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FILM DEPOSITION APPARATUS

Filed Aug. 5, 1966

2 Sheets-Sheet 1

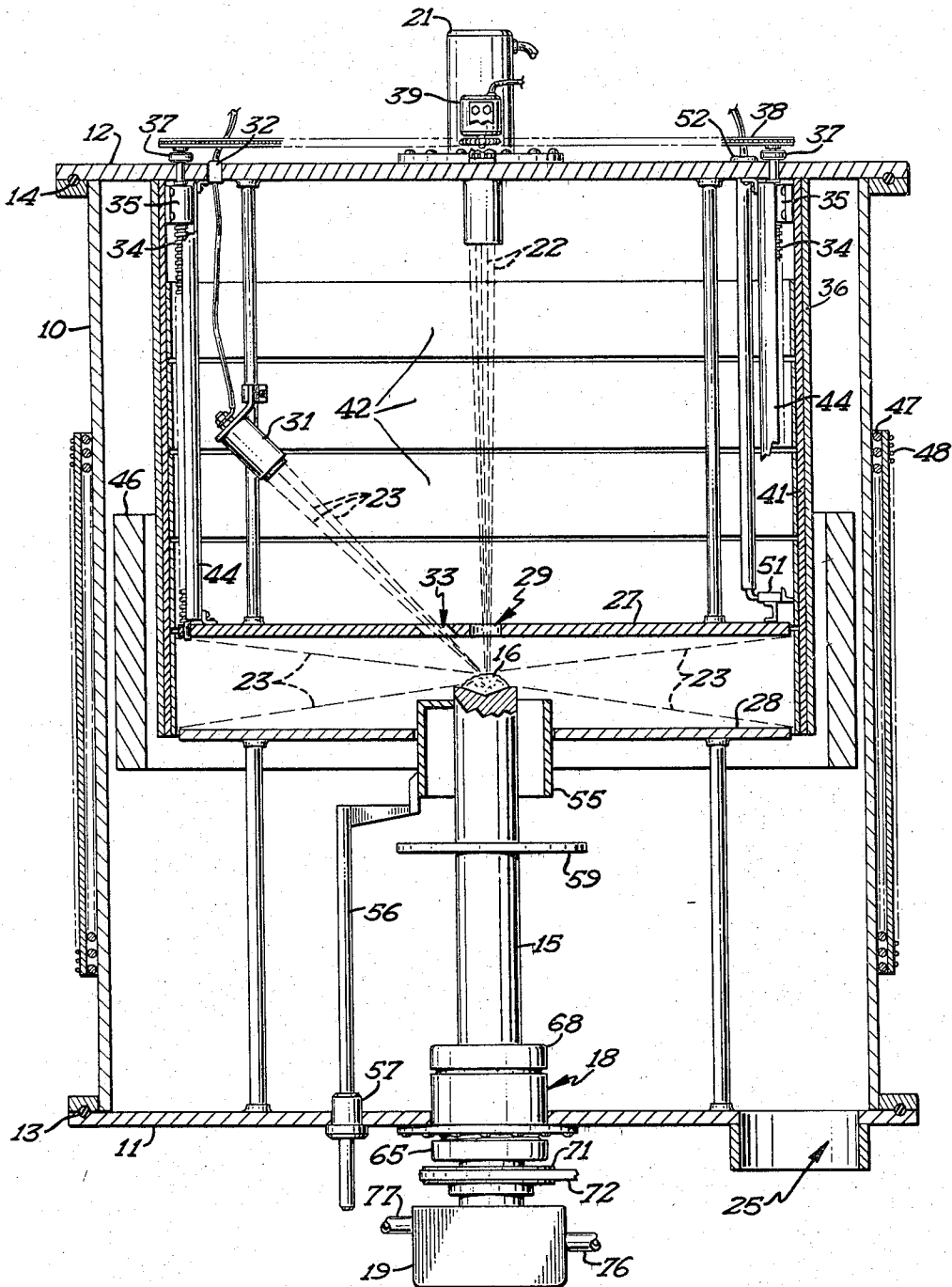


**Fig 1**

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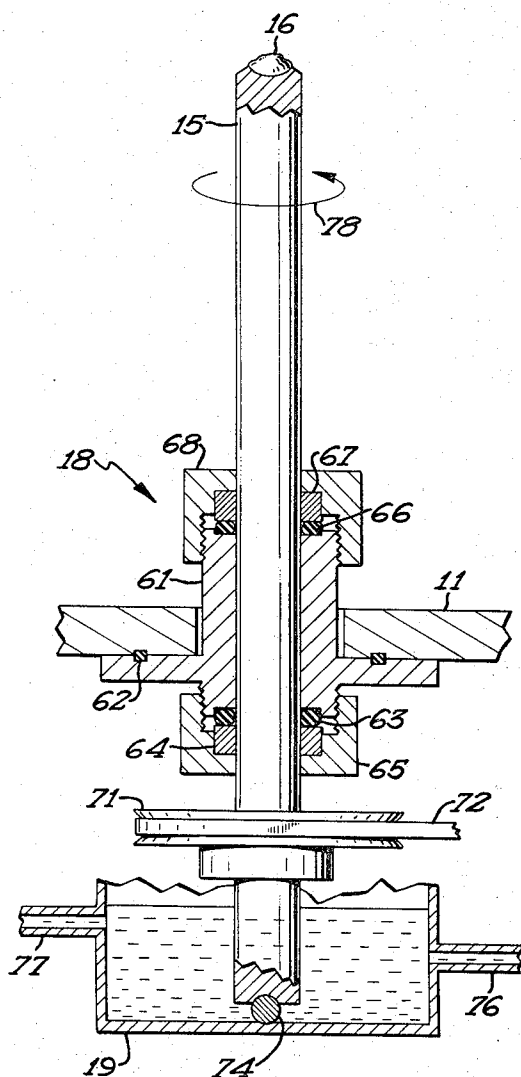


Fig 2

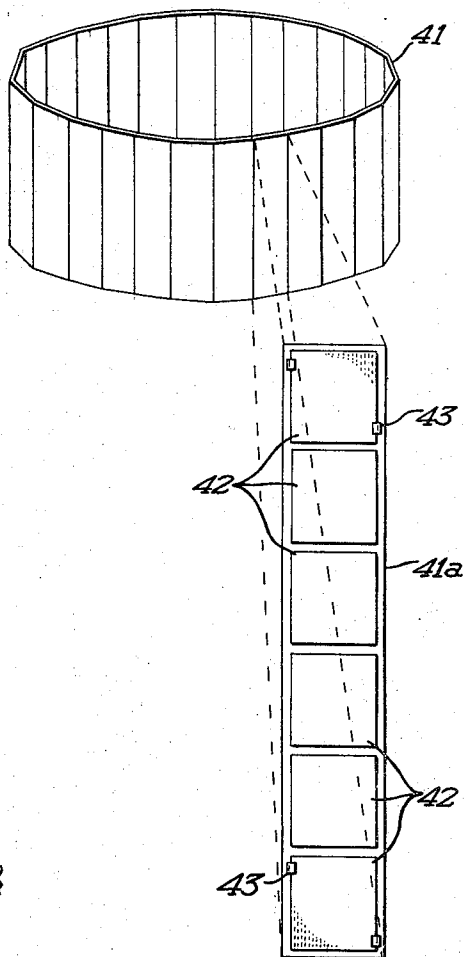


Fig 3

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## FILM DEPOSITION APPARATUS

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This invention is concerned with deposition apparatus, and more particularly with improved apparatus for providing high quality, lower cost deposition of films on a plurality of substrates.

The deposition of materials on a substrate, often referred to as thin film deposition, is fast becoming well known to those skilled in the art. In film deposition apparatus there is generally provided an evacuation chamber in which is mounted a melt. Thermal energy is provided to the melt to cause it to give off depositive vapors which are allowed to deposit on substrates placed in the vapor path. In the deposition of magnetic films, a magnetic field is presented to the area of deposition to cause the desired magnetic properties in the deposited film. Various improvements in deposition, such as heating or preheating substrates, providing cooling coils for maintaining desired temperatures, providing deposition monitor apparatus within the evacuative chamber, and others, have all added to the state of the art of film deposition.

One of the problems still present in the art is that of achieving mass production of deposited substrates without affecting the quality of the deposited film. The apparatus of this invention meets this problem by providing increased deposited substrates per evacuation cycle, thus lowering substrate cost, yet maintaining a high quality of film deposition. Further, the unique apparatus of this invention provides high quality deposition, yet reduces significantly the manual element in the deposition process.

Briefly described, the apparatus of this invention comprises a cylindrical jar defining a vacuum chamber. A base plate and top plate are sealed to the jar to complete the chamber. Within the chamber, the melt is placed on a rotary melt support or pedestal, which can comprise a rod extending from within the chamber at an end where the melt is held to a point outside the chamber where the other end of the rod connects to rotation members and to a cooling reservoir. Around the melt mounted on the rod is placed a substantially cylindrical substrate holding member. The longitudinal axis of this member is substantially in line with the longitudinal axis of the melt holding rod. This holding member is designed to carry a plurality of substrates, which can be aligned in rows and columns. The mounting means for the substrate holding member are adapted to provide vertical motion to the holder member so that a desired group of the plurality of substrates, such as a single row of substrates, can be placed in depositive relation to the melt.

Shielding of the substrates other than the desired group is accomplished by placing a second chamber within the vacuum chamber, within which second chamber the melt is disposed. In the preferred embodiment of this invention described below, this second chamber comprises a pair of horizontally disposed substantially parallel plates. Apertures are provided in the plates so that thermal energy from a member mounted in the vacuum chamber can reach the melts, and so that a limited amount of depositive vapors can reach monitoring apparatus also mounted in the chamber. Heating members and cooling coils are provided as required, as are magnetic field coils when the deposition is to be a magnetic film.

As the monitor indicates that deposition is completed

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on the first desired row of substrates, a device is actuated which moves the cylindrical substrate holder vertically to remove the deposited substrates from the second chamber and replace them with a second desired row of substrates.

As a further feature of this invention, the heating and cooling devices are arranged such that the next succeeding row of substrates to receive deposited vapors is preheated, while the completed deposited substrates are cooled. As a still further feature of this invention, the second chamber is designed such that the angle of incidence of the depositive vapors on the substrates is a maximum angle of approximately 7°.

In the drawings:

FIGURE 1 is a sectional view of the deposition apparatus of this invention;

FIGURE 2 is a detailed partial sectional view of the rotary melt support apparatus of this invention; and

FIGURE 3 is a perspective view of a substrate sled used with the apparatus of this invention, including an introrse view of a section of the substrate sled.

Referring first to FIGURE 1, there is shown a substantially cylindrical vacuum jar 10, which can be of such material as non-magnetic stainless steel. A base plate 11 and a top plate 12 are placed at the ends of jar 10 and are sealed thereto, respectively, by O-rings 13 and 14. When thus connected, jar 10 along with plates 11 and 12 form a vacuum chamber 26. A port 25 is provided in base plate 11 through which chamber 26 can be evacuated by means of a pump (not shown). Within chamber 26 there is shown mounted a rod 15, preferably of an oxygen-free-high-conductivity material. Rod 15 has an upper portion extending into chamber 26, the end of which carries a melt such as 16. The lower portion of rod 15 extends through a feed-through 18, and into a cooling reservoir 19. A preferred embodiment of feed-through 18 and reservoir 19 is discussed below in the description of FIGURE 2.

An electron gun 21 is mounted in top plate 12 and extends into chamber 26. Electron gun 21 provides an electron beam, indicated by the dotted lines 22, which strikes melt 16 to provide thermal energy thereto. The thermal energy results in melt 16 emitting depositive vapors, indicated by dotted lines 23. A first plate 27 is horizontally mounted on plate 12, and extends horizontally above melt 16. A second plate 28 is mounted below melt 16 on plate 11, and extends substantially parallel to plate 27. Plates 27 and 28 form a second chamber within chamber 26. It is within this second chamber that the deposition process will take place, with most of depositive vapors 23 being restrained between 27 and 28.

An aperture 29 is formed in plate 27 to allow beam 22 from electron gun 21 to reach melt 16. There is also shown a deposition monitor 31 mounted in chamber 26, and having electrical leads extending through an electrical feed-through 32 to outside the chamber. Another aperture 33 is formed in plate 27 to allow a portion of depositive vapors 23 to reach deposition monitor 31.

Mounted between plate 27 and plate 12 there are shown a plurality of threaded rods 34. Shields 44 are provided around threaded members 34 to prevent deposition on the thread from interfering with movement of holder 36. Threaded on rods 34 are a plurality of threaded sockets 35. Sockets 35 are connected to a substantially cylindrical substrate holder 36. Threaded rods 34 extend through feed-throughs in plate 12 to idler sprockets such as 37. The idler sprockets are connected by belt or chain 38 to a sprocket drive motor 39. The energization of motor 39 will cause sprockets 37 to turn threaded members 34. This will cause vertical motion of sockets 35 which will carry substrate holder 36 in a vertical direction.

A substrate sled 41, more fully seen in FIGURE 3, is

mounted on substrate holder 36. Substrate sled 41 carries a plurality of rows of substrates such as 42. As substrate holder 36 is moved vertically downward by actuation of motor 39, the rows of substrates will also move downward to remove one row of substrates from the deposition area between plates 27 and 28, and place another row of substrates 42 within the deposition area.

There is also shown a heater 46 in substantially cylindrical form and mounted around holder 36. Many thermal radiation sources can be used for heater 36 to provide a uniform and controllable temperature to substrates 42. For example, commercial quartz infra-red tubular elements arranged in a vertical fashion to form a cylindrical heat source can be used for deposition of magnetic thin films. Heater 46 is of such dimensions that in addition to heating the row of substrates 42 undergoing deposition, it simultaneously preheats the next succeeding row of substrates.

A plurality of cooling coils 47 are shown wrapped in helical fashion around the external periphery of jar 10. Cooling coils 47 provide conduction of radiated thermal energy from the system. Wound outside of cooling coil 47 is a magnetic field winding 48. Winding 48 can provide the necessary orienting of the magnetic field when deposition of magnetic films is desired. Winding 25 is extended almost to base plate 11 so that the deposited magnetic films remain in the orienting field until adequately cooled.

Also shown mounted in chamber 26 on plate 27 is a thermocouple 51, which has electrical connections extending through an electrical feed-through 52 in plate 12. Thermocouple 51 is a sliding contact thermocouple for monitoring the temperature of substrates 42.

There is also shown mounted in chamber 26 a shutter 55, which is connected to a push-pull rod 56 which extends through a sliding feed-through 57 to outside chamber 26. Actuation of push-pull rod 56 causes shutter 55 to selectively expose or shield melt 16, so that depositive vapors can be substantially removed from the area of substrates 42 during vertical motion of holder 36, or at other desired times. A shield 59 mounted on rod 15 helps to prevent downwardly extending depositive vapors 23 from contaminating the apparatus.

Referring now to FIGURE 2, melt support 15 along with its rotary feed-through 18 and cooling reservoir 19 are more fully described. Here it is seen that the lower end of rod 15 extends into a cooling reservoir 19 which may contain a fluid such as water. Water input 76, and output 77 are provided to allow a flow of water through reservoir 19. A bearing 74, such as the Teflon bearing, is mounted between rod 15 and reservoir 19, to allow for rotation of rod 15. A pulley 71 is attached to rod 15 and is driven by belt or chain 72 connected to drive means (not shown) to provide a rotary motion to rod or melt support 15, such as in the direction indicated by arrow 78. This rotary motion of rod 15 causes a similar rotary motion of rod 16 to allow for even deposition on the cylindrical row of substrates 42.

Also in FIGURE 2 it can be seen that feed-through 18 comprises a rotary feed-through 61 sealed to base plate 11 by an O-ring 62. The lower portion of feed-through 61 is secured and sealed by an O-ring 63, a pressure collar 64, and a pressure nut 65. Similarly, the upper end of feed-through 61 is sealed by an O-ring 66, a pressure collar 67, and a pressure nut 68.

As mentioned above, rod 15 is preferably oxygen-free, and of a high heat conductivity material. The preferred embodiment shown in FIGURE 2 is only one of many alternative methods of providing a rotatable cooled melt support such as 15. For low-power operations, where the melt materials exhibit high vapor pressures, a feed-through such as that described for feed-through 18 can be used with an oxygen-free-high-conductive rod 15 which utilizes the cooling water reservoir 19. For high-power operations, such as evaporating refractory metals, an arrangement similar to FIGURE 2 can be used if the cool-

ing water is forced through appropriate channels in rod 15 itself. However, for most materials, the apparatus of the preferred embodiment of FIGURE 2 provides adequate cooling of the melt support 16.

In FIGURE 3 there is shown a substrate sled 41 which is mounted on substrate holder 36. It can be seen that sled 41 comprises a substantially cylindrical polygonal figure. An introrse view of section 41a and of sled 41 discloses that a plurality of substrates 42 are mounted on each side of sled 41, and can be held in place by clips such as rotatable spring clips 43.

For better understanding of the operation of the apparatus of this invention, a complete, typical cycle for mass deposition of magnetic film memory elements will now be described. For this description it is assumed that a removable and replaceable top plate 12 is used in the apparatus of this invention, and that a plurality of such plates are available. To optimize the efficiency of the pumping station, two complete top cover plates, along with the electron gun and substrate holding member assemblies can be used.

A top cover plate 12 including all attached fixtures as shown in FIGURE 1 is removed from the chamber for unloading of the deposited films, installation of monitor crystals in the deposition monitor 31, and loading of uncoated substrates. Substrate sleds 41 as shown in FIGURE 3, are removed from holding assembly 36, unloaded, and loaded with uncoated substrates and vapor shields. The entire top cover plate unit is then reinstalled on jar 10, and evacuation of chamber 26 is accomplished through port 25.

The first cylindrical row of substrates 42 is in position for deposition, as shown in FIGURE 1, where the first row is aligned between plates 27 and 28. Substrates 42 of the first and second cylindrical rows are brought to desired temperature by heater 46, and by supplying the appropriate amount of cooling water to cooling coils 47.

Shutter 55 is pushed into the closed position around melt 16, and electron gun 21 is turned on to provide electron beam 22, to increase the temperature of melt 16 to the temperature corresponding to the desired deposition rate. Shutter 55 is then opened to allow the depositive vapors 23 to reach the substrates in monitor 31. Condensation of the metallic depositive vapors upon the exposed row of substrates 42 and upon monitor 31 then occurs. After the desired film thickness is obtained, as evidenced by deposition monitor 31, shutter 55 is again actuated to the closed position to prevent further deposition on substrates 42 and monitor 31, and electron beam 22 is defocused to reduce evaporation of melt 16.

Sprocket motor 39 is then actuated to turn threaded rods 34 to provide downward vertical motion to holder 36. This lowers substrates 42 until the next succeeding row of substrates is in the chamber formed by plates 27 and 28 and ready for deposition. Deposition monitor 31 is rezeroed at this time. Also, heater 46 will begin to preheat the third row of substrates 42.

After the second row of substrates reaches the desired temperature, electron beam 22 is refocused and shutter 55 is again opened to allow deposition of the magnetic film upon the exposed substrates of the second cylindrical row, and upon monitor 31.

The above sequence is repeated until all rows of substrates 42 have been coated. After the substrates and holding assembly have been cooled sufficiently, the entire top cover plate-fixture arrangement is removed and replaced with an identical system holding uncoated substrates. The remaining melt material 16 can be removed and a fresh melt material installed on melt support 15 prior to closing the chamber for another deposition sequence.

Thus it is apparent that the above described apparatus provides a unique structure for mass production of coated substrates, without loss of quality, in a single evacuation cycle.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In deposition apparatus including a vacuum chamber, means for evacuating the chamber, and deposition monitor means, the improvement comprising:
  - melt support means at least partially mounted in the chamber around a vertically extending longitudinal axis, said support means adapted to carry a melt for forming depositive vapors;
  - means mounted in the chamber for providing thermal energy to the melt;
  - substantially cylindrical substrate holder means including substrate sled mounting means on the inner surface of said holder means, said holder means adapted to carry substrate sleds having a plurality of substrates mounted thereon;
  - means movably mounting said holder means in the chamber, the longitudinal axis thereof being substantially the longitudinal axis of said melt support means;
  - means for vertically moving said holder means, to sequentially move a group of said plurality of substrates into spaced relation with the melt for deposition on the group of substrates, and a pair of vapor deflection plates mounted in the chamber in generally horizontally, spaced relation, above and below the melt to shield the plurality of substrates other than the group of substrates from depositive vapors formed by the melt.
2. The apparatus of claim 1 in which said melt support means comprises:
  - feed-through means mounted to said chamber;
  - an elongated rod mounted in said feed-through means and having an upper portion extending into the chamber for supporting the melt, and a lower portion extending out of the chamber; and
  - cooling means mounted in contact with said lower portion of said rod.
3. The apparatus of claim 2 including:
  - means rotatably mounting said rod in said feed-through means; and
  - means connected to said lower portion of said rod for rotating said rod around the longitudinal axis.
4. The apparatus of claim 1 including:
  - movable shutter means mounted in the chamber;
  - means connected to said shutter means and extending out of said chamber for selectively moving said shutter means to shield the substrates from the depositive vapors formed by the melt.
5. The apparatus of claim 1 wherein said vapor deflecting plates are substantially parallel to one another.
6. The apparatus of claim 5 including:
  - a first aperture formed in said plates and aligned between said means for providing thermal energy and the melt; and
  - a second aperture formed in said plates and aligned between the deposition monitor means and the melt.
7. The apparatus of claim 5 in which:
  - the spaced relation of said substrate holder means and the melt, and the spaced relation of said deflector plates and the melt are predetermined to provide a maximum angle of incidence of the depositive vapors on the group of substrates of approximately 7°.
8. The apparatus of claim 1 including:
  - substrate heater means mounted external to and around the periphery of the chamber; and
  - said substrate heater means being of sufficient dimensions to heat the group of substrates undergoing deposition, and to preheat the next succeeding group of substrates.
9. The apparatus of claim 8 including:

- magnetic field producing means mounted external to and around the periphery of the chamber to provide an orienting field when magnetic films are being deposited; and
- said magnetic field producing means being of sufficient dimension to provide an orienting field to the group of substrates undergoing deposition, and to prior deposited groups of substrates while they are cooling.
10. In deposition apparatus including a vacuum chamber, means for evacuating the chamber, melt support means mounted in the chamber, and means for vaporizing a melt supported by the melt support means, the improvement comprising:
  - substrate holder means adapted to hold a plurality of substrates and comprising an open-ended body of substantially cylindrical form, mounted with its longitudinal axis in a substantially vertical disposition and passing through the melt;
  - means mounting said substrate holder in the chamber and adapted to selectively move said substrate holder relative to the melt on the melt support means to place a desired group of said plurality of substrates in deposition relation with the melt;
  - a second chamber in the vacuum chamber;
  - the melt support means adapted to hold the melt in said second chamber;
  - the movement of said substrate holder adapted to place the desired group of said plurality of substrates in said second chamber, so that said plurality of substrates other than the desired group are substantially shielded from the melt; and
  - said second chamber comprising a pair of spaced, generally horizontally disposed plates mounted in the vacuum chamber above and below the melt.
11. The apparatus of claim 10 including the improved melt support means comprising:
  - a vertically extending rod having upper and lower portions;
  - means mounting at least said upper portion in the chamber, the end of said upper portion adapted to support the melt; and
  - means connected to said lower portion for rotating said rod around its longitudinal axis.
12. The apparatus of claim 10 in which:
  - the dimensions of said second chamber are predetermined to limit the maximum angle of incidence of depositive vapors from the melt on the substrates to approximately 7°.

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