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SPUTTERING OF METALS WHEREIN GAS FLOW IS
CONFINED TO INCREASE THE PURITY OF
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FIG. 1

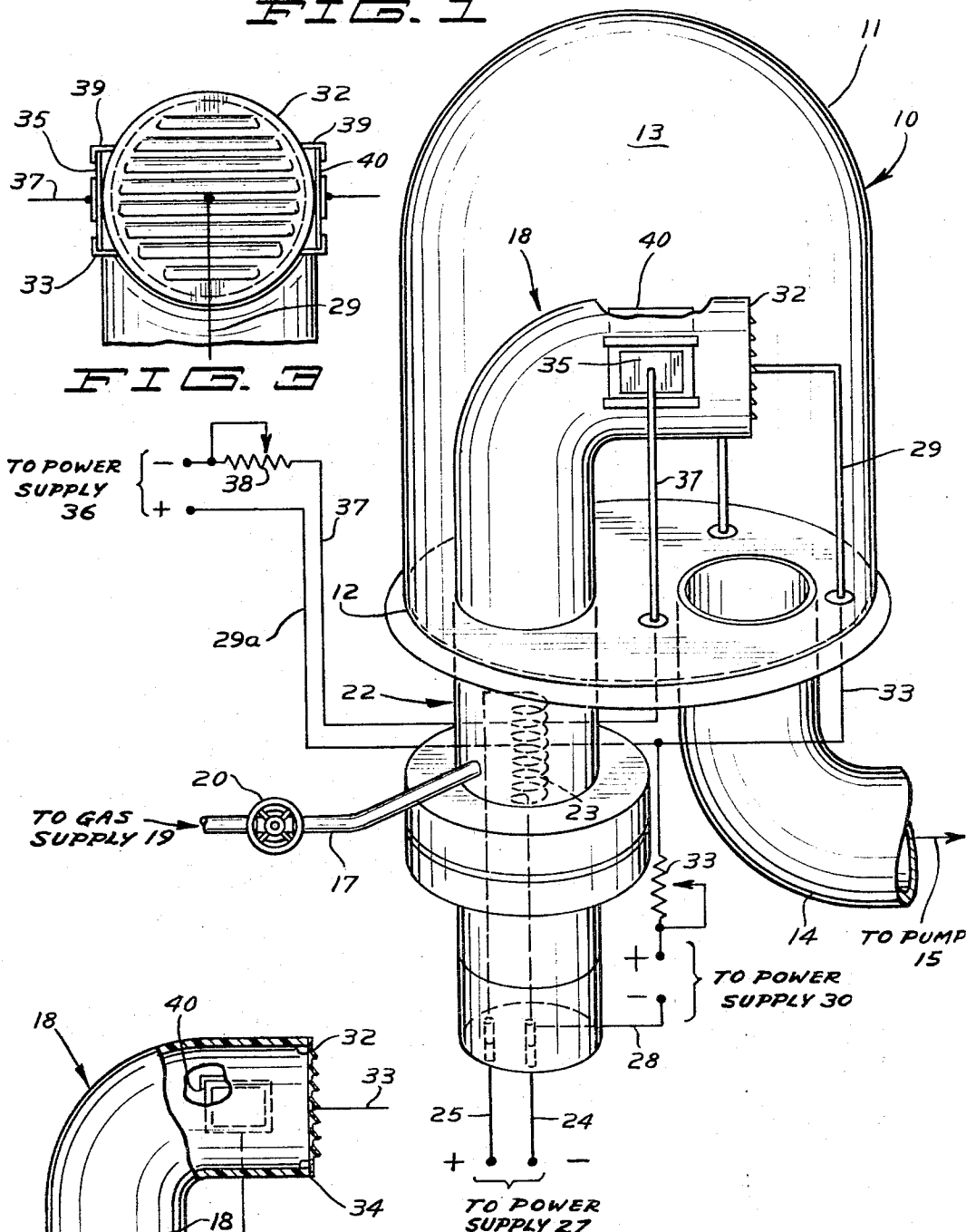


FIG. 2

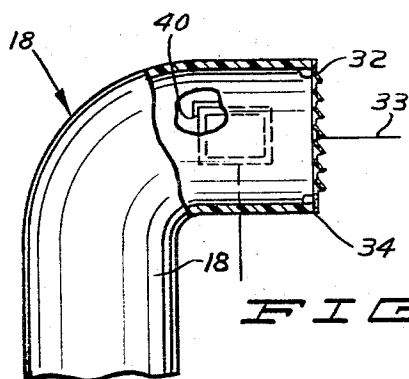


FIG. 2

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SPUTTERING OF METALS WHEREIN GAS FLOW IS CONFINED TO INCREASE THE PURITY OF DEPOSITION

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4 Claims. (Cl. 204—298)

The present invention relates generally to a material deposition system, and more particularly to a film deposition system wherein a material is being deposited on a substrate member, and wherein the deposition chamber, and the medium in which the deposition is being accomplished are maintained at an extremely high degree of purity.

In deposition systems generally, and particularly those in which a gaseous medium is employed, such as in a sputtering deposition technique or the like, contamination from various sources such as the enclosure, the materials or components within the enclosure, and the like, is frequently a problem. Various techniques have been developed in the past minimizing the effects impurity introduction to the deposition system. Inasmuch as the crystalline properties, the magnetic properties, or other parameters are adversely affected by the introduction of any impurity, either solid or gaseous, to the deposits, even in minute quantities, any technique to enhance the purity of the system and minimize the sources of contamination will enhance the characteristics of the finished product.

In accordance with the present invention, a conventional bell-jar enclosure or the like is utilized; however, a plasma tube is introduced within the confines of the bell-jar enclosure in order to control the nature of the atmosphere in which the sputtering operation is functioning. In this regard, the plasma tube is provided with an inlet and an outlet, the inlet and outlet being arranged in spaced apart relationship in the plasma tube. The outlet is vented to the vacuum enclosure, and the inlet is in communication with a highly purified source of inert gas, such as Argon or the like. The sputtering station is located in the gap or space between the inlet and outlet to the plasma tube. Since the electrons are confined to a smaller chamber, the probability of ionization occurring has been found to be greater than would be the case if the source of electrons were in communication with a large volume or the like. In this connection, the electrons are provided in a more directional fashion. The plasma tube also enables the use of mechanical or magnetic modifications in order to increase the probability of ionization within the tube.

Therefore, it is an object of the present invention to provide an improved enclosure for conducting sputtering operations.

It is yet a further object of the present invention to provide an improved enclosure or the like for carrying out a sputtering operation, wherein the enclosure is confined within a second enclosure, and wherein a source of purified gas is introduced into the chamber and caused to flow through the chamber and be available at the point at which the sputtering deposition operation is being carried out.

These and other and further objects of the present invention will become apparent to those skilled in the art upon a study of the following specification, appended claims and accompanying drawing, wherein:

FIGURE 1 is a perspective diagrammatic view of a sputtering chamber prepared in accordance with the technique of the present invention and showing a schematic diagram of an electrical circuit for use therewith;

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FIGURE 2 is a detail side elevational view, partially broken away, showing the features of construction of the plasma tube utilized in the system shown in FIGURE 1; and

FIGURE 3 is a front elevational view of the anode grid element which is utilized in the plasma tube in connection with the sputtering operation in the present invention.

In accordance with the preferred modification of the present invention, the sputtering chamber system generally designated 10 includes a bell-jar 11 situated upon a working base plate or the like 12. The bell-jar 11 and the surface of the working base plate 12 define an enclosure or cavity 13 which provides a working area for the entire apparatus in accordance with the present invention. The conduit 14 is in communication with the enclosure 13, and preferably is operatively associated with a vacuum pump or the like which is referred to in general by the character 15. The pump may be conveniently utilized to evacuate the enclosure 13, if dictated by the requirements of the specific operation being considered. A gas supply system is also utilized in connection with the bell-jar enclosure, the conduit 17 being in communication with the plasma tube generally designated 18, the tube 18 being mounted in sealed relationship about its periphery with the plate 12. The conduit 17 includes a gas valve or the like 20 which is utilized to regulate and control the flow of gas through the enclosure, and particularly through the confines of the plasma tube 18, the line 17 being in further communication with a suitable gas supply 19. Various inert gases may be utilized for either assisting in flushing the enclosure, and also for actual use in connection with the sputtering operation. For example, Argon gas has been found to be particularly desirable for use in an electrical sputtering or plasma deposition operation, particularly in the low pressure supported gas discharge plasma system. For a general description of deposition techniques, such as those techniques which are commonly referred to as "sputtering" techniques today, reference is made to that certain article published in the Physical Review, vol. 102, No. 3, pages 690-704. The electron generating means generally designated 22 includes a heated filament 23 which is thermally emissive. The filament 23 is heated from electrical energy which is provided by way of the conductors 24 and 25, these conductors being operatively associated with a suitable A.C. or D.C. power source such as is diagrammatically designated at 27. Since the requirement of the power source or supply 27 is merely to provide sufficient electrical current to heat the cathode to an emission temperature, the voltage amplitude is determined by the actual requirements of the cathode filament 22. An additional conductor 28 is connected to the negative side of the power supply 27 such as along line 24, conductor 28 also being coupled to the negative side of a unidirectional power supply source 30. The positive side of the power supply 30 is coupled to the anode or plate grid 32 by means of the conductive line and support column 29. A variable resistor 33 is utilized as a current limiter to the anode 32. The anode 32 is electrically isolated from the tube 18 such as by the insulating ring member 34.

An electrode member 35 is mounted on the wall of the plasma tube 18 between the locations of the cathode 23 and anode 32. Furthermore, the location is intermittent the point at which the gas inlet conduit 17 enters the system and the grid portion of the anode 32 where the gas is exhausted. Suitable clamping means 39-39 are utilized to support the electrode 35 on the surface of the plasma tube 18, such as, for example, by suitable channel means or the like. Preferably, the electrode 35 is

mounted in fluid-tight relationship with the plasma tube 18 in order that the gas escaping from the tube 18 pass through the slots defined in the grid anode 32. Conductor 37 is coupled to the negative side of the unidirectional power source or supply 36 to bias the source or target 35. Conductor 29a couples line 29 to the positive side of the power supply 36. A substrate 40 is disposed on the opposite side of the tube 18 from the electrode 35 and is supported therealong by a suitable mounting scheme such as a pair of parallel arranged channels or the like and is clamped by means of the clamps 39-39. The substrate 40 is designed for receiving a film deposit along the surface thereof, the source being the surface atoms of electrode 35. The arrangement is in general similar to the classical sputtering operations, the exception being the imposition of the plasma tube 18 together with the slotted grid element 32. This arrangement permits the gas utilized in the sputtering operation to be continuously introduced at the point where conduit 17 meets the depending plasma tube enclosure, and is continuously exhausted through the grid anode 32 and conduit 14 by vacuum pump 15. The system as defined is preferably arranged to permit and accommodate ready removal of the plasma tube 18 from the confines of the work plate 12 in order to accommodate ready cleaning thereof. Standard cleaning techniques may, of course, be employed in the cleaning of the plasma tube 18.

EXAMPLE I

A substrate comprising microslide glass is mounted in the plasma tube 18 in diametrically opposed relationship to the target or source 35 and is clamped therein. The source 35 is fabricated from 81-19 Permalloy and is likewise clamped to plasma tube 18. The area between the source 35 and the substrate 40 is a plasma generation area which is established in the plasma tube 18 between the electron source 23 and the anode plate 32. The chamber is next evacuated down to a pressure of 10^{-6} Torr and thereafter an Argon atmosphere is introduced in until a pressure of 10^{-3} Torr is achieved. As previously indicated, this gas is continuously introduced into the chamber by means of the supply line 17 and pump 15 operates continuously. In this specific operation, the target or source 35 and the substrate 40 are spaced apart a distance of four inches, this being the diameter of the plasma tube 18.

The cathode filament is then energized with the filament being heated to a temperature which is sufficient to cause thermal emission of electrons therefrom. Simultaneously, the anode 32 is maintained at a potential which is positive relative to that of the filament in order to attract the flow of electrons from the cathode into the area of the anode. While the thermally emitted electrons are flowing toward the anode, and while they are passing through the gas which is present in the enclosure or chamber, collisions will occur with the molecules of the gas, and these collisions will dislodge electrons from the gas atoms and molecules and thereby render the particular gas particles in a positively charged state. All during this operation, the valve 20 is cracked open to such an extent that the pump 15 is continuously removing gas from the enclosure, the pressure being maintained at a level of approximately 10^{-3} Torr. Obviously, the gas entering the system through the conduit 17 is highly purified and thus sources of contamination are substantially minimized. The charged gas particles are subsequently attracted to the surface of the target or source 35, and the collisions which occur between the charged gas particles and the surface of the target 35 cause a dislodging or removal of surface atoms from the surface of the target 35. These dislodged atoms or materials are then free to move toward the substrate 40 and be deposited thereon as a film coating. A statistical quantity of dislodged atoms will arrive at the surface of the substrate. In this operation, a potential of 45 volts was applied to

the electrode 32 while a potential of -500 volts was applied to the surface of the source material or target 35. If desired, the substrate 40 may be removed from the surface of the tube 19, and disposed at a distance therefrom. During operation, the substrate 40 was maintained at floating potential. Accordingly, the gaseous plasma will be attracted to the negatively charged target 35, and the plasma will sputter surface atoms from the surface thereof. The gross rate of the film on the surface of the substrate under these conditions is about 300 Angstroms per minute.

The resultant deposit is highly purified, and may or may not have substantially uniform crystalline orientation, however, if oriented, the orientation is free from anomalies which may otherwise occur due to the presence of impurities along the surface thereof. The control available by the sputtering techniques is obviously desirable, and highly advantageous over that available in a conventional thermal evaporation operation, and when the added purity is found to be available in deposits formed in accordance with the techniques of the present invention, the technique is rendered that much more valuable.

It will be appreciated, of course, that the specific examples given herein are for purposes of illustration only and are not to be otherwise construed as a limitation upon the scope to which the present invention is entitled. Therefore, those skilled in the art may depart from the specific examples without actually departing from the spirit and scope of the present invention.

What is claimed is:

1. In a deposition apparatus for a sputtering operation adapted for the preparation of a film deposit along the surface of a substrate member, an enclosure, means for evacuating said enclosure, chamber means disposed within said enclosure and terminating in an end surface defining a partially open grid structure for confining the working stations of the sputtering operation, and a plurality of operating stations disposed along said chamber means, said operating stations including a pair of operating electrodes including a cathode for providing a supply of free electrons to said apparatus and an anode for attracting said electrons, the electrodes being disposed in spaced apart relationship, one of the electrodes being disposed adjacent said end surface, and defining a gap zone therebetween, and a generally externally accessible target retaining means and substrate retaining means arranged in generally oppositely disposed and mutually operative relationship along the walls of said chamber and within said gap zone, means for introducing and maintaining a flow of inert gas through said chamber including means for exhausting said gas through said grid and into said enclosure.

2. The apparatus as defined in claim 1 being particularly characterized in that said target electrode and said substrate are arranged in oppositely disposed relationship and on the surface of the walls of said chamber.

3. The apparatus as defined in claim 2 being particularly characterized in that said chamber means is an elongated cylindrical body, and said anode forms a vented closure wall along one end thereof.

4. In a deposition apparatus for a sputtering operation adapted for the preparation of film deposits along a surface of a substrate member and having an enclosure, and means for evacuating said enclosure;

- (a) chamber means disposed within said enclosure and terminating substantially in an open grid structure spanning substantially across said end surface for confining said sputtering operation;

- (b) a plurality of operating stations disposed along said chamber means, said operating stations including a pair of operating electrodes including a cathode for providing a supply of free electrons to said apparatus and an anode for attracting said electrons, the electrodes being disposed in spaced apart rela-

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tionship and defining a gap zone therebetween, one of said electrodes being disposed along and defining said grid structure;

- (c) said operating stations including a generally externally accessible target retaining means and substrate retaining means arranged in generally oppositely disposed and mutually operative relationship along the walls of said chamber and within said gap zone; and
 (d) means for introducing a flow of inert gas through said chamber including an inlet port means disposed remote from said grid structure, and means for exhausting said gas through said grid structure and into said enclosure.

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