United States Patent

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[54] **APPARATUS FOR MANIPULATING ARTICLES IN A VAPOR STREAM TO ACHIEVE UNIFORM DEPOSITION LAYER**
9 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** **118/48,** 118/56, 118/503
[51] **Int. Cl.** **C23c 11/00**
[50] **Field of Search** ..... 118/52, 53, 48–49.5, 56, 500, 503; 117/(Inquired re:) 106–107.2; 269/(Inquired); 214/(Inquired)

[56] **References Cited**

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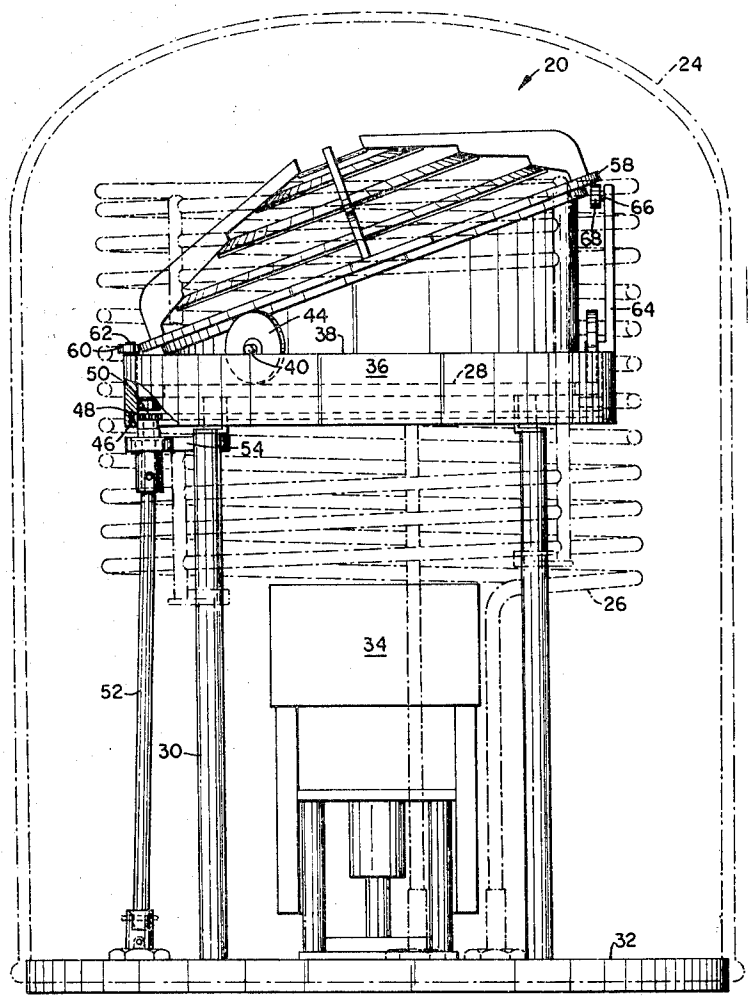
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Primary Examiner—Morris Kaplan
Attorney—Owen, Wickersham and Erickson

ABSTRACT: An apparatus for manipulating a plurality of waferlike devices having relatively sharp edge depressions on one side in a moving stream of vaporized material in order to deposit a layer of the material of substantially uniform thickness on all the surfaces of each device. The apparatus comprises a first rotary ring supported above a source of vaporized material that rises in a steadily moving stream and a means for rotating the rotary ring at a constant speed. A second rotary ring is supported at an angle relative to and is rotated at a different speed than said first rotary ring. A holding rack for mounting a large plurality of devices being coated is supported on said second rotary ring so that as the apparatus operates in the stream of vaporized material the devices undergo a nutational movement that causes the vaporized material to deposit evenly and uniformly on all surfaces of each device.



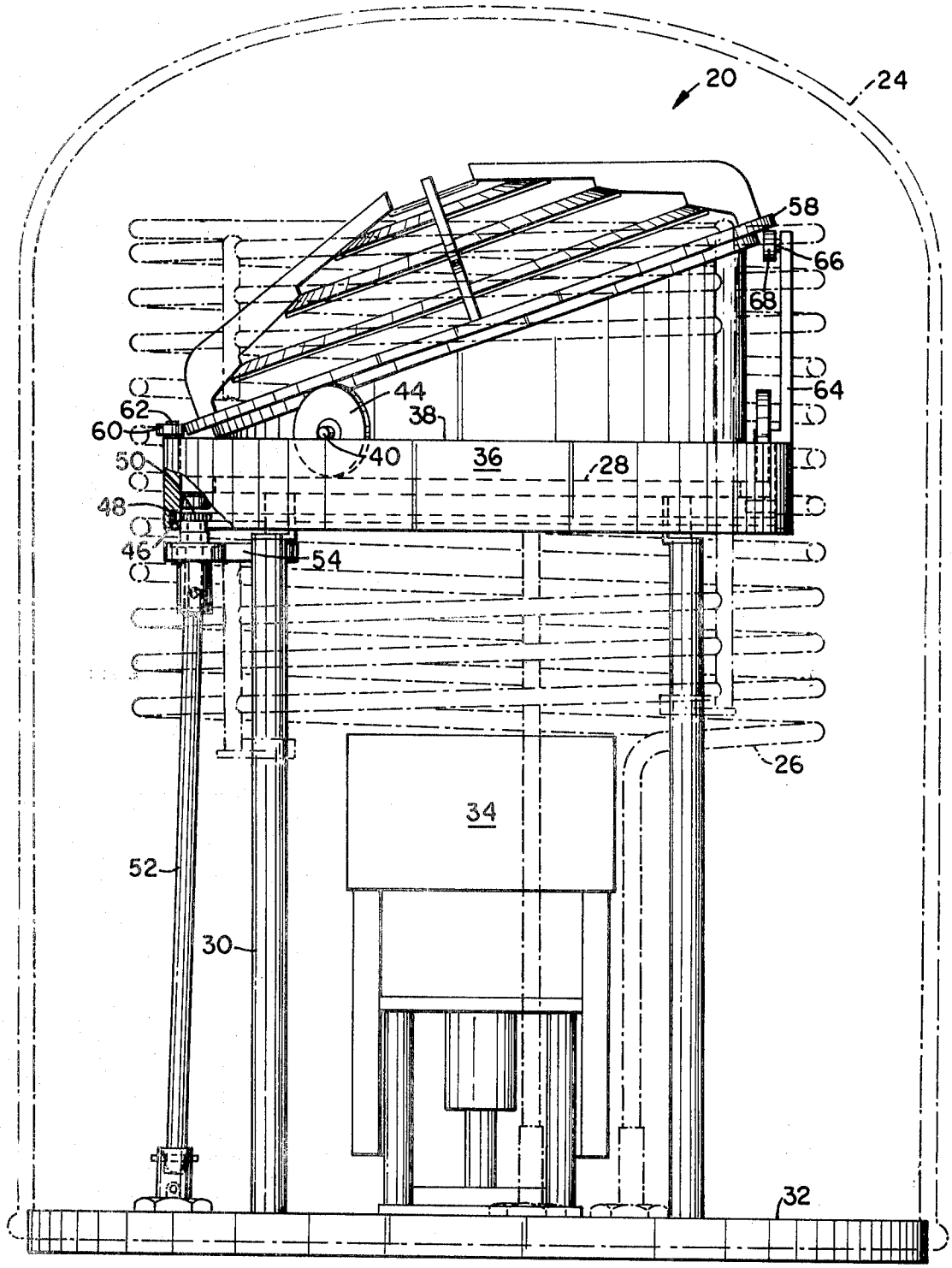


FIG_1

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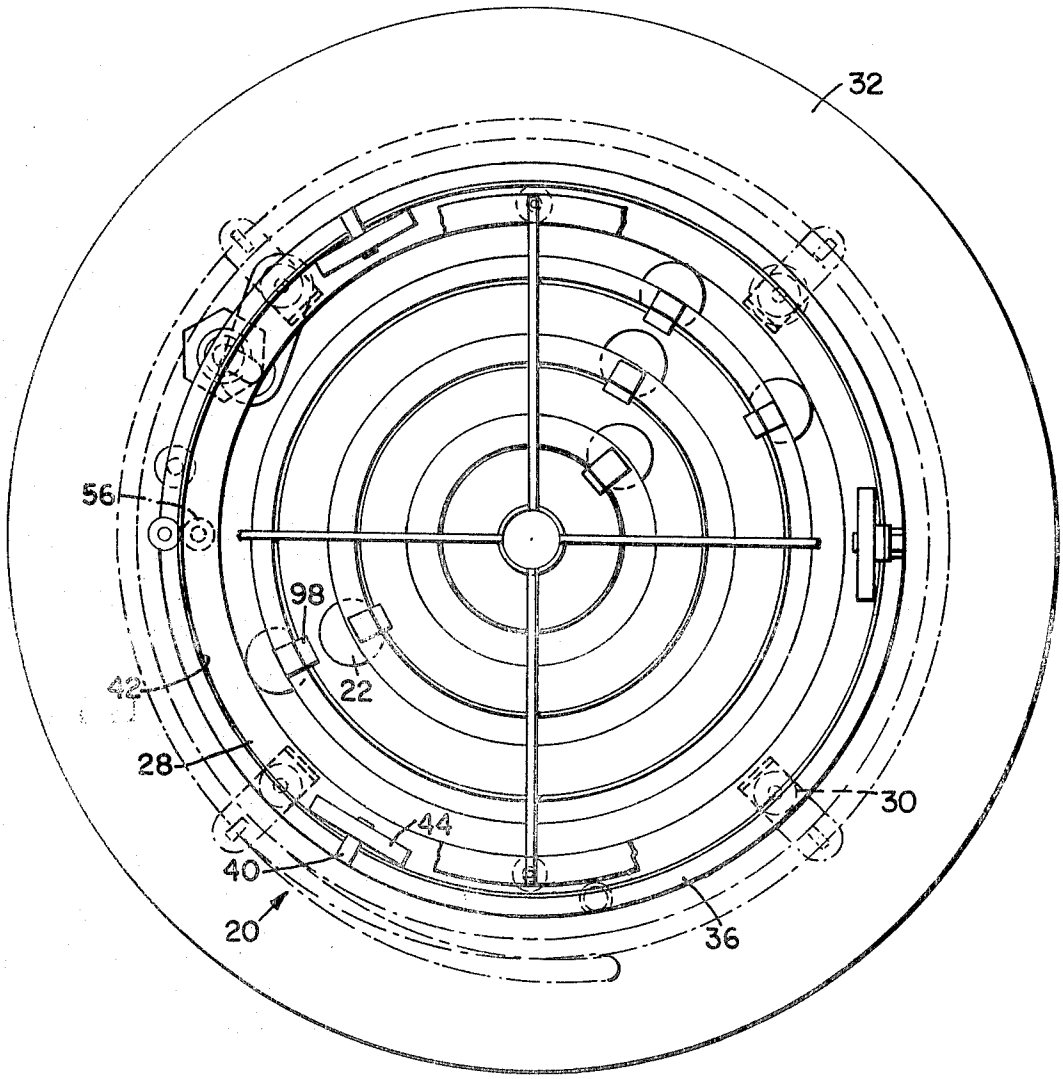


FIG_2

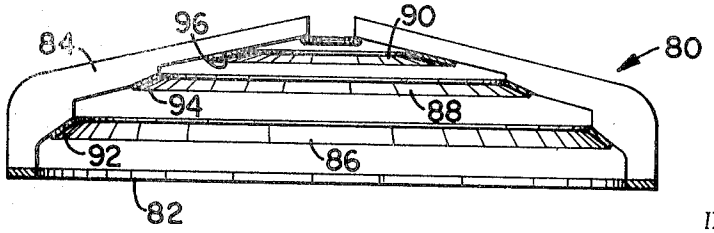


FIG_4

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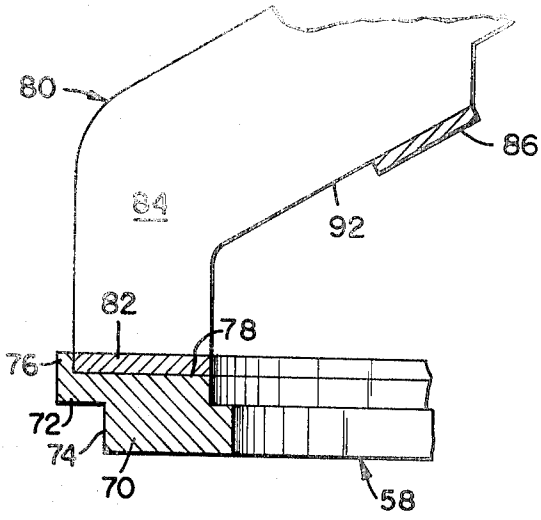


FIG_5

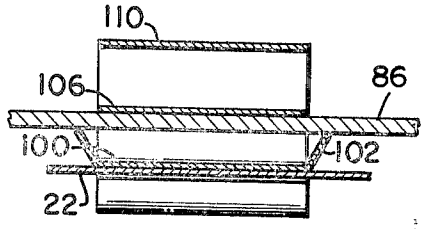


FIG_8

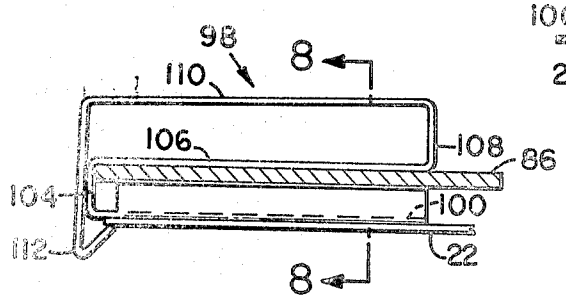


FIG_6

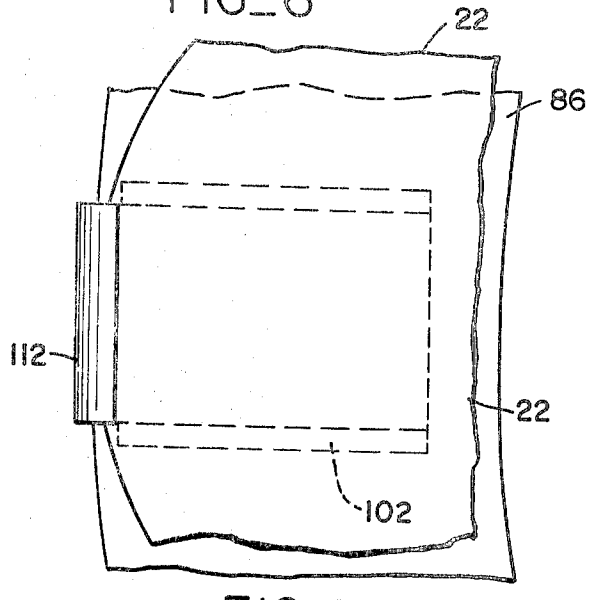


FIG_7

FIG_3

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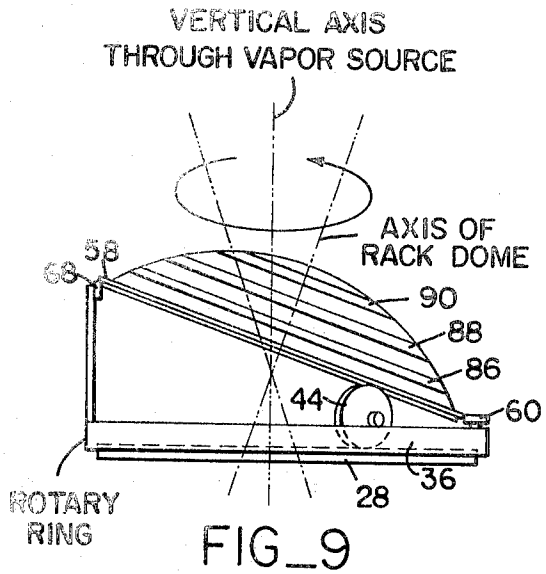


FIG_9

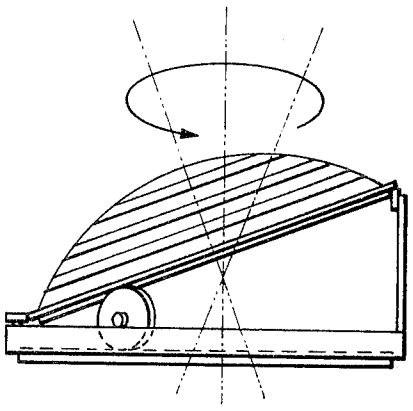


FIG_10

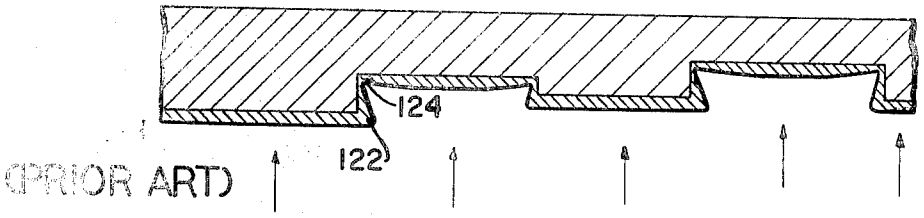


FIG_11

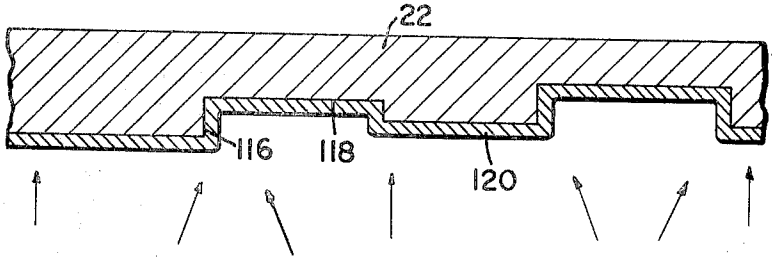


FIG_12

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APPARATUS FOR MANIPULATING ARTICLES IN A VAPOR STREAM TO ACHIEVE UNIFORM DEPOSITION LAYER

This invention relates to apparatus for coating semiconductor devices and more particularly for manipulating semiconductor wafers in a stream of vaporized material so that a substantially uniform layer of material will be deposited on the entire surface of the wafers including recessed areas and the sidewalls of such areas.

In manufacturing semiconductor devices of various types, one or more layers of material are applied to a substrate body, and by well known masking and etching procedures recessed areas and/or crossover paths in a predetermined pattern are formed on the semiconductor surface. It may then become necessary to apply another material to the semiconductor surface such as a layer of metal and it is essential that the layer be applied uniformly to all surfaces thereon including the near vertical sidewall surfaces of the recessed areas. Generally, such layers of material are applied by an evaporation metallization process wherein the metal is vaporized and caused to flow against the wafers so that a layer of the material is deposited on its surface. Heretofore, a problem arose in this evaporation metallization process because it was difficult to produce a uniform layer on all surfaces of the wafer. In some areas on the wafer, buildups of excessive material occurred and in others particularly within recessed areas, insufficient material was deposited. The severity of this problem was increased by the fact that the devices being produced are extremely small as are the depths of the recessed areas and the thickness of the layer of material which is desired.

Heretofore, efforts were made to overcome this problem by rotating the wafers within the stream of vaporized material with apparatus utilizing plane rotary and planetary motions. However, such prior art apparatus was not only complicated and expensive but its operation inherently produced a varying deposition rate on the wafers being processed.

One object of the present invention is to solve the aforementioned problem by providing an apparatus that will assure the application of a completely uniform thickness of material to all surfaces of a semiconductor wafer having depressions with near-vertical sides.

Another object is to provide an apparatus that will continuously manipulate a plurality of semiconductor wafers in the path of a flowing vaporized body of material by constantly changing the position and angle of the wafers in such a manner that the vaporized material will be deposited uniformly on all surfaces on one side of each of the wafers.

Another object of my invention is to provide an apparatus that will manipulate a plurality of wafers to facilitate the coating of all surfaces thereon while maintaining the wafers in a constant deposition rate region of the stream. This feature assures a high quality and uniformity in the wafers coated as well as a larger production capacity than heretofore possible.

Yet another object of the present invention is to provide an apparatus for manipulating a plurality of wafers in a vapor stream in order to coat them with a uniform layer of material which is relatively simple in construction, and thus reliable in operation, easy to operate and maintain, and particularly well adapted for ease and economy of manufacture.

The present invention for accomplishing the aforesaid objectives is characterized by a horizontally oriented rotary drive ring which is rotated at a constant speed. Attached to the drive ring are a plurality of drive transfer wheels which engage a support ring that is mounted on an incline relative to the drive ring. The drive transfer wheels provide a transfer of motion from the rotating drive ring to the inclined support ring so that the latter rotates relative to and thus at a different rate than the drive ring. A domelike rack for supporting the wafers being processed is retained on the support ring and thus a motion is imparted to the wafer which is a combination of that provided by the drive ring and the support ring. As the drive ring rotates the inclination of the rack is constantly changed relative to the vapor source over an angle from one side of the normal to the opposite side. This combined motion insures uniform deposition of the vapor on all wafers held in the rack and provides adequate coverage of the side surface in the depressions on the wafers. Since the ratio between the diameters of the drive ring, the support ring and the drive transfer wheels is not unity, the rack never returns to the same position for small number of turns of the drive ring, thus assuring an even deposition of material on all of the wafers.

A further object of my invention is to provide an apparatus as described having a removable rack for supporting a plurality of semiconductor wafers so that each wafer will be oriented in the same relative position with respect to the vapor source.

Yet another object of my invention is to provide a domelike rack having concentric ring members to which wafers are secured during the coating process so that the surface of all wafers on each ring member would be normal to the vapor stream if the rack axis extended through the vapor source.

Other objects, advantages and features of the present invention will become apparent from the following detailed description of one embodiment presented in conjunction with the accompanying drawings, in which:

FIG. **1** is a view in elevation and partially in section of an apparatus embodying the principles of the present invention;

FIG. **2** is a plan view of the apparatus of FIG. **1**;

FIG. **3** is an enlarged fragmentary view in elevation and in section of one portion of the apparatus in FIG. **1**;

FIG. **4** is a view in elevation and in section of a wafer holding rack for my apparatus;

FIG. **5** is enlarged fragmentary view of one portion of the holding rack of FIG. **4**;

FIG. **6** is an enlarged view in section of the holding rack of FIG. **4** supporting a wafer holding clip;

FIG. **7** is a bottom view of the holding clip of FIG. **6**;

FIG. **8** is a view in section taken along line **8–8** of FIG. **6**;

FIG. **9** is a schematic view in elevation showing a holding rack in one position as it is being articulated according to my invention;

FIG. **10** is a schematic view similar to FIG. **9** showing the holding rack in another position;

FIG. **11** is a greatly enlarged view in section of a semiconductor device with a layer of material applied in accordance with prior art methods; and

FIG. **12** is an enlarged view in section of a semiconductor with a layer applied using apparatus of the present invention.

Referring to the drawing, FIGS. **1** and **2** show an apparatus **20** embodying the principles of the present invention which is operable to hold a plurality of articles to be coated such as semiconductor wafers **22** and to manipulate them within a stream of vaporized coating material. As shown, the apparatus is situated within a bell jar type of enclosure **24** which can be sealed so that a vacuum can be achieved within the enclosure around the apparatus during the vapor deposition process. In accordance with standard evaporation metallization techniques, a high vacuum is produced in part by the circulation of a low temperature fluid such as liquid nitrogen through coils **26** of tubing that surround the apparatus within the enclosure **24**. It should be understood that the bell jar and cooling coils are shown only to illustrate a typical environment of my apparatus during its normal use, but these components are not integral parts of my apparatus for moving the wafers being coated.

In general, the apparatus **20** comprises a stationary support ring **28** which in effect is an annular track with a flat upper surface. This ring is fixed to and supported on the upper ends of four upright legs **30** which are spaced apart and fixed at their lower ends to a base member **32**. Between the legs is a suitable metal vaporizing unit **34** including a supply of metal and a heating element, such as an electron gun that can vaporize the metal and cause it to rise upwardly. This vaporizing unit is not shown in detail since they are well known to those skilled in the art and the present invention does not reside in nor is it limited to any specific form of vaporizing unit.

Supported on the stationary ring **28** is a movable rotary ring **36** which is essentially a short section of a cylindrical sleeve having a uniform wall thickness. Fixed to the annular upper edge **38** of the rotating ring, as by welding, are three axle members **40**, each of which extends radially inwardly beyond the inner wall **42** of the rotary ring **36** on a line that intersects its axial center line. Mounted on each axle member is a drive transfer wheel **44** which rests on and thus is adapted to roll along the flat upper surface of the support ring **28**.

Near the lower edge of the inner surface of the rotary ring an annular groove **46** or slot is provided, and fixed therein is suitable gear means such as a ladder chain **48** of the well-known type. Meshed with the ladder chain is a driving sprocket **50** attached to the upper end of a rotary shaft **52** which extends upwardly through the base member **32** from a suitable constant speed drive motor (not shown). The shaft extends through and is supported by a bearing block **54** that is also connected to one of the adjacent legs.

Mounted on the stationary ring **28** are a series of idler rollers **56** which are located at intervals between the legs **30**. These rollers are journaled in the stationary ring and are located so that they extend a small predetermined amount beyond its outer edge, engaging the inner surface of the rotary ring **36** and thereby retaining the latter in axial alignment as it rotates. Thus, it is seen that the rotary shaft **52** driven at a constant rate causes the rotary ring to rotate with the attached drive transfer wheels **44** supporting it while rolling along the upper surface of the fixed annular ring **28**.

Mounted on top of the rotary ring **36** is a movable, annular-shaped ring or rack holder **58** which is supported at an angle on the rotary ring by a first idler roller **60**. The latter is freely rotatable on a vertical shaft **62** fixed to the upper annular edge surface of the rotary ring and axially aligned with its central axis. On the opposite side of the rotary ring is an upright support bar **64** that extends vertically upwardly from the upper edge of the rotary ring (See FIG. 3). Fixed near the top of this bar and extending perpendicular thereto is a horizontal shaft member **66** on which is mounted a freely rotatable support roller **68**. The rack holder **58** rests at an angle on the latter roller **68** which is located at a predetermined height above the rotary ring so that the rack holder also engages the two drive transfer wheels **44** which are spaced from opposite sides of the idler roller **60**. The lower end of the inclined rack holder bears against and is retained in position on the transfer wheels by the idler roller **60**. Thus, as the rotary ring is turned, its drive transfer wheels **44** that engage the fixed support ring **28** also turn, thereby turning the inclined support ring or rack holder **58**. I have found that for best results the rack holder should be inclined at an angle of around 20° to the horizontal, although this can vary somewhat depending on the distance of the rack holder from the vapor source and other factors.

The rack holder or movable support ring **58**, as shown in FIG. **5**, has, in cross section, a lower base portion **70** and an integral upper portion **72** extending to a greater diameter, thereby forming a shoulder **74** which lies inside the drive transfer wheels **44** and serves to maintain the rack holder in position as it is rotated. Around the outside edge of the upper rack portion **72** is an upwardly extending lip **76** which, with the upper portion, forms an annular seat **78**.

A rack **80** for retaining the semiconductor devices being processed is adapted to be removably seated on the rack holder. As shown in FIG. **4**, it comprises a base ring member **82** whose dimensions are such that it fits in the annular seat **78** just inside the peripheral lip **76** of the rack holder. Attached to and extending from the base ring and at right angles to each other are four frame supports **84** which are joined together at the center of the rack. These frame supports also extend upwardly at an angle and they thereby form a domelike shape for the rack. Fixed to these latter supports are a series of concentric mounting rings for semiconductor devices which are spaced inwardly from the base member **82**. In the embodiment shown, three such mounting rings **86**, **88** and **90** are used, but any convenient number is possible within the scope of the present invention. Each frame support has an irregular inner edge comprised of stepped edge portions **92**, **94**, and **96**, the normal surface extensions of which make different angles with the axial center line of the rack. More specifically, each edge portion is at an angle which is normal to a line from the vapor source if the rack was positioned so that its axis passed through the vapor source. The mounting rings are fixed to these edge portions so that each ring is oriented at a slightly different conical angle with respect to the axial centerline of the rack. Since each mounting ring has a conical angle which is the same as the edge portions to which it is fixed, its annular surface is also normal to a line through the source of the evaporating material, if the rack was mounted horizontally on the rotary ring. This orientation of the mounting rings relative to the source in accordance with my invention helps to produce a relatively constant deposition rate and thus an even coating of all surfaces including the sidewall surfaces of wafers on all of the mounting rings of the rack.

Each semiconductor wafer device is held on one of the mounting rings of the rack by a clip **98** that holds the wafer flat against the underside of the mounting ring. Since each mounting ring is oriented in the same position with respect to an imaginary line from the vaporizing source, the wafers held by the clips on each mounting ring receive the vaporized material at the same angle. As shown in FIGS. **6—8**, the clip **98** is formed from a strip of sheet metal material such as a resilient spring steel that is bent to a predetermined shape, as shown in FIGS. **6**, **7** and **8**. In the embodiment shown, the clip **98** has a first end portion **100** with folded up integral side tabs **102**. A first web portion **104** which is somewhat larger than the width of the side tabs **102** connects the end portion to an upper intermediate portion **106** that is parallel to the end portion and terminates at a second web portion **108**. From the latter web portion the clip extends back with a top portion **110** and then downwardly with a hook portion **112** past the first web portion and back up against the first end portion **100**. As best shown in FIG. **6**, the clip secures it to a mounting ring by gripping the ring between the end portion **100** and the upper intermediate portion **106**. When downward pressure is now applied to the top portion **110** a wafer **22** can be inserted between the end of the hook portion **112** and the first end portion **100**. The movement of the hook portion is essentially provided by the slight bending and pivoting of the top portion from the top of second web section. With the clip configuration, a positive clamping force can be provided at the edge of a wafer to hold it in position against the mounting ring during the entire coating process.

The operation and results obtainable with my apparatus for coating devices in a vapor stream may be readily understood by reference to the schematic views of FIGS. **9** and **10**. As shown in FIG. **9**, the rotating drive ring **36** is being driven in the direction indicated and in the instant shown. The devices being coated are in an angular position with respect to the rising stream of vaporized material indicated by the upwardly directed arrows below the rotary ring. As the rotary drive ring continues to move, its drive transfer wheels **44** move the inclined support ring at a different angular velocity. Thus, as shown in FIG. **10**, when the rotary ring has almost completed one revolution from the position of FIG. **9**, the inclined support ring has reached an entirely different position with respect to the rotary ring. In effect, the support ring and thus the rack and the wafer devices on it, undergo a continuous nutational movement during the rotation of the rack so that the rising vapor will strike all surfaces of each wafer, including all sidewalls **116** of recessed areas **118** with substantially the same incidence varying an equal amount on either side of the normal. (See FIG. **12**). This compound motion of the wafers results in a uniform thickness of the deposited layer **120** of material on all surfaces and eliminates the irregular application of material which heretofore produced overhanging portions **122** and thin or bare spots **124** on the wafer substrate, as illustrated in FIG. **11**.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. An apparatus for manipulating waferlike semiconductor devices having relatively sharp edged depressions on one side in a stream of vaporized material in order to deposit a layer of material of substantially uniform thickness on all the surfaces of the one side of the device, said apparatus comprising:

a fixed annular ring;

means for supporting said annular ring above a source of vaporized material producing an upwardly flowing vapor stream;

a rotary drive ring supported on and movable relative to said fixed annular ring;

drive means for rotating said rotary drive ring;

a rotary support ring;

rack means on said rotary support ring for holding a plurality of semiconductor devices;

means for supporting said rotary support ring on said rotary drive ring at a predetermined angle; and

means on said rotary drive ring and engaging said fixed annular ring for rotating said rotary support ring relative to said rotary drive ring, whereby the combined movements of said rotary drive ring and said rotary support ring produces a nutating motion for all semiconductor devices in the vapor stream.

2. The apparatus as described in claim 1 wherein said drive means comprises a rotating shaft and circular gear means attached thereto and an annular gear means on said first rotary ring meshed with said circular gear means.

3. The apparatus as described in claim 1 wherein said rack means for holding semiconductor devices comprises an outer ring member having a smaller outer diameter than said rotary support ring, a series of support members fixed to and extending radially inwardly toward and connected together near the axial center of said ring member, each support member extending above the plane of said ring member and having a series of radially spaced apart surfaces on its inner concave edge, each said surface forming a different angle with respect to the axial center line of said outer ring member; a series of concentric frustoconically shaped intermediate ring members each one being attached to one said surface on a support member having the same angle, and thereby providing means for holding semiconductor devices so that vaporized material radiating from a source will strike all of the devices on different, intermediate ring members in the same manner.

4. The apparatus as described in claim 3 wherein all of said intermediate ring members are oriented on said support members so that a line extending from the source of vaporizing material strikes each intermediate ring member at a normal angle if the axis of the rack means extends through the vapor source.

5. The apparatus as described in claim 1 wherein said rotary support ring is inclined relative to said first rotary ring at an angle of approximately 20°.

6. The apparatus as described in claim 3 including removable clip means on side ring members for holding waferlike devices at the same orientation as the surface of said ring members.

7. The apparatus as described in claim 1 wherein said means on said rotary drive ring for rotating said rotary support ring comprises a series of drive wheels mounted on axle members spaced apart on said rotary drive ring.

8. The apparatus as described in claim 1 including a plurality of rollers fixed to said fixed annular ring and engaging said rotary drive ring to provide concentric positioning of the two rings while allowing rotary motion between the rings.

9. The apparatus as described in claim 1 wherein said rotary drive ring is a cylindrical sleeve for positioning said drive wheels ride on said fixed annular ring and are in simultaneous contact with said rotary support ring, thereby providing a transfer of motion to said rotary support ring.