United States Patent

Goetz et al.

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[54] A METHOD FOR PROVIDING A FINISHED SURFACE ON WORKPIECES

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Related U.S. Application Data

[62] Division of Ser. No. 715,350, Mar. 22, 1968, Pat. No. 3,550,325.

[52] **U.S. Cl.** **51/318**, 51/328

[51] **Int. Cl.** **B24b 1/00**

[58] **Field of Search** ..... 51/151, 157, 317, 318, 326, 51/328, 292, 33 R, 46, 65, 124, 143, 283, 284, 119, 150, 263

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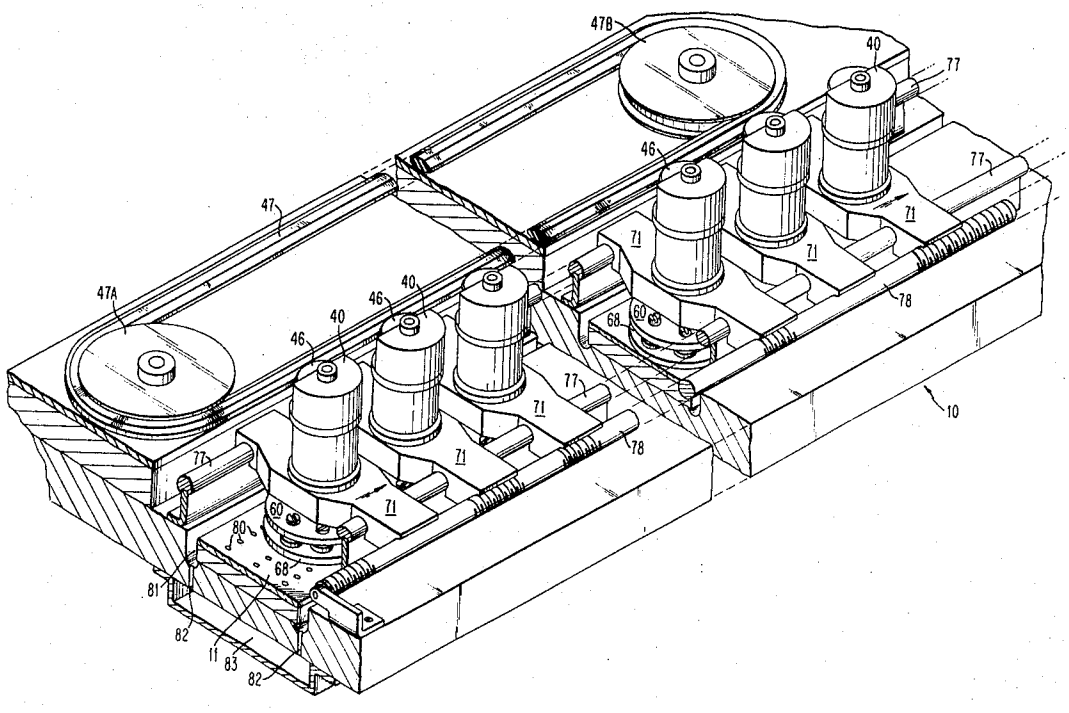
[57] **ABSTRACT**

This patent discloses a method of preparing the surface of a workpiece. The disclosed method teaches the provision of a novel workpiece carrier for engaging the workpiece, and oscillating the workpiece holder relative to a finishing surface while simultaneously providing relative linear movement between the workpiece holder and the finishing surface. The apparatus, by which the method is performed, includes a carrier having drive means for moving the carrier along a linear path of travel. A rotatable mount which is carried by the carrier includes a depending workpiece receiver which is rotatably connected to the mount, the receiver being mounted eccentrically with respect to the carrier. Means are provided for imparting rotation to the mount and separate means such as springs are connected between the receiver and the carrier so as to inhibit rotation of the receiver while permitting oscillation thereof. In this manner, an article being held by the receiver may be engaged and oscillated against the finishing surface in substantially coplanar relationship therewith. In addition, as herein disclosed, the finishing table upon which the carriers ride may be provided with a plurality of finishing surfaces, each adapted for different finishing operations with intermediate cleaning surfaces to clean the workpiece of any residue adhering thereto from a previous finishing surface.

3 Claims, 7 Drawing Figures



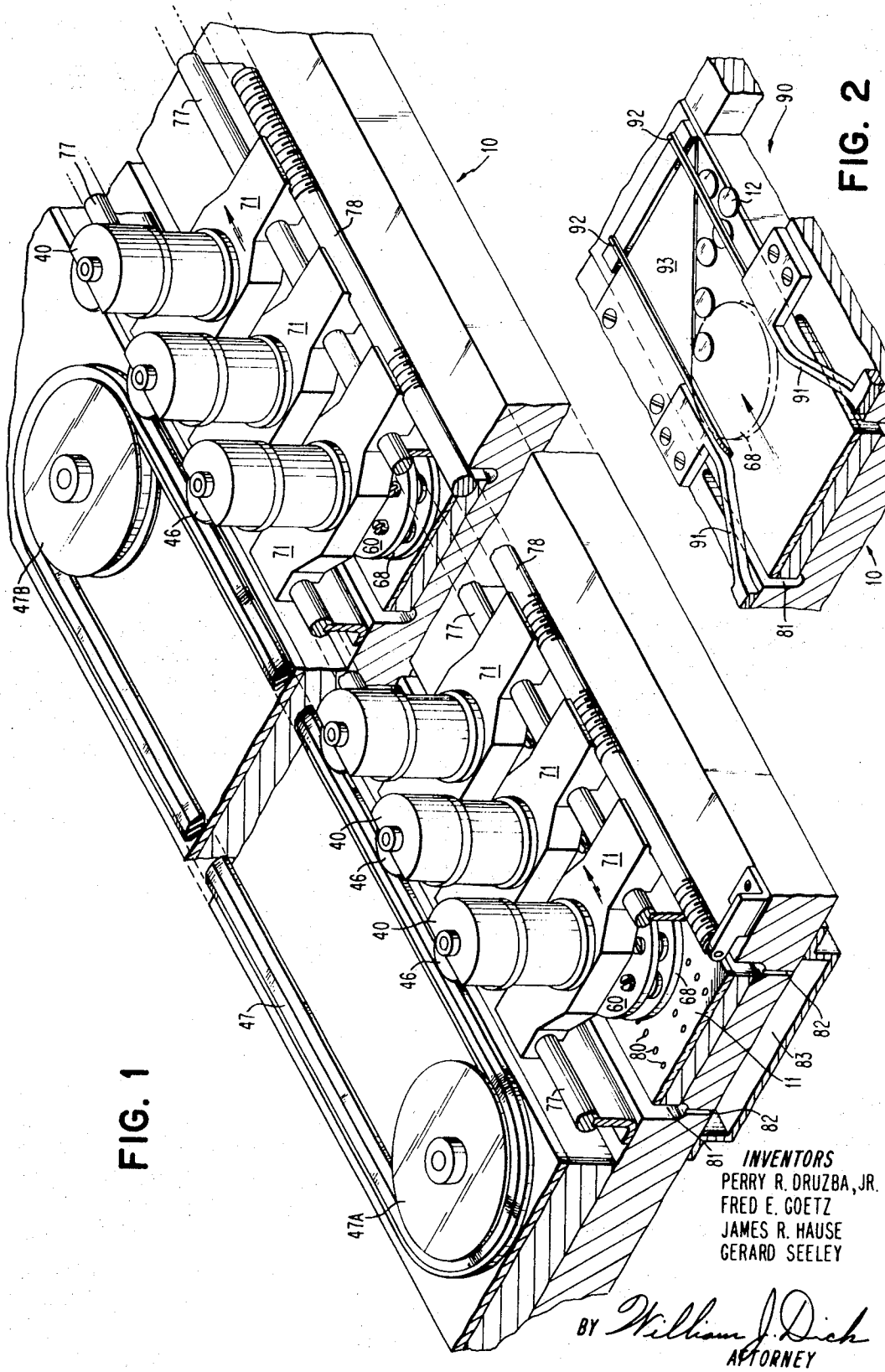


FIG. 1

FIG. 2

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FIG. 3

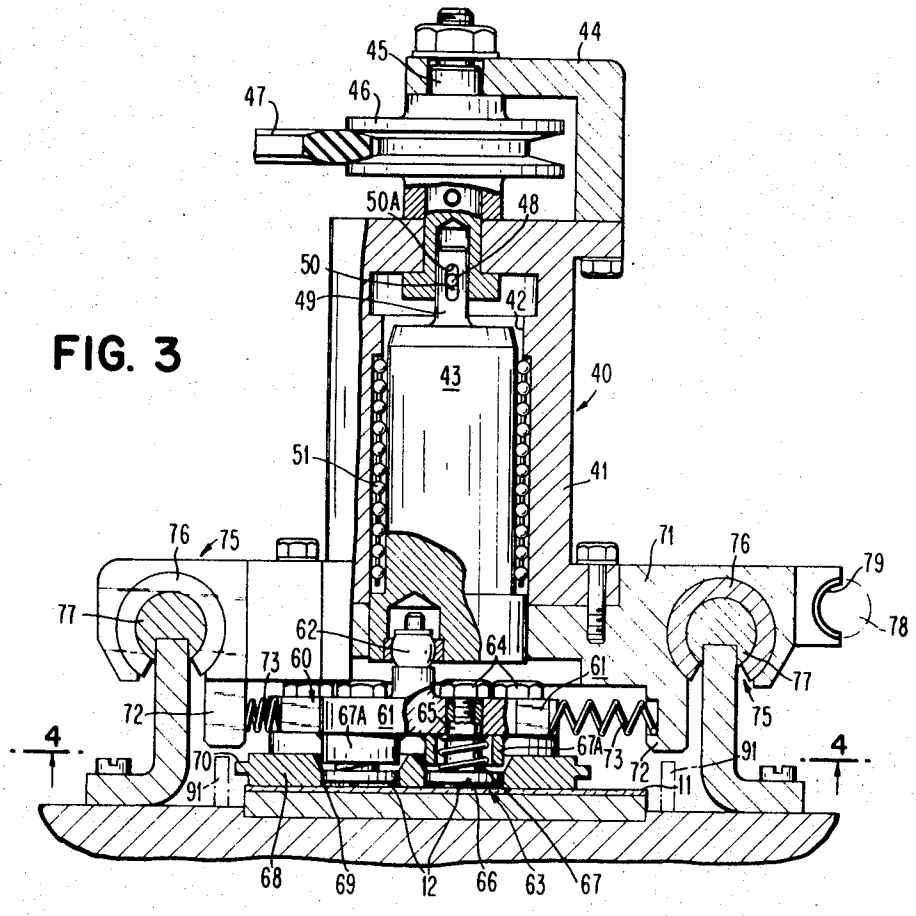
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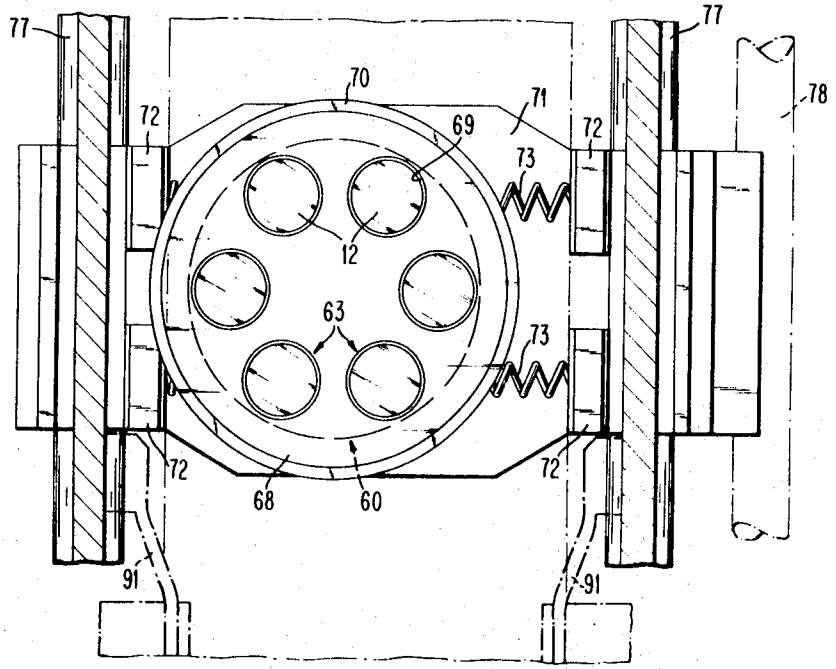
FIG. 4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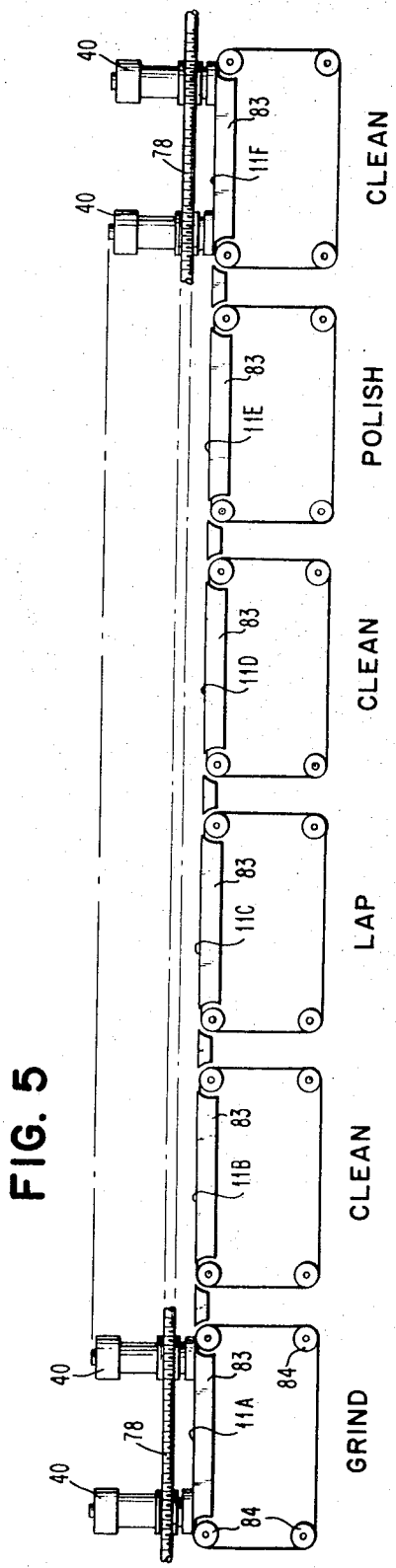

FIG. 5

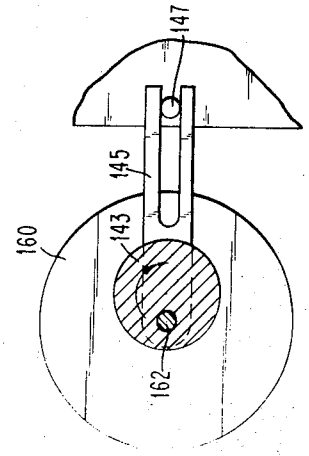

FIG. 7

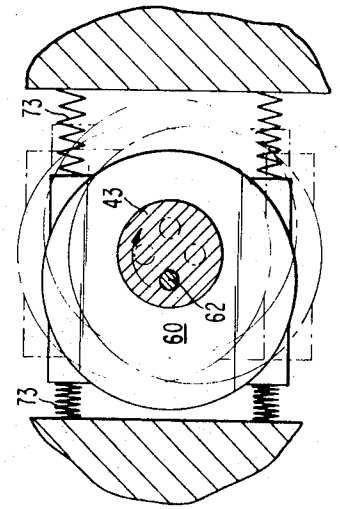

FIG. 6

A METHOD FOR PROVIDING A FINISHED SURFACE ON WORKPIECES

This is a division of U.S. application Ser. No. 715,350 filed on Mar. 22, 1968, now U.S. Pat. No. 3,550,325, issued Dec. 29, 1970.

SUMMARY OF THE INVENTION

The present invention relates to a method for providing a smooth surface on workpieces, and more particularly relates to a method for surfacing thin wafer-like workpieces in which the finished surface is treated uniformly.

STATE OF THE PRIOR ART

Prior to manufacturing integrated circuits on silicon and like wafers, it is necessary that the wafer be finished to a surface smoothness of approximately 1 micro-inch, peak to valley. The present apparatus and method for accomplishing such smooth surfacing of silicon and like wafers is to hold the wafer as by an adhesive or wax, and subject the wafer in a batch-type process to successive lapping, cleaning and polishing operations. In the present state of the art machinery, it is necessary that the wafer surfaces be coplanar with the finishing surface which, under certain circumstances, can lead to a high percentage of rejected wafers. In addition, in the batch-type process, single wafer failure, if the wafer is inadvertently chipped or broken, tends to ruin the remainder of the wafers because of the inability of the apparatus to rid itself of such broken chips or pieces, resulting in scoring of other wafer surfaces.

In view of the above, it is a primary object of the present invention to provide a novel method of effecting a finished surface on a workpiece such as a wafer, which method will substantially reduce the deleterious effects of the apparatus presently utilized in the batch-type process.

Another object of the present invention is to provide a continuous finishing process in which no one portion of the workpiece surface is abraded more than any other portion of the surface.

Still another object of the present invention is to provide a polishing table having a plurality of finishing surfaces which are easily changed so as to provide a fresh surface upon which the workpiece may be finished in a continuous manner.

Other objects and a fuller understanding of the invention may be had by referring to the following specification and claims taken in conjunction with the accompanying drawings in which:

FIG. 1 is a fragmentary perspective view illustrating a plurality of workpiece carriers operating in accordance with the method of the present invention;

FIG. 2 is a fragmentary perspective view of a portion of the finishing table showing the manner in which workpieces may be removed from the workpiece holders as the holders move from left to right in FIG. 1;

FIG. 3 is a fragmentary enlarged sectional view of a typical carrier of the present invention;

FIG. 4 is a fragmentary sectional view taken along lines 4—4 of FIG. 3, and as if FIG. 3 were not in section, with portions of the carrier removed to clarify the structure;

FIG. 5 is a schematic side elevational view of a process line for finishing the surface of a workpiece in accordance with the method of the present invention;

FIG. 6 is a schematic plan view of a portion of the apparatus best illustrated in FIGS. 3 and 4, and showing in broken lines the oscillatory action of the workpiece receiver as the carrier progresses from left to right in FIG. 5; and

FIG. 7 illustrates a modification of the carrier to provide an oscillatory motion to the workpiece receiver.

Referring now to the drawings and especially FIG. 1 thereof, a finishing table 10, having a plurality of carriers 40 thereon is shown progressing from left to right over a finishing surface 11. As will be more fully described hereinafter, as the carrier 40 moves in the longitudinal direction, the workpieces held thereby are provided with an oscillatory motion so that

all portions of the surface of the workpiece 12, bearing against the finishing surface 11 will be exposed to substantially the same amount of travel. Although the workpieces may be of any configuration, in the present instance the typical workpiece (shown in FIG. 2) is a flat wafer of silicon approximately 0.010 in.–0.012 in. thick and 1.25 in. in diameter.

As will be more fully described hereinafter each of the carriers 40 is adapted to hold one or more workpieces 12 against the finishing surface 11 as the carrier is moved longitudinally of the finishing table 10, while simultaneously imparting to the article an oscillatory motion. To this end and referring first to FIG. 3, each carrier 40 includes a casing 41 having a cylindrical cavity 42 therein for accomodating a rotatable cylindrical mount 43. As shown, the upper portion of the carrier includes an off-set bracket 44 on which is mounted drive means, in the present instance, including a shaft 45 and pulley 46 adapted for engagement with a standard double-sided V-belt 47. As shown in FIG. 1, the V-belt 47 is driven by one or the other of sheaves 47A, 47B. The shaft 45 includes a pin 48 at the lower end thereof for coupling thereto a spline extension 49 on the upper portion of the mount 43. As illustrated in FIG. 3, the extension 49 includes an elongated slot 50 which permits the mount 43 to move vertically relative to the pin 48, the downward vertical movement being limited by the upper edge 50A of the slot 50. Circumscribing the cylindrical mount 43 is a ball bearing race 51 which permits rotation of the mount 43 as well as free vertical movement thereof.

In order to engage the workpiece while permitting oscillation thereof relative to the carrier, workpiece receiver means 60 is provided. Referring once again to FIG. 3, the workpiece receiver means includes a housing ring 61 depending from and rotatably supported by a ball joint 62 connected to the mount 43. As will become more clear from the following, the ball joint 62 accomodates for any misalignment due to an uneven surface on a wafer permitting the wafer to find its own plane for finishing. The ring 61 includes at least one, in the present instance a plurality of depending workpiece holders 63, each of the workpiece holders including an adjustment screw 64 which passes through the ring 61 and is threaded into a sleeve 65 having at the lower end thereof a disc 66 substantially corresponding in contour to the shape of the workpiece 12, in the present instance a flat wafer 12. Intermediate the disc 66 and the bottom of the ring 61 and circumscribing the sleeve 65 is a compression spring 67, the compression spring acting upon the disc and ring to provide tensioning of the adjustment screw 64 to adjust the height of the disc for reasons which will become more evident hereinafter. Depending from the housing ring 61 and circumscribing each of the sleeves 65 is a stop 67A, which stop limits the vertical adjustment of the disc 66. Circumscribing each of the discs 66 is a floating ring 68 having a plurality of apertures 69 therein for receiving the workpieces 12, each of the apertures having a peripheral outline to accomodate the periphery of the workpiece to be finished. As shown in FIGS. 3 and 4, the floating ring 68 includes a radially and circumferentially extending flange 70, the ring being free to float in the vertical plane but restricted as to its lateral movement due to the fit of the discs 66 in the apertures 69.

In order to oscillate the workpiece receiver 60 while permitting the weight of the mount 43 to bear against the receiver, and thus the wafers housed in the aperture 69 beneath the disc 66, the ball joint 62 is connected eccentrically of the mount 43 so that as the mount is rotated as by rotation of the pulley 46 the receiver will tend to rotate about an axis eccentric to the carrier 40. The motion of the receiver 60, and thus the workpieces 12 is shown schematically in FIG. 6.

In order to prevent the receiver from rotating in a circular manner about the ball joint 62, whereby outer portions of the workpiece receive a great increment of travel than inner portions across the finishing surface 11, it is necessary to provide restraining means to the workpiece receiver 60 so that the receiver moves in an elliptical path. To this end and projecting radially outwardly from opposite sides of the casing 41, is a

flange 71 having depending pads 72 thereon spaced from the receiver 60. Intermediate the pads 72 and the housing ring 61 is restraining means, in the present instance comprising springs 73, which prevent the receiver 60 from rotating in a circular path about the ball joint 62.

In order that the carriers may be moved rectilinearly of the finishing table 10, guide means 75, in the present instance comprising bearing sleeves 76, are positioned adjacent the outer extremities of the flange 71, the bearing sleeves riding on a pair of longitudinally extending carrier guides 77 (See FIGS. 1, 3 and 4). In order to move the carrier longitudinally of the table, carrier drive means is provided, in the present instance including a longitudinally extending threaded drive rod 78 which cooperates with a threaded drive receiving portion 79 extending outwardly from one of the flanges 71. When loading the workpiece holders 63, the pin 48 associated with the slot 50 of the spline extension 49 bears against the upper edge 50A of the slot. The adjustment screw 64 associated with each of the workpiece holders 63 is backed off raising the disc 66 until the disc is spaced a distance equal to the desired finished thickness of the workpiece 12 of the finished surface 11. In this manner, insertion of the wafers into the apertures 69 will cause the mount 43 to be elevated away from the upper slot edge 50A a distance equal to the amount of material expected to be removed from the individual wafers. Thus the full weight of the mount and receiver is brought to bear against the workpiece as it is oscillated and moved rectilinearly of the finishing surface until the desired amount of material is removed from the workpiece at which time the upper edge 50A of the slot abuts the pin 48 and the mount may descend no further.

In accordance with the method of the present invention, in a continuous process, it is desirable to provide a plurality of carriers such as that heretofore described moving longitudinally of the finishing table 10. Therefore it is desirable to provide various finishing surfaces longitudinally of the finishing table so that a rough wafer placed at the beginning of the finishing table will be finished upon the carrier reaching the opposite end of the table. To this end, as best shown in FIG. 5, and in accordance with another feature of the present invention, a plurality of finishing stations having finishing surfaces 11A – 11F are shown. For example, at the "grind" station a grinding surface 11A may be provided to perform a rough cutting operation on the workpiece or wafer 12, the grinding surface being composed of, for example, a diamond dust impregnated, or other conventional grinding surface suitable for performing a rough finishing operation depending on the type of finish desired and the composition of the workpiece. Alternatively, the rough grinding operation may be accomplished by a recirculating abrasive slurry passed over the surface 11A, the means by which this is accomplished being set forth hereinafter in the description of the cleaning operation.

After the carrier traverses the grinding operation, it may be desirable to clean the wafers to remove any rough or coarse material which has deposited thereon. Accordingly, each successive carrier 40 will move into a cleaning station having a cleaning surface 11B in which water (dionized or detergent laden) may be supplied. Of course, if the workpiece is of a material subject to deterioration by water, other solutions such as oil may be used. The cleaning solution may be sprayed onto the surface 11B through nozzles adjacent the surface or may be supplied through a plurality of apertures 80 in the surface, the excess cleaning solution running off the cleaning surface 11B into troughs 81 on opposite longitudinal sides of the cleaning surfaces and thence through drilled apertures 82 into a basin 83 beneath the finishing table. In the basin, an immersable pump (not shown) may be emerged in the solution for providing a supply of liquid to the surface 11B through the apertures 80. After each carrier has passed over the cleaning station it will pass onto the lapping station in which a liquid, such as water or oil, loaded with lapping substances such as silicon carbide, boron, nitride particles etc. on the order of 10 microns, is supplied to the lapping surface 11C. Once again the manner by which a slurry may be placed on the lapping surface 11C at the lapping station is very similar to that previously described relative to the cleaning station, i.e., either through drilled apertures in the surface 11C and caught in a basin 83, or supplied to the edge of the finishing surface 11C as by nozzles.

Once again it is desirable to clean the surface of the wafers and an identical cleaning station as is heretofore described is provided at 11D.

As the carriers continue their movement along the finishing table 10, at the next station that will be polished, the surface 11E being supplied with a slurry of, for example, cupric acid, silicon oxide or other polishing substances. The type of surface for polishing will depend upon the individual workpiece being polished and if a slurry is desired a system such as heretofore described relative to the cleaning and lapping station, may be provided.

After the polishing operation, the wafer may be subjected to an additional cleaning step to remove any of the material adhering thereto. It may be desirable to replace the finishing surface at predetermined intervals so that any imbedded particles in the finishing surface will not score and thus ruin other workpieces held in subsequent carriers. To this end, the finishing surface 11 may be replaced at any of the stations in a manner shown in FIG. 5 wherein the finishing surface includes an endless belt or the like positioned around rolls 84 which may be driven continuously or at periodic intervals or even moved periodically by hand to provide a fresh or new finishing surface for the carriers. It may be necessary with a continuous or closed loop to periodically subject the loop to a cleaning operation as by ultrasonic or bath-type cleaning procedures. In addition, as it may be necessary to vary the residence time of the carrier on one or more of the stations, the surface length of the various stations may be different. Also, each of the carriers may be supplied with its own drive motor including a pair of contacts riding against a pair of energized rails, so that each of the motors is able to be varied as to its rotational speed. In this manner upon the carriers arriving at a different station along the table, the speed of oscillation may be appropriately varied.

In addition, as a practical matter, it is unnecessary to provide a closed loop cleaning surface at each of the stations and a roll to roll type feed may be advantageous. Also, when it is desirable to finish certain workpieces that are not as delicate as a thin wafer of silicon, the finishing surfaces may be fixed, and even in cases of delicate workpieces such as wafers, if a slurry type system of grinding, lapping and polishing is provided at each of the stations so that the finishing surface is thoroughly cleansed of contamination, fixed surfaces of known types may be provided.

As shown in FIG. 1, a common drive for each of the pulleys 46 is accomplished by the double sided V-belt 47. Each of the carriers 40, as it moves onto the finishing table, is gently engaged by the V-belt so that oscillation of the workpiece receivers 60 is gradual and not sudden or jerky. It should be recognized that a like finishing table 10 may be provided on the opposite side of the structure shown in FIG. 1 so that a new line of workpieces may be finished, the double sided V-belt 47 engaging like pulleys 46 associated with like carriers on the opposite side of the table.

In order to remove the wafers after they have been exposed to the cleaning surface 11F, it is necessary to raise or elevate the mount 43 so that the workpiece or wafer 12 may be removed therefrom. To this end, as each carrier moves towards an unloading station 90, it is disengaged from the V-belt 47, and the carrier moves into a guide chute defined by a pair of converging side rails 91 causing the workpiece receiver to be aligned along the central axis of the carrier. A pair of longitudinally extending lift rails 92 is then engaged by the flange 70 circumscribing the floating ring 68, raising the ring 68 until it engages the stops 67A depending from the lower surface of the housing ring 61. This tends to elevate the mount 43 leaving the finished wafers 12 disposed at the unloading

station. As the wafers have been pressed against the disc **66** of each of the workpiece holders **63**, and tend to adhere thereto due to surface tension, a knife edge **93** peels the wafers from each of the discs, the movement of the carrier being such as to cause the discs to be unloaded.

In certain instances, it may be desirable to provide other restraining means than springs for preventing rotation of the receiver **60** and permitting the same to move in an elliptical path. Referring to FIG. **7**, a receiver **160** is shown schematically as being pivotally connected as by an eccentrically positioned ball joint **162** to a mount **143**. In order to provide oscillation of the receiver **160** upon rotation of the mount **143**, a link **145** is connected to the receiver so that the ball joint may rotate relative to the link. As shown in FIG. **7**, the opposite end **146** of the link is bifurcated to embrace a pin **147** which is mounted outboard of the mount **143**. Thus rotation of the mount will effect oscillation of the receiver rather than rotary motion.

Thus the present invention provides a novel method for placing a finished surface on a workpiece in a continuous finishing process in such a manner that no one portion of the workpiece surface is abraded more than any other portion of the surface. In addition the provision of novel workpiece carriers eliminates the necessity of using adhesives and/or waxes to retain the workpiece against the finishing surface. In addition, the provision of a ball joint type connection between the receiver and the rotating member permits the surface of the workpiece being finished to seek its natural plane.

Although the invention has been described with a certain degree of particularlity, it should be understood that the present disclosure has been made only by way of example and numerous changes in the details of construction, the combination and arrangement of parts and the mode of operation may be made without departing from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. A method of preparing the surface of a workpiece against a plurality of serially arranged surfaces, at least some of said surfaces being different roughness finishing surfaces, in apparatus including a workpiece holder for pressing said workpiece against said finishing surfaces, comprising the steps of: oscillating at least one of said workpiece holder and a finishing surface to provide relative oscillatory movement therebetween; simultaneously therewith propelling said workpiece holder along a linear path over said serially arranged surfaces and applying an abrasive slurry onto at least one of said surfaces.

2. A method of preparing the surface of a workpiece in accordance with claim **1** including the step of applying a cleaning liquid onto at least one of said finishing surfaces.

3. A method of preparing the surface of a workpiece in accordance with claim **1** including the steps of grinding the surface of said workpiece against one of said finishing surfaces; cleaning said surface of said workpiece on another of said surfaces, lapping the surface of said workpiece against another of said surfaces, and then polishing said workpiece surface on still another of said finishing surfaces.

* * * * *