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METHOD OF CATHODE SPUTTERING INCLUDING CLEANING BY ION BOMBARDMENT WHEREIN AN ARTICLE TO BE COATED IS SUBJECTED TO CANAL RAYS

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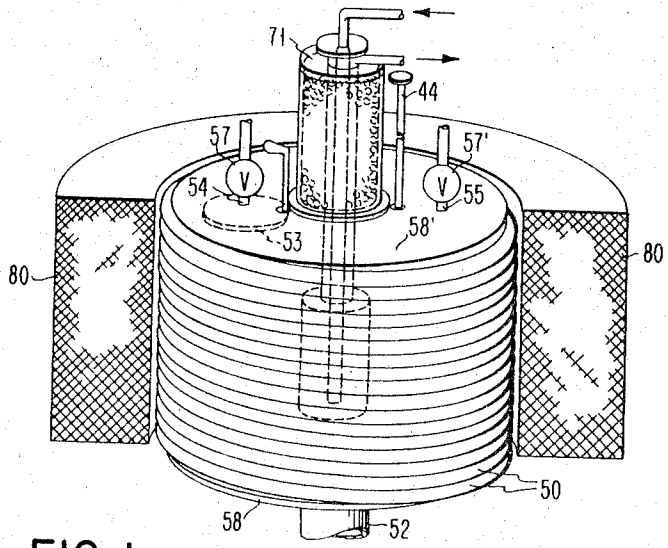

FIG. 1

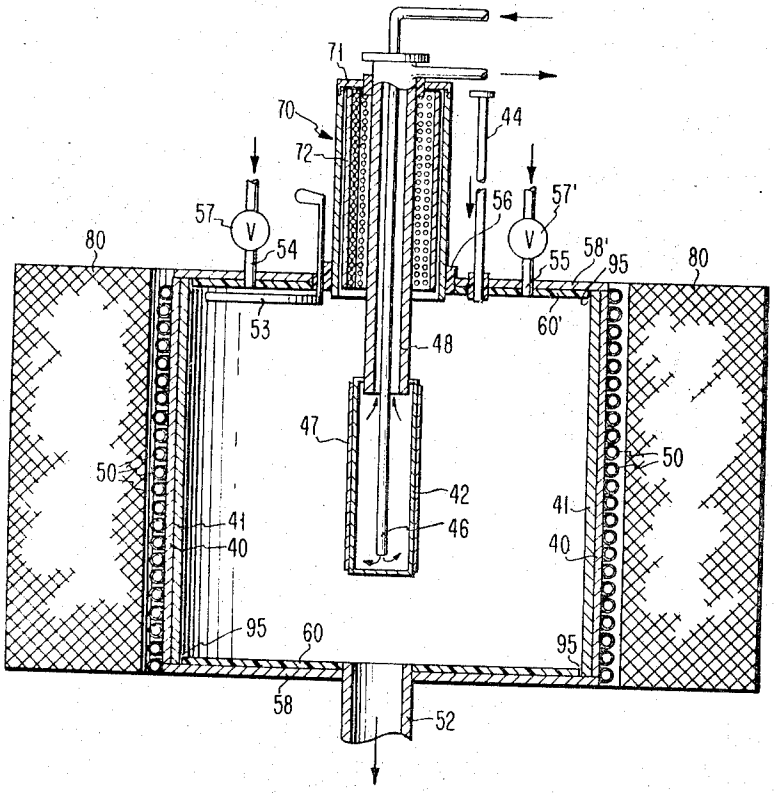

FIG. 2

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METHOD OF CATHODE SPUTTERING INCLUDING CLEANING BY ION BOMBARDMENT WHEREIN AN ARTICLE TO BE COATED IS SUBJECTED TO CANAL RAYS

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Original application Sept. 16, 1963, Ser. No. 309,159, now Patent No. 3,282,816, dated Nov. 1, 1966. Divided and this application Aug. 22, 1966, Ser. No. 574,868
5 Claims. (Cl. 204—192)

This is a division of my application Ser. No. 309,159, filed Sept. 16, 1963 now U.S. Patent 3,282,816, issued Nov. 1, 1966.

The present invention relates to an improved method and improved apparatus for depositing thin films from material which have been sputtered from a cathode and more particularly, to the method and apparatus for pre-cleaning of the substrate and associated exposed apparatus within the sputtering environment.

Problems in the art

Techniques of depositing thin films are becoming increasingly important. One reason is for the study of phenomena which may be controllably generated in such solid-state microcosms. Such phenomena are finding increasing application in magnetic and electronic devices. Attendant upon this interest in films, giant strides forward have been made recently in the art of depositing thin films and, more particularly, in techniques for very finely controlled deposition-control over such things as purity, crystalline structure, etc. Sputtering, or impact evaporation deposition, offers promising superiority for controlling such thin film deposition from several aspects. However, in its present state, sputtering presents some problems of deposition efficiency and practical workability. For example, residual gases or materials in the sputtering environment cause contamination of the sputtered thin film. The sources of contamination can be traced to impurities on the electrodes, the envelope or on other apparatus appearing in the sputtering environment. One obvious way of removing the impurities is to go through the same elaborate and costly procedure utilized in vacuum deposition of complete out-gasing at high temperature, "baking," with subsequent prolonged pumping to reach a 10^{-9} mm. Hg pressure before leaking pure inert gas into the apparatus. However, such a procedure would lose much of the relative simplicity and economy of the glow discharge technique. Another method of pre-cleaning is by pre-operation of the sputtering apparatus before placing the substrate on the anode. However, such pre-cleaning sputtering really erodes some of the cathode and deposits most of the impurities therefrom on the anode. Further, such pre-operation has little effect upon the inner vessel walls within the chamber. Further, impurities are brought in when the substrate is mounted since the apparatus is thereby exposed to the atmosphere. Also, no adequate way is provided to clean the substrate.

Hence, it is an object of the present invention to provide an improved method of pre-cleaning sputtering apparatus.

Yet another object of the present invention is to provide an improved method of efficiently pre-cleaning the substrate or article to be coated.

Still another object of the present invention is to provide a method of pre-cleaning the inner vessel walls within the sputtering chamber and removing the sputtered impurities from the chamber.

Another object of the present invention is to provide an improved apparatus for pre-cleaning sputtering apparatus.

Yet another object of the present invention is to provide improved apparatus for efficiently pre-cleaning the substrate or article to be coated.

Still another object of the present invention is to provide improved apparatus for pre-cleaning the inner vessel walls within the sputtering chamber and for removing the sputtered impurities from the chamber.

The foregoing and other objects, features and advantages of the invention will be more apparent and better understood from the following, more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawings, wherein:

FIG. 1 is a schematic perspective representation, partly broken away, of a sputtering device utilized according to the invention; and

FIG. 2 is a perspective sectional view of a complete sputtering apparatus embodiment utilized according to the invention.

An example of sputtering apparatus incorporating the invention together with a description of the operation of such apparatus and of the prior art is contained in the parent application, above. FIGS. 1 and 2 of this application correspond respectively to FIGS. 3 and 4 of the parent application. The numbering of the elements of FIGS. 1 and 2 thus corresponds identically to the numbering thereof in FIGS. 3 and 4 of the parent application.

The exemplary embodiment includes a cylindrical cathode **40** and a substrate **47**, which is the article to be coated. The substrate **47** is positioned within the chamber formed by the cylindrical cathode **40** and, when sputtering conditions are invoked in accordance with the parent application, above, the substrate will be sputter-coated with a material eroded from cathode sleeve **41** within cathode **40**. The sputtering glow discharge condition is applied between substrate **47**, which is ohmically connected to the positively charged anode **42** and the inner surface of sleeve **41**. Alternatively, the surface of the cathode **40** may be directly eroded by removing sleeve **41**, which is only provided for convenience and versatility. As in any sputtering atmosphere, the eroded material effectively "fills" the discharge chamber with a "gas" having the same composition as sleeve **41** (even if it is a multi-component alloy). This gas comprises a cloud of the material impact evaporated from the surface of sleeve **41**. This gas diffusively emanates toward, and deposits itself upon, the surface of substrate **47** in a uniform, carefully controlled manner.

It will be evident to those skilled in the art, that sleeve **41** of depository material may comprise any suitable material to be deposited on the substrate **47**, as long as it is ohmically and thermally connected to cathode **40**. This allows a convenient change in deposition source-material. Of course, the source-material might comprise a cathode cylinder itself, although it would be preferable not to erode this, keeping it uneroded to serve as a container wall. Likewise, the substrate **47** might alternatively comprise the anode **42** itself which may be introduced axially of the cathode wall through chamber **70**. However, it would be evident that it is more convenient, where possible, to use an inner anode surface so as to provide a constant medium for introducing the object, as well as a constant means for cooling it. Cooling is performed conventionally, see the parent application above, within the structure of anode **42** by introducing a coolant, for instance, through conduit **46**, the heating of which will cause it to exit through outer conduit **48**. However, any convenient coolant system evident to those skilled in the art may be substituted for this. It will be

apparent that auxiliary chamber **70** in conjunction with its removable top **71** provides an access port through which the anode substrate configurations may be axially inserted, allowing the substrate **47** to be introduced quickly and easily into the chamber and thereafter removed.

A second, and wholly unobvious, function of chamber **70** is for clean-up purposes. Such a pre-cleaning arrangement is aided also by the elements comprising rotatable shutter **53**, grid **72**, and auxiliary anode **44**, the latter being axially removable.

The novel pre-cleannig technique using these elements is as follows:

With the substrates positioned in the auxiliary chamber **70** and shutter **53** rotated so as to close off the chamber from the main apparatus, auxiliary anode **44** is introduced into the main discharge chamber and charged to sputtering potential, so as to initiate clean-up sputtering (or erosion) of the inner vessel walls within the chamber. The clean-up material may be captured either by depositing it upon auxiliary anode **44** or by pumping down during sputtering through port **52**, evacuating the eroded clean-up material. Such pre-cleaning by ion bombardment lends itself particularly to the apparatus of the invention, as here described. The provision of the auxiliary anode **44** makes it unnecessary to remove or cover the substrate during clean-up discharge time.

A second clean-up operation may be performed upon the substrate objects while in the auxiliary chamber **70**. Perforated grid **72** is provided for this purpose and, during clean-up, is charged with respect to the substrate so as to bombard the substrate with low energy (about 300 ev.) ions ("Canal Ray" bombardment) passing through the electrode perforations. In this configuration, electrons will be repelled by the perforated grid **72**, keeping the substrate out of the high electron density plasma to avoid electron-induced contamination, e.g., polymerization of oil vapors. Then, after suitable pre-cleaning by ion bombardment, the substrate can be introduced into the sputtering chamber for coating.

It may be noted in connection with auxiliary chamber **70** that it is sealably but insulatedly connected, for instance, by Teflon insulation **56**, to the end plates **58**, **58'** of the main chamber.

End plates **58**, **58'** are provided as the axial closures of the container formed by cylindrical cathode **40**. These end plates are made of metallic material, preferably the same material as cathode **40** so as to extend the effective cathode surface electrically, preventing undesirable sharp field gradients of the cylinder edges. Sheets **60**, **60'** of dielectric material overlie the outer surfaces of end plates **58**, **58'** entirely, except for gaps **95** (of a few mm.) adjacent sleeve **41**. This obstructs the discharge at the end plates, thereby preventing erosion thereon and still avoids a metal-to-dielectric vacuum seal by allowing use of metal closures **58**, **58'**.

It has been found that the above process can in fact reduce the partial pressures of reactive gases to levels equivalent to that attained in bakeable ultra-high-vacuum, vacuum deposition systems, without the necessity of time consuming, expensive and often material-limiting high temperature bake-out. Also, the throughput of inert sputtering gas during such pre-cleaning sputtering helps in reducing the partial pressures of desorbed contaminants by flushing them out of the system.

It is apparent that the above process may be applied to other sputtering systems; for example, the prior art apparatus described in the parent application, above. The anode therein may be modified to be withdrawn into a chamber which may be sealed off and a grid may be imposed between the anode and the chamber. An auxiliary anode may then be inserted into the sputtering enclosure and selective discharges struck between the cathode and

auxiliary anode and the enclosure and auxiliary anode. As described above the perforated grid may then be charged to allow Canal Ray bombardment of the substrate with low energy ions passing through the grid perforations.

The main requirements of the described pre-cleaning are therefore as follows. First, to clean by bombardment all surfaces. Second, to have a large inert sputtering gas throughput while pre-cleaning to flush the contaminants from the system. Third, to separate the substrate configuration effectively from the rest of the apparatus so that decontaminating one surface does not recontaminate another. And fourth, utilizing auxiliary anode **44** not only to provide an electrode for the pre-cleaning discharge, but also as a surface area for condensing the sputtered impurities.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A method pre-cleaning the inner surfaces of a glow-discharge sputtering device, comprising:
- removing the anode-electrode from a discharged chamber into a storage chamber;
- sealing said storage chamber;
- applying Canal Ray bombardment through a biased perforated grid to said anode-electrode;
- inserting an auxiliary electrode into the discharge chambers;
- invoking a sputtering discharge between said auxiliary electrode and the cathode surface;
- removing said auxiliary electrode; and
- reinserting said anode-electrode for the initiation of sputtering deposition.

2. The method of claim **1** wherein said sputtering discharge device comprises a hollow cathode discharge device, whereby said cathode comprises the inner surface of said discharge device.

3. The method of claim **1** including, after inserting said auxiliary electrode into the discharge chamber, the additional step of
- invoking a sputtering discharge between said auxiliary anode and the interior surfaces of said discharge device, not including said cathode surface.

4. The method of claim **2** including the additional step of continuously flushing the interior of said sputtering discharge device with inert sputtering gas maintained at the proper pressure to maintain sputtering discharge conditions therein.

5. The method of claim **3** including the additional step of
- continuously flushing the interior of said hollow cathode discharge device with inert sputtering gas maintained at the proper pressure to maintain sputtering discharge conditions therein.

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