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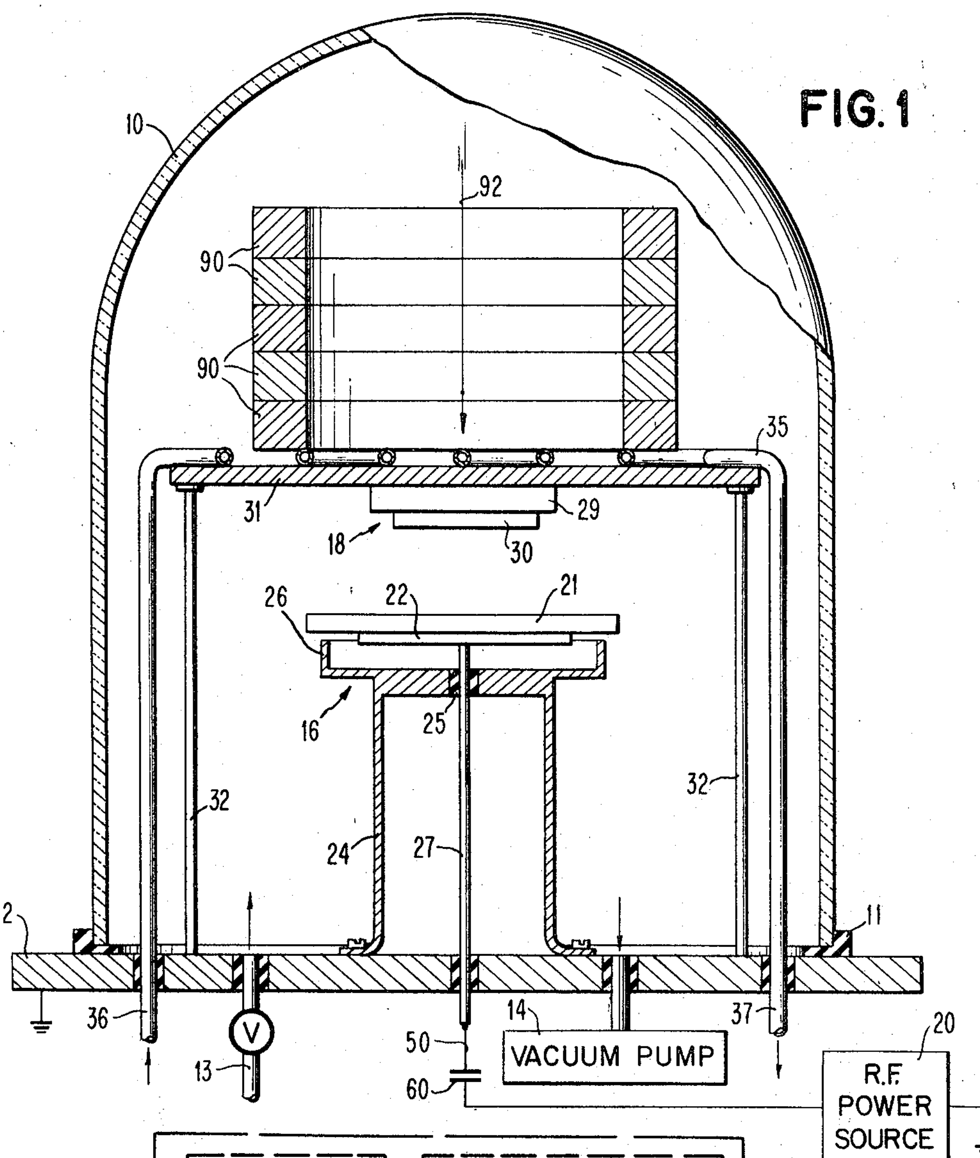

FIG. 1

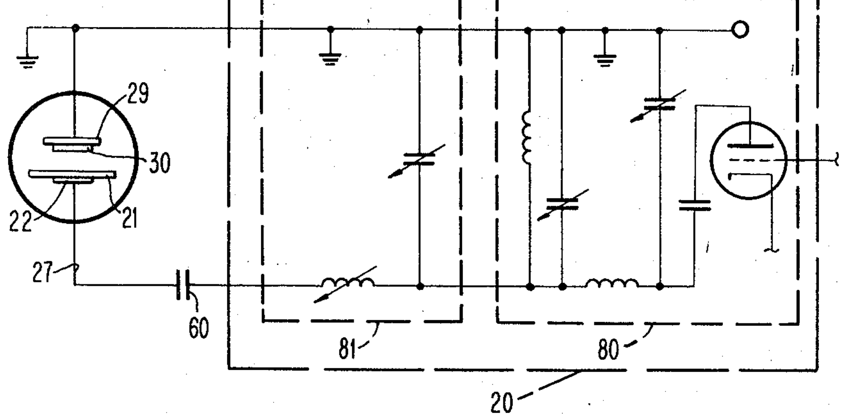

FIG. 2

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METHOD AND APPARATUS FOR THE RADIO FREQUENCY SPUTTERING OF DIELECTRIC MATERIALS

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ABSTRACT OF THE DISCLOSURE

An improvement in a system and method for radio frequency sputtering of a dielectric material to deposit a film on a substrate whereby a radio frequency power source is coupled with an electrode associated with a source of dielectric material in an ionization chamber, an ionizable gas is introduced into said chamber, a glow discharge is produced and dielectric material is sputtered and deposited onto a substrate, said improvement comprising passing the current from the output of the radio frequency power source through a capacitor and thence to the electrode associated with the source of dielectric material.

The present invention relates to an improved method for sputtering dielectric materials. In particular, the invention relates to an improvement in the radio frequency sputtering of dielectric materials in such a way that smooth, defect-free films of the dielectric are deposited onto a substrate.

The sputtering of dielectrics by radio frequency fields is generally disclosed in an article by G. S. Anderson, William N. Mayer and G. K. Werner appearing in The Journal of Applied Physics, vol. 33, No. 10, October 1962. Another method for sputtering dielectrics is disclosed in application Ser. No. 428,733, filed Jan. 28, 1965, now U.S. Pat. 3,369,991.

However, a number of disadvantages attend the use of prior art systems for sputtering dielectrics. First, loading of the radio frequency power supply is difficult. It is also difficult to bring the standing wave ratio down to a low value and small sparks are observed on the grounded surfaces of the vacuum system. More importantly though is the fact that the resulting films deposited by prior techniques are generally rough and defective in that they contain pinholes. Such deficiences make prior processes unsatisfactory for use in the deposition of insulating films, such as, glass insulating films used in the production of semiconductor devices.

Therefore, a primary object of the present invention is to provide an improved method for radio frequency sputtering of insulating materials, such as glasses, which overcomes the disadvantages of prior techniques and results in the deposition of smooth, defect-free, high quality insulating films.

The present invention will be more fully appreciated in the light of the following detailed description of a preferred method for practicing the invention and by reference to the accompanying drawing illustrating a preferred system for carrying out the invention.

In the drawing:

FIG. 1 is a vertical, partly sectional, somewhat schematic view of a sputtering system embodying the invention, and

FIG. 2 is a diagram of an electric circuit useful in the sputtering system of the invention.

In general, the invention is based upon the discovery that smooth, high quality insulating films can be deposited by radio frequency sputtering of dielectric materials by incorporating in the system a capacitor connected in series between the electrode associated with the source of insulating material and the output terminal of a radio frequency generator.

Referring now to FIG. 1 which shows an exemplary form of sputtering apparatus incorporating the principles of the present invention, a gas ionization chamber is enclosed by an envelope **10** in the form of a bell jar made of suitable material, such as "Pyrex" glass, which is removably mounted on a base plate **12**. A gasket **11** is disposed between the jar **10** and plate **12** to provide a vacuum seal. A suitable gas, such as argon, supplied by a source **13**, is maintained at a desired pressure in the enclosure by means of a vacuum pump **14**. Within the gas-filled enclosure are positioned an electrode structure, generally designated **16**, and a substrate support structure, generally designated **18**.

Considering now the construction of the electrode assembly which is generally designated **16**, a target **21**, consisting of the dielectric material which is to be sputtered, is mounted on or positioned adjacent to a metal electrode **22**. This electrode **22** is insulated from a hollow supporting column or post **24**, the bottom flanged portion of which is secured to the base plate **12**. The post **24** is electrically conductive, and being in direct electrical contact with the base plate **12** (which is grounded as indicated in the drawings), the post **24** is maintained at ground potential. Supported on the upper flanged end of the cylindrical post **24** is a metallic shield **26** that partially encloses the electrode **22** adjoining the target **21** and protects the electrode from unwanted sputtering.

Insulating bushing **25**, insulates shield **26** and post **24** from electrode **22**. Conductor **27** passes through base **12** and is electrically connected with electrode **22**. The electrode assembly may also be provided with cooling means, not shown, to control the temperature during operation. The above noted application may be consulted for a more detailed disclosure of vacuum sputtering apparatus useful in the present invention.

Substrate support assembly **18** comprises a support plate **29** on which substrate **30** is mounted by any suitable means. Plate **29** is secured to the underside of plate **31** which is supported by posts **32**, through which plate **29** is electrically connected to grounded base plate **12**.

If the substrate to be coated is of a nature such that it would be damaged by excessive heat, means can be provided for cooling it during sputtering. For example, cooling coil **35** is positioned in heat exchange relationship with metal plate **31**. A cooling fluid is circulated through coil **35** by input and return conduits, **36** and **37**, respectively.

In a particular embodiment, it has also been found desirable to subject the glow discharge to a magnetic field. This may be done by stacking a set of toroidal permanent magnets **90** above plate **31** to provide a steady magnetic field along the vertical axis (arrow **92**) of the toroids, normal to the surface of target **21**. The direction of the magnetic field, up or down, is immaterial.

Electrode **22** and conductor **27** are electrically connected by conductor **50** with the output of a radio frequency power source **20**. Connected in series between the electrode **22** and the radio frequency power source **20** is a capacitor **60**. Incorporation of capacitor **60** in the sputtering system, as shown and described, is the primary feature of the invention. By passing the radio frequency output energy through capacitor **60** and thence to electrode **22**, it has been found that superior dielectric films may be sputtered from a dielectric source **21**, as illustrated. While the exact value of the capacitor used is not critical and will be dependent on the particular system, capacitors having values of from 100 to 20,000 pf. have been used successfully.

Any conventional RF power source **20** may be employed in the described sputtering system. For example, as illustrated in FIG. 2, the power source **20** may comprise a conventional RF power supply **80** and matching circuit **81**. The output of power source **20** is connected electrically with capacitor **60** and thence with electrode **22**.

In operation, the ionization chamber formed by jar **10** and base **12** is evacuated by vacuum pump **14** and an ionizable gas such as argon, is bled in through line **13** to maintain the desired pressure in the chamber. A source of dielectric material and a substrate are positioned in the chamber substantially as shown in FIG. 1. An RF power source is then actuated and the output is passed through capacitor **60** to the electrode **22** associated with the source of dielectric material. The exact conditions of pressure, temperature, power input, etc. are not critical, and may be varied to give the optimum in film thickness and quality for the specific system employed.

Where a magnetic field is employed, fields having a strength of about 100 gauss are effective.

As an example of sputtering in accordance with the invention to produce smooth, defect-free films using the system illustrated in FIGS. 1 and 2, fused quartz has been sputtered under the following conditions:

Pressure—5×10^{-3} torr
Atmosphere—100% argon
RF power input—710 watts
Current frequency—13.56 mc.
Substrate-to-target spacing—1 inch
Diameter of electrode—5″
Time—30 minutes
Film thickness—55,000 A.

Under similar conditions, but using an RF power input of 740 watts, a calcium-aluminosilicate glass (Corning 191CP) was sputtered for 50 minutes to deposit a smooth, defect-free film having a thickness of 26,000 A.

In order to compare the results of sputtering the same glass composition with and without the capacitor in series, the following sputtering runs were conducted using a system substantially as shown in FIGS. 1 and 2. In the first run, no capacitor was employed and in the second run a 250 pf. capacitor was used.

	Without capacitor	With capacitor
Electrode potential	2300 v. pk.-pk	2800 v. pk.-pk.
Forward power	470 watts	295 watts.
Reflected power	205 watts	5 watts.
Net input power to cathode	265 watts	290 watts.
Standing wave ratio	5.5	1.2.
Sputtering time	40 min	120 min.
Film thickness	8,800 A	30,000 A.
Rate of deposition	220 A./min	250 A./min.
Quality of film	Bad—Rough and full of defects.	Excellent—Smooth and defect-free.

The results of the above comparison show that while sputtering dielectrics at substantially the same rates of film deposition, superior films are deposited by the system in which the capacitor is incorporated. Also, sputtering without the capacitor is relatively inefficient in that a much higher power input is required to achieve the same net input to the electrode associated with

the target. Further, with the capacitor, a much lower standing wave ratio is achieved.

It will be apparent to those skilled in the art that superior films of any suitable dielectric may be deposited in accordance with the invention, including, for example, fused quartz, borosilicate glasses, calcium-aluminosilicate glasses, refractory metal oxides, such as alumina, minerals, such as mullite, etc.

Variations may also be made in the specific arrangement of the sputtering apparatus and circuitry, without departing from the spirit and scope of the invention as expressed in the following claims.

What is claimed is:

1. In a system of apparatus for the radio frequency sputtering of a dielectric material to deposit a film onto a substrate, the apparatus consisting essentially of a low-pressure ionization chamber adapted to contain the dielectric material and the substrate, a source of gas, a source of radio frequency power for producing a glow discharge in said gas in said chamber and a diode system consisting essentially of a radio frequency electrode associated with said dielectric material and electrically connected with the output of said source of radio frequency power, and a second electrode

the improvement consisting essentially of a capacitor electrically connected in series between said radio frequency electrode and the output of said source of radio frequency power, and positioned outside said ionization chamber, said capacitor having a value of from 100 to 20,000 pf.

2. The apparatus of claim **1** further including means for subjecting said glow discharge to a magnetic field during sputtering.

3. In a method for sputtering a dielectric material by radio frequency stimulated glow discharge, whereby power from a radio frequency power source is coupled with an electrode associated with a source of dielectric material in an ionization chamber, an ionizable gas is introduced into said chamber, a glow discharge is produced and dielectric material is sputtered and deposited onto a substrate,

the improvement consisting essentially of stimulating said glow discharge by passing the current from the output of said radio frequency power source through a capacitor positioned outside said ionization chamber and thence to a diode system consisting essentially of an electrode associated with said source of dielectric material, said capacitor having a value of from 100 to 20,000 pf. and a second electrode.

4. The method of claim **3** further consisting essentially of subjecting said glow discharge to a magnetic field during sputtering.

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ROBERT K. MIHALEK, Primary Examiner

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