March 8, 1966 R. P. RADKE ETAL 3,238,918

VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

Filed Dec. 26, 1961 8 Sheets-Sheet 1

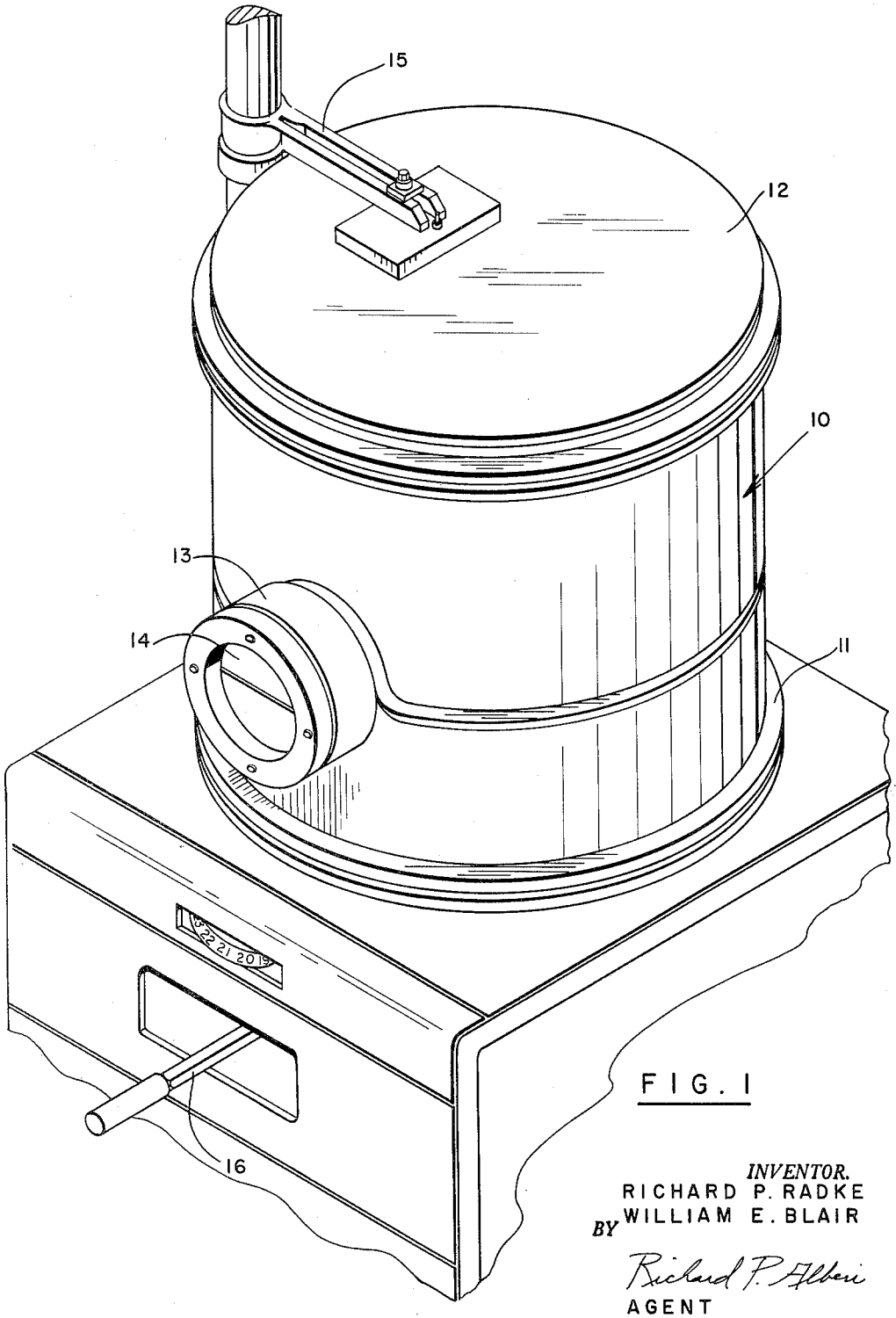


FIG. 1

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VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

Filed Dec. 26, 1961 8 Sheets-Sheet 2

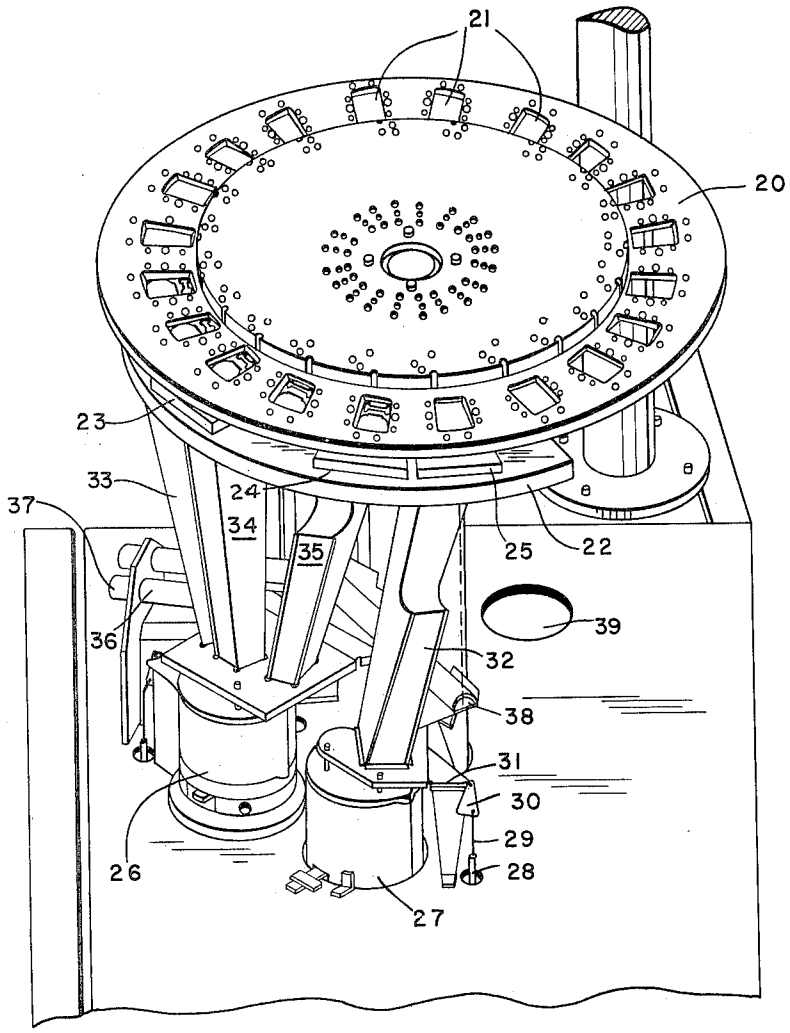


FIG. 2

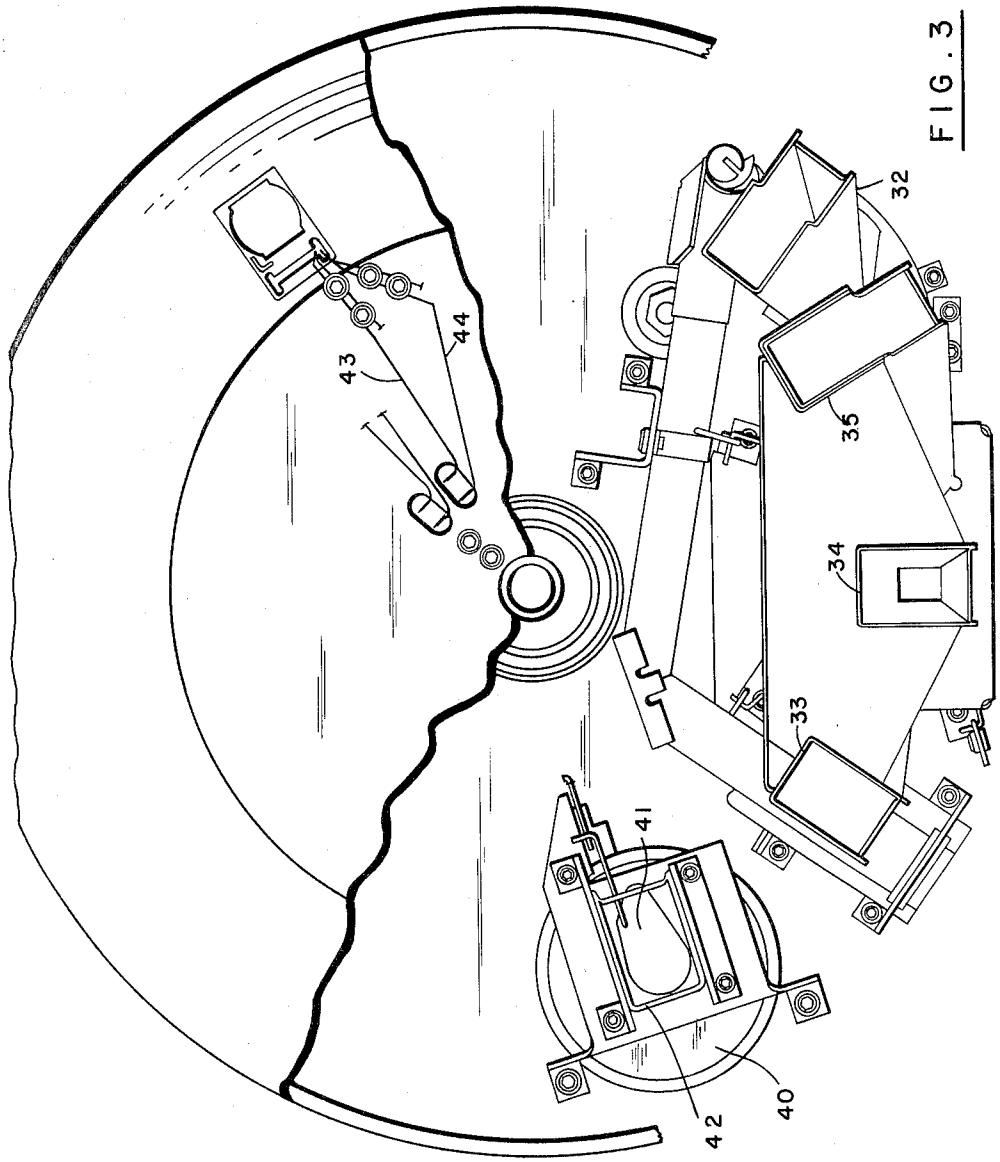
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VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

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FIG. 3



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VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

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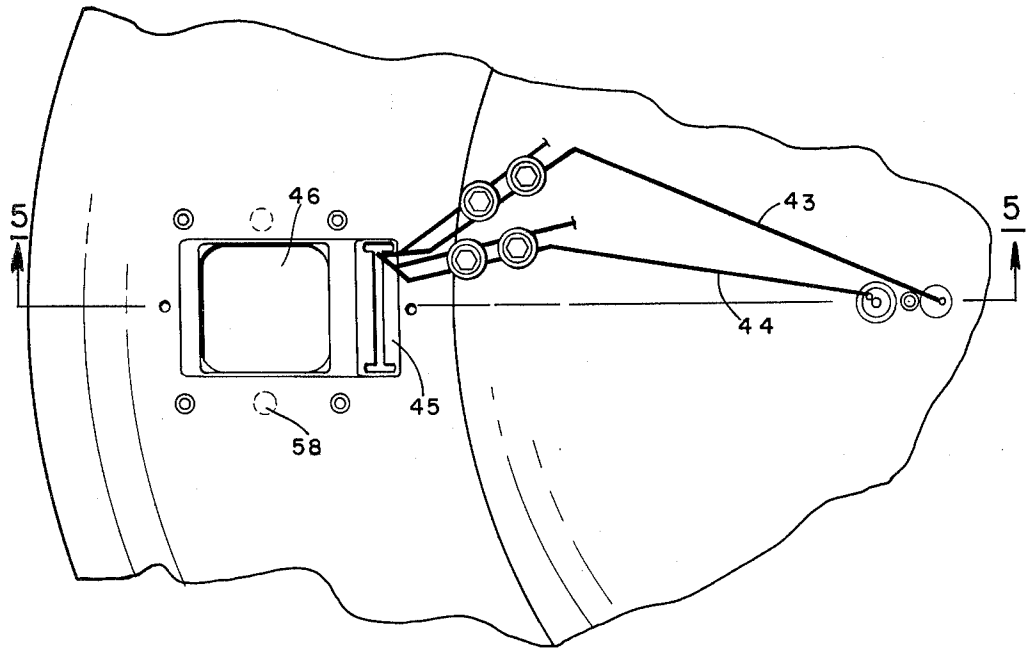


FIG. 4

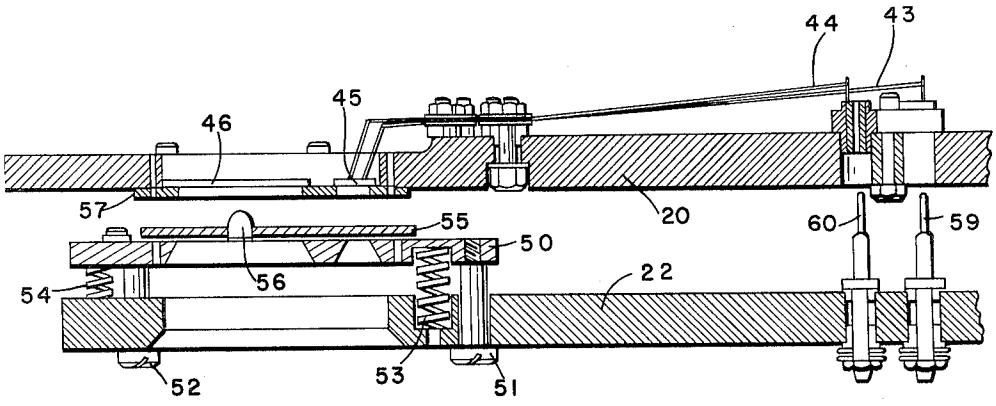


FIG. 5

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VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

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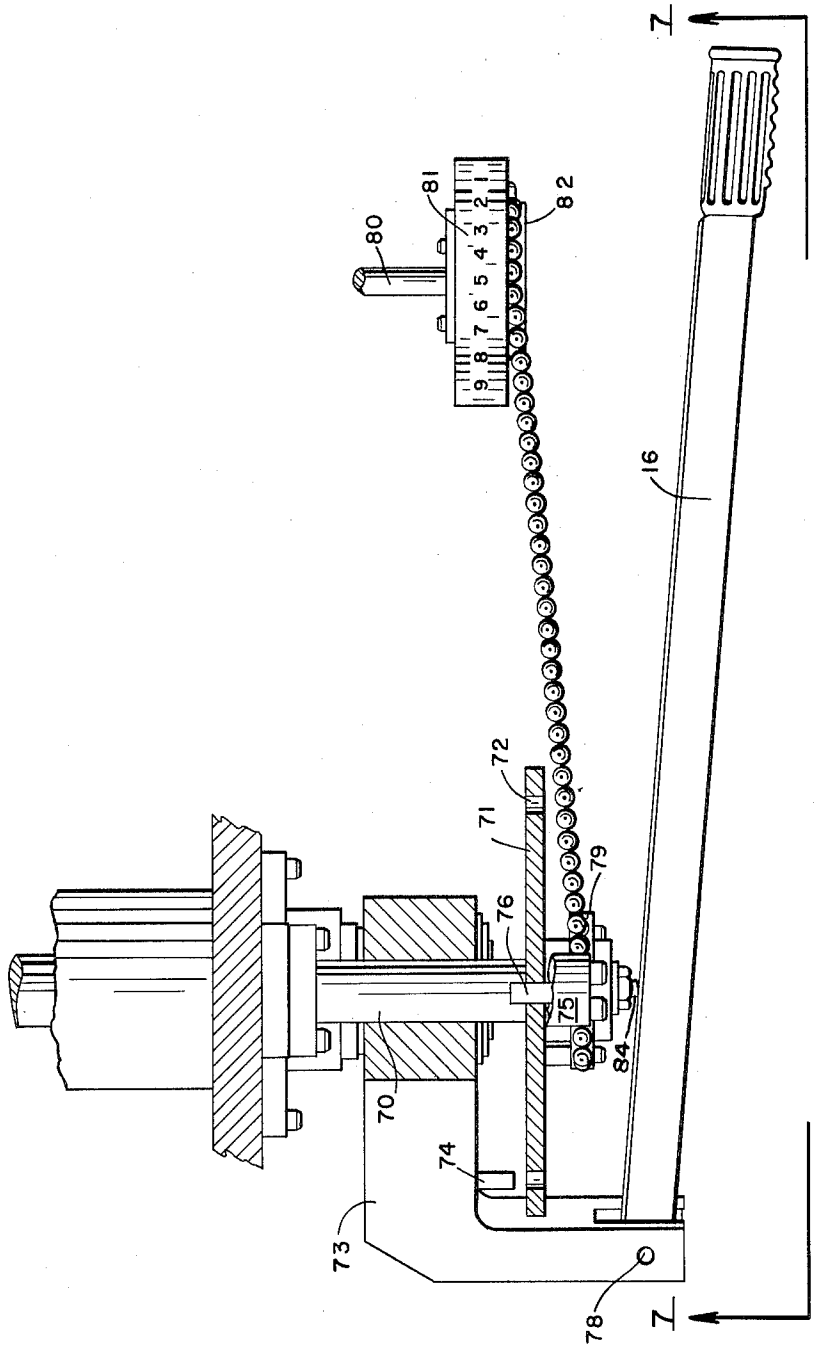


FIG. 6

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VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

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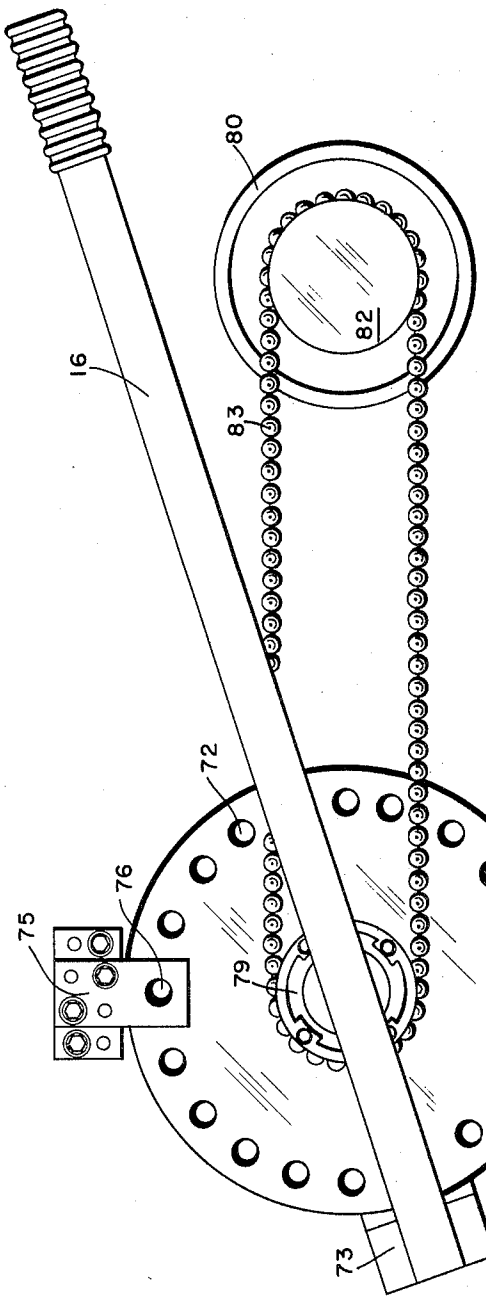


FIG. 7

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VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

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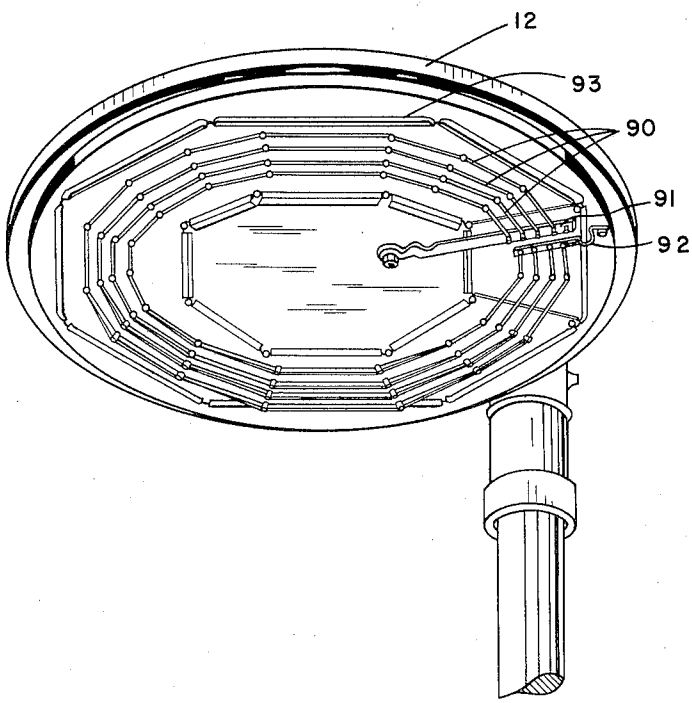


FIG. 8

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VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

Filed Dec. 26, 1961 8 Sheets-Sheet 8

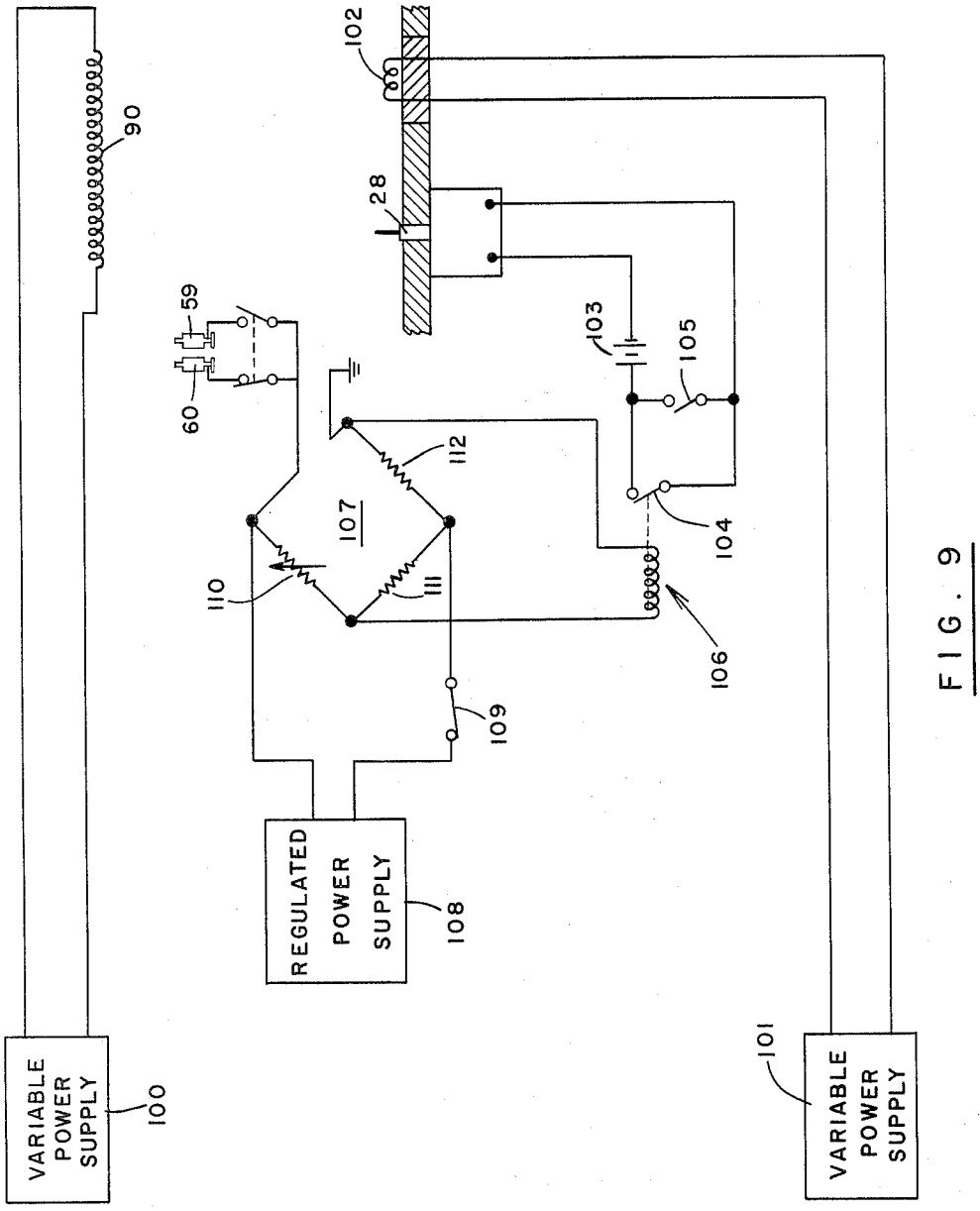


FIG. 9

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United States Patent Office 3,238,918 Patented Mar. 8, 1966

3,238,918

VACUUM DEPOSITION CHAMBER FOR MULTIPLE OPERATIONS

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Filed Dec. 26, 1961, Ser. No. 161,927
8 Claims. (Cl. 118—49.1)

This invention relates to means of evaporating material onto a substrate and more particularly, to means to mass produce substrate having evaporated material thereon in a desired pattern.

Vacuum depositions and sputtering are accomplished in a vacuum chamber. The material to be vacuum deposited or sputtered is placed near a heating element or filament, and a substrate on which the material is to be evaporated, is positioned some distance from the material to be evaporated. A mask is positioned between the material to be evaporated and the substrate so that the evaporated material passes through the mask and condenses on the substrate in the pattern of the mask. This allows, for example, a resistive element to be evaporated or sputtered on a substrate in a zig zag pattern to control the resistance of the element, i.e., the resistance of the element is dependent upon the material chosen, the thickness of the evaporated layer put on the substrate, and the length of the line of material put on the substrate. Because this work is done in a vacuum chamber, once the operation is started there is virtually no mechanical access to the equipment inside the vacuum chamber. In order to get the proper vacuum, a considerable amount of time is required for pump down, while the chamber is being evacuated. Since the past methods used only accommodated one substrate, or at best a few substrates and one mask, the greatest cost in making the microcircuits was in the pump down time and also the cooling time after the circuits had been deposited. The pump down time and the cooling time might be approximately two hours as opposed to twenty or thirty seconds deposition time.

It is, therefore, an object of this invention to provide a mechanism for a vacuum chamber which will permit the deposition of a plurality of microcircuits on several substrates.

Another object of the present invention is to provide a mechanism for a vacuum chamber which permits the vacuum deposition of different components of microcircuits during one pump down of the chamber.

Still another object of the present invention is to provide a mechanism for a vacuum chamber which will allow the vapor deposition of several elements onto a given substrate through the use of a plurality of sources of material to be evaporated and a plurality of masks to be used between the sources of material to be evaporated and the substrate.

Other objects and advantages of the present invention will become apparent from the following description when taken in conjunction with the drawings, in which:

FIG. 1 is a perspective view of a vacuum chamber;

FIG. 2 is a perspective view of the inside of a vacuum chamber;

FIG. 3 is a top view of the present invention;

FIG. 4 is a plan view of a mask holder;

FIG. 5 is a cross-sectional view of the mask holder and substrate holder;

FIG. 6 is a plan view of the rotating mechanism;

FIG. 7 is a view taken along lines 7—7 in FIG. 6;

FIG. 8 is a perspective view of the heater element; and

FIG. 9 is a schematic diagram of the control of the present invention.

Referring to FIG. 1, there is shown a vacuum chamber 10 having a base portion 11, a cover portion 12, and a viewing chamber 13. The viewing chamber 13 has a glass or transparent surface 14 to allow the inside of the vacuum chamber to be viewed from the outside. The cover portion 12 is mechanically connected to the arm 15, which in turn is mechanically connected to a screw jack, not shown. The screw jack raises and lowers the cover 12 for access to the vacuum chamber. The lever arm 16 is mechanically connected to the substrate holder, and its operation will be described below.

The inside of the vacuum chamber is shown in FIG. 2. A substrate holder 20 is mechanically connected to the lever arm 16 shown in FIG. 1 through a mechanical vacuum seal in the base of the vacuum chamber. The substrate holder 20 has slots 21 therein to accommodate substrates. The substrates can be the standard variety of glass or any suitable non-conductor. A mask holder support 22 supports mask holders 23, 24, and 25. The masks used also are the standard type made from a thin metal with a desired pattern cut in the metal. The substrate holder, mask holders, and mask support will be described in greater detail below.

Housings 26 and 27 have inside thereof heater elements and sources of material to be evaporated. A third housing, similar to housing 27, is shown in FIG. 3 and will be described below.

The heating elements and their connection with the source of material to be evaporated are well known in the art and any particular combination of heating elements and material can be used. A typical heater element is shaped like a trough and the material to be evaporated is placed in the trough. The housing 27 has one shutter mechanically operated by solenoid switch 28 by way of the mechanical connections 29, 30 and 31. The shutter is not shown but is positioned between the housing 27 and the duct 32. Three ducts 33, 34 and 35 are positioned above the housing 26. The housing 26 has three shutters, not shown, one for each duct and each actuated by a solenoid similar to solenoid 28. Tubes 36 and 37 originate at the viewing chamber 13 and extend into the larger vacuum chamber using a series of mirrors so that the process of vacuum deposition may be viewed through the viewing chamber 13. Mirror 38 is shown positioned to view the underside of mask holder 25. The duct 32 is cut out to allow the viewing.

The conduits 33, 34, 35 and 32 provide a conduit sheathing means through which vaporized material is deposited on substrates at different angles of incidence, as shown in FIGS. 2 and 3. Conduits 33, 34 and 35 conduct vapors from a single source in housing 26. The vapors can be conducted through one, two or three of the conduits 33, 34 and 35 at the same time depending on whether the individual shutters in these conduits are open or closed. The deposition made on a substrate through conduit 34 is at a first angle of incidence of substantially 90°. The vapors passing through conduit 33 are deposited on a substrate at a second angle of incidence which is greater than 90° when measured counterclockwise for a clockwise rotation of the substrate supporting means or holder 20. Conduit 35 permits for the deposition of vapors on a substrate at a third angle of incidence which is less than 90°. In this construction, the third angle of incidence is smaller than 90° by an amount which is substantially the same as the second angle of incidence is greater than 90°. The vapors coming from source in housing 27 and passing through conduit 32, are deposited at an angle of incidence which is less than 90° but greater than the third angle of incidence. The purpose of the deposition at different angles is to prevent the deposition of a film layer from being deposited

through a pin hole or other imperfection in a previously deposited film and thus causing a short circuit with a second underlying layer.

Generally, the operation is that a separate substrate is positioned in each of the slots **21** in the substrate holder **20**. A separate mask is positioned on each of the mask holders **23**, **24** and **25**. The chamber is evacuated through port **39** by use of a standard vacuum pump connected to port **39**. The material in the housings **26** and **27** are then heated to the evaporation point and the proper shutter is opened allowing the evaporated material to pass through the mask onto the substrate. When the evaporation is complete, the shutter is closed. Each substrate is passed over each mask so as to have a completed circuit when each substrate has been over each of the masks and had the material evaporated onto it through each of the masks.

Referring to FIG. 3, the third housing **40** and shutter **41** are shown with the shutter **41** over the opening to chamber **40**. The shutters over chambers **26** and **27** are not shown because of the angles of the ducts **32**, **33**, **34** and **35**. It can be seen from FIG. 3 that when the solenoid which moves shutter **41** is actuated, the opening to the chamber **40** is in direct connection to duct **42**. Therefore, any material which is heated in the chamber **40** to the state of evaporation, evaporates up through the duct **42** through the mask and onto the substrate. Leads **43** and **44** are positioned on the substrate holder and pass down to the monitor substrate (not shown) used for monitoring the amount of evaporation. The connection of the leads **43** and **44** to the outside of the vacuum chamber will be described below.

FIG. 4 shows the lead **44** contacting the monitor slide **45**. One end of the monitor slide **45** is connected to ground and the other end of the monitor slide **45** is connected to the lead **44**. The monitor slide is painted with a conducting paint, or otherwise provided with an electrical connection with one end of the underside of the monitor slide **45** to lead **44**. The other end of the underside of monitor slide **45** is grounded. It can be seen, then, that prior to evaporation, there is an open circuit between the two ends of the monitor slide **45**. It is to be noted that the mask allows only a hair line to be evaporated onto monitor slide **45**. This is so that when the substrate and monitor slide are moved to another mask, the new mask allows another hair line to be deposited and monitored by the other lead **43**. As the evaporation progresses, the resistance between one end of the slide **45** and the other end of the slide **45** decreases as the material is evaporated. This provides a means for monitoring the amount of material to be evaporated onto the substrate **46**. Only one lead **44** is shown, but lead **43** shown in FIG. 3 is used to monitor the monitor slide **45** in conjunction with a different mask as stated above.

FIG. 5 is a view taken along lines **5—5** of FIG. 4 and shows the mask holder **50** supported by the mask holder support **22**. The mask holder **50** is held to the support **22** by way of screws **51** and **52**. It is to be noted that the screws **51** and **52** are securely fastened to the mask holder **50** but have considerable play in the support **22**. Springs **53** and **54** urge the mask holder **50** away from support **22**. Mask **55** is indexed on mask holder **50** by the indexing pin **56**. The mask **55** has the desired pattern for the circuit to be evaporated through that mask. The plate **57** is secured to the substrate holder **20** and holds the substrate **46** and substrate monitor **45**. When the substrate holder **20** is lowered into position, the indexing pin **56** registers with an indexing hole **58** in the plate **57**. Consequently, the substrate **46** maintains its position in the substrate holder **20** while the indexing pin **56** causes the mask held by the mask holder **50** to make the proper registration against the bottom of the plate **57**. Pins **59** and **60** make contact with the leads **43** and **44**, respectively. The electrical connection to pins **59** and **60** will be described below.

Referring to FIGS. 6 and 7, the shaft **70** is mechanically connected to disk **71**. Disk **71** has a series of holes **72**. Shaft **70** is mechanically connected to the substrate holder **20**. The lever arm support **73** is rotatable with respect to shaft **70**. The lever arm support **73** has a pin **74** extending therefrom and registerable with the hole **72**. Stationary support **75** has a pin **76** extending therefrom and also registerable with the hole **72**. The lever arm **16** extends from the arm holder **73** and is movable about the pin **78** through both the support **73** and the lever arm **16**. A chain gear **79** is mechanically connected to the disk **71** and an indicator **80** rotatable about shaft **81** has another chain gear **82** mechanically attached thereto and a chain **83** is mechanically connected to the chain gear **79** and chain gear **82**.

In operation, the lever arm **16** is raised so that the pin **74** registers with one of the holes **72**. This is caused by the lever arm **16** hitting the bolt **83** and thereby raising plate **71** with respect to pin **76**. Next, the lever arm **16** is moved laterally which, in turn, causes the plate **71** and shaft **70** to rotate, thereby causing the substrate holder **20** to rotate also. When the rotation is complete, the lever arm **16** is dropped and the plate **71** lowers with the pin **76** registering with a new hole **72**. The chain gear **79** being mechanically connected to the plate **71**, rotates with the plate **71** causing the indicator **80** to rotate, thereby giving the operator a visual indication of the position of substrate holder **20**. It should be noted that the shaft **70** is the only movable mechanical connection through the vacuum chamber base. The opening which allows shaft **70** to pass through the base of the vacuum chamber is vacuum sealed in the normal manner.

It is desirable to have the substrates heated at the time the material is deposited on the substrate. As shown in FIG. 8, a plurality of heater wires **90** are connected in parallel between two electrode connections **91** and **92**. The heater wires **90** are supported by and insulated from a reflector shield **93**. The reflector shield, in turn, is mechanically supported by the cover **12**. When the cover **12** is lowered to close the chamber **10**, the heater wires **90** are directly above the substrates, thereby providing the heat for the substrates.

FIG. 9 shows a typical electrical connection to the present invention. A variable power supply **100** is directly connected to and provides the power for the heater wires **90**. A similar variable power supply **101** is electrically connected to and provides the power supply for the heater element **102**. The heater element **102** is a typical heater element which may be in, for example, housing **27**. A solenoid switch, for example, solenoid which **28** is electrically connected to the battery **103** either by way of switch **104** or switch **105**. Switch **105** is a manual switch allowing the opening and closing of the shutter by the solenoid **28** by manual operation. Switch **104** is mechanically operated by relay **106**. Relay **106** is electrically connected to the output of the bridge circuit **107**. The input to the bridge circuit **107** is electrically connected to the regulated power supply **108** by way of switch **109**. A variable resistor **110** forms one leg of the bridge **107** and the slide to be monitored connected by way of either pin **59** or **60** forms another leg of bridge **107**. Resistors **111** and **112** form the two remaining legs of the bridge circuit **107** and are equal in value.

In operation, first, if it is desired to manually operate the system, the heater element **90** is fed by variable power supply **100** and the filament **102** is powered by the variable power supply **101**. When the filament **102** brings the material (not shown) up to the vaporizing point, switch **105** is closed, thereby actuating solenoid **28** to open the shutter and allow the vaporized material to deposit on the heated substrate. Note that in the manual operation, switch **109** is open; therefore, switch **104** is open and solenoid **28** is operated solely by the manual switch **105**. For automatic operation, however, switch **109** is closed and switch **105** is open. Since switch **109** is closed, and

at the start of the operation, the filament **102** has not had time to evaporate the material, then the electrical connection between one side of the monitor slide connected to point **60** and the other side of monitor slide connected to ground is effectively an open circuit. Therefore, the power from regulated power supply **108** goes to the bridge circuit **107**, which is unbalanced, thereby causing a current flow in the relay **106**, and in turn closing the switch **104**. However, when the filament **102** has heated the material to be evaporated sufficiently to cause enough evaporated material to be deposited on the monitor slide, the resistance between the two ends of the monitor slide approaches the resistance set on the variable resistor **110** thereby balancing the bridge circuit **107** and causing the relay **106** to be de-energized, opening switch **104**. Note that resistor **110** is a variable resistor and can be set to any desired resistance value, which, when such resistance value is reached between the ends of the monitor slide, indicates that the proper amount of material has been deposited through the mask onto the substrate.

The apparatus of this invention has been used successfully to vapor deposit microcircuits onto a substrate in a desired pattern and with given values for each of the components deposited.

Although this invention has been particularly described above, it is not intended that it should be limited by the above description, but only in accordance with the spirit and scope of the appended claims.

What we claim is:

1. In a vacuum chamber having means to evacuate gases therefrom, the combination comprising:

(a) a vertically movable substrate supporting means, rotatably mounted in said chamber, for supporting a plurality of substrates in a horizontally disposed plane;

(b) a plurality of material evaporation source housings mounted in said chamber below said substrate supporting means;

(c) evaporating means in said housings;

(d) a pattern mask supporting means, mounted intermediate said evaporation source housings and said substrate supporting means, for supporting a plurality of masks in a plane substantially parallel to the plane in which said substrates are supported;

(e) a plurality of shutters mounted intermediate said source housings and said mask supporting means and operable to be positioned so as to prevent vapors from selected sources from being deposited on predetermined substrates held in said substrate supporting means at a given rotary position of said substrate supporting means;

(f) conduit sheathing means extending from said sources toward said mask supporting means wherethrough vapors of materials from the sources in said evaporation source housings are deposited on a predetermined substrate which is at a preselected position at a plurality of different predetermined angles of incidence.

2. The combination of claim **1** and in addition a heating means mounted above said substrate mounting means to provide heat for said substrates.

3. The combination of claim **1** wherein said substrate supporting means comprises

a vertically movable and rotatably mounted circular substrate mounting means having a plurality of substrate accommodating openings disposed along the radially outer portion thereof;

a retaining plate means attached to the lower surface of said circular means and over said substrate accommodating openings to provide a support for a substrate and a monitor plate to rest on;

said retaining plate means having a plurality of openings therein registering with a substrate accommodating opening to permit vapors to pass therethrough onto said substrate and said monitor plate.

4. The combination of claim **1** wherein said pattern mask supporting means comprises

a support means mounted in a plane parallel to the plane in which said substrate supporting means is mounted, said support means having a plurality of openings which are registerable with a number of the said plurality of substrates supported on said substrate supporting means;

a mask holding member yieldably mounted on said support means over each of said openings, said holding member having openings therein to permit the passage of vapors therethrough;

spring means disposed between said holding member and said support means, yieldably urging said holding member away from said support means and towards a retaining plate means attached to the lower surface of said substrate supporting means; and

an indexing member means integral with said mask holding member which registers with an indexing hole in said retaining plate means when said substrate supporting means is lowered and said retaining plate means contacts the mask that is placed on said mask holding member.

5. The combination of claim **1** wherein the sheathing means are so constructed as to permit vapor of a material from a said evaporating means in a selected source to be deposited on the surface of a preselected substrate supported in said substrate supporting means at a predetermined first angle of incidence, and thereafter upon a repositioning of said substrate by a rotation of said substrate supporting means, to permit vapor from another of said evaporating means in another selected source to be deposited on said surface at a second angle of incidence different from said first angle of incidence.

6. The combination of claim **5** wherein said sheathing means comprises a first sheathing means and a second sheathing means; and

wherein said first sheathing means is constructed so as to permit vapors of a material to be deposited from a first source on the surface of a substrate in a preselected position on said substrate supporting means in a selected one of three predetermined angles of incidence, wherein a first of said angles of incidence is at 90° relative to the surface of said substrate, a second of said angles of incidence is less than 90° measured along the direction of rotation of said substrate supporting means and a third of said angles of incidence is greater than 90°; and

wherein said second sheathing means is constructed so as to permit vapors of a material to be deposited from a second source on the surface of a substrate in a preselected position on said substrate supporting means at an angle of incidence of a magnitude intermediate said first and said second angles of incidence.

7. The combination of claim **1** and in addition a rotating means for rotating said substrate supporting means, comprising:

a disc means fixedly mounted on the shaft means on which said substrate supporting means is mounted, said disc means having a pluarlity of indexing holes near the outer edge thereof;

a stationary support means having a first indexing pin means registering with and passing through one of said indexing holes from the lower side of said disc means;

a lever arm means rotatably and slidably mounted about said shaft, and above said disc means;

said lever arm having a second indexing pin member extending from a lower surface thereof and registerable with said indexting holes;

a lever member having a free end, and another end pivotally connected to said lever arm and positioned to contact the lower end of said shaft, so that by raising the said free end, the said shaft is raised upwardly together with said disc means until said disc

means clears said first indexing pin means from one of said indexing holes and simultaneously engages said second indexing pin member in another of said indexing holes, whereupon a sidewise movement of said free end of said lever member causes said disc means and said shaft to rotate, thereby rotating said substrate supporting means.

8. The combination of claim 7 and in addition a position indicating means operatively connected to said shaft means for indicating the position in which said substrate supporting means is positioned.

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