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3,469,560

CONTINUOUS VACUUM DEPOSITION APPARATUS

Filed May 4, 1966

4 Sheets-Sheet 1

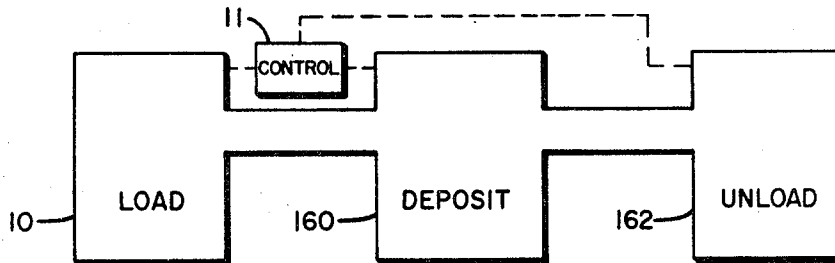


Fig. 1

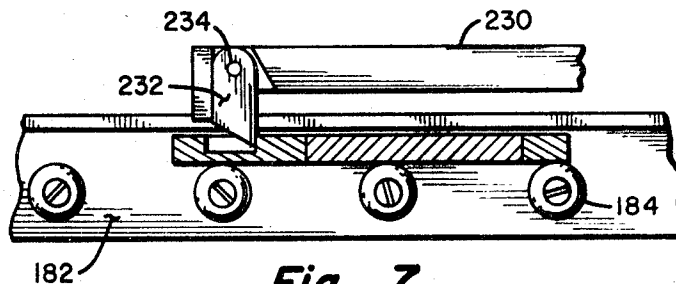


Fig. 7

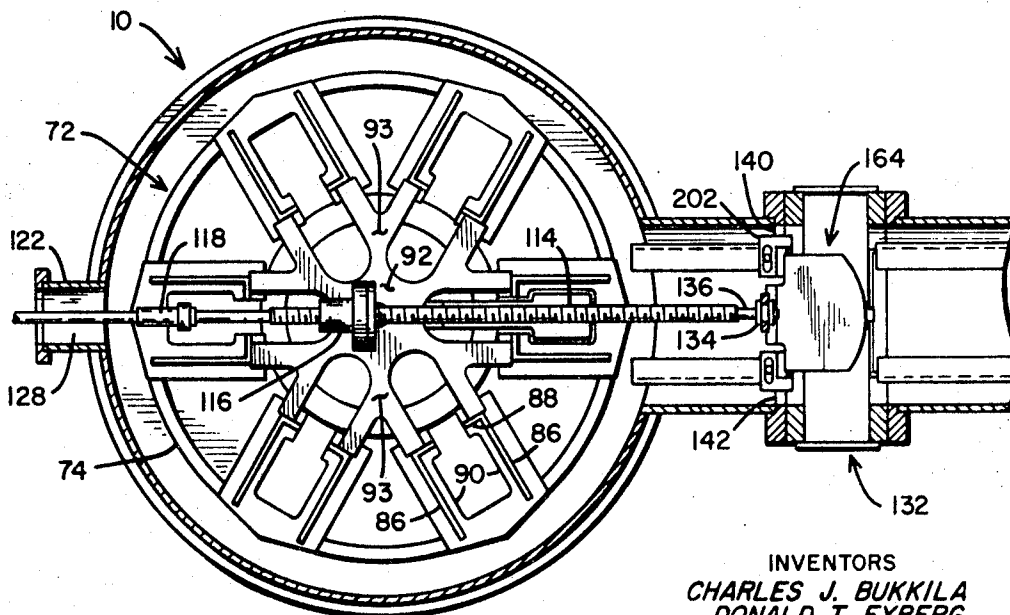


Fig. 3

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4 Sheets-Sheet 3

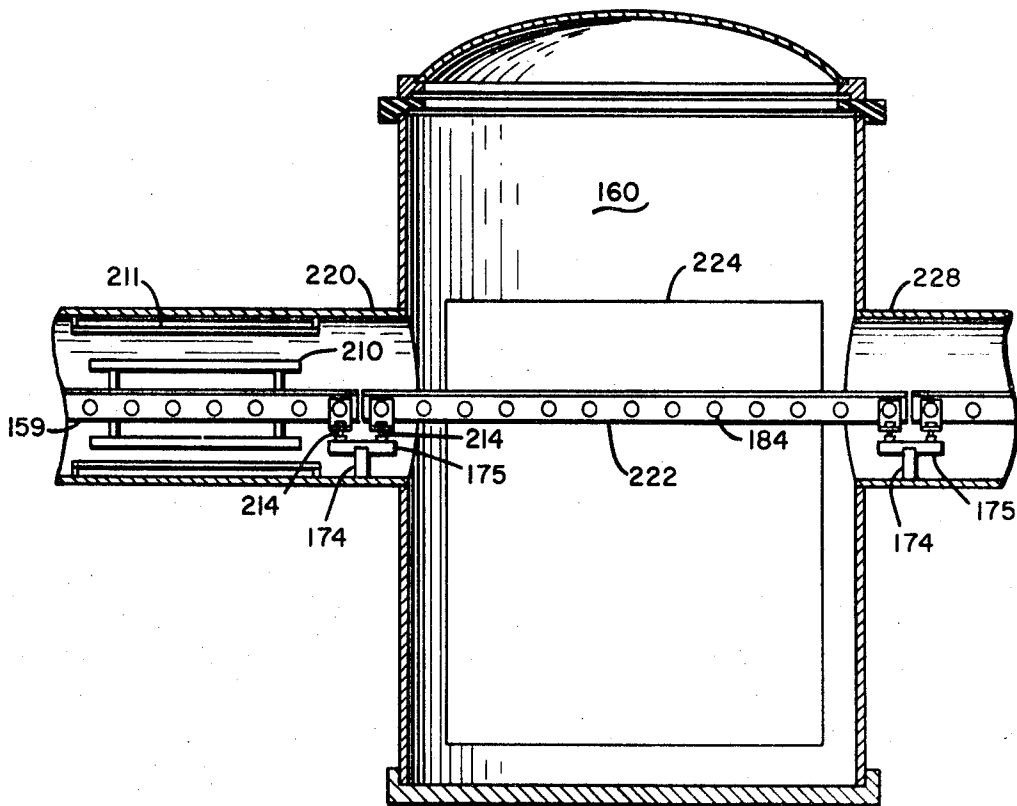


Fig. 2b

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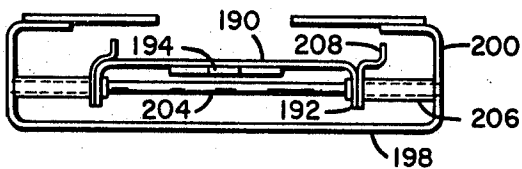
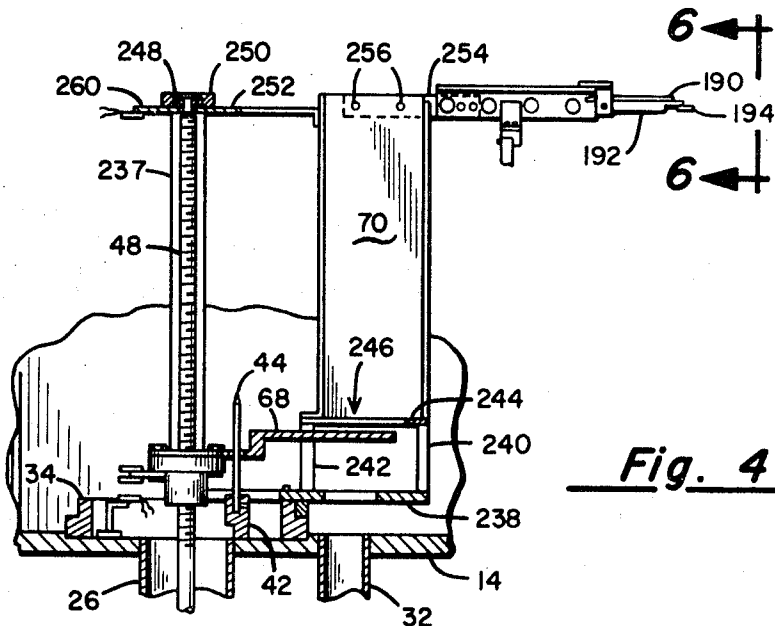
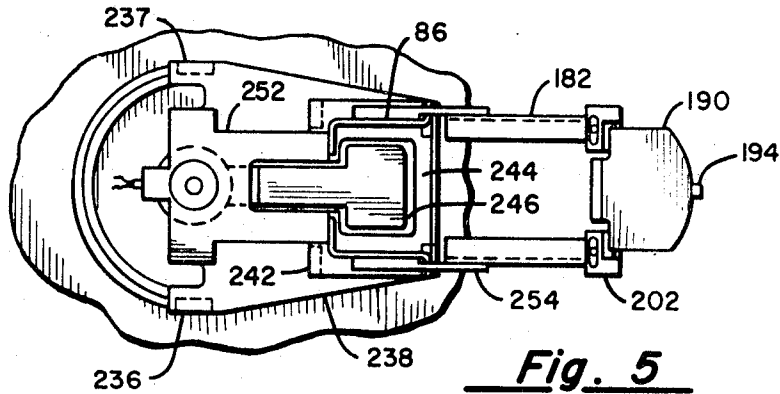
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3,469,560 CONTINUOUS VACUUM DEPOSITION APPARATUS

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10 Claims

ABSTRACT OF THE DISCLOSURE

A tri-stage continuous process evaporation system comprising loading, evaporating and unloading chambers, each chamber being independently evacuable, with interconnection between chambers for the transfer of substrates achieved by a tube-enclosed track system is described. Contained within the loading chamber is a mechanism for supporting and serially inserting a large plurality of substrates onto the track leading to the deposition station. Similarly, the unloading station includes a mechanism for accepting the substrates from the track and storing them in suitable cartridges.

This invention relates generally to a continuous vacuum deposition apparatus for handling substrates and depositing films of materials upon them for forming memory elements.

More specifically, a continuous vacuum deposition system has been developed to provide economical, reliable, and mass production capabilities for fabricating memory elements utilized for large capacity and high-speed computer memories. A memory element represents a basic building block for a memory module. Such memory element may consist of a substrate consisting of a thin sheet of glass onto which are deposited discrete magnetizable spots or "bits" of Permalloy or the like through a graphite or other substrate mask. There may be thousands of such magnetizable spots or bits in the order of .030 x .030 inch in size on a small substrate. Other substrates and bit sizes may be required for particular applications.

Structurally the present system comprises a loading and unloading chamber interconnected through a vacuum deposition chamber, with the chambers being isolatable by valving means between the chambers. Prepared substrates in one embodiment are loaded into an indexable multi-station cartridge substrate holder assembly or, alternatively, in another embodiment into a single station cartridge substrate holder, in the loading chamber. A track assembly interconnects the loading chamber and unloading chamber through the deposition chamber. A master control unit controls handling and feeding of the substrates which are transported along the track assembly through the system by controlling the operation of a feeder assembly for supplying a substrate from the top of a cartridge to the track assembly. After deposition, the substrate or memory element proceeds along the track assembly to the unloading chamber. The latter chamber, advantageously, contains all of the same substrate handling and storing structure as that contained in the loading chamber. The only essential difference is in its mode of operation. That is, as a receiver of the substrates from the deposition chamber, its operational sequences are the reverse of those characterized by the loading chamber. The deposited substrates or thin-film memory elements are subsequently stored in the unloading chamber cartridges and ultimately removed from the chamber. The

master control unit controls all phases of operation in the system.

Known prior art vacuum deposition techniques do not provide continuous deposition operations for the mass production of computer memories. While a variety of systems permit deposition of material upon continuous belts unspooled and threaded through the system, no known systems incorporate the unique features of the present invention wherein there are utilized evacuable loading, deposition, and unloading chambers, automatic feeding, indexing, deposition monitoring, and unloading means for the handling and processing of individual substrates on a mass production basis. Simplicity of construction and operation among the components of the system assure the reliability required for mass production of memory elements. By the duplication of substrate handling apparatus in the loading and unloading chambers substantial cost savings in construction are further realized. As well, the duplication of the construction assure the further reliability of operation of all substrate handling apparatus. Accordingly, the design of the system is one possessing highly reliable mass production capabilities not heretofore recognized in the art. Otherwise complex problems of process and handling control are eliminated by the novel apparatus utilized.

In the fabrication of film memories, precautions must be taken to control film characteristics and properties. Film properties such as coercivity and anisotropy, for example, are parameters that can be materially influenced by temperatures, pressures, degree of cleanliness, deposition rates and amounts, and the like. The present invention is designed to closely administer and control film handling and deposition operations in order to provide a memory of desirable quality for present day data processing equipment.

In modern computing equipment, memory capacity and speed of operation in the ultra fast range are prime factors weighing upon the effective application of the equipment. The present invention provides the capabilities of achieving the requirements of such computer memories by mass production deposition apparatus incorporating novel structural components into an integrated system.

Accordingly it is a primary object of the present invention to provide a continuous vacuum deposition system for the deposition of films of materials upon substrates.

These and other more detailed objects of the invention will be more evident by the specification and drawings, in which:

FIGURE 1 is a schematic exemplary illustration of three interconnected stages of the vacuum deposition system of the present invention incorporating loading, deposition, and unloading chambers.

FIGURE 2a is a side sectioned view of one embodiment of a portion of the system invention incorporating a multi-station indexable type substrate holder in the loading chamber and as likewise used in the unloading chamber, although not shown with the latter in the view, together with the track and bridging assemblies for transporting substrates to the deposition chamber.

FIGURE 2b is a side view in section illustrating track assemblies for transporting through the vacuum deposition chamber. FIGURES 2a and 2b are composite views to be taken together with the track assemblies connected.

FIGURE 3 is a top view of a portion of the apparatus in FIGURE 2a including the multi-station indexable substrate holder and the track and bridging assemblies.

FIGURE 4 is a side sectioned view of an alternative embodiment of the present invention incorporating a single station non-indexable type substrate holder in the loading chamber and as likewise used in the unloading

chamber, although not shown with the latter in the view, together with the track and bridging assemblies.

FIGURE 5 is a top view of the apparatus of FIGURE 4.

FIGURE 6 is an enlarged end view of the bridging assembly taken along line 6—6 of FIGURE 4.

FIGURE 7 is a side view of a puller arm and finger associated with the unloading chamber apparatus of both embodiments.

FIGURE 1 represents a schematic illustration of the vacuum deposition system of the present invention. Although a three stage system is shown, no limitation is made thereto. The system includes a loading stage 10, deposition stage 160, and unloading stage 162, all of which are evacuable and the apparatus associated therewith is coupled to the control unit 11 which maintains a controlling influence on all the operations performed.

FIGURE 2a, shows an evacuable loading chamber or stage 10. The chamber 10 is defined by walls 12, base plate 14, and a removable cover portion 16. Preferably, although not necessarily, the chamber is constructed of stainless steel in order to prevent outgassing of material which would otherwise be adsorbed and/or absorbed on or in the chamber construction itself. A seal member 18 near the top of the chamber 10 is adapted to fit to the walls 12 while a second seal 20 in contact with seal 18 associated with the cover 16 effectively seals the chamber under vacuum conditions. The chamber 10 is preferably circular in design, although not necessarily restricted to such shape. In an upper region of the chamber there is located a vacuum inlet port 22 communicating internally with the chamber and connected to a suitable vacuum producing source (not shown). An outlet port 24 communicating internally with the loading chamber is adapted to receive various structural components to be described below. The base plate or bottom plate 14 is provided with two feedthroughs 26 and 28 for accommodating a lead screw and gear drive arrangement. The feedthroughs are sealed to the base plate by seal housings 30 and 32, respectively for preventing loss of vacuum.

Still referring to FIGURE 2a, a lower half of a ball-race element 34 is suitably secured to the base plate. The race element as shown is annular in configuration and contains along a top surface 36 thereof a recessed groove 38 for accommodating spherically-shaped ball elements 40. The ball elements are fabricated of such material such as stainless steel in order to withstand stress under load and because of their suitable properties under vacuum conditions.

Also secured to the base plate 14 such as by welding or the like is a pin mount 42. A vertically projecting position retaining pin 44 has one end thereof 46 fixedly secured within a recess in the mount 42. The pin 44 projects upwardly as shown for a predetermined distance for a purpose which will be described infra.

A vertically oriented lead screw 48 is disposed centrally of the loading chamber. At a bottom end thereof the shaft is fixedly secured to one half 50 of a magnetic coupling member. The coupling member consists of a large block of non-magnetic material containing or mounting therein selectively disposed magnets. The larger of the two feedthroughs, 26, projects downwardly of the base plate 14 and in its lower regions contains therein the magnetic coupling member 50. Feedthrough 26 is provided with a flanged portion 52 adapted to receive a plate member 54 sealed by a sealing means 56 to the flange. As shown, the plate member 54 and its seal completely close off the feedthrough 26 from the ambient environment to maintain a desired vacuum level within the chamber 10.

Disposed externally of the feedthrough 26 and magnetic coupling member 50 is the driving half 58 of the magnetic coupling suitably connected to a shaft 60 and driving source not shown. As with coupling member 50, coupling member 58 has magnets disposed therein; how-

ever having corresponding poles of opposite polarity. As coupling member 58 is rotated, coupling member 50 is forced to rotate the lead screw.

It is to be understood that the magnetic coupling drive configuration could be replaced by a shaft extending through a suitable seal means. The magnetic coupling is preferable, however, because it deletes any sealing problems that may be caused by projecting a rotatable shaft to the ambient environment. It is preferable to substitute a driving arrangement not utilizing a rotating member projecting into a vacuum chamber because of the danger of introducing impurities from the seal and ambient impurities when the seal becomes worn.

Proceeding with the description, vertically oriented leadscrew 48 has grooves along its periphery beginning at a lower portion thereof. Cooperating therewith is a vertically positionable lead screw mechanism 61 also well known in the art. The mechanism consists of a flange member 62 and a ball retainer housing 64 having disposed therein suitable follower means such as balls or the like for guiding the screw mechanism up and down the lead screw 48 when the latter is driven through the magnetic coupling. Secured to the flange member 62 such as by screws 66 or the like is a pallet member or arm 68. Since the pallet arm is secured to the flange member 62 it is likewise caused to translate vertically in the chamber. The pallet arm contains a hole 69, the function of which will be described subsequently.

The pallet arm 68 projects through an opening in the substrate holder 70 which is a part of the rotatable indexer assembly 72. The indexer consists of a base member 74 having an annular configuration as shown. An upper ball race element 76 is secured to the bottom of the base member 74 such as by screws or the like. The ball race element 76 like the ball race element 34 has a recessed groove extending around its surface for accommodating the balls 40 aforementioned. Extending entirely around a flange portion 78 of the ball race are gear teeth 80 the use of which will be described in the ensuing description.

The base member 74 has an upwardly projection portion 82 completely around its periphery. Secured to a top surface thereof by mounting screws 86 or the like are the substrate holders 70 which contain the substrates. The holders form a portion of the entire indexer assembly 72, of which there are preferably six holders in number, although more or less may be accommodated as desired.

Referring at the same time to FIGURE 3, it can be seen that the substrate holders are defined by side walls 86 forming a partial back wall portion 88, and a partial substrate holder base plate 90. Although only two substrate holders have been shown in FIGURE 2a for purposes of clarity, a greater plurality are disposed around the base member 74, preferably six of them as shown in FIGURE 3. A top support 92, shown in FIGURES 2a and 3, consists of a plate having Y-like extensions 93 having down turned end portions 95 secured to wall portions 88, which maintains the substrate holders in a top supported condition with respect to the indexer assembly. It can be seen that the plate 92 is the supporting structure for the upper part of the substrate holders.

The top plate 92 is in turn journaled in a bearing-like element 94 supported by a shaft terminal portion of lead screw 48 at its uppermost end. The bearing 94 contains a recess or notch around its periphery for receiving the top plate 92 therein. Therefore, as lead screw 48 rotates, it rotates in the bearing 94.

Referring now to the lower end of the loading chamber, there is shown the second feedthrough 28 along with its seal arrangement. Secured to one end of the drive shaft 98 is a driving gear 100 having gear teeth 102 disposed around its periphery. The gear teeth 102 mesh with gear teeth 80 of the upper ball race driving gear 76. Disposed at a lower end of the drive shaft 98 and secured to it is a magnetic coupling member 104. Disposed externally of the feedthrough and plate is the driving half

of the magnetic coupling for effecting rotation of the shaft 98 and is the same construction as that of the magnetic coupling associated with the lead screw 48 above mentioned.

Referring to FIGURE 2a, the lead screw mechanism 61 and pallet arm 68 are shown in their uppermost translational position by phantom lines and in the lower most translational position in full lines. It can be seen that when the mechanism is in its lower most position, the pin 44 projects through the hole 69 in the pallet arm for preventing rotation of the arm as the indexer assembly 72 is indexed.

It is to be noted that a clearance area 109 between the bottom plate 90 of the substrate holders and the indexer base plate 74 is provided to permit room for the pallet arm below the substrate holders 70 when the indexer is rotated. That is, the pallet arm is in a position of noninterference with the indexer assembly.

Magnets 106 and 107 are secured to the lead screw assembly 62 for translation therewith. A support post 108 may be secured to the internal periphery of the ball race element 34 and projects upwardly in the chamber. At its lower and upper end the post may mount conventional reed switch elements 110 and 112 or the like. As can be seen, when the lead screw assembly achieves its uppermost excursion, the magnet 106 affects the switch element 110 to signal a master control unit (shown in FIGURE 1) to effect reversal of rotation of the lead screw 48. Consequently, as lead screw 48 lowers the lead screw assembly, the magnet 107 affects the switch element 112 at that extreme excursion to terminate rotation of the lead screw until the master control unit signals the substrate indexer assembly to index. Then the operation of raising the pallet arm re-commences.

Operational mode of entire assemblies

An operation of the structural description thus far illustrated is briefly set forth. The magnetic coupling associated with the larger feedthrough drives the lead screw whereby the lead screw mechanism translates vertically while simultaneously raising or lowering the pallet arm, depending upon the direction of rotation. As the screw rotates, intermittently, an ejector mechanism to be described ejects substrates from the top of the stack in the substrate holder and ejects them from the loading chamber onto a track assembly also to be described. Assuming that the pallet arm has been raised to its uppermost position by the lead screw, the upper limit switch is actuated whereby lead screw rotation reverses to lower the lead screw assembly and pallet arm to a lower most position until another limit switch terminates lead screw rotation. At this point the pallet arm is entirely below the substrate holders in the clearance area designated. Subsequently, the driving mechanism associated with the smaller feedthrough is actuated to drive the ball race driving gear. Since the indexer base member is secured to it, rotation of the gear rotatably indexes the indexer to the next filled substrate holder position whereupon the indexer is caused to stop. During the indexing sequence, the pallet arm remains in a stationary or non-rotatable position by reason of the pin projecting through the hole in the pallet arm. As these sequences come to an end, the lead screw assembly once again is driven to lift the stack of substrates in the holder intermittently until one by one they are picked from the stack and ejected from the loading chamber onto the track assembly.

Having completed a detailed description of the mechanisms in the lower half of the loading chamber, the ensuing description relates to the ejector assembly located in the upper approximate half of the chamber. Referring to FIGURES 2a and 3, there are shown side and top views respectively of the entire assembly.

A second lead screw 114 horizontally disposed and a lead screw mechanism 116, similarly constructed to that for raising and lowering the pallet arm are utilized. For facilitating assembly of the lead screw 114 and lead screw

mechanism 116 into the chamber or disassembly therefrom, a shaft coupler 118 has a recess in coupler therein. The recess 118 receives a portion of the lead screw 114 and is secured thereby by an adjustment screw 126 or the like. A recess 128 in the feedthrough is adapted to receive a driving source suitably sealed therein to preclude vacuum loss and is interconnected to the coupler 118. The coupler further permits complete removal of the indexer from the loading chamber. For convenience of illustration a conventional shaft-through arrangement is shown.

It is to be understood, that by the use of the aforementioned magnetic coupling as well as with the illustrated arrangement, with adequate sealing precautions and a sufficiently large port, the lead screw and lead screw mechanism could be removed therethrough and the coupler feature 118 deleted. A variety of suitable driving arrangements could be utilized and is believed to be within the skill of the routine designer.

At its other end lead screw 114 proceeds through outlet port 24 of the loading chamber to a mounting 130 secured such as by welding to the internal surface of the port 24 near gate valve 132. A bearing 134 is disposed in the mounting and receives the terminal portion 136 of the screw therein. The lead screw 114 is rotated by the driving source (not shown) above mentioned. A guide member 138 preferably having a guideway opening or slot 148 along its length is secured to posts 140 and 142 secured such as by welding to the loading chamber walls. The guide member 138 is in turn secured to the posts at both ends thereof by screws or dowels 144 or the like. By using dowels, for example, removal may be effected with facility by merely lifting up and out of the loading chamber. A lever 146 is rigidly secured at one end to the lead screw mechanism 116. Near its opposite end a guide stud 150 is secured to lever 146. Preferably, although not necessarily, guide stud 150 is of circular cross-section in order to reduce friction in the guideway. As the lead screw mechanism traverses horizontally along the lead screw, it is prevented from turning on its axis by reason of the guide way restraining rotational motion by reason of the guide stud 150 and lever 146 secured to the lead screw mechanism.

Suitably attached to the guide stud are pairs of magnets 125 and 127 and suitably mounted at both ends of the guide member 138 are limit switch elements 129 and 131. As the ejecter lead screw mechanism traverses along the lead screw in either direction, its excursion is limited by the magnets 125 and 127 actuating the limiting switches, which may, for example be reed switches or the like whose contacts are affected when influenced by the magnets in the proximate vicinity. As the limit switches are actuated, the lead screw 114 is caused to reverse its direction of rotation under the influence of the lead screw driving source. The lead screw mechanism then returns to a starting position in preparation for the next substrate ejection cycle.

An ejector arm 152 is fixedly secured in a suitable manner to the lead screw mechanism. Disposed at its opposite end is a finger 156 for ejecting the substrates from the top of the stack in the substrate holder 70 to a track assembly 158 to be described next.

The track assembly 158 is used to transport substrates from the loading chamber 10 to vacuum deposition chamber or station means 160 of which there may be a plurality; however, only one being shown. From the deposition chamber the substrates are transported to the unloading chamber 162. Interconnecting each of the chambers are tubes for containing the track assembly. The tubes interconnecting the chambers additionally contain preheaters to affect a bake-out process and may be constructed with a cooling jacket in the portion extending from the deposition chamber to the unloading chamber to reduce the temperature of the memory element. A short section of track assembly is mounted in the outlet port 24 of the loading chamber and extends to a gate valve 132, the details of which are not necessary. A bridge assembly 164 spans

the gap in the gate valve and will be described subsequently. From the right hand side of the gate valve 132 a track assembly portion 159 proceeds to the deposition chamber (see FIGURE 2b).

Referring in greater detail to FIGURE 2a, there are secured to the internal periphery of the outlet port 24 block members 170. The block members are preferably welded along an internal arcuate portion to the port. Holes are disposed in the block members 170 to permit widening of the track assembly for certain applications as will be explained subsequently. Disposed upon the top surface of each of the block members 170 are L-shaped guide blocks 174 fixedly secured by screws 176; and secured to the top surface of the guide blocks by screws 178 are small L-shape adjustment blocks 180 preferably welded at a back surface portion thereof to the individual channel tracks or rails 182. Spaced along the tracks at spaced intervals are spherically shaped rollers or balls 184 mounted on screw axles threaded into the rails. Preferably the axles and balls are made of stainless steel for the reasons mentioned above. The balls rotate fully on their axles to permit transport of the substrates along the top of the rollers. A cross member 186 having a slot therein extends across the top of the tracks and is secured thereto by screws 188.

In order to accommodate wider substrates, screws 176 and 188 are loosened to permit outward movement of the tracks along the cross-member. The screws 188 move along the slot in the cross-member. Likewise L-shaped blocks 174 are moved outwardly and screws 176 located in a different hole nearer the periphery of the tube. For that matter, the holes for screws 176 could be replaced by a slot such that when the screws are loosened and when the tracks are moved outwardly, the L-shaped block members 174 slide along the top surface of the block members 170.

When a new supply of substrates is to be inserted into the loading chamber, gate valve 132 is closed so as to isolate the vacuum deposition chamber 160 from the loading chamber. In this way the deposition chamber remains unaffected during the loading operation into chamber 10. As can be seen from FIGURES 2a and 3, a bridging section 164 bridges the valve gap area. Obviously, when the valve is closed to isolate chamber 10, the bridging section 164 must be positioned to a non-interfering position. Referring to FIGURES 2a and 3, the bridging section 164 is pivotally mounted to permit its movement to a non-interfering position in the gate valve 132. As the valve (not shown) is closed, it contacts the bottom of the bridging section. As the valves continue to close, the bridging section pivots counterclockwise to a completely retracted position within the flange of the gate valve 132. The bridging section is shown in detail in FIGURES 5 and 6. The pivoting portion thereof consists of plate member 190 having a downwardly extending lip at each end thereof at 192. The leading edge thereof may be rounded and is provided with a stop tab 194 secured to a bottom surface of the top plate and projecting beyond the curvature. The top tab 194 limits the clockwise pivotal motion of the bridging section by abutting the cross stop bar 196 interconnecting the rails in the track section 159 to the right of gate valve 132 leading to the vacuum deposition chamber. A cross bar 198 of the bridge assembly extends transversely underneath and has upturned portions 200. Adjustment plates 202 are secured to the cross bar and contain notched-out portion or slot 202 for receiving adjustable members such as screws received by threads in the tracks. By loosening the screws the rails can be brought closer together or spaced further apart for receiving different size substrates. The bridge assembly is pivotally supported by shaft 204 rotatably secured to the flanges of the cross bar 198 at either end thereof. Spacer members 206 are disposed between the bridge and the upturned flanges to transversely maintain the position of the bridge assembly. Arms 208 are mount-

ed at one end upon the shaft 204 and are held against the downwardly extending lips of the bridge plate member 190. The arms extend upwardly above the surface of the plate member and act as lateral guides for the substrates as they move over the surface of the plate member across the bridge assembly.

The section of tubing interconnecting the loading chamber to the deposition chamber contains heating members 210 for effecting what is known in the art as bake-out. During this process the substrates are heated by the members 210 which are preferably fused quartz lamps with reflective shields 211 shown schematically in FIGURES 2b for purposes of clarity. During this process the temperature of the substrates is raised to a high temperature to drive off absorbed and adsorbed gases in the substrates. The heater elements are suitably interconnected through the tube by a feedthrough (not shown) with a power source disposed externally of the system. The track assembly section 159 is disposed in this section of tubing; however is mounted differently at the point where the track resumes on the right hand side of the gate valve 132 shown in FIGURE 2a. As aforementioned, block members 170 are secured to the internal periphery of the tubing. Similarly, L-shaped guide blocks 174 are seated on and adjustably secured to the guide blocks, and as before, adjustment blocks 180 are secured to the tracks at their back surface. However, an additional feature is incorporated which is the use of support studs 214 having a truncated cone or chamfered enlargement 216 adapted to be received in a mating recess 218 disposed in the L-shaped guide blocks. This configuration is not intended to be limitative in nature since a variety of suitable mounting arrangements may be utilized. As before, blocks 174 may be repositioned to spread the tracks apart. The present configuration facilitates insertion of the entire track assembly 159 into the tubing during the assembly operation. The track assembly is merely positioned until the support studs are aligned with their respective recesses, and then the assembly drops into a nonmovable position. The track section 159 from the right side of gate valve 132 to the deposition chamber likewise represents one continuous unit. A similar mounting arrangement is made for this section of the track assembly in the inlet port 220 of the deposition chamber with the exception that block member 175 can accommodate two support studs 214. A separate track section 222 is located in the deposition chamber itself. The left end portion thereof seats in the block 175 while the other end of track 222 seats in a like manner in a block 175 located in the outlet port 228 thereof.

Within the deposition chamber there are disposed various apparatus for effecting the deposition of desired films of materials upon the substrates and devices for monitoring the process. For example, separate sources for the evaporation of SiO, Permalloy and copper may be disposed within the deposition chamber. Although specific description as to the apparatus is not referred to herein, it is to be understood that same are utilized to produce the ferromagnetic films upon the substrates. For example, apparatus such as an electron beam gun, feeding apparatus, and monitoring devices also are disposed in the chamber. For convenience of illustration 224 represents the schematic incorporation of such necessary features to produce memory elements.

Inasmuch as the system is substantially symmetrical both in structure and operation, that is, the tubing, track assembly sections, gate valve, bridging section, and unloading chamber also appear on the right or output side of the deposition chamber illustrated in FIGURE 2b, no additional illustrations are considered necessary. The output tubing may be provided with a jacket to permit circulation of a cooling medium therein so that the substrates are cool upon reception in the unloading chamber. A particularly advantageous feature of the present invention is the duplication of the structures contained within the

loading chamber 10 and unloading chamber 162, the only modification made is with respect to the puller arm 230 and finger 232. By way of reference to FIGURE 7 there is shown the arm and finger. It is evident that the ejecter arm in the loading chamber 10 ejects the substrates onto the track assembly while the ejecter arm and finger associated with the unloading chamber, herein termed a puller arm and puller finger, function to withdraw the substrates from the track assembly. The finger 232 is hinged at 234 to puller arm 230. Accordingly, as the arm completes the withdrawal of a thin-film memory element the associated lead screw reverses to reverse the direction of translation of the lead screw mechanism translating therealong. As the puller arm enters the output port of the unloading chamber 162, the finger 232 pivots counterclockwise and when the lead screw reverses its direction of rotation again, the finger contacts the trailing edge of a memory element and withdraws same along the bridging and track assemblies to the substrate holder being filled at this point with the memory elements.

The unloading chamber contains all of the same structural aspects of the loading chamber; therefore, no detailed description or illustrations are made. It is to be understood, however, that the sequence of events are the reverse of that described with respect to the loading chamber. Instead of the pallet arm lifting substrates upwardly in the substrate holder, the pallet arm lowers an incremental distance under the reverse driving direction of its lead screw. When one substrate holder or cartridge is completely filled, a limit switch corresponding to lower limit switch in the loading chamber 10 is actuated to cause the drive gear associated with the ball race element to rotate the indexer a predetermined number of degrees whereby an unfilled substrate holder aligns itself with the track assembly. The unloading operation continues until all the substrates or as many as desired have been withdrawn. Then the gate valve similarly constructed as gate valve 132 is closed and its bridging section raised to completely isolate the unloading chamber from the deposition chamber. The top cover is removed from the unloading chamber and the substrates removed. Upon emptying the substrate holders, the top cover is replaced, the unloading chamber pumped down to the desired vacuum level, and the gate valve opened, and its bridging section disposed in a spanning relationship.

As described above, the structural assemblies within the loading chamber, the vacuum deposition chamber, and the unloading chamber function in a specific sequence of events. To control all of the operations a master control unit (FIGURE 1) is electrically coupled to the system. The master control unit prescribes the timing and operational prerequisites for specific series of events.

Operation

Assuming now that the loading chamber substrate cartridges have been fully loaded and the entire system evacuated to prescribed levels, the magnetic coupling associated with the loading chamber is energized whereby the lead screw begins to raise the pallet arm with the substrate. Assume that the ejecter assembly is completely retracted to a starting position. The control unit energizes the horizontal ejecter lead screw shaft whereby the ejecter arm moves toward the track assembly and removes a single substrate from the stack. The ejecter arm is continually advanced until the trailing edge of the substrate clears the bridging section into the heating tube. As the magnets on the guide stud come into a position in proximity to the switch elements, switching circuitry coupled thereto effects reverse rotation of the lead screw. As the lead screw mechanism retracts from the track assembly, the magnets of the guide stud move into proximity with other switch elements on the other side of the chamber. Upon opening the circuit to the ejecter lead screw driving source, the lead screw stops rotation. The control unit transmits a command pulse to the driving

source associated with the magnetic coupling in turn associated with the pallet raising lead screw. As the lead screw rotates, a new substrate is disposed in alignment with the ejecter arm pawl. After a predetermined time interval, the control unit issues a command to stop rotation of the lead screw. Another command is made to once again energize the ejecter lead screw which translates the ejecter arm to remove the topmost substrate for disposition in the track whereupon the ejecter lead screw retracts the ejecter arm to a start position. The operation continues to function until the inlet port and the vacuum deposition chamber have been filled and with one or more substrates disposed within the deposition chamber itself. The carriers containing the substrates are pushed end to end through the system over the rollers. The control unit then issues commands to the various deposition apparatus. Whenever a substrate holder has been emptied of substrates, the control unit signals the ball race drive gear to rotate the indexer one substrate holder position. Prior to such rotation the pallet arm has been returned to the clearance area beneath the substrate holder so as to be in a non-interfering position. The indexing proceeds from one emptied substrate holder to the next until all have been removed after which a new charge is inserted into the loading chamber. Upon receipt by the control unit of information indicating that the substrate deposition has been satisfactorily completed, the ejecter driving source is again energized to deposit one or more substrates into the track assembly. Likewise, when the completed thin-film memory elements in their carriers are transported to the unloading chamber, the puller assembly under the control of the control unit removes the memory elements and disposes same into the substrate holders. The indexer and puller lead screw drives are rotated at the proper times to withdraw the memory elements, fill up one substrate holder, and index to an unfilled holder.

It can be seen then, that the control unit maintains strict control of all processes and operations in order to assure proper function of all system components required to be operated at a particular time and over a particular time interval.

Referring now to FIGURES 4 and 5, there is illustrated an alternative embodiment for the equipment in the loading and unloading chambers incorporating a non-indexable single station substrate cartridge configuration.

In order to preserve clarity the loading chamber housing or container with the exception of the bottom plate has been deleted. Likewise, the entire ejecter assembly, and so on has been deleted since it is the same as in FIGURE 2a. Turning now to the bottom of FIGURE 4, there are partially shown the magnetic drive coupling housings which are the same as that shown in FIGURE 2b. Likewise the vertical lead screw, and lead screw assembly are the same as that illustrated in FIGURE 2b. Disposed upon the base plate 14 is an annular ring member somewhat like the ball race member of FIGURE 2b. However, in this instance the balls and groove are not utilized because of the single cartridge feature not requiring indexing. Accordingly, the upper half of the race member is deleted. Referring simultaneously to FIGURE 5 there is shown a top view of the substrate holder and lead screw assembly. Secured to the base plate 14 is the pin holder 42 for fixedly securing at one end therein the pin member 44. All of the previous is the same as in FIGURE 2a. Suitably secured such as by screws and the like to the annular ring member 34 are support posts 236 and 237 projecting upwardly in the chamber. Secured to the top surface of the annular ring member 34 is support plate 238 corresponding to plate 74 in FIGURE 2b and containing openings therein so as to reduce pumping requirements in the chamber. Supported at one end thereof are support posts 240 and nearer the center are support posts 242. Disposed and suitably secured to the posts 240 and 242 is substrate

holder base plate member 244 having an enlarged opening 246 to permit pallet arm 68 to raise up and down into and out of the substrate area. Substrate holder 70 is constructed in a manner to that illustrated in FIGURE 2a. To support the upper end of the substrate holder 70, top support plate 252 is secured such as by screws or welding and the like to the substrate holder back wall portion and secured to the vertical support posts 236 and 237 and further supported by the vertical lead screw shaft in journal bearing 248 the top support plate is suitably secured to a bottom surface of the journal housing 250. As shown then, the top surface plate supports the upper end of the substrate holder by its interconnection at one end to the substrate holder and at its other end to the journal housing while the shaft is permitted to fully rotate within the journal bearing 248.

In the immediate configuration, the track assembly is supported in the outlet port 24 in the same manner as in FIGURE 2. However in the present configuration, track extension arms 254 secured at one end to the tracks are secured at the other end to the substrate holder walls at 256 to provide additional support for the substrate holder 70. Screws or the like may be used for the tie-down. In order to provide for reversal of rotation of the pallet arm lead screw, magnets and limiting switches are utilized in a manner similar to that shown in FIGURE 2a. The flange of the vertical lead screw assembly (not shown) mounts, for example, two magnets as in the previous embodiment. An upper switch element in translational alignment with one magnet is mounted on a holder 258 to the annular ring member. Another and lower switch element in translational alignment with the other magnet is projected by a hanger 260 or the like from the top plate 252. Accordingly when the lead screw assembly raises the pallet arm to its upward most excursion at which point the last substrate is positioned in alignment with the ejector and track, the upper limit switch is actuated to cause reversal of operation of the lead screw after the last substrate has been sent on its way to the vacuum deposition chamber. As the pallet arm lowers, the lower limit switch is actuated to cut-off power to the magnetic coupling device. Then the substrate holder is reloaded with a fresh charge of substrates and the operations repeated.

Again as in the other embodiment, the unloading chamber contains the same structure as that contained within the loading chamber. Likewise a puller arm and finger removes the memory elements from the outlet track assembly and loads them into the cartridge. All track sections and bridging assemblies are constructed as those illustrated in the figures.

Inasmuch as the master control unit operates principally, the same as aforementioned, no further explanation is considered necessary. The essential difference is that the control unit need not provide the indexing control function for the substrate since the immediate configuration is not rotatable.

It can be seen then that the only changes in the immediate configuration are those in the loading and unloading chamber. When it is desired to load a great number of substrates, the covers of the loading and unloading chambers are removed, the assemblies removed and the indexing carrier inserted. Accordingly, the interchange feature permits increased capacity for specific applications. As a practical matter, where the application of the invention does not require an indexable multi-station substrate holder, the latter is merely removed from the loading and unloading chambers and the single station substrate holder inserted as a unit. The upper ball race element is removed and the new substrate holder base plate is screwed down to the bottom race element disposed on the base plate.

It is to be understood that the present invention is not limited to the use of only a single deposition, loading, and

unloading chamber. The system is capable of accommodating an expansion whereby additional chambers may be utilized as needed for particular application.

What is claimed is:

1. In a system for depositing selected materials on predetermined areas of substrates for producing memory elements, substrate handling apparatus comprising: loading stage means including a first chamber capable of being evacuated, and substrate transport means for selecting individual ones of a plurality of substrates for processing, said substrate transport means including first substrate support means for supporting the selected substrates; processing stage means including a second chamber capable of being evacuated for processing said substrates, said processing stage mean including second substrate support means; unloading stage means including a third chamber capable of being evacuated, and processed-substrate transport means for stacking and retaining processed substrates, said processed-substrate transport means including third substrate support means for supporting said processed substrate prior to being stacked; first tube means intermediate said loading stage means and said processing stage means for permitting said substrates to be moved from said loading stage means to said processing stage means; first valve means mounted in said first tube means, said first valve means including first bridge means having a first position for coupling said first substrate support means to said second substrate support means for permitting said substrates to be sequentially moved from said loading stage means to said processing stage means, and first closing means for closing off said first tube means for isolating said processing stage means from said loading stage means for loading additional substrates, said first bridge means having a second position for decoupling said first substrate support means from said second substrate support means when said first closing means is operative to close off said first tube means; second tube means intermediate said processing stage means and said unloading stage means for permitting said substrates to be moved from said processing stage means to said unloading stage means; and second valve means mounted in said second tube means, said second valve means including a second bridge means having a first position for coupling said second substrate support means to said third substrate support means for permitting said substrate to be sequentially moved from said processing stage means to said unloading stage means, and second closing means for closing off said second tube means for isolating said processing stage means from said unloading stage means when unloading said processed substrate, said second bridge means having a second position for decoupling said second substrate support means from said third substrate support means when said second closing means is operative to close off said second tube means.
2. The invention of claim 1 wherein each said loading stage means and unloading stage means include:
 - (a) indexable multi-station substrate holder assembly means.
3. The invention of claim 2 wherein said first, second and third substrate support means includes:
 - (a) parallel guide means;
 - (b) adjustable means to permit lateral spacing of the guide means;
 - (c) roller carrier means rotatably supported by each of said guide means for transporting the substrates therealong.
4. The invention of claim 2 wherein each said indexable assembly means includes:
 - (a) a plurality of substrate stack containing compartments;
 - (b) supporting means for supporting said indexable assembly means;
 - (c) feeding means for movably supporting a substrate stack;

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- (d) and driving means coupled to a first driving source and cooperating with said supporting means intermittently for indexing said indexable assembly means one compartment at a time after one compartment is emptied of substrates.
5. The invention of claim 4 including:
- (a) an ejector and puller assembly means mounted in said system and associated respectively with said loading stage means and said unloading stage means for removing substrates individually from the substrate stack and for supplying substrates individually to form a substrate stack, said last named stack being formed in said unloading stage means.
6. The invention of claim 5 wherein said ejector assembly means comprises:
- (a) a second rotatably supported shaft member supported in said system and extending transversely and above the other rotatable shaft member, the second shaft member being aligned with said substrate support means, said second shaft member being coupled to a third driving source;
- (b) a second translatable assembly operatively coupled to said second shaft member;
- (c) and ejector arm means connected to said second translatable assembly for engaging a substrate at the top of the stack and ejecting said substrate into said substrate support means upon movement of said second translatable assembly toward said substrate support means.
7. The invention of claim 6 including:
- (a) motion limiting means associated with each of said translatable assemblies for limiting movement of said translatable assemblies, said motion limiting means being respectively electrically coupled to the second and third driving sources and to a control means coupled to said translatable assemblies to effect a predetermined sequence of operations.
8. The invention of claim 4 wherein said feeding means comprises:
- (a) a rotatable shaft member, said shaft member being connected to a second driving source;

- (b) a first translatable assembly operatively coupled to said shaft member;
- (c) and an arm member secured to said translatable assembly, said arm projecting into a holder compartment for lifting said stack when said shaft member is rotated.
9. The invention of claim 8 wherein said means for supporting said indexable assembly comprises:
- (a) a substrate holder support base means, said substrate holders being secured to said support base means;
- (b) and a ball-race assembly having an upper and a lower portion separated by roller elements to permit relative rotation between the upper and lower portions, said upper portion further having gear teeth around a periphery thereof, and said upper portion being secured to the support base means.
10. The invention of claim 9 wherein said driving means comprises:
- (a) a second shaft member connected to a second driving source, a driving gear secured to said shaft and engaged with said teeth whereby rotation of said driving gear causes rotation of said upper portion and indexing of said substrate holder assembly means.

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