United States Patent

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[54] **VACUUM COATING APPARATUS**

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[58] **Field of Search** ....118/48–49.5; 117/106–107.2; 266/4 B

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[57] **ABSTRACT**

Vacuum coating apparatus is described wherein substrates to be coated supported on a substrate holder may be inserted into and removed from an isolatable region of the vacuum chamber, which isolatable region may be sealed off by a movable gate, whereby the remaining regions of the vacuum chamber may be maintained under vacuum while inserting and removing the substrate holders.

6 Claims, 4 Drawing Figures

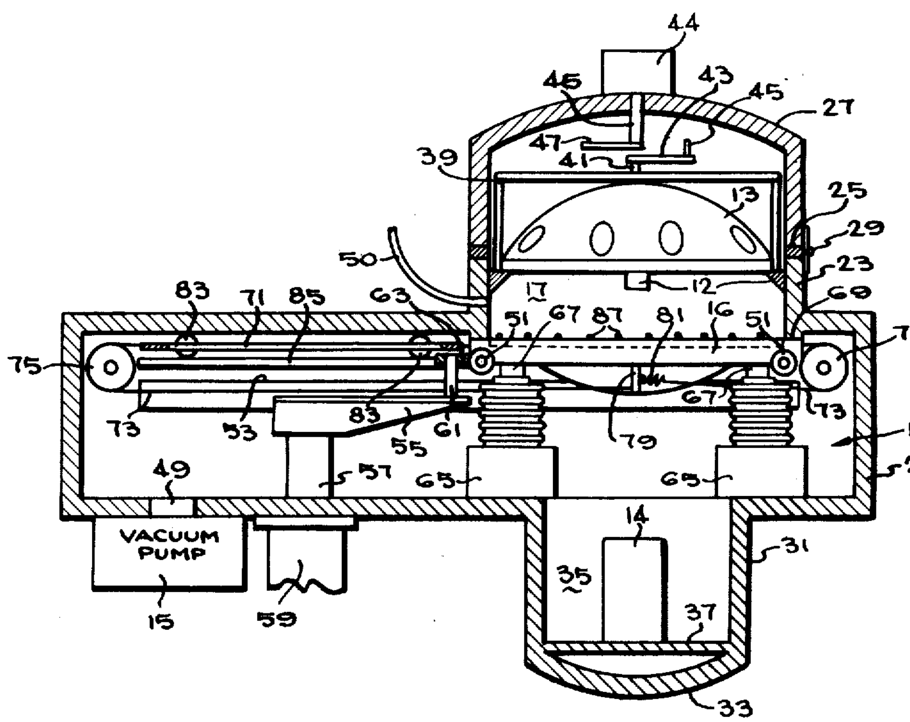

Fig. 1

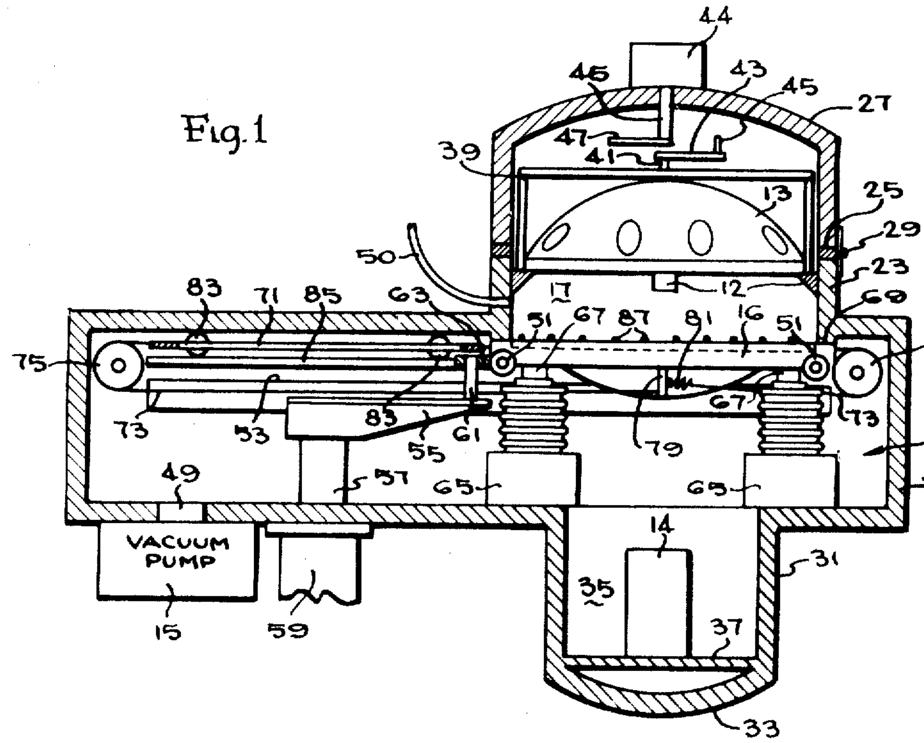

Fig. 2

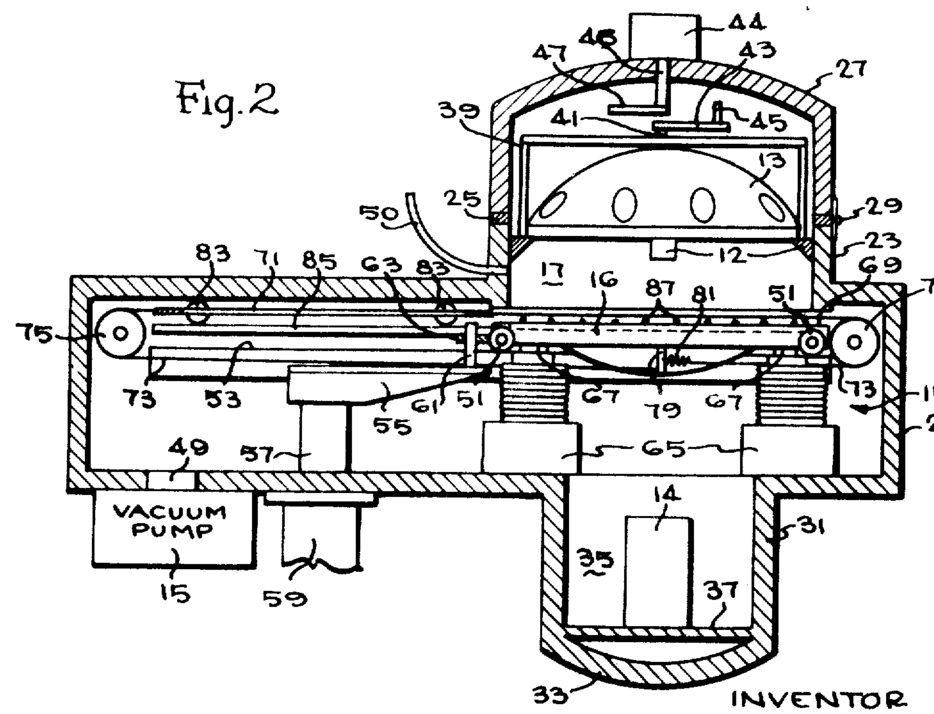

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Fig. 3

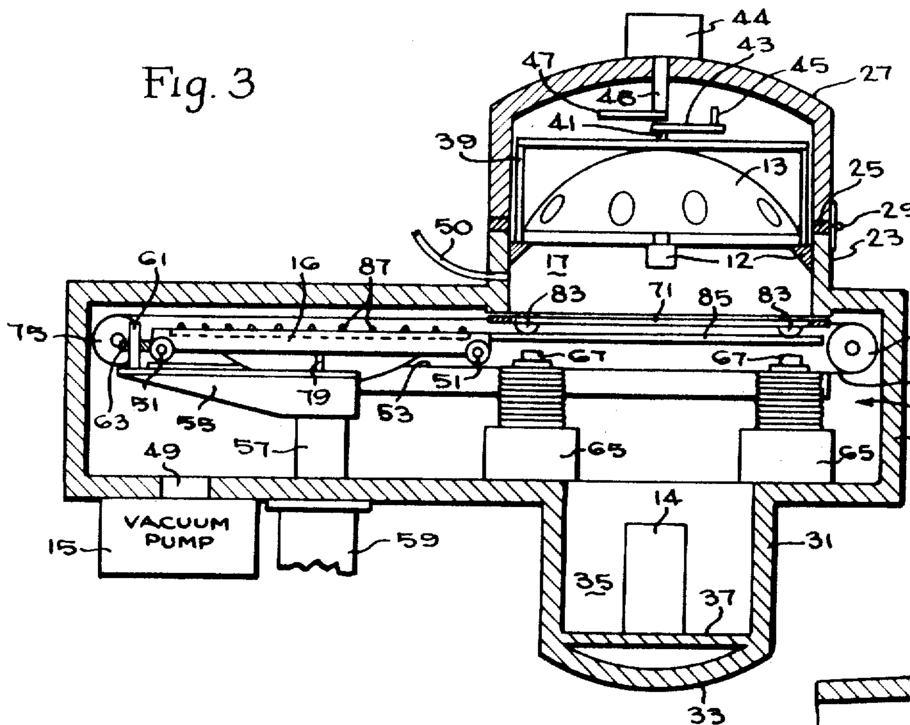
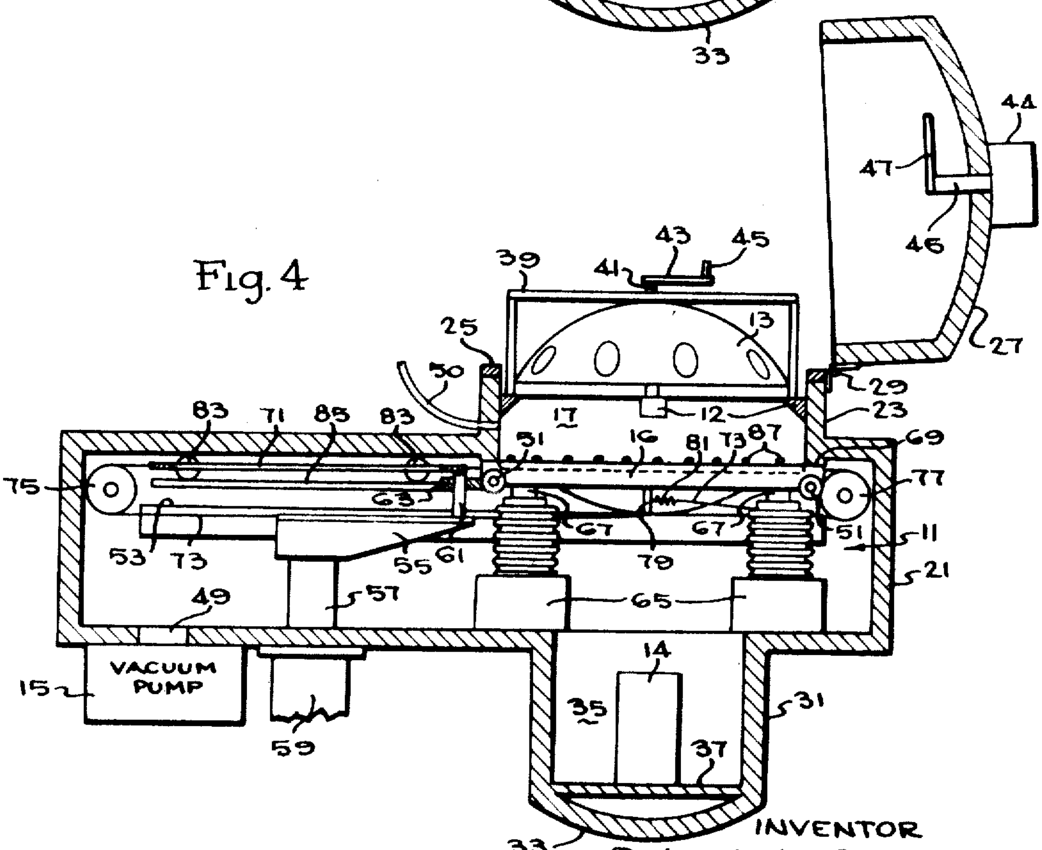


Fig. 4



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VACUUM COATING APPARATUS

This invention relates to vacuum coating apparatus and, more particularly, to vacuum coating apparatus capable of meeting the need for high production rates for a wide variety of substrates and coatings.

The coating of substrates within a high vacuum has been recognized for some time as being a highly advantageous one in many applications. For example, vacuum coating may be used to provide nonmetallic coatings for the control of optical properties of lenses, zinc or aluminum coated papers and plastics for electrical capacitors and decorative applications, refined high-pressure metals, the production of metallic foils, and various other applications where high purity or unusual alloy compositions are desirable.

A typical vacuum coating system includes a vacuumtight enclosure in which a source of vapor or sputter ions is positioned. A sputter ion source may comprise a suitable sputtering cathode connected to an appropriate power supply as is known in the art. A vapor source may comprise a crucible or boat in which molten metal is contained and wherein the molten metal is heated by a resistance heated filament. Where long production runs, high evaporation rates, or high purity is desired, electron beam evaporation may be employed. Typically, in electron beam evaporation, the evaporant is contained within a cooled crucible so that the material to be evaporated is insulated from the crucible by a solid skull of its own composition. The material in the crucible is heated by directing an electron beam or a plurality of electron beams at the surface of the material.

In addition to the vapor or ion source, the substrate to be coated is also positioned within the vacuum enclosure. Frequently it is desirable to rotate or otherwise move the substrate with respect to the vapor or ions in order to ensure uniformity of deposition over the entire surface of the substrate, or with respect to other adjacent substrates. In many cases, the substrate or several substrates may be suitably mounted to a device for supporting and moving the substrate or substrates in the vapor flow prior to the time the vacuum enclosure is evacuated. Such arrangements, most often comprising the well-known bell jar type of vacuum enclosure, are usually unsatisfactory for high production rates. This is because the vacuum enclosure must be pumped down for each new substrate or batch of substrates which are to be coated.

Accordingly, it is an object of the present invention to provide improved vacuum coating apparatus.

Another object of the invention is to provide vacuum coating apparatus capable of very high production rates.

Another object of the invention is to provide vacuum coating apparatus in which it is unnecessary to pump down the entire vacuum coating chamber for each new substrate or batch of substrates which are to be coated.

Other objects of the invention will become apparent to those skilled in the art from the following description, taken in connection with the accompanying drawings wherein:

FIG. 1 is a schematic full sectional view of vacuum coating apparatus constructed in accordance with the invention; and

FIGS. 2, 3 and 4 are views similar to FIG. 1 illustrating a sequence of operation of the apparatus of FIG. 1.

Very generally, the vacuum coating apparatus of the invention includes a vacuum chamber 11 and support means 12 within the vacuum chamber for supporting at least one substrate holder 13 therein at a coating position for coating substrates held thereon. A vapor or ion source 14 is provided within the vacuum chamber and means 15 are provided for maintaining the vacuum chamber under continuous vacuum. A movable vacuum seal gate 16 is positioned within the vacuum chamber and is movable to a first position (FIGS. 1 and 4) wherein the region 17 of the vacuum chamber in which the support means are disposed is vacuum sealed from the regions of the vacuum chamber in which the vapor source and the vacuum maintaining means are disposed. This permits access to the support means from outside the vacuum chamber without losing vacuum in the entire chamber. The gate is movable to a second position (FIG. 3) wherein the regions are in communication with each other and wherein the path between the vapor source and the coating position is unobstructed to allow the coating of substrates.

The vacuum chamber 11 in the illustrated embodiment is defined by a box-shaped vacuum tank 21 having a cylindrical wall 23 surrounding an opening in the top wall of the tank 21. An annular seal 25 surrounds the upper edge of the cylindrical wall 23 and a cup-shaped closure member or lid 27 is seated on the seal 25. A hinge 29 allows the lid 27 to be pivoted out of the way for access to the upper isolated part of the vacuum chamber 11 as shown in FIG. 4. The cylindrical wall 23 and the lid 27 thus define the region 17 in which the substrates to be coated are positioned as will be described below.

An opening in the lower wall of the tank 21 is surrounded by a lower cylindrical wall 31 having a dome-shaped end wall 33. The source 14 is disposed in the chamber 35 thus defined. The source 14 may include one or more suitable means for producing vapor or sputter ions for coating the substrates in the region 17. The various types of vapor sources or sputter ion sources for accomplishing this are well known in the art and will not be described in detail herein. The single or composite source 14 may be mounted on a suitable mounting plate 37, and ready access to the source may be provided by a suitable opening, not shown, in the lower wall 33 through which the plate 37, with the source 14 mounted thereon, may be removable for repair or replacement.

The substrates to be coated may be supported within the region 17 by any suitable substrate holder. In the illustrated apparatus, the substrate holder 13 is a domed structure and may be of any suitable construction. One particularly advantageous type of apparatus is a so-called "domed planetary," several designs of which are presently commercially available from various manufacturers. One particular type of planetary is sold under the designation TP–11 available from Airco Temescal Division of Air Reduction Company Inc., Berkeley, California.

The substrate holder 13 is supported within the region 17 by the support means 12 which, in the illustrated apparatus, comprise three extensions which project inwardly from the cylindrical wall 23 at 120° intervals. A support structure 39 for the planetary or domed substrate holder 13 has three legs which rest upon the extensions 12. The dome 13 or substrate holder is rotatable on a spindle 41 pivoted within the frame structure 39, and a planetary arrangement may be driven in connection with rotation of the spindle 41. An arm 43 extends horizontally from the spindle 41 and a pin 45 projects upwardly from the arm at the opposite end thereof from the spindle. A drive motor 44 mounted in the top of the lid 27 has a drive shaft 46 which extends downwardly through the lid into the vacuum via appropriate vacuum seals, not shown. An arm 47 extends horizontally outward from the shaft 46 and, once the motor 44 is energized and with the apparatus in the position shown in FIGS. 1–3, the arm 47 contacts the pin 45 and thus rotates the spindle 41. This drives or rotates the substrate holder 13 and any planetary mechanism supported thereon. Thus, the substrates supported by the substrate holder may be rotated in the vapor or ion flow in order to provide a more uniform coating on the substrates.

In order to maintain the vacuum chamber 11 in an evacuated condition and to evacuate it initially from atmospheric pressure, a suitable vacuum pumping system may be provided. In the illustrated embodiment, a vacuum pump 15 is shown schematically communicating with the chamber 11 through an opening 49 in the lower wall of the enclosure 21. The vacuum pump may be any suitable pump or series of pumps to provide the desired vacuum, depending upon the conditions required in the vacuum coating region and depending upon the materials which are being used. Preferably, the pump 15 includes a roughing or mechanical pump backing a diffusion pump, as is known in the art. The mechanical portion of the pump is also connected to the upper part 17 of the chamber 11 through a duct 50.

In order to enable an operator to gain access to the region 17 without the necessity of bringing the remainder of the vacuum chamber 11 up to atmospheric pressure, the movable seal gate 16 is employed. The gate 16 is a generally circular plate provided with four extensions to which wheels 51 are mounted. A pair of parallel tracks 53 are provided on opposite sidewalls of the vacuum enclosure 21 and the gate 16 is movable horizontally on the tracks 53 from the position shown in FIG. 2 to the position shown in FIG. 3 and back again. Movement in this manner is accomplished by a pivotal arm 55 mounted on a vacuum sealed pivot 57 which extends through the housing or enclosure 21 through the bottom wall thereof and which is pivotal by a suitable actuator 59, such as a pneumatic actuator of any known design. A pin 61 extends vertically upward from the arm 55 into a slot in a bracket 63. The bracket 63 extends horizontally from one end of the gate 16. As the arm pivots from the position shown in FIG. 2 to the position shown in FIG. 3, the gate is moved horizontally to be positioned out of a line between the vacuum source 14 and the substrate holder 13.

Provision is also made for vertical movement of the vacuum seal gate 16 by the provision of a plurality of piston-type actuators 65 arranged about the space below the region 17. Each of actuators 65 has a piston 67 thereon which, when the actuator is suitably operated, engages the underside of the vacuum seal gate 16 to move it upwardly off the track. An annular rim 69 on the top of the gate 16 thereby enters into engagement with the lower edge of the cylindrical wall 23. This seals the region 17 from the remainder of the vacuum chamber 11. The vacuum seal gate 16 is shown in the raised position in FIG. 1, with the region 17 being sealed off from the remainder of the vacuum chamber 11.

The upper surface of the seal gate 16 is provided with a plurality of heaters 87 and the substrate may be heated with the seal gate in the position shown in FIG. 2 by appropriately energizing the heaters 87. This provides a substantial saving in time for preheating substrates, since they may be preheated easily at the coating position because the heaters may be positioned close to the substrates.

A rectangular shuttle-type shield 71 is provided for protecting the valve sealing surface at the lower edge of the cylindrical wall 23 during the evaporation process. The shield 71 is attached to a pair of cables 73 which pass over pulleys 75 and 77, respectively, mounted at opposite ends of the boxlike vacuum enclosure 21. A pin 79 extends downwardly from the lower side of the vacuum seal gate 16 and one end of one of the cables 73 is attached to the lower end thereof. An end of the other cable 73 is attached by a suitable spring 81 to the midpoint of the pin 79. This enables the cable to expand or contract in its effective length when the vacuum seal gate 16 is moved vertically between the position shown in FIG. 1 and the position shown in FIG. 2. For guidance, the shield 71 is provided with four wheels 83 thereon which ride in a pair of parallel tracks 85 formed in the sidewalls of the vacuum enclosure 21.

Describing in detail the operation of the device, the substrate holder 13, with substrates to be coated suitably mounted thereon, is positioned within the region 17 of the vacuum chamber 11. The seal gate 16 is in the position in FIG. 1 and the remaining portion of the vacuum chamber 11 is at full vacuum. Once the lid 27 is closed, the region 17 is rough pumped by the mechanical section of the pumping means 15 through the duct 50. The seal gate 16 is then moved to the position shown in FIG. 2, thus resulting in communication between the region 17 of the vacuum chamber and the remaining portions of the vacuum chamber. The diffusion portion of the vacuum pump means 15 then operates to reduce the pressure within the vacuum chamber to the desired vacuum level. Because most of the vacuum chamber is continuously maintained at vacuum, and because the substrate holder is inserted while the seal gate 16 is in the position isolating the region 17, the amount of time to reduce the region 17 of the vacuum chamber 11 to the desired vacuum for coating is much less than would be required were the entire vacuum chamber including the region 17 to be evacuated from atmospheric pressure. During the time that the seal gate 16 is in the position shown in FIG. 2, the substrates may be preheated by the heaters 87, and the seal gate operates as a shutter to block the passage of vapor or sputter ions from the source 14 to the substrates.

The seal gate 16 is then moved to the position shown in FIG. 3, the shield 71 therefore moving by the cables 73 to the position shown in FIG. 3 in which the seal surfaces on the lower edge of the cylindrical wall 23 are protected. Vacuum deposition may then begin in order to coat the substrates. Vapor or ions pass through the circular opening in the shield 71. If desired, a suitable shutter may be provided in the region 35 to prevent the passing of vapor or sputter ions until such time as coating is to begin, even though the gate is out of the way. During coating and heating, the motor 44 is energized to produce movement of the substrates on the substrate holder 13 for uniform coating and heating.

Once coating is completed, the seal gate 16 is returned to the position shown in FIG. 2 and then is raised to the position shown in FIG. 4 by operation of the actuators 65. Once this is accomplished, the region 17 may be brought to atmospheric pressure and the lid 27 opened, as shown in FIG. 4, in order to remove the substrate holder and place a new substrate holder with new substrates to be coated in position. During this time, it is unnecessary to evacuate the remaining portion of the vacuum chamber 11.

Because most of the vacuum chamber 11 may be maintained under vacuum at all times, a continuous outgassed condition of the sources and the various other materials within the vacuum chamber occurs. This permits high evaporation rates, reduces contamination, and yields products superior to those produced in conventional bell jar systems. Because the load unload chamber 17 is isolated from the remainder of the vacuum chamber 11, only the loading volume need be brought to atmosphere, greatly reducing the required pumping capacity and pump down time of the system for each substrate load. Substrate heating prior to coating is easily effected by the use of the heaters 87 located in the upper surface of the seal gate 16. Because of the linear vertical motion of the seal gate rather than a sliding seal, a more simple sealing arrangement may be utilized, such as simple annular ring-type sealing arrangements, reducing cost and simplifying construction. Ready access is available both to the substrate holders and to the vapor or ion source 14 for ready servicing. Run to run consistency is easily attainable within close limits since accurate control is maintained over all variables. Contamination from exposure of the evaporation chamber to atmosphere or from outgassing of refractory crucibles and filaments is eliminated.

It may therefore be seen that the invention provides an improved coating apparatus which is capable of very high production rates and in which it is unnecessary to pump down the coating chamber for each new substrate or batch of substrates which are to be coated.

Various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. Vacuum coating apparatus comprising, a vacuum chamber, support means within said vacuum chamber for supporting at least one substrate holder therein at a coating position for coating substrates held thereon, said holder comprising a domed, rotatable member having a crank element extending from the topmost surface thereof, said chamber including a pivotable closure having a driven crank arm depending therefrom whereby said substrate holder is adapted to be rotated by operative contact between said crank arms, a vapor source within said vacuum chamber, means for maintaining said vacuum chamber under continuous vacuum, a movable vacuum seal gate within said vacuum chamber, means for

moving said gate to a first position wherein the region of said vacuum chamber in which said support means are disposed is vacuum sealed from the regions of said chamber in which said vapor source and said vacuum maintaining means are disposed, thereby permitting access to said support means from outside said vacuum chamber without losing vacuum in the entire chamber, said moving means being operable for moving said gate to a second position wherein all said named regions are in communication with each other and wherein the path between said vapor source and the coating position is unobstructed to allow coating of the substrates, and said moving means being operable to move said gate to a third position wherein all said named regions are in communication with each other, and wherein said gate obstructs the path between said vapor source and the coating position to allow evacuation of both said regions by said vacuum maintaining means while preventing deposition of vapor on substrates during such periods.

2. Vacuum coating apparatus according to claim 1 including substrate heating means positioned on said gate on the side thereof toward the region of said chamber in which said support means are disposed for heating the substrates on the substrate holder when said gate is in said third position.

3. Vacuum coating apparatus according to claim 2 wherein said gate comprises a generally annular sealing surface, wherein said moving means include a plurality of actuators for moving said gate axially between said second and third positions, and wherein said moving means include a mechanical linkage for moving said gate laterally between said first and third positions.

4. Apparatus according to claim 1 including a vapor mask for positioning in the vapor flow, and wherein said moving means are operable to move said vapor mask into position in the vapor flow upon moving said gate to said second position.

5. Vacuum coating apparatus according to claim 2 wherein the direction of movement of said gate between said first and third positions is perpendicular to the direction of movement of said gate between said second and third positions.

6. Vacuum coating apparatus comprising, a vacuum chamber having an upper region and a lower region, support means within said upper region of said vacuum chamber for supporting at least one substrate holder therein at a coating position for coating substrates held thereon, a vapor source within said lower region of said vacuum chamber and directly beneath said coating position, means communicating with said lower region of said vacuum chamber for maintaining said vacuum chamber under continuous vacuum and for evacuating said upper region, a movable vacuum seal gate within said vacuum chamber, means for moving said gate to a first position wherein said upper region of said vacuum chamber is vacuum sealed from said lower region of said vacuum chamber, means for providing access to said upper region of said vacuum chamber with said gate in said first position, said moving means being operable to move said gate vertically to a position between said vapor source and said coating position to prevent passage of vapor from said vapor source to said coating position but to provide communication between said upper and lower regions of said vacuum chamber, said moving means being operable for moving said gate laterally to a position displaced from the path between said vapor source and the coating position to allow coating of substrates.

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