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RF SPUTTERING APPARATUS INCLUDING A CAPACITIVE
LEAD-IN FOR AN RF POTENTIAL
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FIG. 1

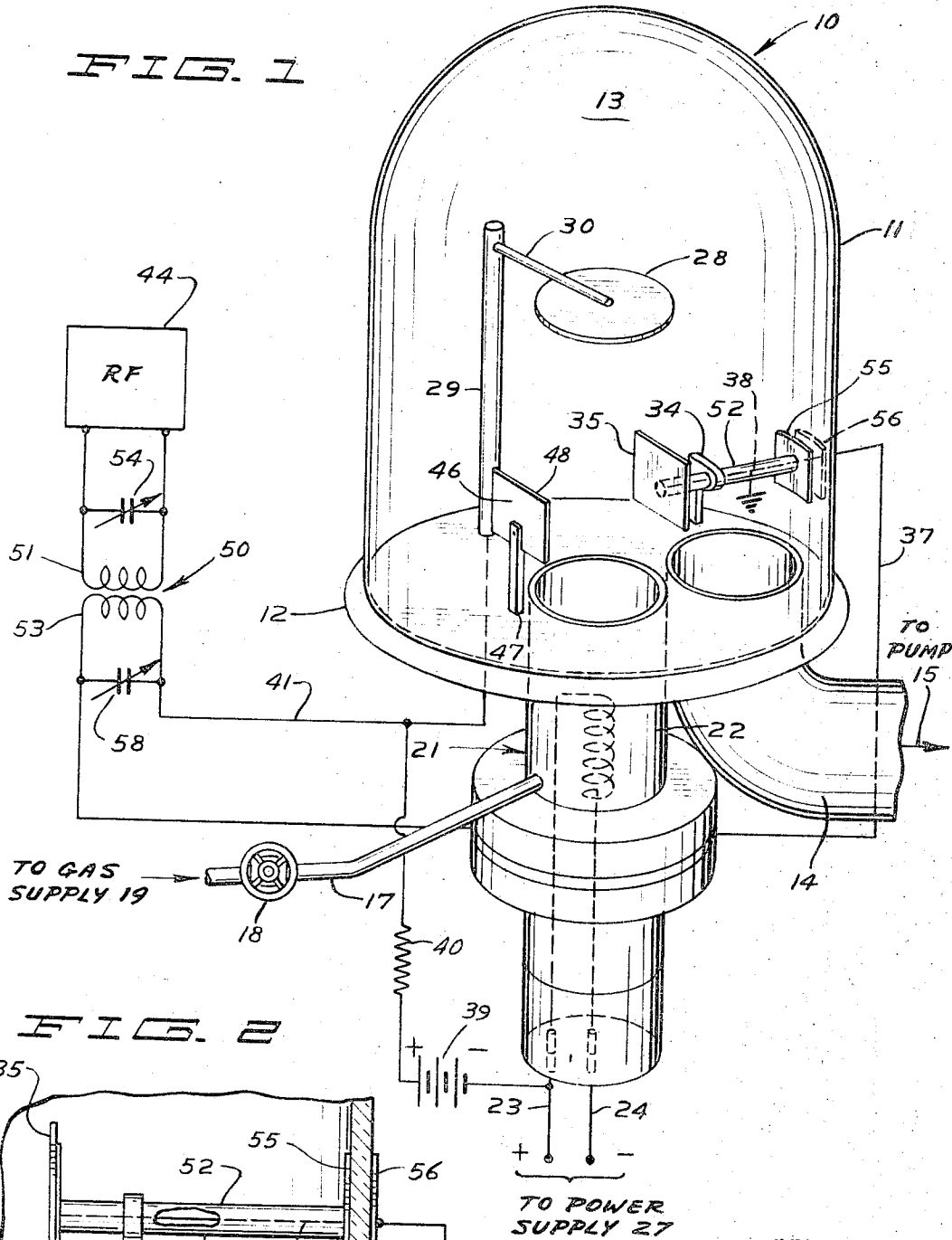
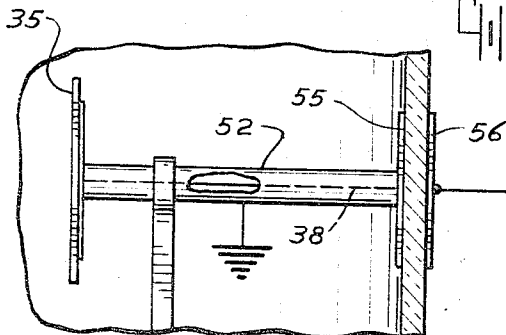


FIG. 2



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RF SPUTTERING APPARATUS INCLUDING A CAPACITIVE LEAD-IN FOR AN RF POTENTIAL

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The present invention relates generally to a material deposition system, and more particularly to a film deposition system wherein one or more specific materials are being deposited upon the surface of a substrate member. The present invention is particularly concerned with a low pressure supported gas discharge plasma or sputtering system wherein a RF field is employed to establish and maintain a negative sputtering potential on an electrode or several electrode elements in a low pressure supported gas discharge plasma zone.

In a deposition system utilizing a gaseous discharge plasma phenomena, a cathode and an anode are arranged in spaced apart relationship across a certain gap zone. The gap zone or area is provided with molecules or atoms of an inert gas, these molecules being subjected to electron bombardment in the gap zone whenever the cathode and anode are respectively energized. The term "molecules" when used in reference to the inert gas employed in the operation is meant to include molecules in the conventional sense as well as atoms or groups of atoms of the inert gas. Collisions occur and the gas becomes partially ionized, forming charged particles. In the gap zone, a target or source is arranged which is adapted to have its surface bombarded by these ionized inert gas atoms and molecules, the impact energy of the ionized gas atom or molecule being adequate to remove surface atoms from the source material. The metallic atom is thereafter free to move through the system and ultimately a certain number of these atoms are condensed or otherwise collected on the surface of a substrate element. Sputtering techniques are particularly adaptable for use in connection with a wide variety of materials including metals, non-metals, compounds, refractory materials including beryllium oxide, and the like. It has been found that sputtering techniques are particularly advantageous in connection with materials which are otherwise difficult to work with when using conventional vacuum deposition techniques, electron bombardment techniques, and the like. The control available from a sputtering operation is furthermore far superior to that control which is available in connection with conventional techniques such as vacuum deposition and the like. In accordance with the present invention, an improvement is available for sputtering operations wherein a RF field is established across certain of the electrodes such as, for example, the target (i.e. source) electrodes, the RF field generating means including a capacitor which has a dielectric material interposed therebetween. Sputtering techniques are particularly valuable for use in connection with the deposition of films of metals, non-metals, compounds such as refractory compositions and the like. The technique is particularly valuable for its versatility and unusual control. It has been further found that a superimposed RF field may be advantageously applied to two or more electrodes, such as, for example, the anode and one of the other electrodes, or between a pair of targets of similar or dissimilar composition, or between the anode and the substrate. The use of this field applied to these electrodes contributes to the enhancement of properties of materials which are prepared in accordance with the use of sputtering techniques. Because of the nature of the sputtering operation, this feature is particularly valu-

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able to the operation of the equipment. In addition, any means by which added versatility can be acquired such as by establishing a RF field at various of the electrodes is likewise considered valuable. In accordance with the present invention, resonant circuit is utilized in connection with the RF field, and the capacitive portion of the RF circuit is obtained by utilizing the capacitive effect of the cross-sectional thickness of the bell-jar envelope which is utilized in establishing the enclosure for the sputtering system. The present invention permits a direct routing of the RF energy to the point of desirable exposure within the enclosure by means of the utilization of a coaxial line which shields the line carrying the RF energy to the conductive plate backing the material which is being sputtered. Thus, the application of RF energy to the target location or source electrode is specific, definite, and controllable. The bell-jar envelope is, generally, fabricated from glass, the thickness being about one-half inch to three-fourths inch in the normal glass bell-jar enclosure. More specifically, a pair of plates are disposed on opposite sides of the glass envelope and the glass therebetween serves as the dielectric for the system. While separate electrodes are normally utilized, it is, of course, possible to employ conductive paint on the outer surface of the jar for the outer electrode, if desired. While the inner electrode may be so fabricated, the particular material forming combinations of source and substrate may prevent the use of this technique on the interior. Of course, balancing means are required between the various portions of the capacitive circuit, such as, for example, a tuning capacitor arranged on opposite sides of the inductively coupled circuit. These means are generally required inasmuch as the precise capacitance value between various integral areas of the bell-jar may not be precisely the same, from one point to another, as well as other parameters in the system may also be changed.

Therefore, it is an object of the present invention to provide an improved technique for use in connection with a sputtering deposition operation wherein the technique employs a superimposed RF field across electrodes or working stations, the glass enclosure of the bell-jar and the capacitance of the source material being utilized for setting up the major portion of the capacitive component of the resonant circuit.

It is still a further object of the present invention to provide an improved coupling technique for superimposing a RF field across certain of the working stations of a sputtering operation, the RF generator being coupled to a resonant LC circuit, the major portion of the capacitive component of the LC circuit being obtained by utilizing the transverse thickness of a glass bell-jar and the transverse thickeners of the source material as the dielectric of a capacitor in the circuit.

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 drawings, wherein:

FIGURE 1 is a perspective diagrammatic view of a sputtering imposition system embodying the aspects of the present invention, the figure showing a schematic illustration of typical circuitry which may be employed in connection with the operation of the equipment illustrated in this figure; and,

FIGURE 2 is a detail view, partially broken away, showing the capacitive coupling feature utilized in connection with the present invention.

In accordance with the preferred modification of the present invention, the deposition system generally designated 10 includes the bell-jar 11 situated upon a working base or support 12. The bell-jar 11 and the surface 12 define an enclosure or cavity 13 which provides the

working area for the apparatus and technique of the present invention. A 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 by the character 15. The pump may be conveniently utilized to evacuate the enclosure 13, whenever this operation is indicated. A gas supply system is also utilized in connection with the bell-jar enclosure, a conduit 17 being in communication with the enclosure 13 through the base 12, and being in operative relationship with a gas regulating valve 18 for controlling the rate of flow of gas from a gas supply such as is designated at 19. Various inert gases may be utilized for either assisting in flushing the enclosure, or for actual use in connection therewith, or both. For example, argon gas is particularly desirable for use in low pressure supported gas discharge plasma deposition operation. 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, pp. 690-704.

The electron generating tube generally designated 21 is shown mounted in depending sealed relationship with the base 12, the tube 21 also being in direct communication with the enclosure chamber 13. The tube 21 includes a thermal emission cathode or filament element 22 which obtains electrical energy from the conductors 23 and 24, these conductors being operatively associated with a suitable power supply designated at 27. Since the requirement of the power supply 27 is merely to provide current to heat the cathode, the voltage amplitude is not critical, and is determined by the actual requirements of the cathode filament 22. The anode electrode 28 which is fabricated from titanium or the like is supported in the chamber 13 by means of the conductive support rod 29, rod 29 being secured to and insulated from the base 12. In order to be able to both support and electrically bias the anode 28, conductor 29 and the arm 30 are preferably fabricated from electrically conductive material and are insulated from the base 12. The post 29 is, of course, insulatively joined to the base plate 12.

An electrode member 35 is disposed in the plasma zone established within the chamber 13 between the cathode 22 and the anode 28, the electrode 35 being supported on the base 12 by the rod 52 and the bracket 34, this bracket preferably being fabricated from an insulator material or otherwise electrically isolated from rod 52. Conductor 37 is coupled to the electrode 35 through the bell-jar capacitor and the coaxial conductor 38 disposed within the rod 52. A unidirectional power source or supply 39 is available in order to provide sufficient DC energy to initiate and maintain the gaseous plasma between the cathode and the anode. Resistor 40 is utilized to control the potential available on these electrodes. Conductor 41 couples one side of the RF power supply 44 to the anode element 28. A substrate or work piece 46 is disposed within the chamber 13 and is supported on the base plate 12 by means of the bracket 47. The substrate 46 is designed for receiving a deposition such as a film deposit or the like along its surface 48. The substrate may be electrically biased, if desired; however for normal sputtering operations this is not required, the substrate being at a floating potential.

Attention is now directed to the circuitry diagram indicated at FIGURE 1. In this regard, a suitable RF source 44 is coupled in an LC circuit as indicated. The main source of the inductive component is found in the transformer generally designated 50 which includes the primary winding 51 and a secondary 53, these windings being coupled together by an air medium. A suitable tuning capacitor such as a blade capacitor or the like is shown at 54 for the purpose to be hereinafter more specifically pointed out. The main source of the capacitive component of the LC circuit is obtained across the bell-jar 11 and the source 35. A pair of conductive plates

55 and 56 are disposed on opposite sides of bell-jar 11, plate 55 being electrically coupled to the coaxial extension element or conductor 52. The conductor 52 is thereafter coupled electrically to the target element 35. The provision of the coaxial extension permits the RF field to be applied specifically to a target or source disposed within a certain specific area of the bell-jar enclosure. Sputtering will accordingly be confined to the desired surface area of the source, such as the source 35. Capacitor 58 is interposed at the secondary of the LC circuit, this capacitor being utilized as a balancing capacitor for the system. In actual practice, the primary of the transformer 50 includes four turns of a copper conductor about a one-quarter inch copper tube, the secondary being one turn of copper conductor about a similar quarter inch copper tube. The two windings are spaced apart by a one-half inch air gap.

The RF source 44 is preferably capable of delivering an output in the range of from one megacycle up to 100 megacycles, and preferably in the range of about 30 megacycles. It is felt that the effect of the RF field in the system may diminish below about one megacycle.

The advantage and improvement is the ability to locate the source in a desirable location in the plasma within the enclosure at a desired area in the plasma zone. In accordance with the technique of the present invention, the RF field is introduced into the chamber by means of a coupling technique which is disposed at a substantial distance from the remaining active stations; hence the effect of this field at the surface of the source is predictable.

While the specific embodiment herein disclosed illustrates a RF field established between the anode electrode and the target electrode, it will be appreciated that other combinations are equally appropriate. In this connection, a RF field may conveniently be established between a pair of dissimilar target elements, the effect being to deposit mixtures of materials on a substrate surface. For example, if a deposit is being prepared which is desirably a mixture of two individual components, a RF field may be established at these individual targets and the coating prepared on the substrate will be a composite of the individual ingredients. For example, it may be desirable to sputter a mixture of glass and copper onto a substrate. In this connection, one target may be fabricated from copper metal while the other may be prepared from a glass surface such as Pyrex glass bonded to a suitable conductive medium such as copper or the like. In this connection, however, the glass surface of the Pyrex glass-copper laminate is the one which is seen or made available by exposure to the substrate element.

Example I

For a specific illustration of a deposition procedure, the following example is provided. The chamber 13 was evacuated by the vacuum pump 15 until a residual pressure of 10^{-6} torr was achieved. The valve 18 was opened and a continuous supply of argon gas was admitted, the flow being parallel of the pump 15, maintaining in the enclosure a pressure of 10^{-3} torr. A target was prepared utilizing a Pyrex coated copper metal, this Pyrex material being available on the surface of the target 35. Pyrex glass, one-eighth inch thick, was coated over the copper metal. The source of RF energy delivered 2500 volts at a frequency of 27.12 megacycles to a primary winding consisting of four turns of a copper conductor on a one-quarter inch copper tube, the secondary being one turn of copper conductor on a one-quarter inch copper tube, the primary and secondary being separated by a one-half inch air gap. The surface of the target was spaced from the surface of the substrate by a distance of four inches, this gap distance being in the plasma generation area which exists between the cathode 22 and the anode 28. The Pyrex bell-jar had a nominal thickness of five-eighths inch, and two one inch by one inch electrodes were arranged on opposite sides thereof.

The cathode is then energized with the element being heated to a temperature which is sufficient to cause thermal emission of electrons therefrom. While the thermally emitted electrons flow toward the anode, which is charged by the power supply 39 to a potential of 45 volts for initiating and maintaining the plasma across a four inch gap, and while these electrons are passing through the gas which is present in the enclosure or chamber, collisions will occur with the atoms and molecules of the gas, the frequency of these collisions being determined, of course, by the mean-free-path existing in the atmosphere between the cathode and the anode. When these collisions occur, electrons will be dislodged from the atom or molecule of the gas and a positively charged gas particle will be thereby formed. These charged particles are attracted to the target or source electrode 35, and the collisions which occur between the charged gas atoms or molecules or particles and the surface of the target 35 cause a dislodging of material from the surface of the target 35, these materials then being free to move toward the substrate 46, and a statistical quantity of the dislodged atoms will lodge on the surface of the substrate. This portion of the operation is, of course, typical and conventional in the sputtering techniques. In this operation, the RF potential of 2500 volts was applied between the surface of the target 35 and the potential of the plasma. The substrate was maintained at a floating potential being isolated from the base 12. Accordingly, the gaseous plasma will be attracted to the negatively charged target 35.

The control available by the sputtering technique is obviously desirable, and with the added feature of a RF field available, the choice of source materials is expanded to include insulators.

While the example specifically utilizes a deposition of Pyrex from a base of copper, it will be appreciated that other materials may be suitably sputtered by this technique, as well as mixtures of materials, multiple sources of materials and the like.

In another operation, a RF field was impressed between the target and the base 12, with suitable potentials being established on the anode, such as a potential of 45 volts, other operations being similar.

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 system utilizing a low pressure supported gas discharge plasma for maintaining an enclosure fabricated at least in part from a dielectric material, an inert gaseous atmosphere of low pressure maintained within said enclosure, a plurality of working stations disposed within said enclosure, and means for establishing a gas discharge plasma therewithin, said working stations including an electron emitting electrode, a plurality of electrodes including an anode for said electron source disposed in spaced relationship from said electron emitting electrode and biased electrically to attract said electrons and defining a reaction zone for said electrons and the gas molecules comprising said atmosphere, and at least one target electrode disposed in said reaction zone, certain of said gaseous molecules being adapted to bombard the surface of said target to remove atoms therefrom, means for collecting said removed atoms, and field generating means for establishing a RF field generating means including capacitive means having a pair of electrically coupled electrode plates disposed in spaced apart relation-

ship on opposite surfaces of the dielectric of said enclosure and including an inner and an outer plate, and coupling means for locating and isolating said RF potential on the target surface disposed within said enclosure and in spaced relationship from said enclosure surface, said coupling means including an electrical conductor extending from said inner plate to said target and a shield disposed about said conductor and generally coextensive with said conductor to electrically isolate the field created along the extent of said conductor from said plasma.

2. The deposition system as defined in claim 1 wherein said dielectric is glass.

3. The deposition system as defined in claim 1 being particularly characterized in that said RF field is established from a resonant LC circuit, and said shield is disposed generally coaxially with said electrical conductor and forms a complete enclosure thereabout.

4. In a deposition system utilizing a low pressure supported gas discharge plasma, an enclosure fabricated at least in part from a dielectric material for maintaining an inert gaseous atmosphere of low pressure maintained within said enclosure, a plurality of working stations disposed within said enclosure, and means for establishing a gas discharge plasma therewithin, said working stations including an electron emitting electrode, a plurality of electrodes including an anode for said electrons disposed in spaced relationship from said electron emitting electrode and biased electrically to attract said electrons, and defining a reaction zone for said electrons and said gas molecules, and at least one target electrode disposed in said reaction zone, certain of said gaseous molecules being adapted to bombard the surface of said target to remove atoms therefrom, means for collecting said removed atoms, and field generating means for establishing a RF potential on the surfaces of at least two of said electrodes, said field generating means including a resonant LC circuit having a primary winding and a secondary winding, and capacitor means coupled to said secondary winding, said capacitor means including a pair of electrically coupled electrode plates disposed in spaced apart relationship on opposite surfaces of said dielectric of said enclosure, and coupling means for locating and isolating said RF potential on a surface disposed within said enclosure and in spaced relationship from said enclosure surface, said coupling means including an electrical conductor extending from said inner plate to said target and a shield disposed about said conductor and generally coextensive with said conductor to electrically isolate the field created along the extent of said conductor from said plasma.

5. The deposition system as defined in claim 4 being particularly characterized in that said coupling means includes a pair of conductors disposed in coaxially arranged relationship, the outer conductor being maintained at ground potential, and completely enclosing the inner conductor.

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