Jan. 7, 1969 W. J. CARLSON 3,420,767

CATHODE SPUTTERING APPARATUS FOR PRODUCING PLURAL COATINGS IN A CONFINED HIGH FREQUENCY GENERATED DISCHARGE

Filed March 3, 1966 Sheet 1 of 2

Fig. 1

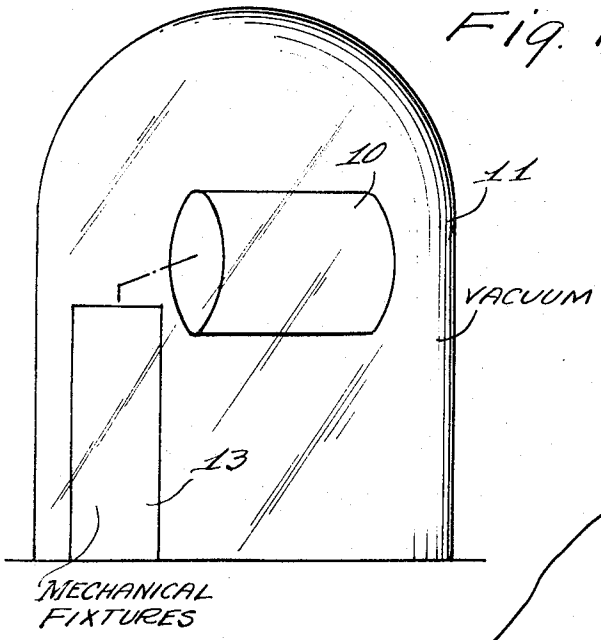


Fig. 4

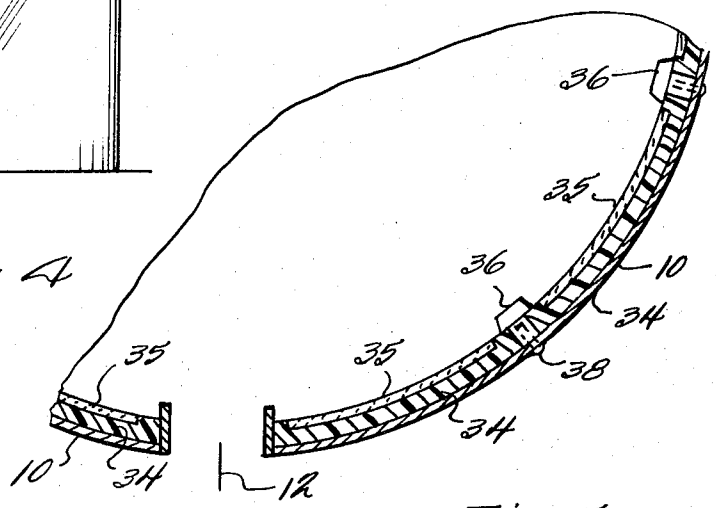
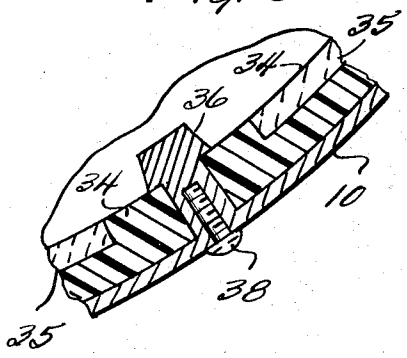


Fig. 5



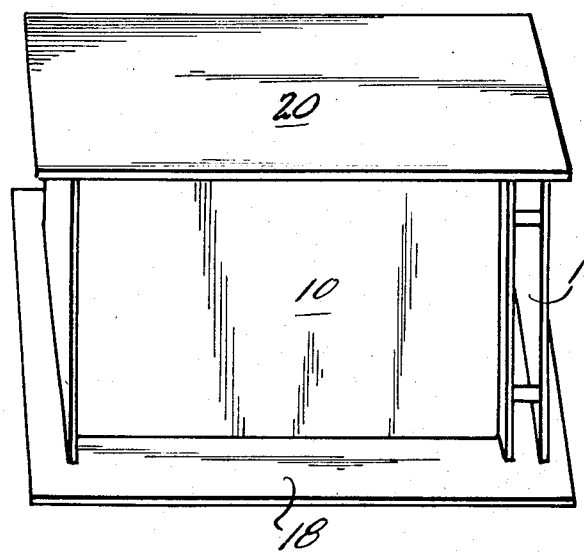


Fig. 6

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Filed March 3, 1966 Sheet 2 of 2

Fig. 2

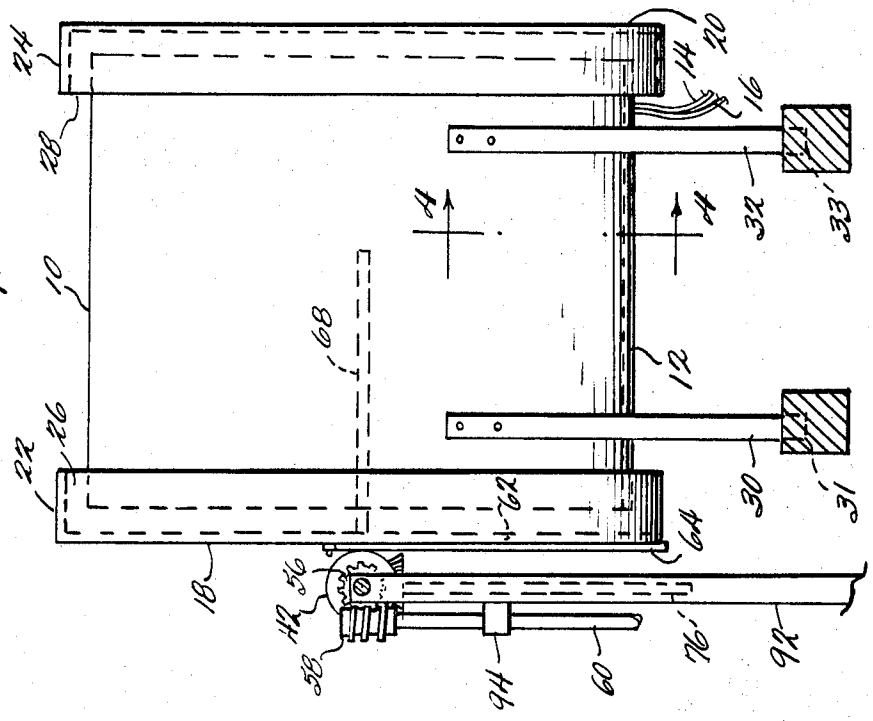
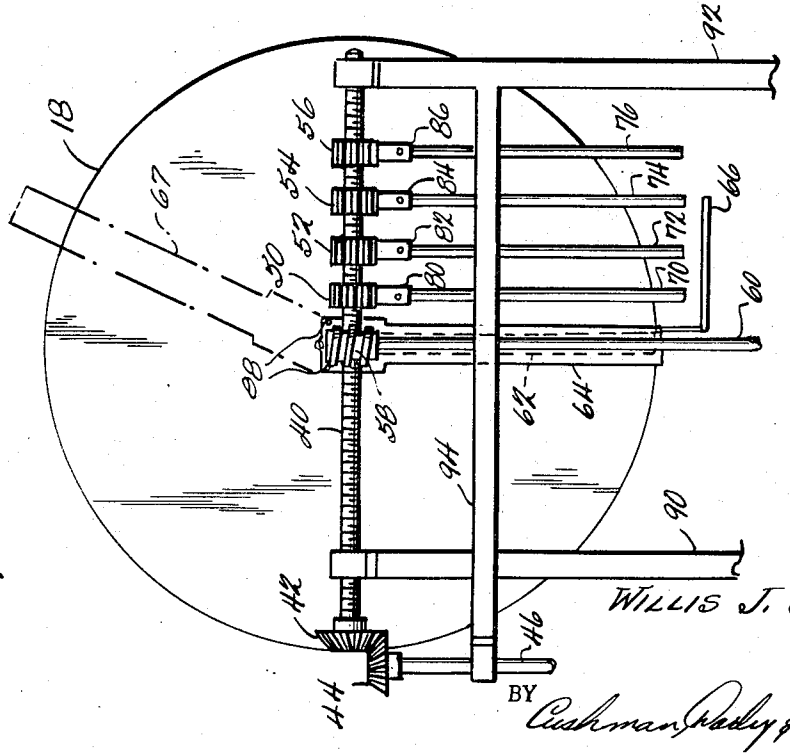


Fig. 3



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CATHODE SPUTTERING APPARATUS FOR PRODUCING PLURAL COATINGS IN A CONFINED HIGH FREQUENCY GENERATED DISCHARGE

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Int. Cl. C23c 15/00

This invention relates to apparatus for producing a plasma in a large container which is maintained at a substantial vacuum and, in particular, this invention relates to means for producing a plasma in a portion only of the large vacuum. Further, this invention relates to apparatus for producing on a plurality of substrates, (for example, by sputtering) a layer of material on each substrate.

In prior art apparatus for sputtering a film or layer of material on a substrate, the number of substrates, upon which the layers can be deposited or sputtered, is limited by the amount of mechanical fixtures which must be associated with the vacuum chamber.

In prior devices, a vacuum chamber containing an inert gas is provided in which the pressure is reduced to a low level so that the sputtering process may be employed. A target electrode is placed in the vacuum chamber together with the substrate upon which the target material is deposited. A radio frequency coil is placed around the outside of the vacuum chamber so that when energized, the low pressure gas is converted into a plasma. A high voltage is placed on the target electrode and the ions of the plasma are attracted thereto with such force that material from the target plate is knocked loose therefrom and transferred to the substrate which is placed a small distance therefrom. A further electrode is placed within the vacuum to provide a return path for the voltage placed on the target electrode.

It is desirable that a large number of substrates have one or more layers deposited thereon during one vacuum cycle and thereby take the manufacture of such products as magnetic thin films from a research type deposit of one or two layers or films per chamber evacuation to a production machine where thirty-two (for example) films can be deposited in one evacuation. Typically, one deposit is possible every hour thereby producing 256 films in an eight-hour day. This would reduce the cost of producing magnetic thin films to $\frac{1}{10}$ of a cent per bit. However, with the increase in the number of substrates, the number of mechanical fixtures which must be provided also increases. This requirement conflicts with the fact that the R-F coil is placed on the outside of the vacuum chamber.

Accordingly, it is an object of this invention to provide improved apparatus for producing a plasma within a large vacuum chamber, where the plasma is restricted or confined to a definite portion of the vacuum, the R-F coil being placed inside the chamber.

Another limitation found in prior art devices is that only one layer can be deposited on a substrate for a given vacuum cycle—that is, once the vacuum chamber is pumped down to a sufficiently low presure, it is possible to deposit only one layer on the substrate with prior art devices. Before another layer can be deposited, it is necessary to break the vacuum to permit a new target of different composition to be entered into the chamber. Then the chamber is pumped down again and the second layer is deposited on the first layer. It is evident that the necessity for creating and destroying the vacuum with each deposition is costly and time consuming and not suitable to mass production.

Therefore, it is another object of this invention to provide improved apparatus for depositing a plurality of layers of material on a substrate during a single vacuum cycle.

It is a further object of this invention to provide improved apparatus for producing a plasma within a restricted portion of a large vacuum.

Other objects and advantages of this invention will become apparent to those of ordinary skill in the art upon reading the appended claims and the following detailed description of an illustrative embodiment of the invention, in conjunction with the drawings, in which:

FIGURE 1 diagrammatically illustrates an embodiment of the invention where a plasma is created within a restricted portion of a vacuum;

FIGURE 2 is a side view of an illustrative embodiment of the invention;

FIGURE 3 is an end view of the embodiment shown in FIGURE 2;

FIGURE 4 is a partial cross-section taken along the line 4—4, shown in FIGURE 2;

FIGURE 5 illustrates a detailed portion of FIGURE 4; and

FIGURE 6 illustrates a further embodiment of the invention.

Referring to FIGURE 1, one of the basic concepts of this invention is illustrated—that is, the creation of a plasma within a restricted portion of the space of the vacuum chamber **11**. A substantially closed coil or sheet **10** of electrically conducting material is placed within the vacuum chamber **11**. Only the inert gas confined within the sheet **10** will be ionized and made suitable for carrying out the sputtering process. Mechanical fixtures are diagrammatically indicated at block **13**, these fixtures also being disposed within the vacuum to facilitate the mass production multi-layer deposition process. These fixtures will be described in detail hereinafter with respect to FIGURES 2 and 3.

Referring to FIGURE 2, there is also shown the cylindrical sheet **10** of electrically conducting material. As shown in FIGURE 4, there is a slit **12** provided along the bottom of the sheet **10** across which high frequency energy, such as a radio frequency (R-F) voltage, may be applied.

Although the sheet is shown having a circular cross-section with respect to the axis of the cylindrical sheet, other cross-sections are also possible—such as, square and rectangular cross-sections as shown in FIGURE 6 where the sheet or coil **10** is nearly closed on four sides. By this method a plasma of sufficient density for sputtering can be developed.

The connecting electrical cables to the opposite sides of the slit are shown in FIGURE 2 at **14** and **16**. This electrical connection may be balanced or unbalanced. Since sheet **10** is of solid construction and has only the slit **12** contained therein, the application of the R-F voltage to the sheet **10** will produce an R-F magnetic field within the sheet which will ionize the inert gas within the sheet **10**, thereby creating a plasma substantially within a confined or restricted portion of the vacuum within the chamber **11**, as shown in FIGURE 1. Thus, the plasma is created in a first space portion of the chamber **11** enclosed by the sheet **10**, whereas the mechanical fixtures **13**, shown in FIGURE 1 and described in more detail with respect to FIGURES 2 and 3, are disposed within a second space portion of the vacuum chamber **11**. The use of the sheet **10** to create the plasma within a restricted portion of the vacuum allows better coupling to the plasma, and a more confined plasma; thereby resulting in less cleanup of the system, less "down" time, and less labor costs.

Plates **18** and **20** are disposed at the ends of the

cylindrical sheet 10 in order to restrict the plasma to the space within the sheet 10. The plates 18 and 20 take the shape of circular disks, shown in FIGURE 3, with peripherally attached projections 22 and 24 provided so that the plasma will be more effectively confined within the sheet 10. This results from the fact that the inside diameter of the projections 22 and 24 is slightly greater than the outside diameter of the sheet 10. A slight gap, as indicated at 26 and 28, must be maintained between the plates 18 and 20 and the sheet 10 to insure the proper distribution of electricity on the sheet 10. The plates 18 and 20 are also normally grounded electrically. Conventional support and grounding means for plates 18 and 20 have not been shown.

Insulated supports 30 and 32, as shown in FIGURE 2, are connected to the cylindrical sheet 10 and mounted at the base of the vacuum chamber 11.

Reference should now be made to FIGURE 4 which is a partial cross-section of the embodiment shown in FIGURE 2 taken along line 4—4. The sheet or coil 10 is also support for substrate holders 34, which extend along the axial direction of the cylindrical sheet 10. Each substrate holder typically contains four substrates 35. Only the ends of substrates are shown in FIGURE 4. The holders are held in the sheet by plates 36 which extend along the axial direction of the cylindrical sheet 10 and by screws 38 attached through the sheet 10. Typically, eight of substrate holders 34 are disposed around the periphery of the sheet 10, as shown in FIGURE 4.

Reference should now be made to FIGURE 5 which illustrates in detail one way that the plates 36 may be employed to provide separation between, and support for, the substrate holders 34. Other expedients will be readily apparent to one having ordinary skill in this art.

Reference should now be made to FIGURES 2 and 3 which illustrate in detail the mechanical fixtures 13, shown in FIGURE 1. The basic purpose of the structure shown in FIGURES 2 and 3 is to provide the capability for depositing on each of the plurality of substrates disposed along the inside of the sheet 10, as shown in FIGURE 4, a plurality of layers or films of various materials during a single vacuum cycle. As already pointed out, the unique arrangement of a plurality of substrates disposed along the inside wall of a cylindrical sheet of electrically conducting material which itself is disposed within a vacuum chamber as brought out in FIGURES 1 and 4, provides the mass production capability of substrates having one layer of material deposited thereon. By combining the structure of FIGURE 4 with that shown in FIGURE 3, the above-mentioned capability of depositing on each substrate a plurality of layers of different materials during a single vacuum cycle is provided. As also mentioned before, a truly efficient mass production capability requires the ability to produce a plurality of layers on each substrate for a single vacuum cycle in order to minimize waste of time and money.

In FIGURE 3 there is shown a threaded rod 40 having a beveled gear 42 mounted at the end thereof, which meshes with another beveled gear 44 mounted on a rod 46 which is connected to a point outside of the vacuum chamber (not shown). The rod 40 has a plurality of pinion gears 50, 52, 54 and 56 threaded thereon. The pinion gears are arranged to mesh with a worm gear 58, which is mounted on a shaft 60, which is also connected to a point outside of the vacuum chamber.

End plate 18 has a slit 62 therein which extends from the bottom of the plate to a point approximately at the center thereof. This slit is normally covered by a rotatable cover 64. Lever 66, which is connected to cover 64, causes the cover to be rotated to a position such as shown at 67, the lever 66 also being connected to a point at outside of the vacuum chamber. Lever 66 is diagrammatically shown and may be connected to cover 64 by any of many well-known methods to cause the rotation thereof.

Respectively associated with each of the pinion gears are target members or rods 70, 72, 74 and 76. Each target rod is made of a different material depending on the materials which are to be deposited on the substrates 35 for a given vacuum cycle. The rods 70 through 76 supply the material which will be deposited on the substrates, the ions of the plasma attacking a given target and loosening therefrom the material to be deposited. In order to attract the ions to the target, high voltage terminals 80, 82, 84 and 86 are respectively connected to the targets 70 through 76 and the pinions 50–56. High voltage terminals 88 are also provided at the center of plate 18.

The purpose of the mechanical structure shown in FIGURE 3 is to move a desired target rod into the space portion enclosed by the sheet 10, the target rod being eventually disposed substantially along the axis of the cylindrical sheet 10 and the electrical terminals associated with the target rod being in contact with the terminals 88 on the plate 18. No electrical wires to the terminals 88 are shown in the drawing. Parts 90, 92 and 94 are supports for the mechanical structure.

Having now described the mechanical structure shown in FIGURE 3, a description of its operation will now be given. The operation will be described in relation to a multi-layer deposition process upon each of a plurality of substrates. Although a certain order of steps will be given in describing the process, it should be clear that many of the steps could be interchanged or their order completely reversed and the order of steps chosen is for the purpose of illustration only.

The coil or sheet 10 is first removed from its mountings 31 and 33, shown on FIGURE 2, from the vacuum chamber. The substrate holders 34, together with the associated substrates 35, are lined along the inside surface of the sheet 10, as shown in FIGURE 4, with the plates 36 being positioned on the sheet 10 to hold the substrate holders at their appropriate places along the inside surface of the sheet 10.

The sheet 10 is next placed back in the vacuum chamber. The lever 66 is then operated to remove the cover 64 from the slit or opening 62 in the plate 18 and to the position shown at 67. The rod 46 is next rotated until one of the targets 70 through 76 is positioned in front of the slit 62. When this one target is in front of the slit 62, the pinion associated therewith will also be in mesh with the worm gear 58. The rod 60 is next rotated to rotate the pinions associated with the desired target. The rotation of the pinion causes the desired target rod to be rotated through the slit 62 and into a position where it extends along the axis of the cylindrical sheet 10 while at the same time the electrical terminals associated with the desired target will be in electrical contact with the terminals 88 on the plate 18. Material from this one target will be deposited as the first layer upon all of the substrates 35 within the sheet 10.

The inert gas is introduced into the vacuum chamber, the pressure is reduced in the chamber, high voltage is applied to the terminals 88, an R-F voltage is applied to the wires 14 and 16, and the cover 64 is returned to its normal position covering the slit 62 in the plate 18. Thus the sputtering process commences and the ions of the inert gas attack the target rod causing material to be loosened therefrom and deposited on the substrates 35 which are all spaced a substantially equal distance from the rod aligned along the cylindrical sheet 10.

After the first layer has been deposited, the following steps take place in preparation for the deposition of the second layer without breaking the vacuum produced in the chamber or without extinguishing the plasma established in the cylindrical sheet 10. First, the high voltage is removed from terminals 88, then the cover 64 is rotated to the position 67, shown in FIGURE 3, by actuation of lever 66, which is connected to a point outside the chamber, as stated before. The shaft 60 is next rotated, from a point outside the vacuum, to remove the target rod involved in the first deposition. The shaft 46, which

is also actuated from a point outside the vacuum is next rotated to position one of the target rods **70–76** which will be used in the next deposition. When the desired rod is positioned in front of the slit **62**, the pinion associated therewith is in mesh with the worm gear **58**; therefore, rotation of the shaft **60** from a point outside the vacuum chamber rotates the next target rod into position along the axis of the cylindrical sheet **10** in preparation for the next deposition.

The cover **64** is returned to its normal position and the high voltage is reapplied to terminals **88** and the sputtering process recommences with the material of the second target being deposited upon the layer first deposited upon the substrate.

Thus, there has now been described apparatus for producing a plurality of layers or films on each of a plurality of substrates (in the example, 32 substrates) during a single vacuum cycle. This is in accord with the objects and advantages stated for the invention.

What is claimed is:

1. Apparatus for depositing on at least one substrate sputtered material from a target electrode, comprising:

a container housing a chamber enclosing a space within said container, means to maintain an ionizable gas at sputterable pressures within said container;

means for moving said target electrode into and out of said chamber,

means for applying energy at high frequencies to said chamber to ionize gas which is confined within the chamber whereby material is sputtered from said target when positioned within said chamber; and

means for positioning said substrate in the path of said sputtered material.

2. Apparatus as in claim **1** wherein each substrate is disposed on the inside surface of said chamber.

3. Apparatus as in claim **1** wherein said chamber has a central axis, each substrate being disposed on the inside surface of the chamber and the target electrode being positioned during sputtering along said central axis.

4. Apparatus as in claim **1** wherein said electrode moving means comprises a device, housed within said container exterior to the chamber, having a plurality of target electrodes associated therewith and having means for selectively moving individual ones of the electrodes into and out of said chamber.

5. Apparatus as in claim **1** wherein said chamber has a slit along one side thereof, said energy applying means supplying energy across said slit.

6. Apparatus as in claim **1** wherein said chamber is a sheet of electrically conducting material having a substantially central axis and open ends, the chamber further including a pair of plates disposed at the open ends of the sheet and spaced a small distance therefrom.

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U.S. Cl. X.R.

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