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R.F. CATHODIC SPUTTERING APPARATUS HAVING AN
ELECTRICALLY CONDUCTIVE HOUSING
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FIG. 1

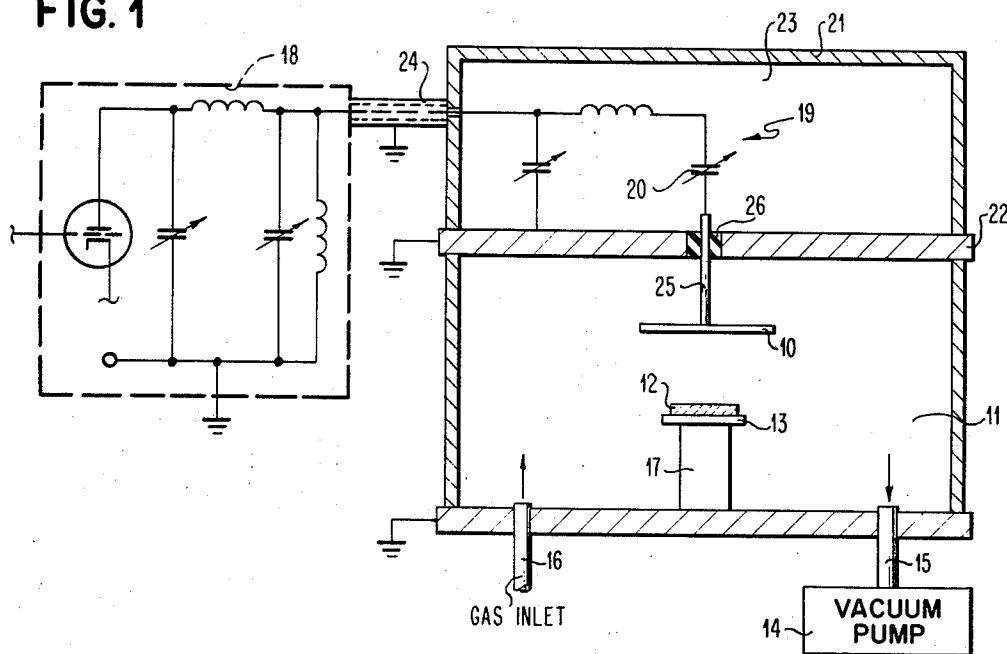
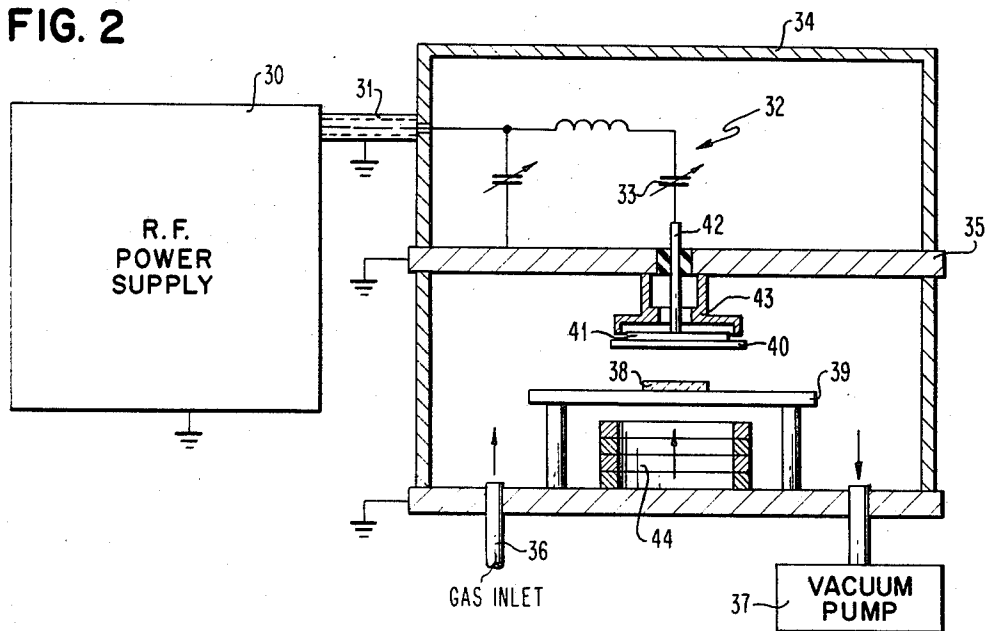


FIG. 2



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R.F. CATHODIC SPUTTERING APPARATUS HAVING AN ELECTRICALLY CONDUCTIVE HOUSING

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9 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for the radio frequency sputtering of both dielectric and conductive materials to deposit films of said materials on substrates in a plasma such as a glow discharge produced in a low pressure ionization chamber containing the substrate. A radio frequency power supply is connected through an impedance matching circuit to an electrode associated with the material to be sputtered located in the chamber to produce the glow discharge. Both the impedance matching circuit and the ionization chamber are enclosed in a common conductive housing which is grounded.

Background of invention

The present invention relates to improved apparatus for sputtering dielectric and conductive materials by radio frequency sputtering.

The process of sputtering involves exposing a solid material to be sputtered (called the "target") to bombardment by ions in a low-pressure gaseous glow discharge, thereby causing atomic particles of the bombarded material to be dislodged and deposited upon an object which is to be coated. Radio frequency sputtering is used to deposit both conductive and dielectric materials. The sputtering of dielectrics by radio frequency fields is generally disclosed in an article by G. S. Anderson, William N. Mayer and G. K. Wehner appearing in The Journal of Applied Physics, volume 33, No. 10, October 1962. Apparatus and methods for sputtering of dielectrics are described in copending applications S.N. 428,733, now U.S. Patent 3,369,991 and S.N. 514,853, filed Dec. 20, 1965 assigned to assignee of the present application, and apparatus for sputtering of conductive materials is described in copending application E.N. 514,827, filed Dec. 20, 1965 also commonly assigned. In conventional radio frequency sputtering, the "target" material to be sputtered is associated with the electrode in a low pressure ionization chamber in which the glow discharge is produced. If the material is a dielectric, it is mounted on a conductive electrode and if the material is conductive, it may be the whole or a part of the electrode.

The glow discharge is created by a radio frequency field in the chamber produced by a source of radio frequency power, the output of which is connected to said electrode. Conveniently, as shown in said copending applications, the source of radio frequency power comprises a radio frequency power supply such as any standard oscillator or amplifier circuit and an impedance matching circuit for adjusting or matching the optimum impedance of the power supply to the impedance of the ionization chamber. Since the impedance in the ionization chamber may vary to a certain extent, means are provided to change the impedance of the matching circuit to match the impedance of the chamber with that of the supply. The output of the supply is connected to the matching circuit and the output of the matching circuit is connected to the electrode. In addition, as set forth

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in copending applications S.N. 514,853 and S.N. 514,827, the efficiency of the sputtering operation may be enhanced to a certain extent by placing a capacitor in series between the output of the impedance matching circuit and the sputtering electrode. Also, applications S.N. 428,733 and S.N. 514,853 set forth that sputtering of dielectrics may be enhanced by subjecting the glow discharge in the chamber to a magnetic field.

While the radio frequency sputtering methods and apparatus described in the above mentioned applications produce satisfactorily coatings, the practice of these methods has been hampered by their inability to produce consistent results. The use of the same equipment, components, electrical parameters and times does not give consistent results on successive or repeated sputtering cycles. Variations in the thicknesses and other properties of the applied coatings in repeated cycles are often substantial. The stability of the glow discharge is less than completely desirable as evidenced by sparking and sudden changes in the glow intensity.

In addition, the operators handling existing equipment are frequency subjected to skin burns apparently caused by undesirable stray R.F. currents throughout the sputtering equipment.

Summary of the invention

The present invention is based upon the discovery that consistent results in the above described radio frequency sputtering apparatus as well as stable glow discharge and elimination of operator skin burns may be achieved by enclosing both the low pressure ionization chamber and the impedance matching circuit in a common conductive housing which is grounded.

In addition to overcoming the aforementioned problems, the improved apparatus increases the rate of coating deposition. With all other factors maintained constant, radio frequency sputtering apparatus incorporating the housing of this invention displays about a 20% increase in coating deposition rate as compared to the apparatus of the prior art in which the impedance matching circuit and the ionization chamber are separately housed.

The apparatus of the present invention also eliminates the external conductor line which connected the impedance matching circuit with the "target" electrode in the prior art structures. The transmission of radio frequency power through this conductor line is believed to have resulted in varying degrees of power loss through radiation which in part contributed to the inconsistent results in the apparatus and the instability of the glow discharge. In addition, undesirable R.F. waves were generated which interfered with other apparatus such as broadcasting equipment or sensitive measuring equipment.

The drawings

FIGURE 1 is a circuit diagram and a schematic view of one preferred embodiment of the sputtering apparatus of this invention.

FIGURE 2 is a partial circuit diagram and partial schematic view of another embodiment of this invention.

Preferred embodiments

The apparatus shown in FIGURE 1 is arranged to sputter a conductive material. The individual components are similar to the individual power supply, impedance matching circuit and glow discharge components described in copending application S.N. 514,827. Electrode 10 comprises the target metal to be sputtered by radio frequency stimulated glow discharge in ionization chamber 11 to deposit a film of metal onto substrate 12 positioned on support 13. Vacuum pump 14 permits the evacuation of chamber 11 through conduit 15 to maintain at a desired pressure a suitable ionizable gas supplied

through conduit 16 to the chamber. While support 13 need not be grounded, it is preferably grounded as in the structure shown through electrical connector 17. A conventional radio frequency power supply 18 is connected to electrode 10 through an impedance matching circuit 19 and preferably through a capacitor 20.

Grounded housing 21 made of a conductive material such as metal forms a common enclosure for both the impedance matching circuit 19 and the ionization chamber 11. The enclosure formed within housing 21 is subdivided by conductive plate 22 into ionization chamber 11 and impedance matching circuit enclosure 23.

The output of radio frequency power supply 18 is connected to the input of impedance matching circuit 19 through power transmission line 24 and the output of matching circuit 19 is connected to target electrode 10 through capacitor 20 and conductor 25 which passes through an aperture in plate 22 insulated from plate 22 by suitable insulators 26 which also provide a vacuum tight seal between chamber 11 and enclosure 23.

It should be noted that there is substantially no loss of radio frequency power due to radiation from power transmission line 24 because power transmission lines are conventionally shielded against such loss (e.g., coaxial lines). It is also noteworthy that such power transmission lines cannot be used in the prior art structures in place of the power-losing external conductor lines to connect the impedance matching circuits with the distant "target" electrode in the chamber. Power transmission lines have a fixed characteristic impedance and can only be efficiently used to transmit power to an input equal to the characteristic impedance. Because the impedance in the glow discharge component varies, power transmission lines cannot be used.

In operation, ionization chamber 11 is evacuated by vacuum pump 14 and an ionizable gas such as argon is bled into chamber 11 through conduit 16 to maintain a desired pressure in the chamber, e.g., a pressure in the order of from 2 to 25×10^{-3} Torr. The gas may be inert, such as argon, neon, etc., reactive, such as oxygen, nitrogen, hydrogen, etc., or admixture of several inert and/or reactive gases. The mean free path in reactive sputtering should be relatively small, thus promoting collisions between the reactive gas molecules and the sputtered species. The target electrode 10 may be any conductive material including metals such as aluminum, molybdenum, gold, platinum or copper and alloys of metals as well as semiconductors such as silicon and germanium.

Radio frequency power supply 18 is then actuated and the output is passed through transmission line 24 to impedance matching circuit 19 which may be adjusted to match the constant impedance of the supply with the varying impedance of the glow discharge component. The output of the impedance matching circuit is connected to target electrode 10 to result in the stimulation of a glow discharge in the gas in chamber 11 which in turn causes the sputtering of the conductive material in the target electrode 10 and the deposition of a coating of sputtered material onto the surface of substrate 12.

Preferably, the output of the impedance matching circuit is connected to the target electrode 10 through capacitor 20. The use of this capacitor as set forth in copending applications S.N. 514,853 and S.N. 514,827 permits the sputtering of conductive targets, and in the case of dielectric targets, eliminates defects in and increases the quality of deposited coatings. In the structure shown, capacitor 20 has a variable capacitance and actually forms part of the impedance matching circuit. However, a capacitor of fixed capacitance may also be used in which case, a variable inductance is preferably used in place of the fixed inductance in circuit 19. Also, the improvement of the apparatus of this invention would be applicable to structures from which capacitor 20 were eliminated. The improvement of this invention is ap-

plicable to combinations of conventional R.F. power supply, impedance matching circuits and glow discharge sputtering chambers irrespective of the design of the specific components.

FIGURE 2 shows another embodiment of the apparatus of this invention. R.F. power supply 30, power transmission line 31, impedance matching circuit 32, capacitor 33, common grounded housing 34, plate 35, gas conduit 36 and vacuum pump 37 perform the same functions as do their corresponding elements in the apparatus of FIGURE 1. The apparatus of FIGURE 2 is constructed for the sputtering of a dielectric material onto a substrate 38 positioned on support 39. Dielectric material target 40 is affixed to electrode 41 which is connected to the output of matching circuit 32 by conductor 42 which passes through an aperture in plate 35 insulated from the plate. Conductive shield 43 attached to plate 35 partially encloses electrode 41 and protects the electrode from unwanted sputtering. The shield is insulated from the electrode. The application of R.F. power to electrode 40 results in the stimulation of a glow discharge in the gas in chamber 11 which in turn causes the sputtering of the target dielectric material 40 and the deposition of a coating of sputtered material onto the surface of substrate 38. This embodiment further contains a stack of toroidal permanent magnets 44 to subject the glow discharge to a steady magnetic field in the direction shown by the axial arrow normal to the surface of target 40. The direction of the field may be up or down. As set forth in copending application S.N. 428,733, the use of a magnetic field helps to stabilize the glow discharge and increases the deposition rate. The use of magnetic fields is not limited to apparatus in which dielectric materials are being sputtered. Magnetic fields may be used in apparatus for sputtering conductive materials. The magnetic field element may be incorporated into the apparatus of FIGURE 1.

Dielectric materials which may be sputtered by the apparatus of this invention include fused silicon nitride quartz, borosilicate glasses, calcium - aluminosilicate glasses, refractory metal oxides such as alumina and minerals such as mullite.

As illustrative of a specific combination of operating conditions in the apparatus of FIGURE 2, silicon dioxide films have been sputtered under the following conditions:

R.F. power input to electrode	-----watts--	3000
Frequency	-----mc./sec--	13.57
Pressure	-----Torr--	10×10^{-2}
Atmosphere	-----percent argon--	100
Diameter of electrode	-----inches--	11.5
Diameter silicon dioxide target	-----do--	12
Deposition rate	-----A./min--	350
Film thickness	-----A--	15,000

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In apparatus for the radio frequency sputtering of a material to deposit films of said material on substrates including a low pressure ionization chamber adapted to contain said material and said substrate, a source of radio frequency power for producing a glow discharge in a gas in said chamber comprising a radio frequency power supply and an impedance matching circuit, and an electrode associated with said material and connected to output of said radio frequency power source through said impedance matching circuit,

the improvement comprising a grounded conductive housing forming a common enclosure for both the

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ionization chamber and the impedance matching circuit.

2. The apparatus of claim 1 wherein the material to be sputtered is a dielectric material.

3. The apparatus of claim 1 wherein the material to be sputtered is conductive and is incorporated in the electrode.

4. The apparatus of claim 1 wherein a capacitor is connected in series between said electrode and the output from said impedance matching circuit.

5. The apparatus of claim 1 further comprising means for subjecting the glow discharge to a magnetic field during sputtering.

6. The apparatus of claim 4 further comprising means for subjecting the glow discharge to a magnetic field during sputtering.

7. The apparatus of claim 1 wherein the housing contains a grounded conductive partition separating the ionization chamber from the impedance matching circuit, said partition having formed therein an aperture permitting the passage therethrough of the connection be-

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tween the electrode and the output from the impedance matching circuit.

8. The apparatus of claim 7 wherein said aperture is vacuum sealed.

9. The apparatus of claim 1 wherein said radio frequency power supply and said impedance matching circuit are connected by a power transmission line of a fixed impedance characteristic.

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