers are inserted or removed during loading or unloading of the magazine. Communicating with the cutout portion and defining the same are a series of parallel vertically spaced lips 13, best seen in FIGS. 5 and 6, which define therebetween a series of vertically spaced slots 14 in which the supply of wafers W is received.

As noted from FIGS. 2 and 4, slots 14 between the adjacent lips are provided with straight, generally parallel side faces connected with each other by a generally arcuate end face. The width and height of the respective slots is substantially greater than the size of the wafers shown positioned therein, so that wafers of varying sizes may be accommodated in the magazine. It should be noted that the Y-shaped cutout portion 12 of the magazine extends substantially to the end face of the respective slots, as seen in FIG. 2, so that the cutout portion underlies substantially the entire surface of each wafer carried in the supply magazine. Such wafers are supported along opposite edges thereof by their engagement with the respective lips 13 of the magazine but are generally free of support throughout their central sections.

As the magazine is indexed in step fashion by the indexing means to be described, successive wafers are automatically fed from the magazine by the withdrawing out-feed means to be disclosed. The magazine indexing means in the preferred embodiment illustrated includes a support base 16 for the magazine (FIGS. 2 and 3). Pivotal lock structure for the magazine, generally designated 17, is provided in conjunction with the support base. Such lock structure comprises an elongated pin 18, extending through a bore 19 in the support base, having a locking cam 21 on its inner end and a manually operable handle 22 on its outer end. The base of the supply magazine is provided with an opening 23 therein in which the locking cam is receivable when handle 22 is pivoted to the upper locking position shown in FIG. 3. Thus, when a magazine is positioned on the support base and is properly oriented thereon, the handle 22 is rotated to the upper position to engage the locking cam 21 with the magazine and to hold the magazine securely in place and in proper orientation for feeding of wafers therefrom. It should be understood, of course, that the support base has a slot therethrough in which the locking cam 21 is movable between its respective locked and unlocked positions of engagement with the magazine.

As noted from FIG. 2, support base 16 is defined by a generally rectangular plate having a planar upper surface from which spaced shoulders 24 project upwardly to define therebetween a magazine receiving slot. The shoulders include opposed outwardly diverging faces 26 which terminate

in generally straight parallel faces 27, the latter of which are engaged by the outer parallel sidewalls of the magazine when a magazine is positioned on the support base. The diverging faces 26 facilitate proper insertion of the magazine into its wafer out-feed position.

The shoulder portions of the support base are provided with parallel vertical bores 28 through which guide structure for the support base extends. Such guide structure in the embodiment illustrated comprises a pair of spaced circular cylindrical rods 29 along which the support base 16 is slidable during vertical indexing movement of the supply magazine. Guide rods 29 in turn are secured to and supported in rigid upstanding relationship by a main base plate 31 of the supporting framework of the apparatus as seen in FIG. 3. Such guide rods may be threadedly engaged with the base plate 31 or otherwise suitably secured thereto at one end thereof. Preferably, bearings 32 are positioned in bores 28 and surround the guide rods as seen in FIG. 2 to facilitate indexing movement of the support base. Such bearings are held in place in the bores of the shoulder portions of the support base by capscrews 33, positioned to extend through and draw together adjacent spaced portions of the base plate shoulders which are separated by adjustment permitting slots 34, as seen in FIG. 2.

Vertical movement of the support base 16 and the supply magazine therewith in the illustrated embodiment is effected by a movable rod 36 which is actuated in predetermined vertical increments by a suitable power source or drive mechanism to be described. In the preferred embodiment illustrated, the movable rod is operatively engaged with the support base so that movement of the rod effects vertical movement of the support base. To that end, a threaded bore 37 is provided in the support base adjacent one of the guide rods 29 therein and rod 36 is correspondingly threaded for substantially its full length. Thus, support base 16 and the supply magazine carried thereby are moved in a predetermined direction, either upwardly or downwardly as desired, in accordance with the direction of rotation of the movable rod 36. With the illustrated construction, rotation of rod 36 one revolution effects vertical indexing of the associated magazine an increment equal to the distance between adjacent slots 14 in the magazine. Of course, other relationships may be employed if preferred.

While various power source drive mechanisms may be employed to move the rod 36, such as hydraulic or pneumatic mechanisms, in the preferred embodiment illustrated herein, an electromechanical mechanism is employed, namely a servomotor 38 of known type secured in depending relationship by means of a series of bolts 39 from the under surface of the main base plate 31 of the apparatus. A flexible coupling 41 operatively connects the servomechanism of the motor 38 with the movable rod 36 in known fashion to effect rotation of the rod in predetermined increments (preferably one revolution per indexing step, as noted previously) in response to signals received by the motor from a suitable control source following movement of each wafer in sequence from the supply magazine. That is, rod 36 is rotated sequentially by the servomotor in amounts sufficient to move the supply magazine sequentially the distance of the spacing between adjacent slots 14 in the magazine so that successive wafers are presented at a wafer withdrawing position.

In that connection, upon initial operation of the apparatus with a filled supply magazine placed on the support base 16, the lowermost wafer in the magazine is first withdrawn and the support base, with the magazine thereon, is indexed vertically downwardly in step fashion to present each successive lowermost wafer to the withdrawing position until the supply magazine is empty, at which time suitable control means interrupts further operation of the withdrawing procedure until the support base is relocated in the upper position and another filled magazine is positioned on the support base.

Referring to FIGS. 2 and 4, indexing sequence control signals are transmitted to the servomotor 38 from a control source located adjacent the feed station. The control source

preferably comprises a light source which is interrupted by each successive wafer passing from the supply magazine. Such light source in the preferred embodiment, as seen in FIG. 2, preferably comprises a fibre-optic sensor 46 positioned adjacent the supply magazine and supported by the wafer out-feed and transfer means to be described. As the leading edge of each wafer withdrawn from the supply magazine passes over the sensor 46, the interruption of light passage to the sensor transmits a signal in known fashion to the motor 38. This first signal is disregarded by the motor, through use of suitable and conventional control devices provided as part of the overall electronic control of the apparatus. However, as the trailing edge of each wafer clears the sensor, a second signal is transmitted to the motor, in response to which the motor is actuated in known fashion to effect rotation of the drive rod 36 one revolution to effect downward indexing of the supply magazine one step to bring another wafer into its out-feed position. Such second signal also interrupts flow of wafer supporting fluid until indexing and wafer centering are completed, as will be described. Details of the fibre-optic sensor utilized have not been disclosed herein because such a device, and its control relationship to a power drive source mechanism, such as a servomotor, and a fluid valve, are well known in the control art.

Also provided in conjunction with the supply magazine indexing means are other control means for permitting the initiation of the indexing operation and termination thereof automatically when the supply magazine is empty. In that regard, referring to FIG. 3, upper and lower limit switches, designated 47 and 48 respectively, are supported in any suitable fashion on the apparatus framework adjacent a guide rod 29 at one side of the apparatus. In the embodiment illustrated, such limit switches are adjustably positioned to project from one of a pair of spaced upright mounting plates 49 projecting upwardly from the main base plate 31 of the apparatus. Secured in depending relationship from the base support 16 is a switch actuator 50 shown intermediate its upper and lower extremes of travel in FIG. 3.

When the base plate 16 is raised toward its uppermost position with a full magazine positioned thereon, switch actuator 50 engages the toggle arm 51 of switch 47 which transmits a signal in known fashion to the motor 38 to preclude any further upward movement of the base plate. In this position, the bottom slot of the supply magazine is located one index increment above the lowermost wafer withdrawing position.

When the switch actuator 50 is carried with the support base to its lowermost position in which the last wafer has been withdrawn from the magazine, the toggle arm 52 of the lower limit switch is engaged and a signal is transmitted to motor 38 in known fashion to preclude any further downward movement of the support base 16, thereby effectively shutting off the wafer out-feed operation until the support base is repositioned and a filled magazine is located in place of the empty magazine. Repositioning of the support base may be effected by a suitable override control (not shown) which effects reverse operation of the servo motor and drive rod 36 associated therewith until switch actuator 50 contacts the upper limit switch arm 51 as described.

As also seen in FIGS. 2 and 3, the control means for the indexing means includes a switch which precludes the indexing operation unless a supply magazine is properly positioned on the support base. Normally projecting from the upper surface of the support base is an arm of switch 53 which is depressed into an accommodating slot in the support base when a magazine is properly positioned thereon. In the absence of such a magazine, switch 53 effects an override control on the servomotor and precludes indexing movement of the support base in the manner described previously. That is, such switch senses the presence or absence of a feed magazine and locks out automatic indexing of the support base when no magazine is present.

Because the construction and control operations of the upper and lower limit switches and the magazine presence

sensing switch are conventional, details of their mode of operation and construction have not been included herefrom.

WAFER OUT-FEED AND TRANSFER MEANS

5 Withdrawing of successive wafers from the supply magazine is effected by the wafer withdrawal or out-feed and transfer means 2. As seen in FIGS. 2 through 8, such transfer means in the illustrated embodiment includes improved fluid-bearing mechanism defined by an air-bearing track structure positioned closely adjacent to and at least partially underlying the supply magazine body 11. As best seen in FIGS. 2 through 4, such bearing track structure includes a generally T-shaped metal or plastic retainer plate 56 supported at its laterally opposite ends as seen in FIG. 2 by the aforementioned spaced upstanding mounting plates 49, above the main base plate 31 of the apparatus. Suitable screw fasteners 57 maintain the retainer plate engaged with the upstanding plates 49.

As shown in FIGS. 4 through 6, a series of parallel open slots 58, three in number in the embodiment illustrated, are formed in the upper surface of the retainer plate and extend longitudinally of the apparatus for the full length of the retainer plate. Slots 58 are generally rectangular in vertical cross section having generally planar parallel sidewalls 59 (FIG. 6). A plenum chamber 61 extends transversely of the retainer plate as also seen in FIG. 6, and a series of spaced openings 62 extend upwardly through the retainer plate and connect the plenum chamber with the slots 58.

A metal or plastic closure plate 63 is secured in any suitable fashion, such as by bolts 64 (FIG. 6) to the undersurface of the retainer plate to seal off the plenum chamber. Gasket means (not shown) may be employed to insure an airtight seal. Passing through closure plate 63 is a bore in which a fitting 66 is threadedly engaged. Fitting 66 is connected by means of a hose 67 or like connection with a source of supply of the wafer supporting fluid to be introduced into the plenum chamber through the fitting. Such source of supply in the preferred embodiment comprises a quantity of pressurized air provided by a compressor (not shown) in known fashion.

It will be noted from FIGS. 4 and 5 that the aforementioned sensor 46 projects through retainer plate 56 and closure plate 63 and is supported thereby in the operative position noted previously.

The fluid-bearing track structure illustrated is completed by a series of parallel nozzle bars 68 each of which is positioned in and substantially fills an associated slot 58 in the retainer plate. It will be noted from FIGS. 2 and 4 that the bars are contoured to conform closely to the transverse dimension of the respective slots 58 and are of a length to substantially fill such slots. It will also be noted that the center bar is substantially longer than the side bars because of the increased length imparted to the center slot by the T-shaped configuration of the retainer plate. The center bar defines that portion of the fluid bearing which projects into the supply magazine body 11 and effects withdrawal of wafers therefrom in the sequential manner referred to earlier. That is, the center bar 68 underlies each successive wafer indexed in the withdrawing position so that air introduced through the center bar may lift the wafer from its supporting lip in the supply magazine and transfer the same from the magazine for subsequent processing.

To effect such wafer withdrawal, the air introduced through the retainer plate by the nozzle bars is directional in nature and such direction is imparted thereto by the improved and novel configuration of the air passages provided by the nozzle bars as seen in FIGS. 5 through 8.

As best seen in FIGS. 7 and 8, each of the bars 68 is provided with a generally T-shaped configuration having generally parallel side faces 69 which are cutaway along the bottom of the bar to provide elongated channels 71 extending longitudinally of the bar. Such channels communicate with the openings 62 passing through the retainer plate 56 from the plenum chamber 61 so that air from the plenum chamber may pass the full length of the bars. Such channels 71 terminate in-

wardly of the opposite ends of the bars, however, to seal off the ends of the slots 58 in which the bars are positioned. Note FIG. 6.

The nozzle bars are dimensioned to substantially fill the retainer plate slots 58 and upper edges of the bars lie substantially coplanar with the upper surface of the retainer plate to thereby provide a smooth bearing surface over which the wafers may pass. To retain the bars in place, as seen in FIG. 4, a series of screws 72 pass upwardly through the retainer plate into the bars.

The opposite side faces 69 of the bars engage the smooth opposed side faces 59 of the respective retainer plate slots. To provide air passages, the bar side faces are provided with means which define an improved air nozzle construction. Such air passages comprise a series of spaced grooves 73 formed in the opposite side faces of the bars. For most effective air bearing, each of the grooves is directionally formed to impart longitudinal motion to wafers supported thereby.

In that regard, such directional capability is produced by providing each groove with a predetermined exit angle inclination relative to the longitudinal axis of the bar. Further in that regard, each groove 73 preferably is formed with a nozzle configuration provided by forming such groove wider and deeper at the end thereof which communicates with the channel 71 and progressively tapering the groove so that it becomes narrower and less deep at the exiting end thereof. note FIGS. 7 and 8. Such nozzle construction has been found highly effective in insuring positive control and movement of wafers or other articles to be transported by fluid-bearing structure of the type disclosed.

As noted by the dotted lines 70 in FIG. 5, preferably each of the nozzle grooves 73 is formed as a portion of the arc of a large circle, the center of which is spaced from the axis of the bar. The exiting angle of air passing from the arcuate grooves may be varied to meet a particular need in accordance with known considerations, such as the speed and extent of longitudinal movement desired for transporting articles. Such inclination also may be varied in accordance with the weight of the articles to be handled as well as other factors known in the fluid-bearing art. By way of example, an exit angle within the range of 15° to 25° has been found effective for transporting many articles, of which wafers are exemplary.

Except for their length, each of the bars 68 is substantially identical in configuration in the embodiment illustrated although it should be understood that modifications and variations in the construction between the respective bars may be effected if desired. For example, if it is desired to impart positive wafer centering control to the air-bearing track structure to insure passage of successive wafers generally along the longitudinal axis of the track structure, the opposite side bars may have the nozzle grooves thereof formed to extend inwardly toward the longitudinal axis of the track structure to impart an inward direction to the airflow emanating therefrom. Also, by varying the contour or size of the nozzle grooves in the side bars relative to the grooves in the center bar, thereby imparting a pressure differential to the air emanating from the side bars relative to the center bar, such centering control may also be obtained.

While in the embodiment illustrated it is contemplated that air will pass continuously through the bars when the bearing is operating to transport articles, by the inclusion of a suitable and known air pulsing mechanism (not shown) into the air supply line 67, air may be intermittently introduced through the air-bearing track structure to move the wafers in successive up and down steps along the length of the air bearing. For certain articles being handled with an air bearing of the subject type, such air pulsing has been found desirable for more effective transfer of articles therealong.

Furthermore, while the air-bearing embodiment described has single directional capability, an alternative embodiment described hereinafter is contemplated also in which the air-bearing structure is imparted with bidirectional capability so that articles may be alternately moved along the same bearing

structure in opposite directions relative to a reference location, as may be required in a particular handling procedure.

In the illustrated embodiment, the air-bearing track structure described transports wafers in succession from the supply magazine to the adjacent centering station at which a centering operation is performed on the wafers for the purpose to be described.

WAFER CENTERING MEANS

Referring to FIGS. 2 through 5 and 9, means for receiving and centering successive wafers fed thereto from a suitable source of supply prior to their transfer to the treating station is illustrated. While a supply magazine is shown herein as such source, it should be understood that wafers could originate from other supply sources, such as another processing machine or an infeed supply conveyor of any suitable type.

Such centering means comprises the aforementioned centering unit designated 3 which is defined by a generally flat metal or plastic dish 76 which, as seen in FIGS. 2 and 4, is generally square in outline when viewed from above. The dish is formed with a shallow regular concave upper surface 75 which deepens increasingly from the respective outer edges of the dish in regular contour toward the center thereof, designated 77 in FIG. 4. The dish is secured directly to and supported by the retainer plate 56 of the air-bearing structure by means of cap screws 79 extending through the retainer plate into one edge 78 of the dish, as best seen in FIG. 4. Around its periphery on the other three edges of the dish is a continuous lip, which projects above the upper concave surface of the dish and is provided by a series of flat metal bands 81 secured to the dish edges by capscrews 82. The continuous lip formed by the metal bands forms a retainer which precludes inadvertent movement of wafers over an edge of the dish during a centering operation. From FIGS. 2, 4 and 5, it should be obvious that wafers are introduced directly by the air-bearing structure onto the upper concave surface of the centering dish for handling therein.

Wafer centering in dish 76 is effected by fluid passing upwardly through the dish to engage individual wafers positioned in sequence on the upper surface 75 thereof. Wafer supporting fluid, preferably of the pneumatic type, is passed through series of air passages provided through the dish. In the embodiment illustrated in which the dish is cast or machined from a metal or plastic plate, such air passages comprise a series of regularly spaced holes 83 provided along radii emanating from the center 77 of the dish and arranged in concentric circles located thereabout. However, it should be understood that alternative constructions are contemplated, such as by forming the dish from a porous metal, such as powdered bronze, which because of its inherent porous structure includes myriad air passages therethrough. The dish construction illustrated, however, is preferred for the handling of wafers as disclosed herein.

A plenum chamber 84 is provided beneath the dish and is formed by a closure plate 86 secured by capscrews 87 (FIG. 5) to the undersurface of a peripheral flange 88 of the dish. The closure plate 86 interfits with flange 88 and a shoulder 89 of the plate is engaged beneath the flange as shown in FIG. 5. To prevent air leakage from the plenum, an O-ring seal 91 is interposed in a groove provided between the flange 88 and shoulder 89.

Extending through the closure plate and communicating with the plenum chamber 84 is a fitting 92 connected by a hose 93 to an air supply source, such as a conventional air compressor (not shown). Air introduced through hose 93 and fitting 92 passes into the plenum chamber and through the spaced openings 83 upwardly through the dish to emanate therefrom into contact with a wafer positioned on the concave surface 75.

By utilizing a conventional air pulsing unit (not shown), air introduced onto the upper surface of the dish may be caused to exit in rapid pulsations so that a wafer engaged thereby is

lifted and dropped repeatedly and rapidly, yet without damage thereto. Such reciprocation of the wafers by pulsing air currents moves the wafer from adjacent the periphery of the dish to the center thereof. The air pulsations are continued for a predetermined time sufficient to move the wafer until its center overlies the center 77 of the dish. Once the wafer is positioned over the dish center, continued air pulsations will not disrupt the centered orientation. When the pulsations are stopped, the wafer settles onto the dish with its center concentric with the dish center 77.

While the frequency of the pulsation cycles will vary with the type and size of articles being centered, for silicon wafers a pulsing frequency in the range of 1 to 10 cycles per second has been found effective, with 2 to 4 cycles being generally suitable. As noted previously, the centering mechanism can accommodate articles of widely varying sizes.

Mechanism also is provided to elevate each properly centered wafer above the dish to permit the same to be engaged by the aforementioned pickup and transfer means to be described in detail hereinafter. Such elevating mechanism comprises a hollow pin 96 (FIGS. 4, 5 and 9) which extends through a bore 97 formed concentric with the center 77 of the dish. The axis of pin 96 is similarly concentric with the dish center. It will be noted from FIGS. 5 and 9 that the dish is formed with a depending cylindrical extension 98 through which pin 96 passes. Extension 98 in turn is snugly received within a depending cylindrical extension 99 of the aforementioned closure plate 86 and an O-ring seal 100 is positioned in a suitable groove 101 and is interposed between the respective extensions to preclude air passage therebetween.

The bore 102 of the hollow centering pin 96 is connected at its lower end to a vacuum source, designated generally by the fitting 103 in FIG. 9. As the pin is moved upwardly from the lower position in FIG. 5 to the elevated position shown in dotted lines in that figure and in solid lines in FIG. 9, vacuum is automatically applied through bore 102 against the undersurface of a wafer positioned above the pin, thereby maintaining the wafer securely engaged with the upper end of the pin with its center essentially coincident with the axis of the pin.

Movement of the pin 96 upwardly, and subsequent movement of the pin downwardly, is effected by a conventional air cylinder, generally designated 104 in FIG. 9. Pin 96 is connected within the cylinder to a slidable piston contained therein. In known fashion, upon introduction of air against the underside of the piston in the cylinder, the pin will be elevated and upon exhausting of air from the underside of the piston and introduction of air into the cylinder above the piston, the pin will be retracted. The piston control sequence in that regard, coupled with the introduction and removal of vacuum from the pin bore, is effected automatically by control means in the manner to be described hereinafter.

It should be understood that fluid is shutoff to the out-feed fluid bearing 2 while centering of a wafer is being effected to preclude interference with such centering by another wafer.

Centered wafers are transferred in succession from the centering unit by pickup and transfer means to the treating station adjacent the centering station. The transfer means for moving wafers from the centering unit to the treating station is operatively interconnected with other transfer means for moving treated wafers from the treating station toward the discharge station. Prior to describing the respective first and second interconnected pickup and transfer means, and their actuating mechanisms, details of the components of the wafer treating unit located at the treating station will first be described.

WAFER SPINNING AND COATING MEANS

Properly centered wafers are transferred in succession into and received by the treating unit designated 6. In the embodiment illustrated herein in which silicon wafers intended for the manufacture of electronic components are being treated, the treating unit disclosed is designed to apply a measured amount of fluid material, such as a liquid photoresist material com-

monly employed in the electronics industry, to each wafer positioned at the treating station and to distribute such material evenly across the upper surface of each such wafer. Such photoresist material, by way of example, may be Eastman Kodak Company's "KPR," "KMER" or "KTFR," commonly used in the trade.

Details of the treating unit for spinning and coating wafers are shown in FIGS. 2, 3 and 11. Projecting upwardly from and secured to main base plate 31 in any suitable manner, such as by welding, is a dispensing mechanism support plate, designated 111 in FIGS. 2 and 3, from the top of which projects in generally parallel relationship to the main base plate 31 a mounting plate 112 which is secured by a series of bolts 113 to the upright support plate 111. As seen in FIG. 11, a fluid dispenser head assembly, generally designated 114, is supported above plate 112 by an intermediate hollow mounting housing 116 secured by dowels 117 to plate 112. Other dowels 118 in turn secure the head 114 to the housing 116.

Housing 116 is provided with a central bore 119 in which a dispensing nozzle 121 is located. Dispensing nozzle 121 in turn is connected by suitable valve structure 122 with a supply hose 123 which in turn is connected with a pressurized supply container 124 (FIG. 2) of known construction in which a quantity of photoresist material is maintained under pressure for dispensing in predetermined measured amounts in response to opening of the valve structure 122 which regulates the nozzle 121. Nitrogen is commonly used as the pressure-producing medium in container 124. The dispensing head and supply structure employed are conventional and further details thereof will not be presented herein.

As best seen in FIG. 11, located directly beneath the dispensing nozzle 121 is a rotatable spindle 126 on the upper end of which successive wafers are to be placed by the pickup and transfer means to be described. Such wafers are located on the spindle with their centers essentially coincident with the vertical axis of the spindle 126. It will be noted that spindle 126 is provided with a hollow bore 127 running the length thereof which in turn is in operative communication by means of a fitting 128 and supply hose 129 with a vacuum source. Upon the application of vacuum to the spindle, wafers placed on the upper end of the spindle are firmly held in place thereon during high speed rotation of the spindle for the purpose to be described.

Rotation of the spindle may be effected in any suitable manner, such as by a small electric servomotor, generally designated 131, the operation of which is effected in sequence as wafers are properly oriented on the spindle upper end. It should be understood that photoresist fluid dispensing and spindle rotation are effected in timed relationship with each other so that photoresist material placed on each successive wafer will, upon rotation of the spindle, be spread by centrifugal force equally across the face of the wafer to effect uniform coating thereof.

If desired, several photoresist material layers may be applied to the same wafer depending upon the subsequent utilization intended for the wafer in later manufacturing steps. Also, each wafer may be rotated by motor 131 in two stages if desired, the first of which is a slow speed rotation to effect spreading of the photoresist material, and the second of which is a high speed rotation to insure even distribution of the photoresist material.

The spinning and coating unit of this invention includes improved features comprising mechanism provided to maintain the unit free of solidified photoresist fibers which may be thrown from the wafers during spinning thereof. Such mechanism is in the form of an extensible and retractable cup structure, generally designated 132 in FIG. 11, which is cooperable with the aforementioned housing 116. The cup structure comprises a generally cylindrical cup 133 open at its top and having a central opening 134 in its base 135 which allows the cup to surround and move longitudinally of spindle 126. The inner wall of the cup is tapered inwardly towards its open top and extends a substantial distance upwardly from its

base 135 to catch any photoresist material fibers which are thrown outwardly by centrifugal force during wafer coating operations. As noted in FIG. 11, structure is provided to selectively elevate the cup from the solid line retracted position shown to the dotted line extended position shown.

It will be noted from the dotted line showing of FIG. 11 that, when cup 133 is in the elevated position, its wall surrounds and substantially encloses the lower portion of the housing 116 which as seen is provided with a downwardly extending peripheral flange 136. Thus, the wall of the cup 133 and the flange 136 cooperate to define a substantially enclosed chamber surrounding the wafer when the cup is in the elevated position which eliminates the possibility of photoresist material fouling up adjacent components of the apparatus.

It will also be seen from FIG. 11 that exhaust structure is provided to remove solidified or unsolidified photoresist material from the cup during a coating operation, such structure comprising a vacuum exhaust tube 138 secured to the base of the cup 135 and a support plate 137 therefor and extending therethrough. The exhaust tube is connected to an exhaust hose 139 which in turn is connected with a source of vacuum and a waste disposal outlet (not shown).

The structure provided for elevating and retracting cup 133 is designated 141 in FIG. 11. In the preferred embodiment, the support plate 137 to which the base of the cup is secured is provided with a lateral extension 142 to which is secured a connector 143 which forms a seat for a piston rod 144 engaged therewith. Rod 144 in turn extends into an air cylinder 146 and is connected within the cylinder to a piston (not shown) by means of which the support plate 137 and the cup carried thereby may be selectively elevated or retracted in accordance with the introduction of air against one side or the other of the piston in known fashion. The timing sequence for piston operation to extend or retract the cup in conjunction with the sequence of operation of other components of the apparatus will be described hereinafter.

As seen in FIG. 3, cylinder 146 is secured by a bracket 147 to the main framework of the apparatus in any suitable fashion. A guide bearing 148 is mounted atop the bracket 147 and a slidable guide rod 149 is movable through the bearing. The end of the guide rod is secured by a connector 150 to the lower end of aforementioned piston rod 144. The connector at opposite upper and lower ends of the stroke of piston rod 144 contacts depressible upper and lower limit switches 140 and 145 respectively for the control purpose described hereinafter.

Following photoresist coating or other similar treatment of individual wafers in sequence at the treating station, they are transferred from the treating station towards the discharge station by pickup and transfer means provided for such purpose.

WAFER PICKUP AND TRANSFER MEANS

In the apparatus embodiment illustrated the aforementioned first and second means 4 and 7 are provided for picking up and transferring wafers from one station to another. Such means are utilized to move wafers in timed sequence, first, from the centering station to the treating station, and second, from the treating station toward the discharge station.

In the apparatus embodiment illustrated, the respective pickup and transfer means employed are operatively interconnected with each other to effect simultaneously movement of one wafer from the centering station to the treating station while another wafer is being moved from the treating station towards the discharge station. However, it should be understood that operatively discreet but intertimed pickup and transfer means could be employed if preferred, rather than the directly interconnected first and second transfer means illustrated herein.

The construction of the pickup and transfer means and the relationship thereof to the other components of the apparatus is illustrated in FIGS. 2, 3 and 9 through 16. In general terms the pickup and transfer means comprises a pneumatic cylinder

actuated slide structure on which wafer pickup structures, preferably in the form of vacuum arms, are carried. Upon actuation of the cylinder, the slide structure is moved between predetermined positions in which the respective pickup arms are engaged with wafers supported on the centering pin 96 and spinning spindle 126 at the centering-treating stations respectively.

Reference is directed to FIGS. 12 and 13 for a detailed showing of the preferred embodiment of the slide structure which comprises a generally U-shaped flat slide plate 151 having an elongated slot 152 which extends substantially the full length thereof from one end thereof. The slide plate is positioned to extend below the centering and treating stations and slot 152 permits movement of the plate relative to spinning spindle 126, vacuum exhaust tube 138 and cup elevating piston rod 144, as well as the centering pin air cylinder 104, as seen in FIG. 12.

The slide plate is mounted for longitudinal movement of the apparatus relative to the stations mentioned by means of three slide bearings 153, 154, and 156 respectively secured by suitable screw fasteners 157 to the under surface of the plate. The bearings in turn are slidably positioned around two cylindrical guide tracks 159 and 161 which extend in parallel relationship beneath the slide plate. The guide tracks are supported between opposite end mounting brackets 162 and 163 which project upwardly from an inverted U-shaped mounting channel 164. Mounting channel 164 provides the main base or support for the slide structure and it in turn is supported in any suitable fashion, such as by bolting or welding, to an upright frame member 166 connected with the main base plate 31 of the apparatus as best seen in FIG. 3. It should be understood that the mounting channel has suitable apertures provided therethrough at spaced locations therealong to accommodate those upwardly projecting components of the apparatus previously described which are positioned at the centering and treating stations.

Referring again to FIGS. 12 and 13, it will be noted that guide track 159 is provided adjacent its opposite ends with enlarged portions 167 which define stop shoulders 168 which are engageable by the bearings to restrict movement of the slide plate within positive limits. To effect movement of the slide plate, air cylinder structure 171 is provided which is supported by a laterally extending upright brace 172 from the apparatus framework in any suitable fashion. Cylinder 171 is secured at one end to the brace 172 by a bolted connector 173. Projecting from the other end of the cylinder is a piston rod 174 having an L-shaped connector 176 bolted to its outer end. Such connector in turn is secured by bolts 177 to an adjacent edge of the slide plate 151. Thus, upon introduction of air against one surface or the other of the piston in the cylinder which is connected with the piston rod 174 in known fashion, the slide plate may be moved selectively towards the right or left in FIGS. 12 and 13.

Projecting upwardly from opposite corners of the slide plate are wafer transfer arms 181 and 182. Each of the transfer arms is designed to support a wafer on its upper surface and to maintain the wafer engaged therewith by the application of vacuum thereto. To permit proper positioning of the wafers during engagement and disengagement thereof with the respective vacuum arms, the vacuum arms are mounted for selective vertical movement within well defined limits.

Each of the vacuum arms is similarly mounted on the slide plate for such vertical movement and reference will be directed to the showing of FIGS. 12 and 13 with respect to the mounting structure for vacuum arm 182 only, it being understood that the mounting arrangement for vacuum arm 181 is identical in construction therewith, only reversely oriented because of the reverse orientation of arm 181 relative to arm 182.

A notch 183 is provided in the side edge of slide plate 151 generally centrally of its opposite end edges as best seen in FIG. 12. In such notch is positioned a generally rectangular mounting block 184 which is secured to the slide plate by

screw fasteners 186. The mounting block depends below the undersurface of the slide plate and a pivot pin 187 is positioned to extend laterally outwardly therefrom. Pivot pin 187 in turn carries thereon a pivotal lever arm 188 on one end 189 of which vacuum pickup arm 182 is secured by means of screw fasteners 191. Thus, it should be understood that up and down movement of the pickup arm within predetermined limits is permitted as lever arm 188 pivots about the axis of pin 187.

Lever arm 188 is urged in a counterclockwise direction (FIG. 13) by a compression coil spring 192 interposed in bores provided in the slide plate and the end of the lever arm which is opposite from the pickup arm 182. Spring 192 thus tends to urge the pickup arm towards its raised position. Limits are placed on the amounts of clockwise or counterclockwise movement by means of a pair of adjustable set-screws 193 and 194 depending from the slide plate into engagement with the upper surface of the lever arm. Thus, the extended and retracted positions of the pickup arm carried by the lever arm may be adjusted within predetermined desired limits.

It will be noted from FIG. 12 that lever arm 188 is provided with an elongated slot 196 which accommodate therein the mounting block 184. Slot 196 permits pivotal movement of the lever arm for the purpose described.

As best seen in FIGS. 9 and 15, the pickup arms 181 and 182 are substantially identical in construction with minor distinctions therein being prompted by the relationship of the respective arms to the stations to and from which wafers are transferred thereby. In FIGS. 9 and 15 corresponding numerals are used to identify corresponding components of the respective arms. Each pickup arm includes an upright generally flat body portion 196 having a vacuum channel 197 passing therethrough. A horizontal generally flat upper body portion 198, through which an extension of channel 197 projects, is integrally connected with the upright body portion and such horizontal portion terminates in an upwardly extending head portion 199. It will be noted that the head portion of arm 181 is longer than the corresponding head portion of the arm 182 because of the interrelationship of arm 182 with the fluid-bearing track structure 8 (FIG. 15) when a wafer is discharged onto the track structure.

As seen in FIGS. 10 and 16, the vacuum channel 197 in each of the vacuum arms terminates in an enlarged transversely extending chamber 200, such chamber being closed by a flathead plate 201 secured by screw fasteners 202 to the upper surface of the head portion 199 of the respective transfer arms. A series of spaced openings 203 extend through the respective headplates to permit vacuum atmosphere to be introduced against the undersurface of a wafer engaged by a pickup arm in the manner illustrated in FIGS. 9 and 15.

FIGS. 9 and 15 also show vacuum fittings 204 which are connected with the respective lever arms 188 from which the pickup arms project. Such fittings communicate with bores 205 provided in the lever arms in alignment with the vacuum channels 197 formed in the pickup arms. The respective fittings are connected by hoses 206 with a suitable vacuum supply.

It should be understood that vacuum is introduced selectively into the individual pickup arms as each is brought into engagement with the undersurface of a wafer and that such arm is selectively elevated and retracted about the pivot axis of its associated lever arm 188 in conjunction with engagement and transfer of such wafer. The sequence of operation and control means employed for selectively elevating and retracting the pickup arms and for actuating the slide plate on which the arms are carried is described hereinafter.

As noted previously, the coil spring 192 tends to urge its associated lever arm counterclockwise (FIG. 13) which in turn urges the pickup arm mounted thereon toward its upper extended position. However, to permit proper positioning of the respective headplates 200 of the pickup arms relative to wafers to be picked up or released therefrom, structure for

drawing the respective vacuum arms downwardly and holding them in the lower retracted position is provided. In the illustrated embodiment, such structure takes the form of duplicate air cylinders 207 (FIG. 13) each of which is connected by a hose 208 with a suitable air pressure source. Within each cylinder 207 is provided a single action piston which is operatively engaged with a lever arm 188. That is, the piston is mounted on and secured to the lever arm in any suitable fashion and a piston rod 209 projects from the upper end thereof and is engaged with the undersurface of slide plate 151. Upon introduction of air against the under surface of the piston, piston rod 209 is urged upwardly against the slide plate to force the piston downwardly and to rotate the lever arm clockwise against the urging of spring 192 to lower the pickup arm. Thus, so long as air is introduced against the piston in cylinder 207, the pickup arm carried by the lever arm will be held retracted.

Such retracted positioning of the pickup arms is maintained during the major portion of the cycle of movement of the slide plate 151 described previously. Periodically, however, air is exhausted from the respective cylinders 207 to permit the springs 192 to elevate the pickup arms in the timed sequence necessary to effect wafer transfer between the centering, treating and discharge stations.

The sequence of up and down movement of pickup arm 182 is as follows. As the pickup arm is moved from the rest position of slide plate 151, the arm is held retracted. When the pickup arm is aligned by the slide plate with the centering pin 96 at the centering station, the arm is elevated in conjunction with simultaneous retraction of the centering pin and withdrawal of vacuum from the pin and introduction of vacuum into the arm to effect wafer pickup. Slide plate 151 then moves the pickup arm toward the treating station and the arm is retracted when it is aligned with spinning spindle 126. Vacuum is then withdrawn from the arm and vacuum is introduced into the spindle to effect transfer of a wafer to the spindle. The pickup arm is held retracted until it is again aligned at the centering pin at the centering station.

The sequence of up and down movement of pickup arm 181 is as follows. As pickup arm 182 is moved to the centering station, pickup arm 181 is moved to the treating station and is held retracted during such movement. When pickup arm 181 is aligned with spinning spindle 126, the arm is elevated and vacuum is introduced thereinto as vacuum is withdrawn from the spindle to effect wafer pickup by the arm. Slide plate 151 then moves the pickup arm toward the discharge station and when the arm is properly positioned with respect to the wafer infeed and transfer fluid-bearing track structure 8, the arm is retracted as vacuum thereto is withdrawn therefrom to deposit the wafer on the track structure for introduction thereby into the discharge magazine. The pickup arm is held retracted until it is again aligned with the spinning spindle at the treating station.

WAFER INFEED AND TRANSFER MEANS

Introduction of successive coated wafers into the discharge magazine is effected by the wafer infeed and transfer means designated 8 and best seen in FIGS. 2, 3, 14 and 15. In this connection, the wafer infeed and transfer means of the illustrated embodiment comprises a fluid-bearing track structure which preferably is in all essential respects substantially identical to the out-feed and transfer means described previously in conjunction with the supply magazine. Therefore, a detailed description of the infeed fluid-bearing track structure which is interposed between the treating station and the discharge magazine will not be set out in detail. However, corresponding reference numerals, primed, are used in the drawings to designate those components of the infeed fluid-bearing track structure which correspond to the counterpart components of the previously described out-feed fluid-bearing track structure.

However, the infeed track structure includes one important modification not incorporated into the previously described out-feed track structure. Such modification is most evident from FIGS. 2, 14 and 15 and comprises the provision of a vacuum pickup arm accommodating slot 212 which extends from an edge thereof into retainer plate 56' so that pickup arm 181 may position a coated wafer directly over the track structure prior to retraction of the arm as previously described. Thus, a wafer may be deposited directly on the upper surface of the track structure for transfer thereby directly into the adjacent discharge magazine 11'.

Note should also be given to the fact that the infeed fluid-bearing structure includes in conjunction therewith a fibre-optic sensor 46' of the type described previously which regulates airflow to the track structure during indexing of the discharge magazine in the same manner described previously with respect to sensor 46.

WAFER DISCHARGE MAGAZINE STRUCTURE AND INDEXING MEANS

Reference is directed to FIGS. 1 through 3 for an illustration of the components of the apparatus employed at the wafer discharge station 9. As mentioned previously, at such station is provided a wafer discharge magazine 11' in which are receivable a plurality of wafers, the number of which corresponds to the number of wafers withdrawn from the supply magazine 11 provided at the feed station 1.

The discharge magazine and the indexing means therefore are in all essential respects identical to the feed magazine 11 and the indexing means therefor as described herein previously. Therefore, a detailed description of the discharge magazine and its indexing means will not be set out. Those components of the apparatus employed at the discharge station which correspond to counterpart components at the feed station are identified by corresponding reference numerals, primed, in the drawings.

However, the indexing means at the discharge station differs from that provided at the feed station in several respects in that the direction of discharge magazine indexing is opposite from that at the feed station. Servo motor 38' at the discharge station is actuatable to effect vertical movement of the discharge magazine 11' in an upward direction as the magazine becomes increasingly filled with wafers. That is, in the initial stages of operation, the discharge magazine is positioned with its uppermost slot one step above the surface of the infeed fluid-bearing track structure 8. Then, upon actuation of the indexing means, the uppermost slot and then the underlying slots are brought sequentially into alignment with the track structure as the magazine is moved upwardly with the support base 16' indexed by the servomotor 38'.

Such upward indexing may be effected by employing a servomotor which rotates its associated threaded drive rod 36' in a direction opposite from that in which the drive rod 36 at out-feed station rotates or, alternatively, drive rod 36' may be provided with threads of an opposite hand from those on drive rod 36. In any event, indexing of the supply magazine and the discharge magazine preferably is effected in opposite vertical directions for most effective wafer handling.

APPARATUS CONTROL AND OPERATION SYNCHRONIZING MEANS

The various operations of the respective apparatus components and units previously described are regulated by a series of solenoid controlled air and vacuum valves which in turn are actuated through a series of switches in predetermined sequence to effect transfer and treatment of a series of wafers in the apparatus without interfering with each other. The circuitry for such control switches has not been illustrated or described in that such circuitry is conventional and within the skill of those knowledgeable in the electrical control art.

Reference is directed to FIG. 20 for a generally schematic showing of the respective air valves and pistons actuated

thereby, as well as the respective vacuum valves employed. From a study of such figure, the operation of the respective valves, and the control functions performed thereby, should become evident when taken in conjunction with the disclosure of the apparatus components regulated thereby presented previously herein.

Operation and control of the supply magazine and discharge magazine indexing means has already been described. The sequence of operation and control of the vacuum pickup arms 181 and 182 with respect to the operations and control of the centering pin 96 and the spinning spindle 126 are the important control functions remaining to be described.

As noted previously, the respective pickup arms 181 and 182 are movable sequentially upwardly and downwardly in response to actuation of the lever arms 188 on which they are mounted by their associated air cylinders 207 and coil springs 192. As also has been mentioned, each wafer is held on the centering pin and the spinning spindle, and on the pickup arms during wafer transfer, by a vacuum atmosphere. If a wafer spinning and coating cycle is taking place at the coating station, a wafer is held on the centering pin until the spinning cycle has been completed. During such waiting interval, the respective pickup arms are generally midway between the ends of their wafer transfer paths so that the arms do not interfere with the cup 133 which catches excess photoresist material when the cup is elevated. That is, referring to FIG. 13, the respective pickup arms are held in the intermediate "rest" position shown in dotted lines in FIG. 13.

Upon completion of the spinning cycle, slide plate 151 is moved towards the right in FIG. 13 to the end of its path by air cylinder 171 to move pickup arm 182 into alignment with centering pin 96 and to simultaneously move pickup arm 181 into alignment with spinning spindle 126. Following wafer pickup by the arms, the slide plate is moved towards the left in FIG. 13 to the other end of its path to present pickup arm 182 to the spinning spindle and pickup arm 181 to the infeed bearing track structure. Upward and downward movement of the respective arms is effected as described previously. As seen in FIG. 20, air and vacuum valves are provided to effect the various operations of the transfer arms and the slide plate to insure effective wafer transfer. The described sequence is repeated in succession until all wafers from the supply magazine have been treated and transferred into the discharge magazine, at which time the apparatus is automatically shut off until subsequent supply and discharge magazines are properly positioned.

Reference is directed to FIGS. 12 and 13, taken in conjunction with FIG. 20, for an illustration of the control switches which are activated to initiate certain pickup arm and slide plate movements and functions described. In the subject embodiment, four such control switches are illustrated, identified by reference numerals 216, 217, 218 and 219, respectively, and are mounted on the aforementioned mounting channel 164. It will be noted that switch 217 is mounted externally of channel 164 while the remaining switches are mounted internally thereof. Also, switch 217 is fixedly mounted on the channel while the remaining switches preferably are adjustably mounted by means of adjustment slots 221 and 222 formed through the sidewall of the channel.

The respective switches have toggle arm actuators 223, 224, 225, and 226, respectively, operatively engaged therewith in known fashion. Upon depression of the respective toggle arms, the associated switches transmit control signals in known fashion to the respective solenoid activated air or vacuum valves shown in FIG. 20. Mounted on the outer edge of slide plate 151 is a switch actuator plate 227 aligned with the toggle arm 224 of switch 217 as best seen FIG. 12. Upon movement of the slide plate towards the left in FIG. 12, plate 227 will contact and depress toggle arm 224 to actuate switch 217. The remaining switches 216, 218 and 219 have their respective toggle arms aligned with the aforementioned slide bearings 154 and 156. As seen in FIG. 13, bearing 156 is positioned for engagement with the toggle arms 225 and 226 of

switches 218 and 219. Bearing 154 is positioned for engagement with the toggle arm 223 of switch 216.

Switch 219, when toggle arm 226 thereof is depressed by bearing 156 as seen in FIG. 13, transmits a signal to the solenoid valve which controls air cylinder 171 which actuates the slide plate 151. The slide plate is halted so that pickup arms 181 and 182 are located in the positions shown in FIGS. 12 and 13 in which such arms are accurately aligned with the respective axes of the centering pin and the spinning spindle. Switch 216, when its toggle arm 223 is depressed by bearing 154, transmits a signal to the solenoid valve which controls air cylinder 171 to effect accurate positioning of the pickup arms 181 and 182 over the discharge air-bearing track structure and the axis of the spinning spindle respectively. Thus, the two switches 216 and 219 control the end limits of the path of travel of the slide plate and the transfer arms carried thereby and limit longitudinal movement of the slide plate when such switches are activated as described.

Referring to FIG. 13, when the slide plate is in its extreme left-hand position, switch actuator plate 227 will be positioned to depress the toggle arm 224 of switch 217. When switch 217 is thus actuated, a signal is transmitted to the solenoid valves which regulate the respective cylinders 207 which control the up and down movement of the respective pickup arms. As such signal is transmitted, air is introduced into the cylinders and the pickup arms are moved downwardly in the manner previously described.

Movement of the slide plate toward the right from its extreme left hand position in FIG. 13 will bring bearing 156 into contact with toggle arm 225 of switch 218 which transmits a signal to deactivate air cylinder 171 and bring the slide plate to a halt with the pickup arms located in the intermediate rest position so that cup 133 may be raised during a spinning operation. The slide plate remains in the rest position until cup 133 is retracted and a complete new cycle can be initiated. Initiation of a new cycle is effected by the centering pin 96 as follows.

The centering pin is elevated, following a suitable established time delay to permit completion of wafer centering, by a signal transmitted as sensor 46 is cleared by a wafer. Such signal activates the centering pin piston 104 to raise the pin. As the pin reaches its top position, a limit switch (not shown) is activated which actuates slide plate cylinder 171 to move the slide plate from its rest position to the extreme right-hand position seen in FIG. 13, at which time switch 219 is activated to stop the slide plate, to raise the pickup arm 182 by deactivating cylinder 207, to initiate retraction of the centering pin, and to introduce vacuum into the pickup arm, as it is withdrawn from the centering pin.

When the centering pin is fully retracted, another limit switch (not shown) is activated which initiates movement of the slide plate toward the left in FIG. 13, with pickup arm 182 extended. As arm 182 comes into line with spinning spindle 126, slide plate cylinder 171 is deactivated by bearing 154 contacting switch 216. Simultaneously, actuator plate 227 activates switch 217 to retract pickup arm 182 and to introduce vacuum into the spindle as vacuum is shut off from the pickup arm. Full retracting of the pickup arm activates slide plate cylinder 171 and the slide plate is moved to and stopped at the rest position with the pickup arms retracted.

When the slide plate reaches the rest position, cylinder 146 is activated to raise cup 133. As the cup reaches its upper limit, the limit switch 140 is activated to initiate the photorealist dispensing and spinning cycle. The cylinder 146 is again activated to retract cup 133 after a predetermined time delay sufficient to permit completion of the spinning cycle. As the cup is retracted, limit switch 145 is activated to move the slide toward the right in FIG. 13 so that another cycle is initiated.

As pickup arm 182 is moving as described, pickup arm 181 is being similarly moved by the slide plate and periodically elevated and retracted at the treating station and adjacent the discharge station as described previously.

As the valve and switch control features may vary in details known in the control art, details thereof have not been incorporated herein. Accordingly, it should be understood that, so long as the disclosed air-vacuum-movement sequence is produced, the control features and devices employed may be selected in accordance with available technology.

BIDIRECTIONAL FLUID BEARING TRACK STRUCTURE

The fluid-bearing structure described herein previously is readily adaptable for bidirectional article movement in a manner heretofore unknown in the fluid-bearing art. In that connection, reference is directed to FIGS. 17, 18 and 19 in which an exemplary bidirectional fluid-bearing track structure is illustrated. In basic respects, the modified track structure shown in these figures corresponds to the track structure described previously and comprises a generally T-shaped retainer plate 251 having a series of elongated generally rectangular open grooves 252 provided in the upper surface thereof in which air bearing nozzle bars 253 are positioned and held in place in the manner described previously. A closure plate 254 is secured to the undersurface of the retainer plate. Each of the nozzle bars is generally T-shaped in cross section to provide longitudinal channels 256 along opposite sides therein to form air passageways along the length of the bars. Such passageways in turn communicate with plenum chambers formed in the under surface of the retainer plate.

An important distinction in the bidirectional track structure embodiment shown from that described previously resides in the fact that two adjacent plenum chambers are provided in the retainer plate which are identified in FIG. 17 by reference numerals 257 and 258 respectively. The respective plenum chambers in turn are connected by fittings 259 and 261 respectively with a source of pressurized fluid, such as an air compressor, not shown.

It will also be noted from FIG. 17 that the respective plenum chambers are operatively but separately connected with the channels 256 formed on opposite sides of the respective nozzle bars. That is, plenum 257 is connected by means of a series of holes 262 with the left-hand channel of the nozzle bars (as viewed in FIGS. 17 and 18) while plenum 258 is connected by a series of holes 263 with the right hand channel of the respective nozzle bars.

In that same regard, referring to FIG. 19, the right side faces of the respective nozzle bars are provided with directional grooves 266, each of which preferably has the improved tapered and curved nozzle configuration described previously. It will be noted from FIG. 19 that grooves 266 on the right side faces of the bars are directed longitudinally toward the right. On the opposite left-side faces of the bars, similar directional nozzle grooves 267 are formed. However, as also seen in FIG. 19, the left side grooves 267 are oppositely directed from the grooves 266. That is, grooves 267 are directed longitudinally toward the left.

From the foregoing, it should be understood that by the selective introduction of air through the respective plenums 257 and 258, an article, such as a wafer, positioned on the bidirectional fluid-bearing track structure shown may be moved longitudinally of the track either to the right or to the left, depending upon which plenum has fluid pressure introduced thereinto.

Suitable valve control mechanism, not shown, is available to effect selective introduction of air or other suitable supporting fluid into and through the respective plenums in predetermined sequences or cycles. The improved track structure thus described has the advantage of being utilizable, for example, to withdraw individual articles from a station (such as a wafer magazine) and to move the same to a treating station. Following treatment at such station, the same track structure may be used to transfer the same article back to the same station (and to reintroduce the same into the magazine in the illustrative example) in a fashion heretofore unknown with fluid bearing structures. Thus, the bidirectional track structure imparts spe-

cialized article handling capability to the subject invention in a manner requiring minimum alteration of the basic unidirectional track structure principally disclosed.

Having thus made a full disclosure of preferred illustrative embodiments of the invention incorporated in the subject apparatus and method, and the various components and sub-combinations which cooperate to define such apparatus, reference is directed to the appended claims for the scope of protection to be afforded thereto.

We claim:

1. In combination in an apparatus for handling and treating articles, such as silicon wafers, without manual handling,
 - A. a supply magazine having a quantity of said articles spacedly positioned therein,
 - B. means for withdrawing articles from said supply magazine,
 - C. means for indexing said supply magazine sequentially to present articles therein to said withdrawing means for removal thereby in sequence,
 - D. means at a station spaced from said supply magazine for accepting articles presented thereto in sequence,
 - E. transfer means for moving articles in sequence to and from said station prior to and following acceptance of said articles thereat,
 - F. a discharge magazine for receiving a quantity of said articles in spaced relationship therein following release thereof from said station,
 - G. means for receiving articles in sequence from said transfer means and for introducing such articles in sequence into said discharge magazine, and
 - H. means for indexing said discharge magazine sequentially to permit introduction of such articles thereinto in sequence,
 - I. said means for withdrawing articles from said supply magazine and said means for introducing articles into said discharge magazine each comprising,
 1. a fluid-bearing track structure positioned in close proximity to the respective supply and discharge magazines associated therewith,
 2. a source of article supporting fluid in communication with said track structure, and
 3. control structure for regulating introduction of supporting fluid into and through said track structure in accordance with sequential indexing of said magazines by said indexing means associated with the respective magazines.
2. The apparatus of claim 1 in which each said supply magazine and said discharge magazine comprises,
 1. a generally U-shaped body in horizontal cross section, and
 2. a series of lips spaced one above the other in said body which are spaced from each other by open slots defined by adjacent pairs of said lips,
 - a. each said slot opening toward the respective means associated therewith for withdrawing articles from such body and for introducing articles into such body.
3. The apparatus of claim 1 in which each of said means for indexing said supply magazine and said discharge magazine comprises,
 1. a support base for such magazine,
 2. guide structure for said support base,
 3. a drive rod engaged with such support base which is actuable in predetermined sequential increments determined by the spacing between adjacent articles in such magazine, and
 4. power source mechanism for sequentially actuating said rod to effect incremental movement of said rod and such support base therewith.
4. The apparatus of claim 3 in which the respective movable rods engaged with the respective supply and discharge magazine support bases are movable by their associated power source mechanisms in opposite directions so that one of said magazines is indexed sequentially upwardly and the other of said magazines is indexed sequentially downwardly.

5. The apparatus of claim 1 in which each said transfer means comprises

1. a movable plate structure,
 2. a vacuum pickup arm mounted on said plate structure for movement therewith relative to said station,
 3. vacuum structure for maintaining an article on said pickup arm when said arm is presented to such article, and
 4. means for moving said plate structure and said arm therewith sequentially toward and away from said station during picking up and transfer of articles relative thereto.
6. The apparatus of claim 5 in which said transfer means further includes
5. structure mounting said pickup arm for selective up and down movement relative to said plate to facilitate pickup and discharge of articles by said arm, and
 6. mechanism for actuating said mounting structure in predetermined timed sequence to elevate and retract said pickup arm during article pickup and discharge.
7. In combination in an apparatus for handling articles, such as silicon wafers,
- A. a magazine for receiving a quantity of said articles therein in stacked relationship,
 1. said magazine having a series of spaced article receiving slots therein,
 - B. a support base on which said magazine is positioned,
 - C. fluid-bearing means, a portion of which extends into said magazine when said magazine is supported on said base, positioned adjacent said support base for moving articles relative to the interior of said magazine, and
 - D. means for indexing said magazine in sequence in response to movement of individual articles relative to the interior of said magazine,
 1. said indexing means sequentially aligning said magazine slots in sequence with said portion of said fluid bearing means which extends into said magazine to permit movement of individual articles in sequence by said fluid-bearing means relative to the respective slots of said magazine.
8. The apparatus of claim 7 in which said fluid-bearing means comprises,
1. a track structure which projects into said magazine positioned on said support base, including
 - a. a series of directional fluid passages extending through said track structure,
 - b. said passages being oriented relative to the interior of said magazine to impart the desired direction of movement to said articles relative to said magazine,
 2. a source of supply of article supporting fluid in communication with said passages, and
 3. control structure for regulating introduction of supporting fluid into said passages in accordance with sequential indexing of said magazine by said indexing means.
9. The apparatus of claim 8 in which said passages in said track structure are directionally oriented to move articles inwardly into said magazine when fluid passes through said passages.
10. The apparatus of claim 8 in which said passages in said track structure are directionally oriented to move articles outwardly from said magazine when fluid passes through said passages.
11. The apparatus of claim 8 in which said track structure further comprises
- c. at least two series of said directional fluid passages,
 - d. one of said series of passages being directionally oriented to move articles in a first direction relative to said magazine,
 - e. the other of said series of passages being directionally oriented to move articles in another direction relative to said magazine,
- and in which said control structure for regulating introduction of supporting fluid into said passages comprises
- a. structure permitting introduction of said supporting fluid selectively into a predetermined one or the other of said series of passages.

12. The apparatus of claim 8 in which each of said passages is generally arcuately curved in configuration from the lower end thereof toward the upper end thereof which opens to the upper surface of said track structures.

13. The apparatus of claim 12 in which each of said passages is larger at the lower end thereof than the upper end thereof, whereby a curved nozzle configuration is imparted thereto.

14. The apparatus of claim 7 in which said fluid-bearing means comprises a track structure which includes

1. a retainer plate having a series of generally parallel slots formed in an upper surface thereof,
2. a chamber formed in a lower surface of said retainer plate in communication with a source of article supporting fluid,
3. openings extending through said retainer plate between said chamber and said slots through which such fluid may pass into said slots, and
4. a series of bars received in and substantially filling said slots,
5. the upper surfaces of said bars lying generally in alignment with said upper surface of said retainer plate and joining therewith in defining a bearing surface over which said articles are passable,
6. each of said bars having
 - a. a series of spaced grooves formed in a side face thereof,
 - b. said grooves being formed to extend at a predetermined angular inclination relative to the longitudinal axis of such bar.

15. The apparatus of claim 14 in which each of said bars further comprises

- c. another series of spaced grooves formed in the other side face of said bar,
- d. said other series of grooves also being formed to extend at a predetermined angular inclination relative to the longitudinal axis of said bar.

16. The apparatus of claim 15 in which

- e. the series of grooves along said one side face of said bar extend in an inclination which is generally opposite to the inclination at which the series of grooves extend along said other side face, whereby bidirectional article movement capability is imparted to said fluid-bearing means.

17. The apparatus of claim 7 in which said magazine comprises,

1. a generally U-shaped body in horizontal cross section, and
2. a series of lips spaced one above the other in said body which are spaced from each other by open slots defined by adjacent pairs of said lips,
 - a. each said slot opening toward said fluid-bearing means associated with said magazine for moving said articles relative to the interior of said magazine body.

18. The apparatus of claim 7 in which said means for indexing said magazine comprises,

- a. guide structure for said magazine support base,
- b. a drive rod engaged with said support base which is actuatable in predetermined sequential increments determined by the spacing between adjacent slots in which articles are positioned in said magazine, and
- c. power source mechanism for sequentially actuating said rod to effect incremental movement of said rod and said support base therewith.

19. The apparatus of claim 18 in which said drive rod is threadedly engaged with said support base, and in which said power source mechanism comprises,

- i. a drive motor for rotating said rod a predetermined amount following movement of each article relative to said magazine so that said rod will index said support base one position to present another article receiving slot to said fluid-bearing means.

20. The apparatus of claim 18 which further includes

- E. control means for regulating operation of said power source mechanism comprising,
 1. a sensor past which each article passes as it is moved relative to said magazine,

2. each said article causing said sensor to transmit an indexing control signal to said power source mechanism.

21. In combination in an apparatus for handling and treating articles,

- A. a supply magazine for a quantity of said articles,
- B. fluid-bearing means for withdrawing articles individually from said supply magazine,
- C. means for treating articles presented thereto in sequence,
- D. transfer means for receiving articles with drawn from said magazine to move the same in sequence to said treating means and from said treating means following treatment thereof,
- E. a discharge magazine for receiving a quantity of treated articles, and
- F. fluid-bearing means for receiving articles in sequence from said transfer means and for introducing such articles in sequence into said discharge magazine.

22. The combination of claim 21 which further includes

- G. means cooperable with said first and second mentioned fluid-bearing means for sequentially indexing said supply magazine and said discharge magazine in response to movement of said articles sequentially from said supply magazine and into said discharge magazine.

23. The apparatus of claim 21 in which each said supply magazine and said discharge magazine comprises,

1. a generally U-shaped body in horizontal cross section, and
2. a series of lips spaced one above the other in said body which are spaced from each other by open slots defined by adjacent pairs of said lips,
 - a. each said slot opening toward the respective fluid-bearing means associated with the respective magazines for withdrawing articles therefrom and for introducing articles thereto.

24. The apparatus of claim 21 in which each of said means for indexing said supply magazine and said discharge magazine comprises,

1. a support base for each said magazine,
2. guide structure for each said support base,
3. a drive rod engaged with each said support base which is actuatable in predetermined sequential increments determined by the spacing between adjacent articles in such magazine, and
4. power source mechanism for sequentially actuating each said rod to effect incremental movement of such rod and its associated support base therewith.

25. The apparatus of claim 24 in which the respective movable drive rods engaged with the respective supply and discharge magazine support bases are movable by their associated power source mechanisms in opposite directions so that one of said magazines is indexable sequentially upwardly and the other of said magazines is indexable sequentially downwardly.

26. The apparatus of claim 24 in which each said drive rod is threadedly engaged with its associated support base, and in which each said power source mechanism comprises,

1. a drive motor for rotating its associated rod a predetermined amount following movement of each article relative to its associated magazine so that said rod will index said support base one position to present another article receiving slot to the associated fluid-bearing means for moving said articles relative to such magazine.

27. The apparatus of claim 24 which further includes G. control means for regulating operation of each said power source mechanism comprising,

1. a sensor past which each article passes as it is moved relative to an associated magazine,
2. each such article causing said sensor to transmit an indexing control signal to its associated power source mechanism.

28. Fluid-bearing means for transporting articles from one station to another comprising

- A. a track structure which includes

1. a series of directional fluid passages extending through said track structure each of which is oriented to direct bearing fluid against an article on the upper surface of said track structure to urge such article in a predetermined direction,
 - a. each said fluid passage being generally arcuately curved in configuration from a lower end thereof toward the upper end thereof which opens onto said track structure upper surface, and
- B. structure for introducing bearing fluid into and through said passages to support an article positioned on said upper surface.
29. The fluid-bearing means of claim 28 in which said structure for introducing fluid into said passages includes
 1. mechanism for effecting intermittent pulsating flow of said fluid into said passages.
30. The fluid-bearing means of claim 28 in which said track structure further includes
 2. a second series of directional fluid passages extending through said track structure each being generally arcuately curved in configuration from a lower end thereof toward the upper end thereof, 3. the passages of said second series opening onto said track structure upper surface in a direction which is generally opposite from the direction in which the passages of said first mentioned series open onto such surface,
 4. The passages of said second series being connected with said structure for introducing fluid, whereby bidirectional article moving capability is imparted to said track structure.
31. The fluid-bearing means of claim 28 in which each of said passages is defined by a curved tapered groove the lower end of which is larger than the upper end thereof, whereby a curved nozzle configuration is imparted thereto.
32. Fluid-bearing track structure for transporting articles from one station to another comprising
 - A. a retainer plate having a series of generally parallel slots formed in an upper surface thereof,
 - B. a chamber formed in a lower surface of said retainer plate in communication with a source of article supporting fluid,
 - C. openings extending through said retainer plate between said chamber and said slots through which such fluid may pass into said slots, and
 - D. a series of bars received in and substantially filling said slots,
 1. the upper edges of said bars lying generally in alignment with said upper surface of said retainer plate and joining therewith in defining a bearing surface over which said articles are passable,
 2. each of said bars having
 - a. a series of spaced grooves formed in a side face thereof which open onto the upper surface of said retainer plate,
 - b. said grooves being formed to open onto said upper surface at a predetermined angular inclination relative to the longitudinal axis of such bar.
33. The track structure of claim 32 in which each of said bars further includes
 - c. another series of spaced grooves formed in the other side face of said bar,
 - d. said other series of grooves also being formed to open onto said upper surface at a predetermined angular inclination relative to the longitudinal axis of said bar.
34. The track structure of claim 33 in which
 - e. the series of grooves along said one side face of said bar extends at an inclination which is generally opposite to the inclination at which the series of grooves extend along said other side face, whereby bidirectional article movement capability is imparted to said track structure.
35. The track structure of claim 32 in which each of said grooves is formed with a curved tapered nozzle shaped configuration which is deeper and wider at the lower end thereof

- that at its upper end which opens onto the upper surface of said retainer plate.
36. Means for orienting the center of a generally flat article comprising
 - A. a shallow dish having a concave upper surface onto which an article to be centered is deposited,
 - B. a plurality of fluid passages extending through said dish and surrounding the center of said upper surface,
 - C. structure connecting said passages with a source of supply of article supporting fluid, and
 - D. mechanism for effecting intermittent pulsating flow of said fluid into and through said passages onto said dish upper surface to produce generally reciprocating movement of an article on said surface until such article is positioned with its center overlying said center of said surface.
37. The means of claim 36 which further comprises
 - E. a bore extending through said dish,
 1. the axis of said bore being aligned with said center of said upper surface,
 - F. a centering pin in said bore coaxial therewith, and
 - G. mechanism for raising said pin when an article is centered thereabove to elevate said article above said surface to permit engagement of such article by means for picking up and transferring the same from said dish while retaining the centered orientation thereof.
38. The means of claim 37 which further includes
 - H. vacuum structure in conjunction with said centering pin for maintaining an article thereon as said pin is elevated to present such article to such pickup and transfer means.
39. A method of handling articles, such as generally flat silicon wafers, to orient their centers in a predetermined location comprising,
 - A. providing a centering dish having a shallow concave upper surface and air passages extending therethrough opening onto said upper surface,
 - B. positioning an article to be centered on said upper surface,
 - C. introducing a supporting fluid through said passages into contact with said article on said upper surface, and
 - D. causing the flow of said supporting fluid to pulse as it passes into said upper surface to intermittently raise and lower said article and in so doing to move said article toward the center of said surface.
40. The method of claim 39 which further includes
 - E. elevating said article above said upper surface after the center of said article has been aligned with the center of said surface, and
 - F. retaining the centered orientation of said article during such elevation until the article is engaged for transfer to another station for subsequent treatment.
41. A method of withdrawing articles in sequence from a supply magazine in which a plurality of such articles are positioned comprising
 - A. providing a fluid-bearing track structure adjacent said magazine having a portion thereof which extends in underlying relationship relative to the articles in said magazine,
 - B. indexing said magazine to bring successive articles into a withdrawing position which is generally in alignment with said portion of said track structure,
 - C. introducing article supporting fluid through said track structure into engagement with each successive article located in said withdrawing position, and
 - D. imparting outward directional flow to said fluid with said track structure to cause said fluid to move each said successive article from said magazine.
42. A method of inserting a plurality of articles in sequence into a magazine comprising
 - A. providing a fluid-bearing track structure adjacent said magazine having a portion thereof which extends in underlying relationship relative to said magazine,
 - B. positioning articles in sequence upon said track structure,

- C. introducing article supporting fluid upwardly through said track structure into engagement with each successive article positioned thereon,
- D. imparting inward directional flow to said fluid with said track structure to cause said fluid to move each said successive article into said magazine, and
- E. indexing said magazine following insertion of an article thereto to prepare said magazine to receive a subsequent article.
43. A method of handling articles for movement between two stations comprising
- providing a fluid-bearing track structure which extends between said stations,
 - placing an article on said track structure,
 - introducing article supporting fluid through said track structure into engagement with said article,
 - imparting directional flow to said fluid with said track structure to cause said fluid to move said article from one of said stations to the other, and
 - following treatment of said article at said other station imparting reverse directional flow to said fluid with said track structure to cause said fluid to move said article back from said other station to said one station.
44. In combination in an apparatus for handling articles, such as silicon wafers,
- an indexable magazine for receiving a quantity of said articles therein in stacked spaced relationship,
 - said magazine having a series of spaced article receiving slots therein,
 - a support base on which said magazine is positioned,
 - fluid-bearing means positioned adjacent said magazine when said magazine is supported on said base for supporting said articles thereon and for moving said articles in sequence relative to the interior of said magazine, and
 - means for indexing said magazine in sequence in response to movement of individual articles by said fluid-bearing means relative to the interior of said magazine,
 - said indexing means sequentially aligning said magazine slots in sequence relative to said fluid-bearing means to permit movement of individual articles in sequence by said fluid-bearing means relative to the respective slots of said magazine.
45. The apparatus of claim 44 in which said magazine comprises,
- a generally U-shaped body in horizontal cross section, and
 - a series of lips spaced one above the other in said body which are spaced from each other by open slots defined by adjacent pairs of said lips, each said slot opening toward said fluid-bearing means positioned adjacent said magazine for moving said articles in sequence relative to the interior of said magazine body.
46. The apparatus of claim 44 in which said means for indexing said magazine comprises,
- guide structure for said magazine support base,
 - a drive rod engaged with said support base which is actuable in a predetermined sequential increments determined by the spacing between adjacent slots in which articles are positioned in said magazine, and
 - power source mechanism for sequentially actuating said rod to effect incremental movement of said rod and said support base therewith.
47. The apparatus of claim 46 in which said drive rod is threadedly engaged with said support base, and in which said power source mechanism comprises,
- a drive motor for rotating said rod a predetermined amount following movement of each article relative to said magazine so that said rod will index said support base one position to present another article receiving slot to said fluid-bearing means.
48. The apparatus of claim 46 in which said indexing means further includes
- control means for regulating operation of said power source mechanism comprising
 - a sensor past which each article passes as it is moved relative to said magazine,
 - each such article causing said sensor to transmit an indexing control signal to said power source mechanism.
49. In combination in an apparatus for handling and treating generally flat articles, such as silicon wafers, without manual handling,
- centering means to which articles are presented in sequence for orienting each article presented thereto with its center in a predetermined location comprising,
 - a shallow generally flat dish having a concave upper surface onto which individual articles are deposited,
 - a plurality of fluid passages extending through said dish surrounding the center thereof operatively connected with a source of supply of a supporting fluid, and
 - mechanism for pulsing supporting fluid from said source through said passages to effect generally reciprocating movement of an article on said surface until such article is positioned with its center overlying the center of said dish,
 - transfer means, for picking up and moving articles in sequence from said centering means and for presenting such articles to a station spaced from said centering means while retaining the centered orientation thereof, and for subsequently moving articles in sequence from said station.
50. A method of handling and treating articles, such as silicon wafers, without manual handling, comprising
- providing a supply of articles at a feed station,
 - sequentially withdrawing individual articles from said supply and placing the same in sequence on a fluid-bearing track structure adjacent said supply,
 - moving such withdrawn articles in sequence to a centering station on said fluid-bearing track structure,
 - locating the centers of such withdrawn articles in sequence at said centering station,
 - transferring such centered articles in sequence to a treating station,
 - positioning said centered articles in sequence at said treating station in a predetermined orientation for treatment at such station, and
 - placing such articles following treatment thereof in sequence on a fluid-bearing track structure and transferring such articles on said last mentioned fluid-bearing track structure to a discharge station.
51. A method of withdrawing articles in sequence from a supply magazine in which a plurality of such articles are positioned comprising
- providing a fluid-bearing track structure adjacent said magazine having a portion thereof adjacent to the articles in said magazine,
 - indexing said magazine to bring successive articles into a withdrawing position which is generally in alignment with said track structure,
 - withdrawing articles in sequence from said magazine and placing the same on said track structure,
 - introducing article supporting fluid through said track structure into engagement with each successive article located thereon, and
 - imparting outward directional flow to said fluid with said track structure to cause said fluid to move each said successive article away from said magazine.
52. A method of inserting a plurality of articles in sequence into a magazine comprising
- providing a fluid-bearing track structure adjacent said magazine having a portion thereof adjacent to said magazine,
 - positioning articles in sequence upon said track structure,
 - introducing article supporting fluid upwardly through said track structure into engagement with each successive article positioned thereon,
 - indexing said magazine to position the same to receive an article therein from said track structure,

E. imparting inward directional flow to said fluid with said track structure to cause said fluid to move each said successive article placed thereon into said magazine, and
F. indexing said magazine following insertion of an article thereinto to prepare said magazine to receive therein a subsequent article.

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