July 24, 1973 J. C. PROVENZANO ET AL 3,748,253

APPARATUS WITH LABYRINTH HEAT EXCHANGER FOR THE SPUTTERING DEPOSITION OF THIN FILMS

Filed Jan. 24, 1972 2 Sheets-Sheet 1

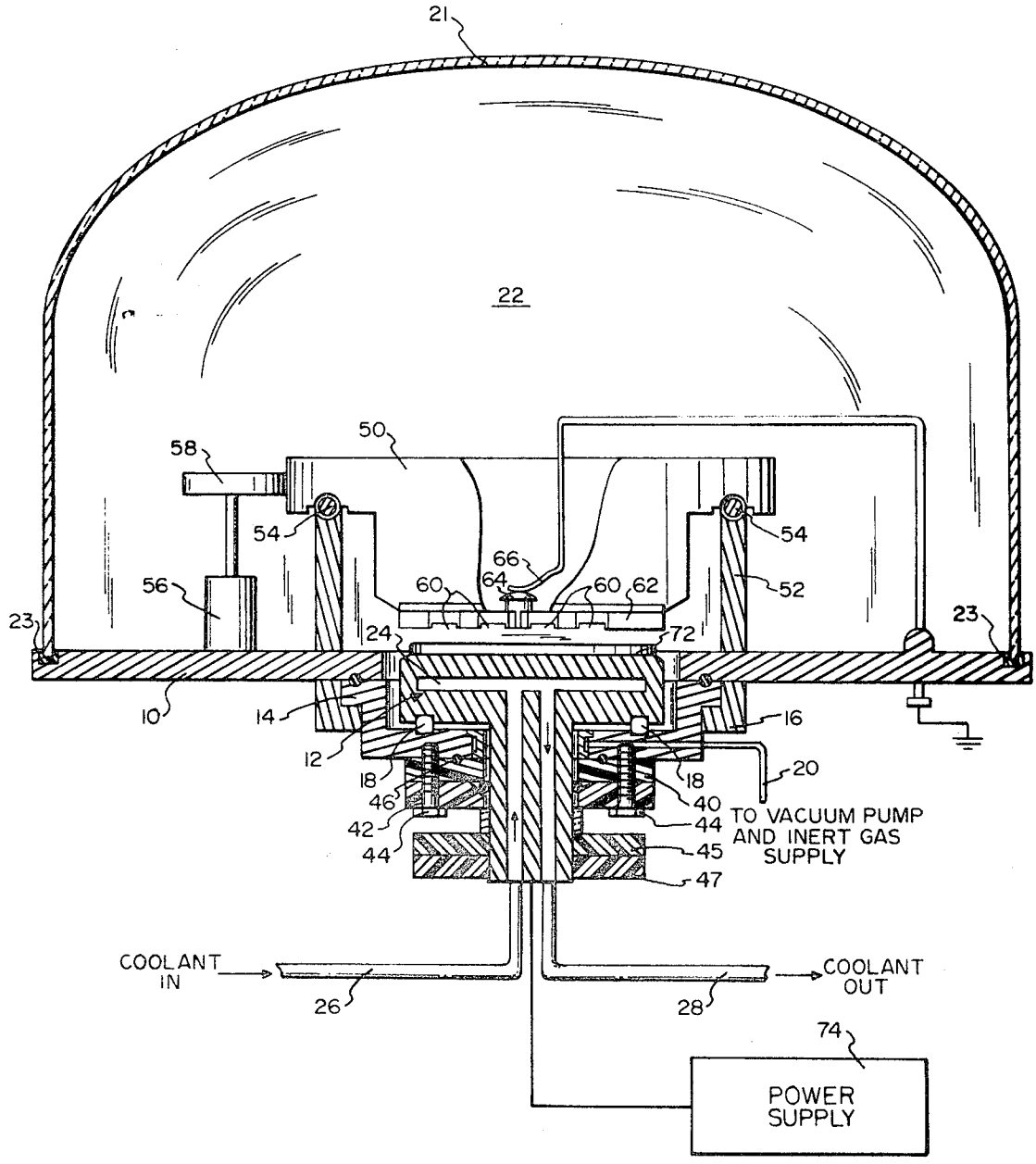

FIG. 1

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APPARATUS WITH LABYRINTH HEAT EXCHANGER FOR
THE SPUTTERING DEPOSITION
OF THIN FILMS
Filed Jan. 24, 1972 2 Sheets-Sheet 2

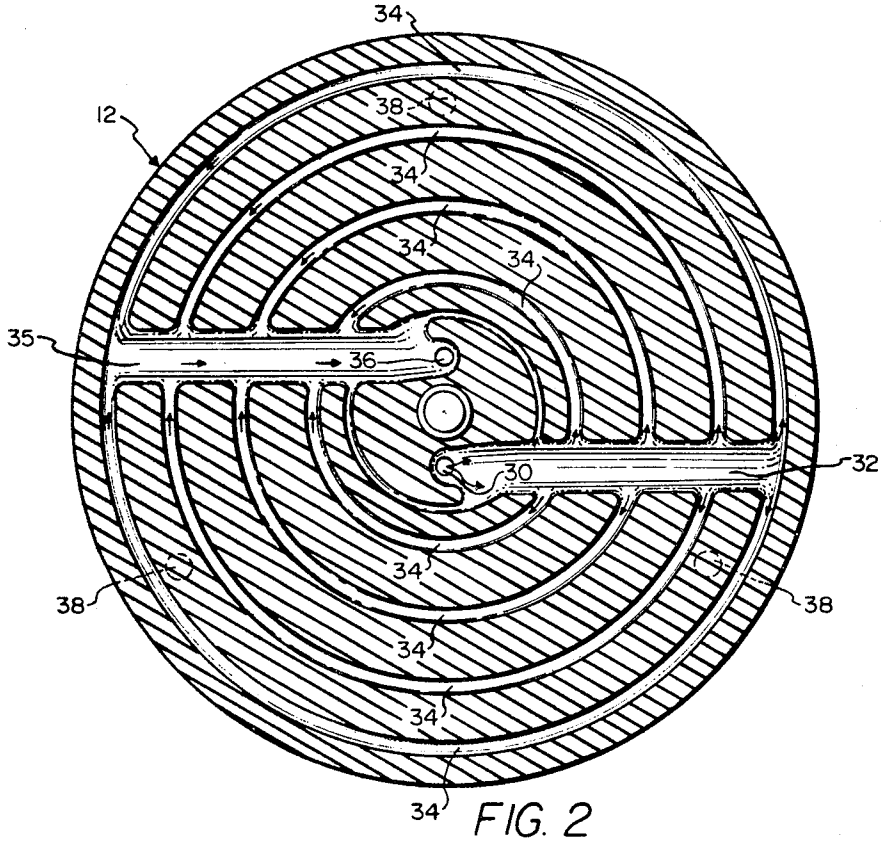

FIG. 2

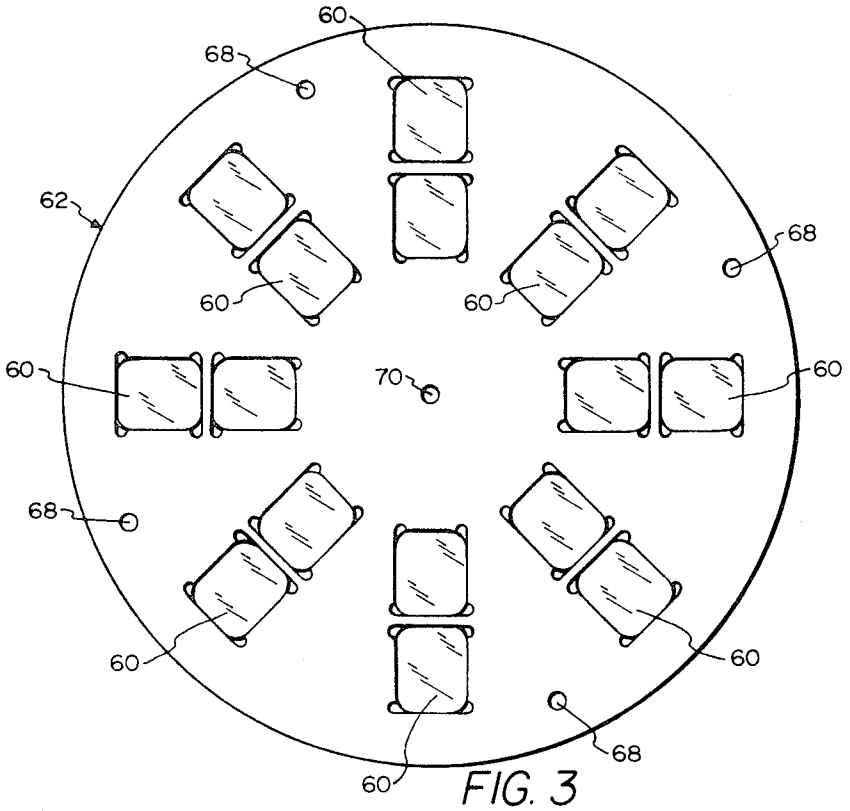

FIG. 3

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3,748,253

APPARATUS WITH LABYRINTH HEAT EXCHANGER FOR THE SPUTTERING DEPOSITION OF THIN FILMS

Joseph C. Provenzano, Glenview, and Richard E. Govednik, Schaumburg, Ill., assignors to GTE Automatic Electric Laboratories Incorporated, Northlake, Ill.

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ABSTRACT OF THE DISCLOSURE

Sputtering apparatus is improved by providing the cathode thereof with an integrally formed graded labyrinth heat exchanger through which a coolant is circulated to maintain the cathode and target material at a uniform temperature. Coolant parts and power input provisions are made such that the sputtering chamber may be hermetically sealed with a single seal.

BACKGROUND OF THE INVENTION

The deposition of thin films of a variety of materials by the process known as sputtering is well known. Typically a cathode is provided with a layer of sputtering or target material and the substrate on which the material is to be deposited forms an anode. The anode and cathode are hermetically sealed in a vacuum chamber containing an inert gas. A high potential is applied across the anode and cathode to deposit the sputtering material on the substrate. Since the target material receives on the order of 95% of the input power in a vacuum, its temperature will rise to unacceptable levels unless cooling is provided. The high temperature target material tends to radiantly heat the fixtures used in the apparatus which results in the release of contaminant gases into the vacuum chamber. This outgassing of contaminants may cause uncontrollable sputtering plasma changes which degrade the quality of the deposited thin films.

Cooling may be provided, however, it is important that the target material temperature be maintained as uniform as possible in order that non-uniformities in sputtering rates at different portions of the surface are avoided. Typically, in prior art sputtering apparatus the coolant input and output hoses as well as the electrical power input were introduced through the vacuum side of the sealed chamber through separate seals thus constituting significant points of potential failure while the apparatus was operated under a high vacuum.

OBJECTS AND SUMMARY OF THE INVENTION

From the preceding discussion it will be understood that among the various objectives of the present invention are included:

The provision of new and improved apparatus for the sputter deposition of thin films;

The provision of apparatus of the above-described character having improved target material cooling provisions; and

The provision of apparatus of the above-described character having an improved hermetic sealing arrangement.

These and other objectives of the present invention are efficiently achieved by providing the cathode on which target material to be sputtered is carried with an integrally formed graded labyrinth through which a coolant may be circulated to uniformly cool the cathode surface to a selected temperature. Coolant inlet and outlet lines as well as the electrical power input are provided through the

structure of the heat exchanging cathode such that the vacuum chamber may be sealed with a single seal.

The foregoing as well as other objects, features and advantages of the present invention will become more apparent from the following detailed description taken in conjunction with the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical cross-section view of an improved sputtering apparatus in accordance with the principles of the present invention,

FIG. 2 is a horizontal cross-section view of the heat exchanging cathode of FIG. 1; and

FIG. 3 is a top view of a substrate holding fixture useful with the description of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning to FIG. 1 there is illustrated a sputtering apparatus including a generally circular base plate **10** having a central aperture through which a sputtering cathode **12** may be inserted. A vacuum chamber **22** is provided by any suitable means such as the illustrated bell jar **21** hermetically sealed to the base plate **10** in seals **23**. The cathode **12** is held in a sputtering flange **14** which is secured to the underside of the base plate **10** by a collar **16**. The cathode **12** is supported in a spaced relationship with respect to the sputtering flange **14** by a plurality of ceramic positioning and spacing stand-offs **18** such that an inert gas such as helium introduced through a gas inlet **20** may circulate around the cathode **12** and into the vacuum chamber **22**. The cathode is further provided with an integrally formed graded labyrinth **24** through which a suitable coolant may be circulated via inlet and outlet couplings **26** and **28** respectively. The labyrinth is more clearly shown in the horizontal cross-section view of the cathode in FIG. 2. A coolant entering the labyrinth at the inlet port **30** flows radially outward through passage **32**, semi-circumferentially through passages **34** back via return passage **35** and exits via the outlet port **36**. It will be noted that graded spacing of circumferential passages **34**; i.e., spacing between passages increases with radial distance from the center of the cathode; allows the maintenance of the cathode at a uniform temperature. The recesses **38** adapted to receive the ceramic stand-offs **18** of FIG. 1 are illustrated in phantom.

The sputtering cathode **12** is positioned in the sputtering flange **14** by the stand offs **18** and first and second electrically insulative spacers **40** and **42** fixed to the sputtering flange **14** by bolts **44**. A first dielectric "O" ring **46** is disposed in a recess in the upper surface of the first spacer **40**. The second spacer **42** is provided with a beveled inner edge adapted to receive a second dielectric "O" ring **48** which provides hermetic sealing of the vacuum chamber **22** from the environment. Once in proper position the cathode **12** is held in place by first and second dielectric jam nuts **45** and **47** threaded on the lower end of the cathode **12** pulling it down against a spacer **49** between the second spacer **42** and the first jam nut **45**.

The upper surface of the base plate **10** is provided with a substrate holder **50** carried by a holder support **52** on bearings **54** such that the holder **50** may be driven in rotation about its longitudinal axis. The provision for driving the substrate holder **50** is schematically illustrated as a motor **56** having a friction wheel **58** which engages the periphery of the holder **50**. A plurality of thin film substrates **60** are retained in a frame **62** fixed to the underside of the holder **50**. An electrically conductive post **64** is disposed through the substrate holder **50** and in electrical contact with the substrate retaining frame **62**. Electrical contact with the post **64** is made through a spring

contact 66 which is coupled to the base plate 10 which is maintained at ground potential.

The configuration of a typical substrate retaining frame 62 will be more clearly understood from the horizontal view of FIG. 3. The frame 62 is provided with a plurality of apertures which receive and retain the substrates 60 on which thin films are to be deposited. A plurality of mounting holes 68 are provided through which the frame is fixed to the holder 50 and a central aperture 70 is provided to receive and engage the conductive post 64.

In operation of layer of sputtering or target material 72 is placed on the upper surface of the cathode 12, the chamber 22 is evacuated and an inert atmosphere introduced. The power is then applied from a suitable supply 74 to the cathode 12, and the substrate holder rotating motor 56 is actuated in order that an even deposition of target material is provided.

It will be noted from the illustrated construction of the sputtering cathode 12 that the complete cooling system for the apparatus is at the atmosphere side of the vacuum chamber 22 and that hermetic sealing is efficiently achieved through the use of the dielectric "O" ring 48. By integrally forming the coolant inlet/outlet passages and heat exchange labyrinth 24 in the structure of the sputtering cathode 12 a significant potential failure point has been eliminated while uniform cooling of the target material is maintained. It will thus be apparent that the applicants have provided an apparatus whereby the objectives set forth hereinabove are efficiently achieved. Since certain changes in the above-described construction will occur to those skilled in the art without departure from the scope of the invention it is intended that all matter contained in the foregoing description or shown in the appended drawings shall be interpreted as illustrative and not in a limiting sense.

Having described what is new and novel and desired to secure by Letters Patent, what is claimed is:

1. Improved apparatus for the sputter deposition of materials on substrates comprising

a vacuum chamber,

an electrically conductive cathode structure disposed partially within said vacuum chamber, adapted to receive on its upper surface a layer of target material to be sputtered and having integrally formed therein coolant inlet and outlet ports and a graded labyrinth heat exchanger in communication with said inlet and outlet ports,

said graded labyrinth heat exchanger comprising a first radially extending inlet passage, a second radially extending outlet passage and a plurality of substantially concentric semi-circumferential passages in direct communication with said first and second radially extending passages,

means for hermetically sealing said cathode structure to said vacuum chamber,

a substrate holder disposed vertically adjacent said cathode structure and adapted to be driven in horizontal rotation,

means for driving said substrate holder in rotation,

means for coupling said substrate holder to ground potential, and

a source of electrical power coupled to said cathode structure.

2. Apparatus as recited in claim 1 wherein

the distance between adjacent circumferential passages is increasingly greater with radial distance from the center of said cathode structure.

3. Apparatus as recited in claim 1 wherein

said means for coupling said substrate holder to ground potential comprises an electrically conductive post disposed substantially through the center of said substrate holder and adapted to rotate therewith, and a spring loaded electrical contact engaging said post and coupled to ground potential.

4. Apparatus as recited in claim 3 wherein

said substrate holder comprises an electrically non-conductive basket, and an electrically conductive substrate retaining frame having a plurality of apertures therein each adapted to receive and retain a substrate upon which target material is to be deposited, said frame being affixed to the under surface of said basket and rotating therewith, and

said electrically conductive post extending through said basket and being electrically continuous with said substrate retaining frame.

5. Apparatus as recited in claim 1 wherein

said vacuum chamber comprises a base plate having a centrally disposed aperture therein and a bell jar hermetically sealed to said base plate enclosing said aperture, said cathode structure extending through and electrically isolated from said base plate and further including

means for retaining said cathode structure in a fixed spatial relationship with respect to said base plate.

6. Apparatus as recited in claim 5 wherein

said cathode structure retaining means comprises an electrically conductive flange affixed to the underside of said vacuum chamber base plate and having a central aperture and a plurality of recesses disposed in the interior horizontal surface thereof about said aperture,

said cathode structure extending through said aperture in said flange and having a like plurality of recesses disposed in the horizontal under surface thereof,

a plurality of electrically insulative stand offs disposed in said recesses to thereby electrically isolate said cathode structure from said base plate and said flange and retain said cathode structure in a fixed spatial relationship with respect thereto,

electrically insulative means for securing said cathode structure in position against said stand offs, and

a dielectric "O" ring disposed between said cathode structure and said securing means to thereby hermetically seal said cathode structure to said vacuum chamber.

7. Apparatus as recited in claim 1 further including

means for introducing a selected gaseous atmosphere into said vacuum chamber.

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JOHN H. MACK, Primary Examiner

S. S. KANTER, Assistant Examiner

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