Nov. 3, 1970 L. F. HERTE ET AL 3,537,973

SEQUENTIAL SPUTTERING WITH MOVABLE TARGETS

Filed Sept. 15, 1967 2 Sheets-Sheet 1

FIG. 4

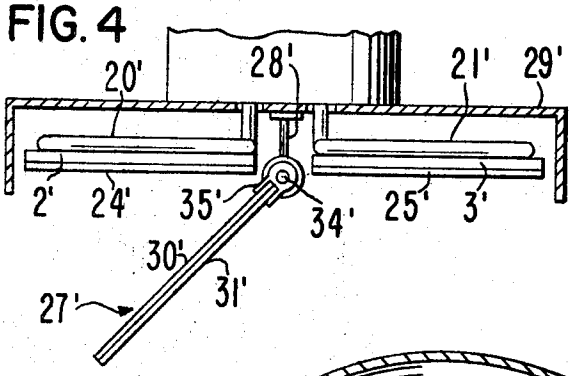


FIG. 5

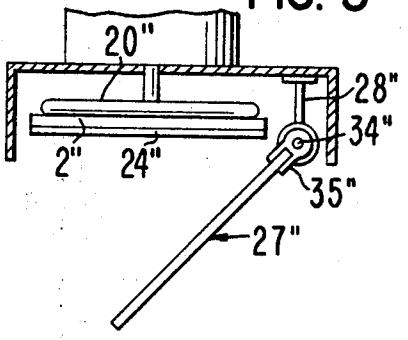
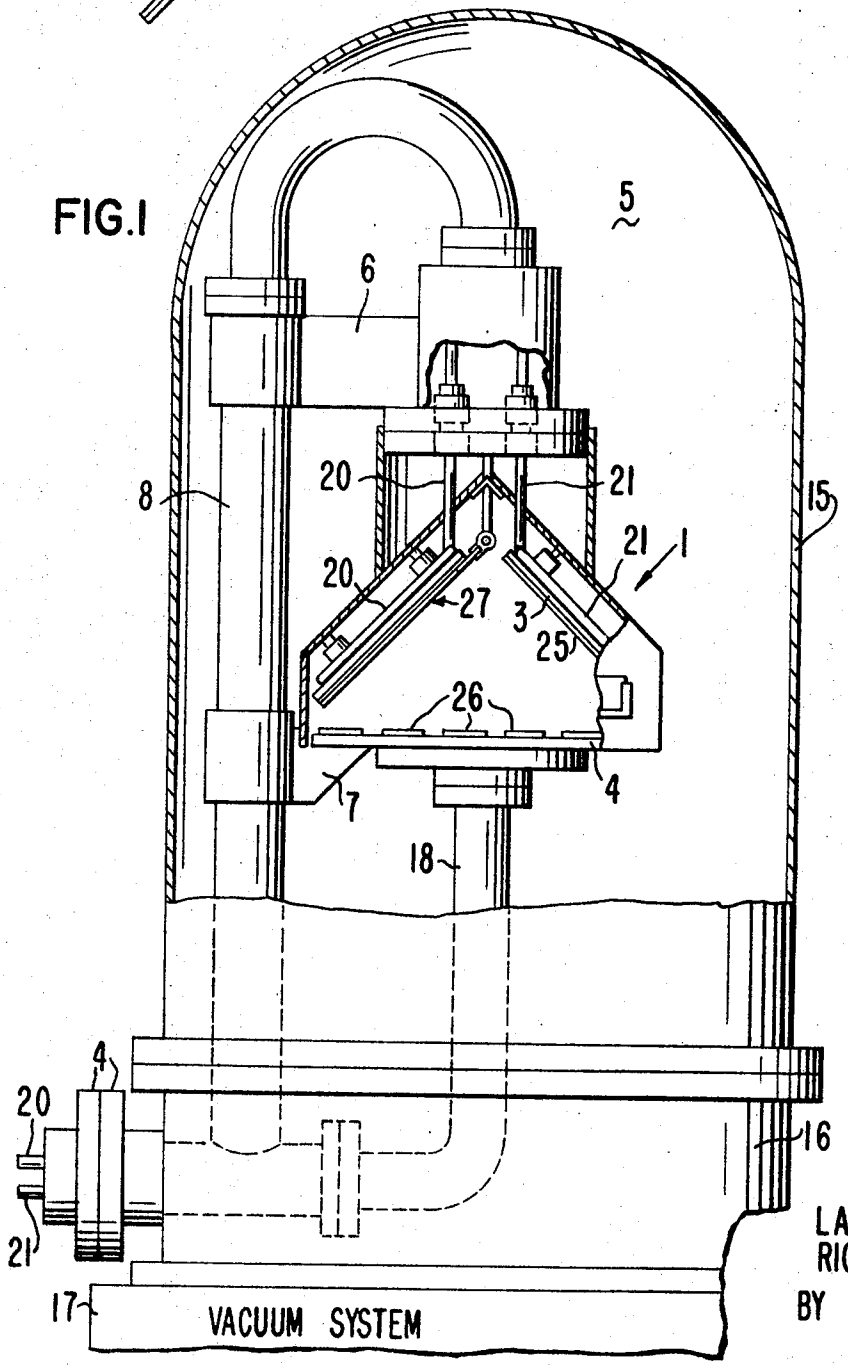


FIG. 1



INVENTORS
LAWRENCE F. HERTE
RICHARD F. LAIB
BY Leon F. Herbert
ATTORNEY

Nov. 3, 1970 L. F. HERTE ET AL 3,537,973

SEQUENTIAL SPUTTERING WITH MOVABLE TARGETS

Filed Sept. 15, 1967 2 Sheets-Sheet 2

FIG.2

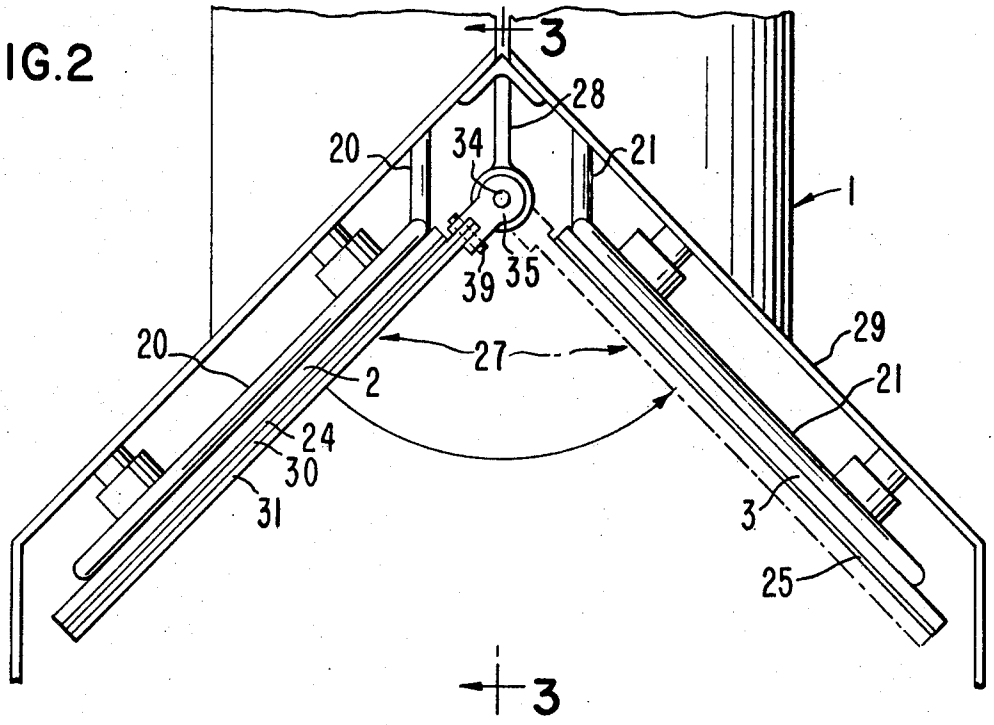
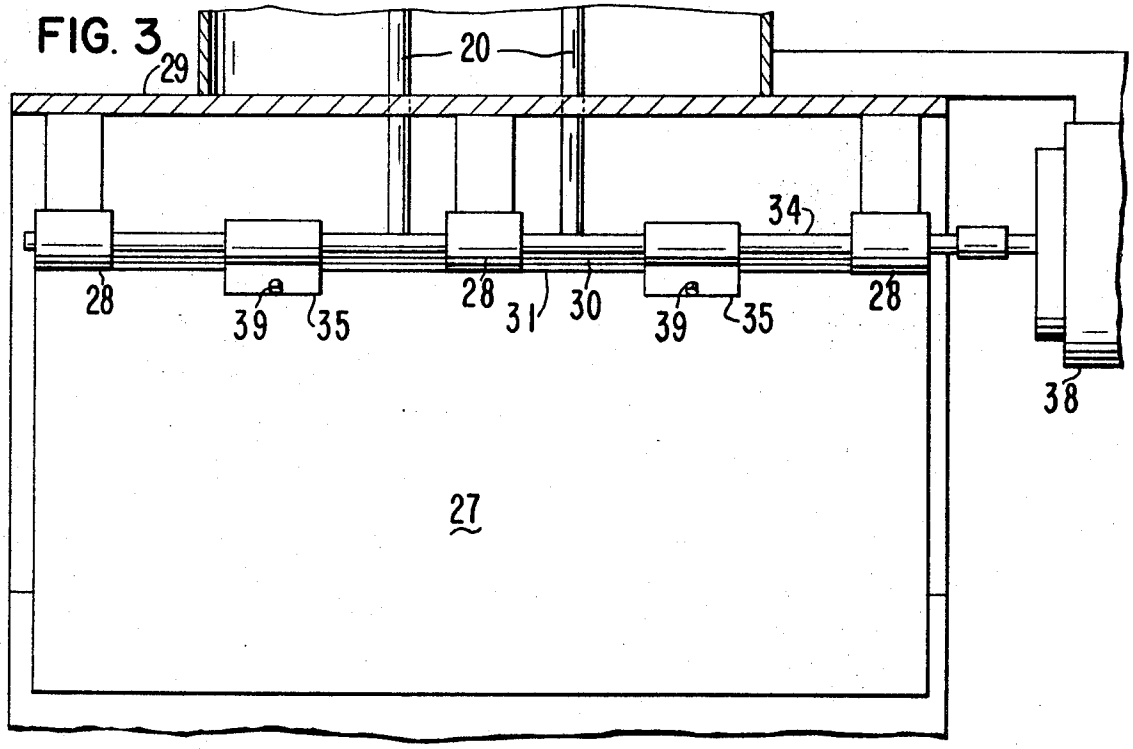


FIG. 3



INVENTORS
LAWRENCE F. HERTE
RICHARD F. LAIB

BY Leon F. Herbert

ATTORNEY

United States Patent Office

3,537,973
Patented Nov. 3, 1970

3,537,973

SEQUENTIAL SPUTTERING WITH MOVABLE TARGETS

Lawrence F. Herte, Palo Alto, and Richard F. Laib, Sunnyvale, Calif., assignors to Varian Associates, Palo Alto, Calif., a corporation of California

Filed Sept. 15, 1967, Ser. No. 668,107
Int. Cl. C23c 15/00
U.S. Cl. 204—298 4 Claims

ABSTRACT OF THE DISCLOSURE

Sequential deposition of two or more layers of sputtered material is made possible in sputtering apparatus employing peaked as well as plane parallel target electrodes by means of one or more movable, laminated, two layer targets. The two layer laminated target in which each layer is composed of different target material is pivotably supported on a shaft intermediate between two fixed target electrodes. In a first position, the laminated target is held against one of the fixed target electrodes exposing target material of a first composition for sputtering. After a predetermined time, the laminated target is positioned and held firmly against another of the fixed target electrodes exposing a second target material for sputtering. The targets are moved by a reversible drive motor which is mechanically coupled to a shaft supporting the laminated targets. The drive motor is provided with a holding circuit for firmly holding the laminated targets in position during sputtering.

BACKGROUND OF THE INVENTION

The present invention is related in general to cathodic sputtering apparatus. In particular, it is directed to sequential sputtering apparatus for use in making laminated thin films and as such represents an improvement over such prior known sputtering apparatus as are disclosed in copending United States application Ser. No. 625,733, filed Mar. 24, 1967 and application Ser. No. 662,637, filed Aug. 23, 1967, and both assigned to the assignee of the present invention.

In application Ser. No. 625,733 there is disclosed sputtering apparatus employing two planar target electrodes disposed at an angle relative to one another in such a manner as to form a peak or roof over the adjacent substrates. In application Ser. No. 662,637 there is disclosed sputtering apparatus employing two plane parallel target electrodes disposed horizontally relative to the adjacent substrates.

In copending U.S. application Ser. No. 674,539, filed Oct. 11, 1967 and assigned to the assignee of the present invention there is disclosed sequential sputtering apparatus employing a novel shield and substrate holder; however, as in the first two mentioned cases, the target electrodes and targets are rigidly fixed and immovable during any single sputtering cycle.

To the extent that means are provided in the present invention to position targets of various sputtering material for sputtering during a single sputtering cycle, the present invention is an improvement over the above referred to inventions and prior known conventional sputtering apparatus all of which employ fixed immovable targets.

SUMMARY OF THE INVENTION

In contrast to prior known sputtering apparatus in which both the targets and target electrodes are held in a fixed position throughout a sputtering operation, the present invention permits repositioning of targets at intermediate stages in order to facilitate the making of laminated thin films rapidly, for less cost and without defects caused by atmospheric contamination.

As more fully described hereinafter, a movable laminated target consisting of two layers of different target material is supported intermediate two fixed target electrodes. In one position of the laminated target, target material on one of the fixed target electrodes and one layer of the laminated target is exposed to the substrates for sputtering material. In a second position of the laminated target, target material on the second of the fixed targets and on the opposing layer of the laminated target is presented to the substrates. As a consequence, laminated thin films of different materials can be produced during a single sputtering operation or pump down cycle.

In terms of specific apparatus embodying the invention, a reversible motor is mechanically coupled to a rotatable shaft supporting the laminated target for pivoting the laminated target to either of two sputtering stations. The motor may be, for example, an SS50 Slosyn motor. In operation, 60 cycle power is applied to the motor to drive the laminated target to the desired position after which a small D.C. voltage is applied to hold the target in position. Alternatively, over-the-center latches may be affixed to the surrounding shield to catch and hold the laminated target in position. Since efficient sputtering demands as low a residual gas pressure as possible in terms of both high rates as well as purity of film deposition, it is becoming more and more imperative that all sputtering operations on any single substrate be performed during a single pump down cycle. This is particularly true where the thin film devices are intended for use in research as well as commercially produced cryogenic and microminiature electronic circuits.

While operational plasma pressures may be considerably higher during sputtering, certain applications requiring extremely well controlled atmosphere establish initial sputtering conditions which necessitate pumping vacuums to pressures as low as 10^{-6} torr. Vacuum pumping of that nature with presently existing equipment exceeds elapsed times of 30 minutes.

Accordingly, a primary object of the present invention is sputtering apparatus for making thin films more efficiently, at less cost and without atmospheric contamination during intermediate stages of processing.

Another object of the invention is sputtering apparatus for making laminated thin films by means of a movable laminated, two layer target.

Another object of the invention is sputtering apparatus as described in which the laminated target is driven by an externally controlled reversible motor.

These and other objects, features and advantages of the invention will become apparent from the detailed description hereinafter when considered together with the accompanying drawings in which:

FIG. 1 is a front elevational view of a sputtering system embodying the present invention,

FIG. 2 is an enlarged view of the sputtering head of FIG. 1,

FIG. 3 is a side view of the sputtering head as shown in FIG. 2, and

FIGS. 4 and 5 are alternative sputtering heads embodying the present invention.

DETAILED DESCRIPTION

In FIG. 1 there is shown a sputtering module **1** including a pair of adjacent target electrodes **2, 3** and a substrate holder **4** supported within a vacuum chamber **5** by means of two brackets **6, 7** adjustably attached to a vertically rising stainless steel pipe **8**. The provision for adjusting brackets **6, 7** along the length of pipe **8** is for setting the target to substrate distance, which is a primary factor in obtaining optimum rates of sputtering and deposition.

Vacuum chamber **5** in which sputtering module **1** is enclosed is formed by a vacuum envelope **15**, such as a bell jar, seated in a vacuum tight manner on a stainless steel spool-type vacuum manifold **16**. A high vacuum pump system **17** is connected to manifold **16** in a vacuum type manner for evaculating chamber **5** of residual gas to a pressure as low as 10^{-7} torr. Provision is made also in pump system **17** for back filling vacuum chamber **5** with an inert chemically pure gas, such as argon, from which a glow discharge is generated and maintained during sputtering. The reduction of residual gas and back filling with an inert gas insures there is sufficient ionization for efficient sputtering and at the same time avoids contamination and deterioration of the thin film and substrates due to chemical reaction with gases which may be present in air.

Pipe **8** connected to the upper section of sputtering module **1** together with a pipe **18** connected to the substrate holder **4** provide conduit for fluid cooling lines used in cooling electrodes **2, 3** and substrate holder **4**. A pair of cooling tubes **20, 21** running to the electrodes **2, 3** may be made of either dielectric or conductive material. When made of conductive material they may function as transmission lines for electrical energy for electrodes **2, 3**. In addition to functioning as conduit for cooling fluids and electrical energy to electrodes **2, 3**, tubes **20, 21** may be mechanically fixed to the upper surface of electrodes **2, 3**, as by brazing, and serve to mechanically support electrodes **2, 3** in a peaked configuration as shown in FIG. 1 or in a plane parallel configuration as shown at **2', 3'** in FIG. 4.

Target material **24, 25** is affixed to the lower surfaces of electrodes **2, 3** in any well known manner, as by clips (not shown). In operation, ions from the glow discharge formed in the space between electrodes **2, 3** and substrate holder **4** are accelerated to electrodes **2, 3** and upon impact with target material **24, 25** eject mostly neutral particles of target material which then deposits on and adheres to substrates **26** supported on substrate holder **4**. Target **24** is made of one material and target **25** is made of a different material.

To produce laminated thin films on substrates **26**, a third target **27** is pivotably disposed between electrodes **2, 3**. Target **27** has laminae of target material of differing composition on opposed surfaces. One lamina **30** of target **27** is identical to the target material **24** affixed to electrode **2**. The other lamina **31** of target **27** is identical to the target material **25** affixed to electrode **3**. When positioned for sputtering, target **27** and one of the targets affixed to electrodes **2, 3** thus present identical sputtering material to substrates **26** for sputtering.

Referring to FIG. 2, there is shown the upper section of sputtering module **1**. Electrodes **2, 3** supported by tubes **20, 21** are held in a fixed position relative to substrate holder **4**. Three brackets **28** for supporting laminated target **27** are attached to a grounded shield **29** intermediate electrodes **2, 3**. The lower ends of brackets **28** are formed to accept a shaft **34**. Laminated target **27** is attached to shaft **34** at intermediate points along the length of shaft **34** by two laminated target retaining collars **35**.

Fasteners **39**, such as pins or screws, hold the laminated target **27** within collar **35** and permit easy interchange of laminated target **27** with laminated targets of different composition.

Referring to FIG. 3, a vacuum compatible reversible motor **38**, such as an SS50 Slosyn motor, is coupled to the end of shaft **34**. Shaft supporting brackets **28** for supporting shaft **34** are positioned near the ends and center of shaft **34**. Target retaining collars **35** are positioned intermediate brackets **28**.

In operation, target **27** is driven by motor **38** to a position abutting either target **24** or **25** and is held in place by application of a small D.C. holding voltage to motor **38**. Alternatively, over-the-center latches may be fixed to a shield **29** for catching and holding target **27**. As shown in solid lines in FIG. 2, target **27** is abutting target **24**, thereby blocking sputtering from such target and positioning material **31** in its place for sputtering. In the illustrated solid line position, target material **31** of target **27**, and target material **25** affixed to electrode **3**, are exposed for sputtering. In a second position (shown in dot-dash lines) of the target **27** in which it abuts target material **25**, it blocks sputtering from such material and target material **30** of target **27** and target material **24** affixed to electrode **2** would be exposed for sputtering. Thus, in accordance with the invention as described, laminated thin films of different compositions can be produced without bringing the vacuum chamber up to air to change target material.

As will be apparent to those skilled in the art, the target material on each of target **27** and electrodes **2, 3** exposed for sputtering need not be the same. Differing target material would permit deposition of composite thin films. Similarly, the invention is not limited to a single laminated pivotable target but encompasses plural laminated targets which may be selectively positioned by appropriate controls.

An alternative embodiment similar to that described above is shown in FIG. 4 wherein modified parts are identified with primed reference numbers. In FIG. 4 electrodes **2', 3'** are positioned in parallel planes.

A third alternative, as shown in FIG. 5, is similar to both the peaked and plane parallel electrode configurations above described. It consists of a single target electrode **2''** with a movable target **27''**, shaft **34''** and drive motor (not shown) positioned at one end of the target electrode.

Since movable target **27''** is moved only into a single sputtering position, it is not necessary that it be laminated; however, it will be readily seen that laminated targets could be used though one side, the side nearest the target electrode **2''**, would be ineffective.

Other embodiments and alternative features will be obvious to those skilled in the art. Accordingly, the described embodiments shall be considered as illustrative only and in no way limiting the scope of the invention.

What is claimed is:

1. Sputtering apparatus for depositing films of different materials on substrates, said apparatus comprising at least two target electrodes, each of which is adapted to hold a target material on a surface for sputtering by ionic bombardment of particles of the material therefrom; a substrate holder spaced from said surfaces of said target electrodes for holding substrates to be coated in position for deposition of material sputtered from said electrodes; and a movable target assembly being pivotally mounted within said apparatus having means to hold target material on each of two opposed surfaces thereof, said target assembly being pivotable between a first position blocking sputtering from a first one of said target electrodes and presenting in its place for sputtering a first one of said two opposed surfaces, and a second position blocking sputtering from the other one of said target electrodes and presenting in its place for sputtering the other one of said two opposed surfaces.

2. The sputtering apparatus of claim 1 wherein said surfaces of said target electrodes are adjacent one another and said target assembly is pivotally mounted therebetween for said movement between said first and second positions, and drive means is coupled to said target assembly for selectively pivoting the same between said positions.

3. Apparatus according to claim 2 including a shaft between said target electrodes, said movable target assembly being attached to said shaft, said shaft being coupled to said drive means, and said drive means being an electric motor.

4. Apparatus according to claim 4 wherein said target assembly is held in either selected one of said first or second positions by the application of a low D.C. voltage to said motor.

References Cited

UNITED STATES PATENTS

3,418,229	12/1968	Lakshmanan et al.	204—298
3,325,393	6/1967	Darrow et al.	204—192

FOREIGN PATENTS

1,428,243	1/1966	France.

JOHN H. MACK, Primary Examiner

S. S. KANTER, Assistant Examiner