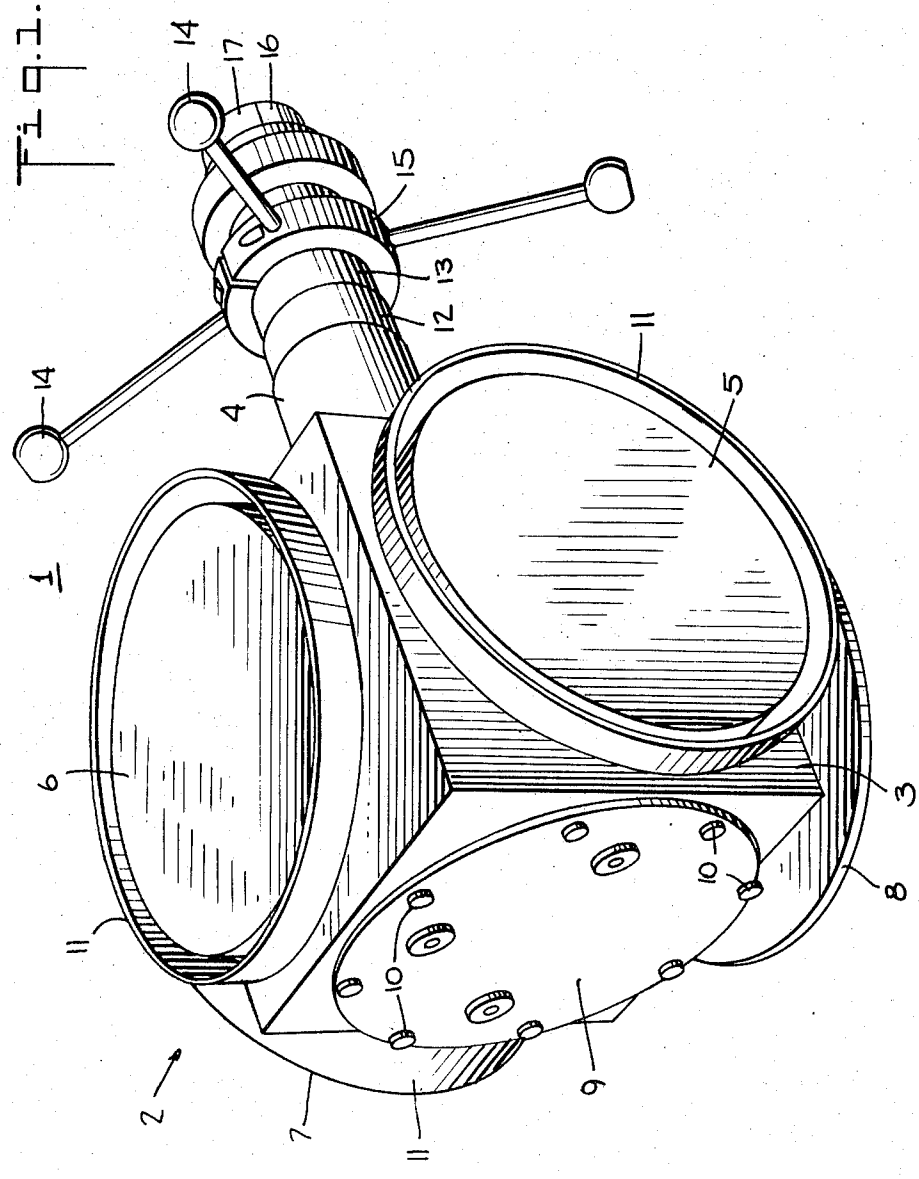
Sept. 4, 1973 S. HURWITT 3,756,939

TARGET MOUNTING DEVICE FOR SEQUENTIAL SPUTTERING

Filed Oct. 14, 1971 2 Sheets-Sheet 1

Fig. 1.



Sept. 4, 1973 S. HURWITT 3,756,939

TARGET MOUNTING DEVICE FOR SEQUENTIAL SPUTTERING

Filed Oct. 14, 1971 2 Sheets-Sheet 2

Fig. 2.

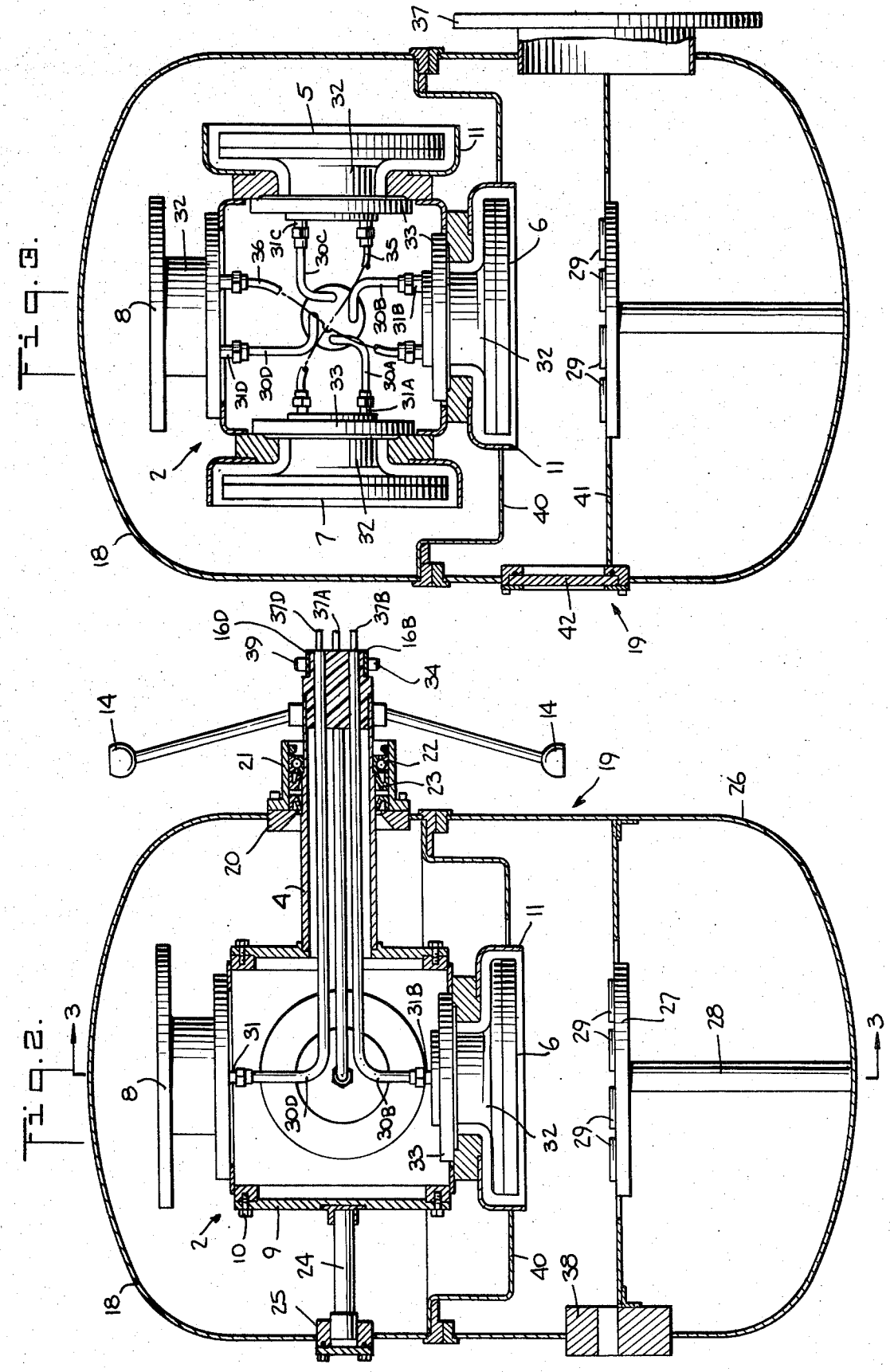


Fig. 3.

United States Patent Office 3,756,939
Patented Sept. 4, 1973

3,756,939

TARGET MOUNTING DEVICE FOR SEQUENTIAL SPUTTERING

Steven Hurwitt, Park Ridge, N.J., assignor to Materials Research Corporation, Orangeburg, N.Y.

Filed Oct. 14, 1971, Ser. No. 189,156
Int. Cl. C23c 15/00
U.S. Cl. 204—298 7 Claims

ABSTRACT OF THE DISCLOSURE

An improved target mounting device provides capability for sputter etch precleaning of substrates followed by sputtering deposition from a number of targets in sequence in a vacuum chamber of relatively small diameter without moving the substrate support or requiring movable shutters. The mounting device holds the targets in spaced angular location relative to an axis of rotation such that each target in sequence faces a substrate support when the mounting device is rotated through a corresponding plurality of angular positions about its axis. The mounting device is preferably in the form of a polygonal turret head mounted on a rotatable tubular shaft. The shaft projects through the chamber wall and carries a commutator on its outer end for selectively connecting a source of electrical energy to each of the targets in turn as they rotate to face the substrate support.

BACKGROUND OF THE INVENTION

This invention relates to sputtering apparatus and more particularly to apparatus for sputter depositing thin films of different materials in sequence.

The process of depositing a thin film of one material upon an item of different material by means of gas ion bombardment of a target of the first material is known as sputtering. This process is assuming increasing commercial importance in the production of homogeneous thin films of elements, alloys or compounds on a variety of substrates ranging from semiconductor devices to razor blades.

Apparatus for sputtering typically includes a sealable chamber, a pumping system for evacuating the chamber, and a source of electrical energy, either high negative potential direct current (DC) of high potential radio frequency (RF). The items to be coated, called substrates, are placed on a conductive substrate support, and an item of the desired coating material, called a target, is mounted on a target support plate facing the substrate support. The chamber is then sealed and evacuated, typically to a pressure of about 10^{-6} torr (i.e. 10^{-6} mm. of mercury) to remove most of the surface contaminants on the target and substrate materials as well as the atmospheric gases and water vapor. An inert gas, such as argon, is then bled in until the chamber reaches a pressure sufficient to support a glow discharge, typically about 5 to 35 microns.

The source of negative DC (3000 to 4000 volts) or RF energy is then connected to the target, the substrate support usually being maintained at or near ground potential. The target thus becomes the cathode and the substrate support the anode of a gas discharge system. The flow of electrons from cathode to anode ionizes the intervening gas, and the positive argon ions are accelerated by the electrical field toward the target. Bombardment of the target by these ions causes ejection of particles of target material, which are deposited on the substrate.

Quite often a particular application will require deposition of more than one material in successive layers on the substrate. To avoid lost time and contamination resulting from opening the chamber to replace targets between successive sputtering steps, it is common to mount all the necessary targets in the chamber and to position the substrate opposite each target in sequence. The usual arrangement is to suspend the targets in a circle from the upper portion of a cylindrical chamber and to place the substrates on a revolving tray for rotation to positions facing each target in sequence.

For a given target size, this arrangement can more than double the required chamber diameter with resulting increased chamber cost and evacuating time. Furthermore, film deposition tends to be less uniform when performed off the chamber axis. Also, it is usually necessary to add a rotatable shutter between the targets and substrate to protect from contamination those targets not being used in he particular sputtering step.

The problem of arranging a number of targets compactly at or near the axis of the chamber is complicated by the need to provide high DC or RF electrical energy and connections for a liquid coolant supply to the target support plate. For this reason, the targets are conventionally mounted in fixed relation to the chamber, and the substrates, which normally are at or near ground potential and are not normally directly cooled, are moved in relation to them.

For example, it is well known to arrange a plurality of substrates on a movable support, such as the rotatable tray previously described, for sequential sputtering from one or more fixed targets in order to increase the production from one loading and evacuation cycle of the chamber. In place of a tray rotating about the axis of the chamber like a lazy Susan, U.S. Pat. No. 2,103,263 issued on Dec. 28, 1937 to H. Kott discloses the use of an hexagonal substrate support journalled for rotation about an axis perpendicular to the chamber axis to expose substrates attached to each of its six sides sequentially to a single target mounted in the chamber on a fixed axial upport.

U.S. Pat. No. 3,400,066 issued on Sept. 3, 1968 to H. L. Caswell et al. discloses an octagonal substrate support, similar to the hexagonal support of Kott, mounted in the center of a cylindrical chamber between two targets mounted on fixed axial supports, one at each end of the chamber. Rotation of the octagonal substrate support exposes each substrate in turn, first to sputtering deposition from one target and then, a half turn later, to sputtering deposition from the second target. The Caswell device thus permits sequential sputtering upon a number of substrates from fixed targets mounted on the chamber axis, but the arrangement is limited to a maximum of two targets.

One solution to the problem of providing cooling liquid and sputtering voltages to compactly arranged movable targets is disclosed in U.S. Pat. No. 3,537,973 issued on Nov. 3, 1970 to L. F. Herte et al. The Herte apparatus employs two rectangular target electrodes fixedly mounted adjacent each other, either in the same plane or at an angle with one another, and facing a fixed substrate support plate. Hollow conductors supply sputtering voltage to the fixed electrodes and also serve as conduits for liquid coolant.

A target of one material is attached to one electrode and a target of a different material is attached to the other electrode. A two-layer laminated target of the same two materials is pivotally mounted between the two electrodes for movement from one electrode to the other in the manner of turning a page in an open book. For sequential sputtering, the movable target is turned to a first position where it contacts and covers one of the electrodes. The exposed lamination of the movable target is of the same material as that of the exposed other electrode. This material is then sputtered onto the substrate. Next, the movable target is turned to contact and cover the other electrode, thus exposing a lamination of material identical to that of the now-exposed first electrode. The second material is then sputtered onto the substrate.

In effect, the movable target of the Herte apparatus provides a means for changing the exposed material on the faces of the target electrodes without having to move the electrodes themselves. Herte thereby avoids the problem of supplying electrical energy and liquid coolant to movable targets. Again, however, the Herte device is limited to only two different target materials, and the movable target, not having any direct cooling, operates at an unfavorably high temperature.

SUMMARY OF THE INVENTION

The present invention provides an improved target mounting device with capacity for any practical number of different targets and with the capability for rapidly locating each target in sequence as desired at a position on the axis of a cylindrical chamber facing a substrate support for sputtering operations. The invention further provides cooling liquid to all targets and electrical power selectively to the target being sputtered while isolating the remaining targets from contamination. Despite its multiple target capacity, the device of the invention is compact, simple, quick to manipulate, and adaptable to a wide variety of sputtering operations using either DC or RF powder. Furthermore, it requires only one rotatable vacuum seal and eliminates the need for complicated movable shutters.

The target mounting device of the invention includes means for holding a number of targets in spaced angular location relative to an axis of rotation such that each target in sequence faces a substrate support centrally located in a vacuum chamber when the mounting device is rotated through a corresponding number of angular positions about the axis of rotation.

A preferred embodiment of the target mounting device is in the form of a hollow polygonal turret head supported on a tubular shaft for rotation about the shaft axis in a bearing fixed to the wall of the chamber. If the device is used in the conventional cylindrical chamber, the shaft is preferably mounted with its axis perpendicular to and intersecting the chamber axis. In addition, lines perpendicular to and passing through the center of each of the polygonal sides of the turret head preferably intersect and are perpendicular to the shaft axis; also, they preferably lie in a plane including the chamber axis.

In this manner, rotation of the turret head on its shaft will successively locate targets, mounted on the polygon faces, at a position on the chamber axis facing a substrate support also located on the chamber axis in proper relation for sputtering deposition of target material upon substrates placed on the support.

The tubular shaft support for the turret head preferably projects through the wall of the chamber at one end. A commutator fixed to the outer end of the shaft supplies DC or RF voltage through hollow conductors inside the shaft to each target selectively when it is rotated to sputtering position. The hollow conductors also serve as conduits for cooling liquid to the targets during the sputtering operation. Because the shaft and hollow turret head form a pressure-tight unit, the inside of the shaft and turret head can be at atmospheric pressure. Only one rotating vacuum seal is needed, therefore, preferably inboard of the shaft bearing to protect the chamber from contamination by the bearing lubricants.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the invention are more fully revealed in the following description of the preferred embodiment and illustrated in the drawings, in which:

FIG. 1 is a perspective view of a preferred embodiment of the target mounting device of the invention.

FIG. 2 is a side view in cross section of the embodiment of FIG. 1 mounted in a sputtering chamber.

FIG. 3 is a cross section taken along the lines 3—3 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the target mounting device of the invention is shown in FIG. 1 before assembly into a sputtering chamber of conventional design. The target mounting device **1** includes a means for holding the targets in spaced angular relation about an axis, the holding means preferably being in the form of a polygonal turret head **2**. In the illustrated embodiment, turret head **2** is in the form of a hollow cube **3**, one side of which is secured to a supporting means, such as tubular shaft **4**, for rotation about an axis perpendicular to that side.

Targets **5**, **6** and **7** are fixed to three of the four faces of cube **3** adjacent to the one side. On the fourth face is fixed a metal plate **8** for a purpose to be described below. Alternatively, if desired, targets could be attached to all four faces of cube **3**. An access plate **9**, sealingly attached to the sixth side of hollow cube **3** by bolts **10** permits access to the interior of the cube for connection of electrical and coolant lines (see FIGS. 2 and 3) to the rear of the target support plates. Surrounding the back and side of each target are dark space shields **11** for suppressing glow discharge from any surface but the face of each target.

Machined surfaces **12** and **13** on tubular shaft **4** provide a matching fit for a rotary vacuum seal and a bearing, respectively, when mounting device **1** is installed in a sputtering chamber. Handles **14** are attached to the shaft outboard of bearing surface **13** by clamp **15** for rotating the turret head to a desired angular position. At the outer end of shaft **4** is a segmented commutator **16** inset in an insulating plug **17** for selectively connecting each one of the targets to a source of electrical energy (not shown) when the target is rotated to sputtering position. The commutator has the same number of segments as there are target positions on the turret head. For example, for the four-sided turret head of the illustrated embodiment there are four segments **16A**, **16B**, **16C** and **16D** corresponding to targets **5,**, **6** and **7** and metal plate **8**, respectively.

Referring next to FIGS. 2 and 3, the target mounting device of FIG. 1 is shown installed in the upper section **18** of a cylindrical sputtering chamber **19**. The outer end of tubular shaft **4** projects through an annular flange **20** in the wall of the chamber. A flanged housing **21** bolted to flange **20** contains a bearing **22** for supporting the shaft and turret head for rotation about an axis perpendicularly intersecting the chamber axis. A rotary vacuum seal **23** in board of bearing **22** prevents leakage between shaft **4** and flange **20** when the chamber is evacuated. A stub shaft **24** extends from the center of access plate **9** to a blind bearing **25** in the wall of the chamber opposite flange **20** to provide additional support for turret head **2**.

In lower section **26** of chamber **19**, a metal plate **27** attached to a conductive rod **28** extending from the bottom of the chamber along the chamber axis supports substrates **29** in proper position for sputter coating from an opposite facing target on turret head **2**, for example, target **6**. Conductive rod **28** may be connected directly to the grounded shell of chamber **19**. Preferably, however, it is insulated from the chamber shell to permit the application of biasing or sputtering voltages to the substrates, if desired.

An important advantage of the target mounting device of the present invention is the provision of simple means for selectively providing electrical power and a flow of liquid coolant to the target in use for a given sputtering step. The hollow interior of tubular shaft **4** and turret head **2** permits running separate hollow conductors **30A**, **30B**, **30C** and **30D** from the outer end of shaft **4** for connection respectively to pipe stubs **31A**, **31B**, **31C** and **31D** extending from the back of each target mounting plate **32**. The target mounting plates **32** are all permanently secured by means of insulators **33** to turret head **2** so that the turret head and shaft can be maintained at electrical ground potential.

Each hollow conductor **30** is connected to a segment of commutator **16** corresponding in angular position to its respective target. In the illustrated embodiment, the commutator, for example, has four segments spaced 90° apart. A commutator brush **34** delivers either DC or RF sputtering voltage from a power supply (not shown) selectively to the commutator segment **16B** corresponding to the one target (for example target **6**) facing substrates **29** when sputtering is being conducted.

In addition to connecting the sputtering targets to the source of electrical energy, hollow conductors **30A** through **30D** serve as conduits for liquid coolant to the target mounting plates. To minimize the number of supply and return lines, the targets may be interconnected by additional tubes within the turret head. For example, non-conductive tube **35** connects the mounting plate of target **5** to the mounting plate of target **7**, and non-conductive tube **36** connects the mounting plate of target **6** to the mounting plate of metal plate **8**.

Coolant flow can can established to all targets in sequence, for example, simply by connecting a flexible supply line (not shown) to threaded coupling **37A** at the outer end of hollow conductor **30A**, a flexible exhaust line (not shown) to threaded coupling **37B** at the outer end of hollow conductor **30B**, and a short insulated return bend (not shown) between threaded couplings **37C** (not shown) and **37D** at the ends of conductors **30C** and **30D**, respectively. The coolant flow path is then in through conductor **30A** to target **5**, then to target **7** through tube **35**, out through conductor **30C** and immediately back in through conductor **30D** to metal plate **8**, then to target **6** through tube **36**, and finally out through conductor **30B**. Because the total rotation of the turret required to place any of the targets into downward facing sputtering position is less than 360 degrees, there is no need for a great degree of flexibility of the coolant connecting lines. The entire coolant supply system is thus simple, inexpensive, and requires no movable or rotatable seals.

In a typical operating cycle, the upper chamber section is lifted from the lower section, the substrates to be coated are placed on metal plate **27**, and targets of the desired coating materials are attached to mounting plates **32**. Upper chamber section **18** is then lowered into place to make sealing contact with flange **39**.

The chamber is next evacuated through pump-out fitting **40** by means of a conventional pumping system (not shown), preferably to a vacuum of at least 10^{-6} torr. A suitable gas, such as argon, is then bled in through a bleed valve (not shown) attached to inlet flange **41**. Usually the vacuum pumping system continues in operation so that a constant stream of argon sufficient to maintain a chamber pressure of about 5–35 microns flows through the chamber and carries away contaminants liberated during the sputtering process.

The initial high vacuum step not only purges atmospheric gases and water vapor but also tends to boil off surface contaminants such as cleansing fluids from the substrates and targets. Nevertheless, a thin film may still remain on the substrates that will adversely affect the adherence of subsequently deposited target material. Consequently, it is a common procedure to superclean the substrates by so-called sputter etching. This is merely reverse sputtering, in which the sputtering voltage is applied to the substrate support and a thin layer of substrate material is sputtered onto the facing surface.

To avoid contaminating the surface of one of the targets **5**, **6** or **7**, turret head **2** is rotated by handles **14** until metal plate **8** faces downward toward the substrates. Then the DC or RF power is connected to rod **28**, and lower commutator brush **34** (which contacts commutator segment **16D** corresponding to plate **8** in this position of the turret head) may be connected to ground by suitable switches (not shown). In addition, targets **6**, **7** and **8** may be cleaned by presputtering in a similar manner while facing the grounded surfaces of the chamber and having sputtering voltage applied through corresponding commutator brushes such as upper brush **42**.

After completion of the presputtering step, turret head **2** is rotated until the target of the first material to be deposited is positioned facing the substrates. A supply of cooling fluid is connected to the targets in the manner described above and the desired sputtering voltage applied through commutator brush **34**. At the same time, brushes contacting the other commutator segments are preferably grounded, so that all surfaces of the turret head and targets will be at ground potential except for the target facing the substrates. Sputtering will thus take place only from that one target and, because of dark space shield **11**, only from the face of that target. The other targets are also protected from contamination by the sputtering target by grounded annular shield **43**, which surrounds the dark space shield of the sputtering target with just enough clearance to permit rotation of the turret head.

The substrate support meanwhile has either been grounded or, preferably, connected to a conventional DC or RF bias supply (not shown). The purpose of biasing the substrates is to lightly scrub them with positive argon ions to remove loosely held entrapped gas atoms deposited along with the adherent sputtered film. A film of higher density and better adhesion can result. A lower grounded annular shield **44** surrounds the substrate support plate **27**.

The progress of the sputtering operation can be observed through viewport **45**. When deposition of the first film is completed, sputtering voltage is turned off and the turret head rotated to place the next target in sputtering position. The corresponding commutator segment for the second target then automatically contacts lower brush **34** for connection to the source of sputtering power. The process is then repeated until the desired number of films has been sputtered in sequence upon the substrates.

Although the illustrated turret head device is in the form of a cube, a polygonal head with any reasonable number of faces can be used, depending on the number of different target materials required. As indicated above, a sputtering region centered on the chamber axis is preferred, but this is not essential. The axis of rotation of the turret head, for example, could coincide with the chamber axis and a number of substrates be placed around the turret head facing radially inward. Alternatively, the turret head faces could be angled with respect to the axis of rotation or even lie in a plane perpendicular to the axis of rotation (i.e. the target holding means could be in the form of a revolving tray).

I claim:

1. In sputtering apparatus of the type having a vaccum chamber, at least one sputtering target mounted in the chamber, a source of electrical energy for causing sputtered material removal from said targets, and means for supporting at least one substrate within the chamber for sputtered deposition of material from each target sequentially upon the substrate, an improved target mounting device comprising:

a hollow turret head structure rotatably mounted in a central position in the chamber, the turret head having an elongated hollow support member sealingly projecting through an opening in the wall of the chamber, the interior of the turret head and support member being unexposed to the chamber environment;

a plurality of targets mounted on insulated supports spaced in angular relation around the turret head, the arrangement of insulated supports being such that each target in sequence faces the substrate supporting means when the turret head is rotated through a corresponding number of angular positions about the longitudinal axis of the support member, and the rear surface of each target is accessible from the interior of the target head;

means for selectively connecting each one of the targets through the hollow support member to the source of

electrical energy when the turret head is rotated to the angular position at which the corresponding target faces the substrate supporting means.

2. The device of claim 1 wherein the means for selectively connecting each target to the source of electrical energy comprises:

a plurality of hollow conductors, one conductor connected to each target, leading through the hollow support member to terminals outside the chamber and

first contact means connected to the source of electrical energy and positioned for selectively contacting each conductor terminal when the turret head is rotated to the angular position at which the corresponding target faces the substrate supporting means.

3. The device of claim 2 wherein the conductor terminals comprise segments of a commutator mounted on the outer end of the support member, each segment of the commutator being positioned in fixed angular relation to a corresponding target, and the first contact means is positioned in proper angular relation to the commutator so as to contact that segment connected to the target facing the substrate supporting means.

4. The device of claim 2 further comprising:

means for circulating fluid coolant through the hollow conductors to and from each target, whereby all electric and coolant connections to the targets pass through the one opening in the vacuum chamber wall.

5. The device of claim 3 further comprising:

a second contact means spaced angularly from the first contact means and

switching means for selectively connecting the first or second contact means to the source of electrical energy, the source when connected to the second contact means transmitting electrical energy through the contacted commutator segment to a corresponding target facing away from the substrate support means for sputter cleaning the target without contaminating the substrate.

6. The device of calim 3 wherein the shaft and turret head structure are maintained at ground potential for shielding the conductors, and the device further comprises a dark space shield surrounding the sides of each target and conductively attached to the turret head, whereby glow discharge occurs only from the face of the energized target.

7. The device of claim 1 wherein the source of electrical energy is a source of radio frequency energy.

References Cited

UNITED STATES PATENTS

3,616,451	10/1971	Gallez	204—298
3,400,066	9/1968	Caswell et al.	204—192

JOHN H. MACK, Primary Examiner

D. R. VALENTINE, Assistant Examiner

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,756,939

DATED : September 4, 1973

INVENTOR(S) : Steven Hurwitt

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 29: change "5" to --7--, and
change "7" to --5--;

line 44: delete "flange 39" and insert --lower section 26--;
line 46: change "40" to --38--;
line 49: change "41" to --38--;
Column 6, line 2: change "42" to --39--;
line 16: change "43" to --40--;
line 26: change "44" to --41--;
line 28: change "45" to --42--;
line 50: delete "vaccum" and insert --vacuum--;
line 72: after "target" insert --support--;
line 73: delete "target" and insert --turret--.

Signed and Sealed this

Twenty-seventh Day of July 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,756,939 Dated September 4, 1973

Inventor(s) Steven Hurwitt

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2, line 13: change "he" to --the--.

Col. 3, line 24: change "powder" to --power--.

Col. 4, line 47: change "in board" to --inboard--.

Col. 8, line 12: change "calim" to --claim--.

Signed and sealed this 18th day of December 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents