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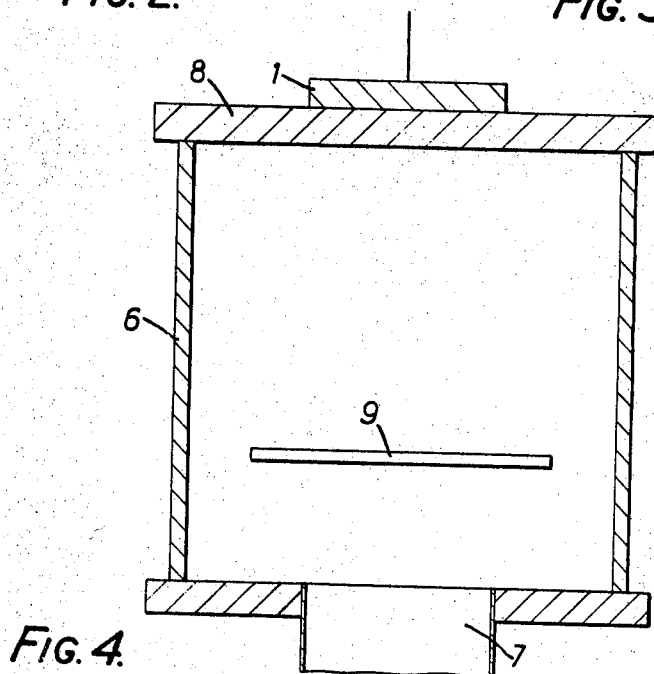
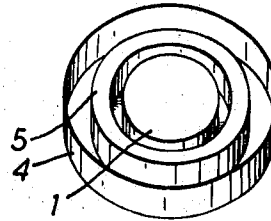
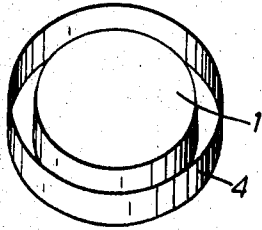
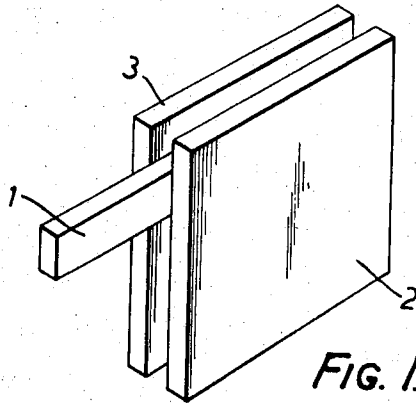
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3,558,467

RELATING TO RADIO FREQUENCY SPUTTERING

Filed June 21, 1968

2 Sheets-Sheet 1



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RELATING TO RADIO FREQUENCY SPUTTERING

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2 Sheets-Sheet 2

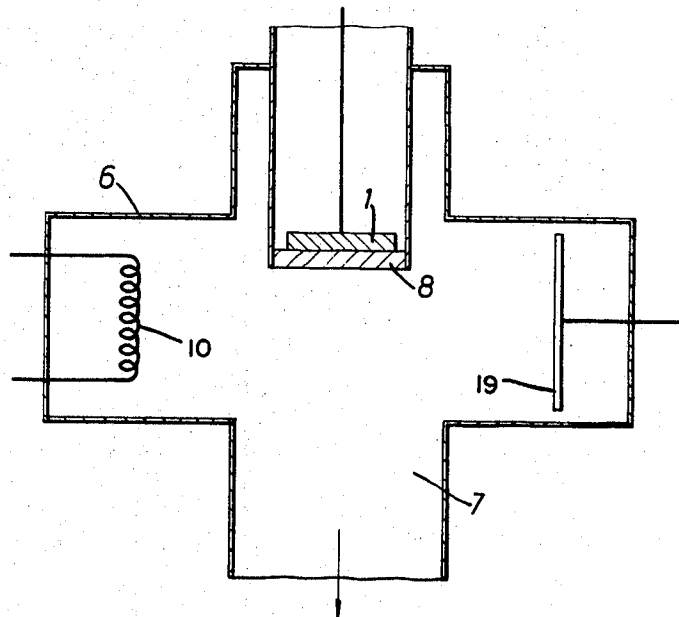


FIG. 5.

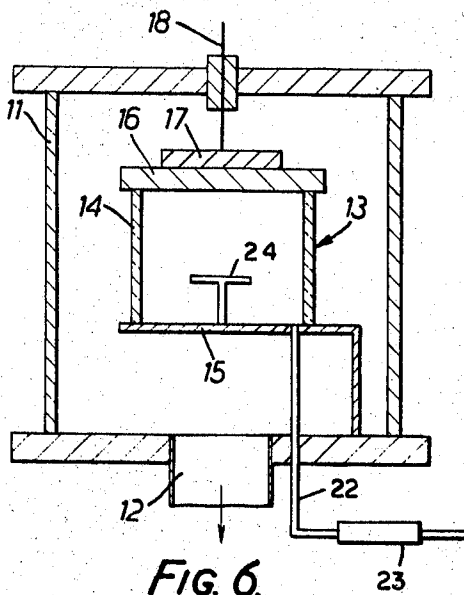


FIG. 6.

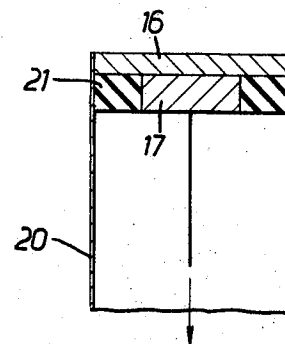


FIG. 7.

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RELATING TO RADIO FREQUENCY SPUTTERING
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3 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for radio frequency sputtering of an insulating target by making the target part of the wall of an evacuable sputtering deposition chamber and attaching a radio frequency electrode to the target outside the deposition chamber in a further evacuable region. The further region is reduced in pressure when a radio frequency voltage is applied to the electrode so as to prohibit earthy discharges.

This invention relates to radio frequency sputtering of insulators.

Sputtering is a term to define a vacuum process in which a target is bombarded by energetic ions or atoms so that the target is eroded, the eroded material being "sputtered" off the target and transported through the environment to be deposited on any suitable available surface. Such surfaces can be provided by substrates which are desired to be coated by the target material. There are many common techniques for controlled sputtering of metal targets, but these fail when the target comprises an insulator. This is due to the fact that the bombardment of an insulator with charged particles gives rise to a build up of charge on the insulator surface. This charge gives rise to a potential which repels the bombarding particles so that sputtering very soon decreases considerably or even stops.

However, the sputtering of insulators has been achieved by the technique known as radio frequency (R.F.) sputtering. Basically this consists of immersing a dielectric target which is backed by a metal electrode in a plasma. A suitable R.F. voltage is then applied to the electrode so that the front face of the dielectric target takes up an alternating voltage due to the capacitive coupling with the electrode. Due to the greater mobility of electrons than that of ions in the plasma, the R.F. voltage results in a net D.C. negative bias being built up on the front surface of the target and energetic ions are permitted to bombard it whereby sputtering takes place.

R.F. sputtering techniques fall into two classes, those using a plasma generated in a glow discharge between a thermionic cathode and an anode, and those using the R.F. electric field to generate an R.F. glow discharge. For both these techniques the plasma is generated in a region which has a characteristic pressure typically in the range 5×10^{-4} to 10^{-2} torr.

It is desirable that breakdown discharges are prevented from occurring between metal electrodes—i.e. between an R.F. electrode and earth—since this reduces or prevents sputtering of the dielectric while sputtering of the electrode takes place. Such breakdown discharges have been prevented in the past by three methods. These are diagrammatically illustrated in FIG. 1, FIGS. 2 and 3 and FIGS. 4 and 5 respectively of the accompanying drawings. FIG. 1 shows an R.F. electrode 1 associated with a dielectric target 2, the breakdown discharge being prevented by providing a solid dielectric shield 3 which shields those parts of the electrode not shielded by the target. This arrangement is not normally used with a R.F. gen-

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erated plasma because it does not utilise R.F. power efficiently.

FIG. 2 shows a R.F. electrode 1, the top surface of which is provided with the dielectric target (not shown). The electrode is surrounded by an earthed metal shield 4 situated at a distance from the target which is insufficient for a breakdown discharge to occur. FIG. 3 shows a similar arrangement with twin R.F. electrodes 1 and 5, the arrangement surrounded by a similar earth shield 4. In these arrangements the separation between the electrode and the shield must not be too small because the capacitance effects increase as the separation decreases. However, if the separation is too large, electrons accelerated across the gap ionise enough atoms of the environmental gas for the undesirable breakdown to occur. The capacitance effects referred to are undesirable as they lead to some or all of the following:

- (a) frequency change;
- (b) change in electrode load impedance;
- (c) loading of the supply so that it fails to operate or is unstable in operation.

The maximum gap allowable to decrease these effects is dependent on the environment gas and its pressure. Typically a $\frac{1}{4}$ " gap at a pressure of 5×10^{-3} torr is used for argon.

The third method is shown in FIGS. 4 and 5, which show arrangements for a R.F. self generated plasma and an anode/cathode generated discharge respectively. FIG. 4 shows a vacuum chamber 6 having a pumping outlet 7 and an end plate 8 which comprises the dielectric target. A metal electrode 1 is attached to the outer surface of the dielectric plate and is thus located in a region at atmospheric pressure. The other side of the R.F. supply is grounded and an earthed plate 9 serves to balance the self generated plasma. The plate 9 may also be arranged to support the work or substrate to be covered by the sputtered dielectric material. FIG. 5 also has a chamber 6, a pumping outlet 7, a dielectric target 8 which forms a limiting surface of the chamber and an R.F. electrode 1. In this case the discharge occurs between a cathode 10 and an anode 19. These arrangements are suitable in that the R.F. electrode is, in each case, at atmosphere pressure whereby breakdown to earth can be eliminated. However, they are not used for high R.F. powers because erosion of the dielectric target 8 weakens it so that it may not be able to withstand the pressure differential across its surfaces and there is a danger of implosion.

It is an object of the present invention to provide an apparatus which may be operated safely and without any substantial risk of breakdown discharges occurring between the R.F. electrode or electrodes and earth.

According to the present invention a method of radio frequency sputtering comprises the steps of providing a first evacuable chamber with a limiting wall portion which comprises a target of insulating material, said evacuable chamber being the sputtering deposition chamber, attaching a target electrode to the surface of the said target outside the first evacuable chamber, reducing the pressure within the first evacuable chamber to that pressure required for sputtering of the target, reducing the pressure outside the said first chamber and in the region of the electrode to such a value that breakdown discharges from the electrode are unlikely during use of the apparatus, and applying a radio frequency voltage to the electrode in such conditions that sputtering of the target is achieved.

Radio frequency sputtering apparatus for carrying out the above-method includes a first evacuable chamber or region, being the sputtering deposition chamber, a metal target electrode and a target of insulating material in face-to-face relation, the face of the target remote from the electrode providing a part of the interior surface of the

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first evacuable chamber or region and the electrode being situated in a second evacuable chamber or region.

When using such an apparatus the evacuable region containing the electrode should be kept at a pressure which is low enough almost completely to prevent any possibility of an earthy discharge occurring between the electrode and any other metal (i.e. earthed) components.

In the case of a twin R.F. electrode system, or any R.F. system with more than one R.F. electrode, each R.F. electrode will be located in an evacuable chamber other than the sputtering chamber.

The invention will now be described in greater detail, by way of example, with reference to FIGS. 6 and 7 of the accompanying drawings in which:

FIG. 6 is a diagrammatic representation of sputtering apparatus embodying the invention; and

FIG. 7 is a diagrammatic representation of an R.F. electrode arrangement of a modified apparatus embodying the invention.

Referring now to FIG. 6, a vacuum chamber 11 is provided with a pumping outlet 12 and contains an inner chamber 13. Chamber 13 comprises a glass tube 14 closed at one end by a metal earthed plate 15 and at the other end by an insulating target 16. Attached to the outer surface of target 16 is an R.F. electrode 17 to which an R.F. voltage is applied by means of lead 18. As shown in FIG. 6, plate 15 is provided with an aperture which is connected as by a conduit 22 to a pumping system 23. Alternatively the chamber 14 may be pumped by a small restrictive aperture leading to chamber 11. There is also (not shown) an inlet through plate 15 in the form of a gas jet for introducing gas to any desired pressure. It will thus be seen that chambers 11 and 14 can both be evacuated, but to different pressures. In operation one side of the R.F. supply is grounded whilst the other side is applied via line 18 to the electrode 17. With a single R.F. electrode 17 a plasma can be generated at a pressure in the region of 10^{-2} torr. Some difficulty is experienced in its generation at lower pressures although once started it can be sustained at a pressure which is lower by about a factor of 10. The combination of evacuation through the aperture (not shown) in plate 15 and introduction of gas through the jet (not shown) permits the chamber 14 to be brought to the desired process pressure in a desired environment, for instance argon. The plasma generated in chamber 14 causes sputtering of the target 16 for deposition on a substrate or substrates which may conveniently be fixedly or rotatably attached to or mounted on plate 15 by suitable supporting means, indicated at 24.

Independently of chamber 14, chamber 11 is pumped down to a pressure which is low enough, say not substantially above 10^{-5} torr, to prevent a discharge between electrode 17 and any earthed metallic chamber components. The differential pressure across the target 16 is now minimal compared with that in the arrangements of FIGS. 4 and 5 and there will be little or no danger of implosion.

Clearly, if more than one R.F. electrode was to be used, each would be arranged within chamber 11 with a capacitive coupling through one or more dielectrics to the interior of chamber 14.

In small pumping systems, of the order of 12" sputtering chamber dimensions, pressures up to about 5×10^{-4}

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torr may exist in chamber 11 although this will ultimately depend on the geometry of the system. In smaller systems in which the components spacings are 10 cms. or less higher pressures can be tolerated as there will be less likelihood of discharges being formed between the R.F. electrode or electrodes and earth components as the electron paths will be too small for ionisation to occur. Pressures of 10^{-2} torr or higher may exist within the sputtering chamber 14 depending upon the sputtering conditions required.

FIG. 7 shows an electrode arrangement which is a combination of low pressure electrode environment, as required for operation of the invention, and dielectric shielding. Thus the insulating target 16 has one face open to a sputtering chamber (not shown) and its other face attached to a R.F. electrode 17 arranged in tube 20 connected to a vacuum system which maintains a sufficiently low pressure to prevent a discharge from occurring.

The surface of the electrode facing the walls of the tube 20 are shrouded by a dielectric shield 21 which ensures breakdown will not occur between these surfaces and the walls of the tube under typical operating conditions. This electrode arrangement may be used for a self generated plasma such as is shown in FIG. 6 or in a system similar to that illustrated in FIG. 5 in which the glow discharge is provided by an anode/cathode.

From the above it will be seen that use of apparatus as described is suitable for sputtering at widely differing pressures without the necessity of providing earth shielding of the R.F. electrode or electrodes. As is well known, sputtering rates can be enhanced and a lower pressure self generated plasma using a single R.F. electrode can be obtained if means are provided for setting up a magnetic field in the region of the R.F. electrode.

I claim:

1. Radio frequency sputtering apparatus including in combination:

- (a) a first evacuable chamber;
- (b) a second evacuable chamber;
- (c) a metal electrode supported in said first chamber and arranged for connection to a radio frequency power supply;
- (d) an insulator target in surface contact with said metal electrode and comprising a wall portion separating said first chamber and said second chamber;
- (e) means for maintaining said chambers at different pressures; and
- (f) means for supporting a substrate in said second chamber.

2. Apparatus according to claim 1 in which said second chamber is situated within said first chamber.

3. Apparatus according to claim 1 including a dielectric shield covering an otherwise exposed surface of said electrode.

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