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FOR USE THEREWITH

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SPUTTERING SYSTEM AND TARGET ELECTRODE CONSTRUCTION FOR USE THEREWITH

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ABSTRACT OF THE DISCLOSURE

Sputtering system having a housing forming an enclosed chamber with means for supplying a vacuum to the chamber in the housing. Supporting means is provided within the chamber for supporting an article to be coated. The housing is provided with a support plate having an opening therein which is generally opposite the support means. A target electrode is disposed in the opening and faces the support means. An insulating member is secured to the target electrode and to the support plate to support the target electrode so that it is spaced from the side wall of the support plate forming the opening and has its innermost surface generally flush with the innermost surface of the support plate and so that the space between the edge of the target electrode and the wall of the support plate defining the opening is less than one Debye length. Means is provided for supplying a voltage to the target electrode.

BACKGROUND OF THE INVENTION

This invention relates to sputtering systems and more particularly to the construction of the target electrode for such sputtering systems.

In sputtering systems provided in the past, the electrodes utilized in such sputtering systems have had a very high electrical capacitance to ground. This has been found to be particularly troublesome when RF sputtering is utilized. A large electrical capacitance to ground leads to excessive circulating currents to and from the electrode to which the radio frequency energy is supplied. In order to prevent the leads from burning up, it has been necessary to make such leads inordinately large. Also, in prior art sputtering systems, in order to prevent glow discharge from the electrode to which the RF energy is supplied, it has been necessary to provide a shield which is closer to the electrode than one Debye length which also greatly increases the capacitance between the electrode and ground. There is, therefore, a need for a new and improved sputtering system and target electrode construction for use therewith which overcomes such difficulties.

SUMMARY OF THE INVENTION AND OBJECTS

The sputtering system consists of a housing which forms an enclosed chamber. Means is provided for supplying a vacuum to the chamber. Supporting means is provided within the chamber for supporting an article to be coated. The housing includes a support plate which has an opening therein generally opposite the support means. A target electrode formed of a conducting material is then provided. An insulating member is secured to the target electrode and to the support plate and serves to support the target electrode in said opening so that the target electrode faces the support means within the housing and so that the edge of the support plate is spaced from the wall defining the opening in the support plate by a space which is less than one Debye length and so that the innermost surface of the target electrode is generally flush with the innermost surface of the support plate.

In general, it is an object of the present invention to provide a sputtering system with a target electrode in

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which the electrical capacitance to ground is reduced significantly.

Another object of the invention is to provide a sputtering system in which only inert gas is utilized and in which only a portion of the target electrode is exposed to the inert gas.

Another object of the invention is to provide a sputtering system of the above character in which the target electrode can be readily cooled.

Another object of the invention is to provide a sputtering system of the above character in which the target electrode has its side edge and back side shielded.

Another object of the invention is to provide a sputtering system of the above character which can be utilized for depositing a wide variety of materials on the substrates.

Another object of the invention is to provide a sputtering system of the above character in which a dark space shield is provided.

Additional objects and features of the invention will appear from the following description in which the preferred embodiment is set forth in detail in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional view with certain parts broken away of a sputtering system incorporating the present invention.

FIG. 2 is an enlarged partial isometric view of the area encompassed by the line 2—2 in FIG. 1 and in particular shows the construction of the target electrode assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The sputtering system incorporating the present invention is comprised of a housing 11. The housing 11 consists of a cylinder 12 formed of a suitable material such as glass. The cylinder 12 is open at the bottom and top ends which are adapted to be closed by top plate 13 and a bottom or base plate 14. Gaskets 16 and 17 are provided for establishing an air-tight seal between the cylinder 12 and the top and bottom plates 13 and 14 so that a vacuum chamber 18 is formed within the housing 11. Means is provided for supplying a vacuum to the chamber 18 and consists of a vacuum pumping system 19 which is connected to a fitting 21 threaded into the bottom or base plate 14 and which is in communication with the chamber 18.

A cylindrical enclosure 22 formed of a suitable material such as sheet metal is mounted on the top side of the top plate 13. The enclosure is provided with a cylindrical side wall 23 and a planar top wall 24. The side wall 23 is provided with an intumed bottom portion or lip 23a which can be secured to the top plate 13 by suitable means such as screws (not shown). Means is provided for supplying a gas to the chamber 18 and consists of a gas supply 26 in the form of Argon or other suitable gas which is supplied through a control valve 27 to a pipe 28 that extends through the side wall 23 of the enclosure 22 and thence into a fitting 29 threaded into the top plate 13 and opening into the chamber 18.

Supporting means 31 is provided within the chamber 18 for supporting an article to be coated. The supporting means consists of a substrate holder 32 which is provided with an upper planar horizontal surface 33. The holder 32 is supported by a pipe or tube 34 which extends through a boss 36 provided on the bottom or base plate 14. O-rings 37 are provided for establishing an air-tight seal between tube 34 and boss 36. Means is provided for cooling the substrate holder or table 32. For this reason, the substrate holder 32 is hollow and is connected to two tubes 38 and 39 provided within the large tube 34

and are in communication with the space (not shown) provided within the substrate holder 32. As can be seen, the tube 38 is provided as an inlet for the water, whereas the tube 39 is provided as an outlet for the water. In certain applications as hereinafter described, the tube 38 can also be utilized as a conductor for supplying RF to the substrate holder.

The substrate holder 32 can be formed of a suitable material such as aluminum. However, to prevent corrosion from the water, the inner surface exposed to the water can be plated with copper. The tubes 38 and 39 can be formed of copper. It is apparent that, if desired, the tubes 38 and 39 could be in the form of coaxial tubes. The tube 34 can be formed of a suitable material such as stainless steel.

The substrate which is to be coated is placed upon the substrate holder 32. Thus, there has been provided a substrate 41 as shown in FIGS. 1 and 2 which is adapted to be coated as hereinafter described.

The top plate 13 is provided with a hole or opening 46 which is generally opposite the substrate supporting means and in particular the substrate holder 32. This hole or opening 46 is defined by an annular vertical side wall 47. The top plate 13 is also provided with an annular recess 48 which has a diameter slightly larger than the diameter of the opening 46 as shown in FIG. 1.

A target electrode assembly 51 is mounted in the hole or opening 46 opposite the substrate holder 32 and consists of a target electrode or plate 52. The target electrode can be formed of any suitable material such as aluminum. The target electrode 52 is generally circular as shown and is provided with a bottom or innermost planar generally horizontal surface 53. It is also provided with an outer annular side surface 54 which is at right angles to the surface 53. The target electrode also has a top planar surface 56 which is parallel to the surface 53. The target electrode is also provided with an upstanding annular rib 57 and a centrally disposed upstanding boss 58. An annular recess 59 is formed by the rib 57 and the boss 58.

The target electrode assembly 51 includes means for supporting the target electrode 52 in the opening 46 and for insulating the same from the top plate 13. This means consists of an insulating support member 61 formed of a suitable insulating material such as Delrin. The support member 61 is of such a size so that it can fit into the annular recess 48. The insulated support member 61 is provided with a centrally disposed opening 63 and has an O-ring 64 mounted in an annular recess 66 which opens sideways into the opening 63. The insulating support member 61 is adapted to fit over the outer side of the annular rib 57 and the O-ring 64 is adapted to form a seal with respect to the same.

The insulating support member 61 is also provided with another O-ring 67 disposed in an annular recess 68 which is adapted to establish a sealing engagement with the top plate 13. The support member 61 is provided with a deep annular slot 71 which opens through the bottom side as shown in FIGS. 1 and 2 and which is provided for a purpose hereinafter described. The support member 61 is also provided with a relatively shallow wide annular recess 72.

The target electrode assembly 51 includes a cap 76 formed of a suitable material such as aluminum. The cap is provided with a centrally disposed boss 77 which is of such a size so that it is adapted to fit within the recess 59. The cap 76 is also provided with a bore 78 which is adapted to accommodate the boss 58 as shown in FIG. 2. Suitable sealing means is provided in the form of O-rings 79 and 81 disposed in annular recesses 82 and 83. A retaining screw 86 extends through a hole 87 provided in the cap 76 and is threaded into the boss 58 of the target electrode 52. A thumb-nut 88 is threaded onto the screw 86 and is provided for pulling the cap

76 downwardly toward the target electrode and to thereby clamp the insulated support member 61 between the target electrode and the cap 76.

When the target electrode assembly 51 is in place, it can be seen that the side surface or edge 54 of the target electrode is spaced a relatively small distance from the side wall 47 of the top plate 13. For reasons well known to those skilled in the art, this space should be less than one Debye length. In addition, it can be seen that the surface 53 is generally flush with the innermost surface of the top plate 13.

The cap 76 is provided with a pair of additional holes 91 extending through the cap and which are in communication with the recess 59. Fittings 92 are threaded into the holes 91 and are adapted to be connected to a water supply in such a manner that one of the fittings is connected to a pipe or tube 93 which supplies water to the recess 59 and the other is connected to a pipe or tube 94 which takes water out of the recess 59. Thus, it can be seen that means has been provided for water cooling the target electrode 52.

Means is provided for supplying electrical energy to the target electrode 52 and consists of a cable 96 which is attached to the cap 76 by a screw 97. The cable 96 is connected to an appropriate matching network 98 which, in turn, is connected to a suitable RF power supply 99.

The target electrode assembly 51 also includes a dark space shield assembly 101. The dark space shield assembly 101 consists of a plurality of flat rings 102 which are spaced apart by spacers 103 and which are secured to the bottom side of the top plate 13 by screws 104. The dark space shield assembly 101 also includes an annular skirt 106 which is L-shaped in cross-section and which extends downwardly from the top plate adjacent the outer extremities of the rings 102. It should be noted that the inner extremities of the rings 102 are generally in line with the annular side wall 47 forming the hole or opening 46. It also should be noted that the target electrode 52 has substantially the same diameter as the diameter of the surface 33 of the substrate holder 32.

Means is provided for shielding the substrate holder 32 from the target electrode 52 and consists of a shutter 111 which is carried by an arm 112. The arm 112 is secured to a shaft 113 which is rotatably mounted in bushing 114 provided in the top plate 13. The shaft 113 is adapted to be rotated manually or, if desired, a rotary solenoid or other suitable means can be provided for rotating the same.

Operation and use of the sputtering system utilizing the target electrode assembly incorporating the present invention may now be briefly described as follows. Let it be assumed that the top plate 13 has been removed and that a substrate such as semiconductor substrate 41 has been provided upon the substrate holder 32 and that it is desired to coat the same. Also, let it be assumed that the target electrode 52 has been selected so that the appropriate material will be deposited upon the substrate 41. A vacuum such as 2×10^{-2} torr is applied to the chamber 18. Electrical energy in the form of RF power is then supplied to the target electrode to cause sputtering to take place. Sputtering is a well known phenomenon in which atoms from the target electrode 52 are driven off or sputtered by bombarding ions. In this process, the momentum of the bombarding particles is more important than their energy. For example, a hydrogen or helium ion accelerated to 3000 ev. will cause very little sputtering compared to an ion of argon (which is chemically inert) with the same 3000 ev. energy simply because much light hydrogen or helium ion carries very little momentum.

The sputtered atoms travel until they strike the substrate 41 where they deposit to form the desired layer. As individual atoms, they are chemically active and readily form compounds with the atoms of the bombarding gas. This is why inert argon is used as a bombarding gas. In some applications, however, a reactive gas is

purposely added to argon so that the deposit is a film of a chemical compound rather than of the target material.

When the argon ions strike the target, the electrical charge is neutralized and the ions return to the process as atoms. If the target is an insulator, the neutralization process results in a positive charge on the target surface. This charge may grow to the point where the bombarding ions are repelled and the sputtering process stops. To continue the process, the polarity must be reversed to attract enough electrons from the discharge to eliminate the surface charge. This periodic reversal of polarity is done automatically by applying RF voltage onto the target electrode assembly (hence the term RF sputtering). The target and discharge system have a diodectifier-like behavior. This is caused by the vast difference in mobility of ions and electrons. The electrons, being so much lighter, are attracted in much greater numbers to the target during the positive half period of the RF voltage than are the heavy ions during their half period.

Various types of sputtering can be utilized with a sputtering system of the type herein described. In the sputter deposit mode, all the RF power is applied to the target electrode, i.e. only the target is bombarded by ions and sputtered. The substrate support or table is grounded.

In the bias sputter mode, RF power is applied to the target but a small amount of RF power is also applied to the substrate support or table. Consequently, the substrates on the support or table are also bombarded by ions but to a much smaller degree than the target.

In the sputter etch mode, all RF power is applied to the substrate support or table and material is removed (etched away) from the substrate by ion bombardment. In the D.C. bias mode, all of the RF power is applied to the target but in place of grounding the substrate support or table, a D.C. bias is applied to the substrate table from an external D.C. power source.

Target materials can be bonded onto the target electrode or cathode using various techniques such as brazing, soldering or epoxy bonding.

It has been found that the sputtering system is particularly effective for all types of sputtering operations. This is primarily due to the greatly reduced electrical capacitance between the target electrode 52 and the grounded parts of the housing 11 and the enclosure 22. It has been found that this electrical capacitance has been reduced by a factor of approximately 2:1. By way of example, prior art equipment had a capacitance of approximately 130 picofarads with a 6 inch target, whereas the present system with a 6 inch target has a capacitance ranging from 70 to 80 picofarads. This 70 to 80 picofarad represents a residual electrical capacitance between the edge of the target 52 and the top plate 13 and the dark space shield assembly 101. The electrical capacitance has been substantially reduced because the back side of the target electrode now faces the insulated support member 61. Only the innermost surface 53 and the side surface 54 are exposed to the interior of the chamber 18 and the spaces therein. The closest grounded parts to the back side of this target electrode 52 are the top wall 24 of the enclosure 22 which in a typical installation could be at least 6 or 7 inches above the target electrode.

The dark space shield assembly 101 serves two basic purposes. It focuses the discharge and provides grounding surfaces for the discharge. It also prevents excessive cross-contamination of targets by sputtered material where more than one target is utilized. The mounting of the target electrode is such that the back side and the side edges are shielded so that sputtering will only occur from the front side.

The construction of the target electrode 51 is relatively simple and makes it possible to readily remove the target electrode assembly so that different target electrodes 52 can be provided or so that the target electrode can be covered with the appropriate material. The target electrode assembly 51 is also constructed in such a manner

so that a good seal is formed with the top plate. For this purpose, it has been found that the Delrin forms an excellent material for the support member 61 particularly when it is provided with the annular slot 71 which permits the Delrin to flex and to thereby make it possible to obtain a better seal with the top plate. As shown, it is desirable to provide the annular recesses for the O-rings within the Delrin because the Delrin is easy to machine. The slot 77 is also advantageous in that it prevents electrical shorts due to spurious deposition on the insulated support member 61.

It is apparent from the foregoing that there has been provided a new and improved sputtering system and in particular a target electrode assembly for use therewith in which greatly reduced electrical capacitance to ground has been obtained to thereby eliminate excessive circulating currents. Both the target electrode 52 and the substrate holder are water-cooled. In addition, the construction of the target electrode assembly is such that an excellent seal is obtained between the target electrode assembly and the top plate. The surface of the target electrode from which sputtering occurs is the only significant surface which is exposed to the inert gas utilized.

We claim:

1. In a sputtering system, a housing forming an enclosed chamber, means for supplying a vacuum to the chamber in the housing, supporting means within the chamber for supporting an article to be coated, said housing including a metallic plate having an opening therein generally opposite the supporting means, a metallic target electrode having a front side and a back side and an insulating member secured to said target electrode and mounted on said plate to support said target electrode in said opening in said plate with the front side facing the supporting means and with a space surrounding said target electrode between the edge of the target electrode and the plate, said insulating member being spaced from and directly facing the back side of the target electrode and having a size which is larger than the back side of the target electrode.

2. A system as in claim 1 wherein the innermost surface of said target electrode is flush with the innermost surface of the plate on which it is mounted.

3. A sputtering system as in claim 1 together with a dark space shield assembly secured to the bottom side of said plate and generally surrounding said target electrode.

4. A system as in claim 3 wherein said dark space shield assembly include a plurality of spaced rings surrounding the space underlying the target electrode.

5. A system as in claim 1 wherein said target electrode assembly includes a cap and means securing said cap to said target electrode whereby said insulated support member is clamped between said target electrode and said cap.

6. A system as in claim 1 together with means for supplying a cooling liquid to the target electrode.

7. A system as in claim 1 wherein said insulated support member is provided with a deep annular slot to permit said insulated support member to flex.

8. A system as in claim 7 wherein said slot has a greater radius than said target electrode.

9. In a target electrode assembly for use with a sputtering system, a target electrode having a planar surface, an insulating member spaced from and mounted on said target electrode and having a size greater than the size of the target electrode, a cap extending over said insulated support member, and means for securing said cap to said target electrode to clamp said insulated support member between the same.

10. An assembly as in claim 9 together with means for establishing an air-tight seal between the insulated support member and the target electrode.

11. An assembly as in claim 9 wherein said target electrode is provided with an upstanding rib together with means for forming an air-tight seal between said insulated support member and said cap.

12. A system as in claim 1 wherein said insulating member has an inner surface parallel to said back side of said target electrode and wherein there is a space between said inner surface of said insulating member and said target electrode.

13. A system as in claim 1 wherein said insulating member extends over the space between the edge of the target electrode and the plate.

14. In a target electrode assembly for use with a sputtering system, a target electrode having a planar surface and insulating member secured to said target electrode on the side of said target electrode opposite said planar surface, said insulating member extending beyond the outer periphery of the target electrode, at least the outer margin of the side of said target electrode facing the insulating member being spaced from said insulating member and means extending through said insulating member for making electrical contact to said target electrode.

15. A target electrode assembly as in claim 14 wherein the outer margin of the side of said target electrode opposite said planar surface is provided with a planar sur-

face parallel to said first named planar surface and wherein said insulating member is provided with a surface which is spaced from said additional planar surface and is substantially parallel to said additional planar surface.

16. An assembly as in claim 15 together with a metallic cap extending over said insulating member on the side opposite said target electrode, said cap having a planar surface parallel to said additional planar surface of said target electrode.

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