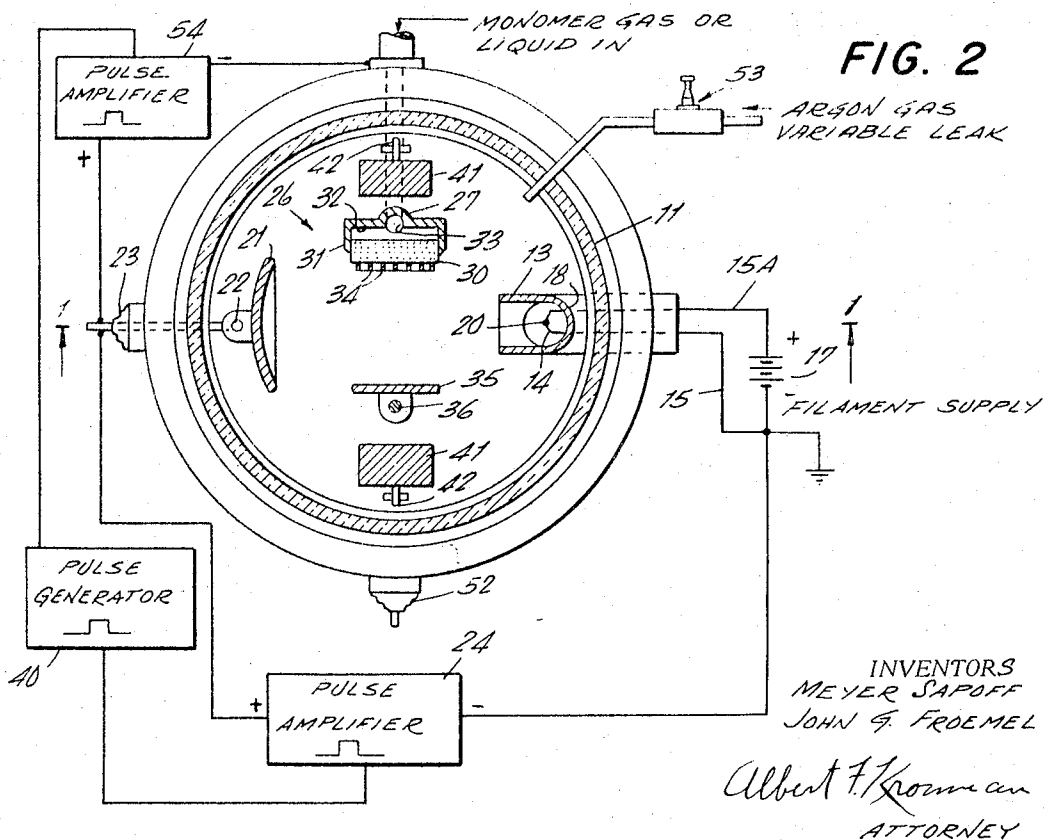
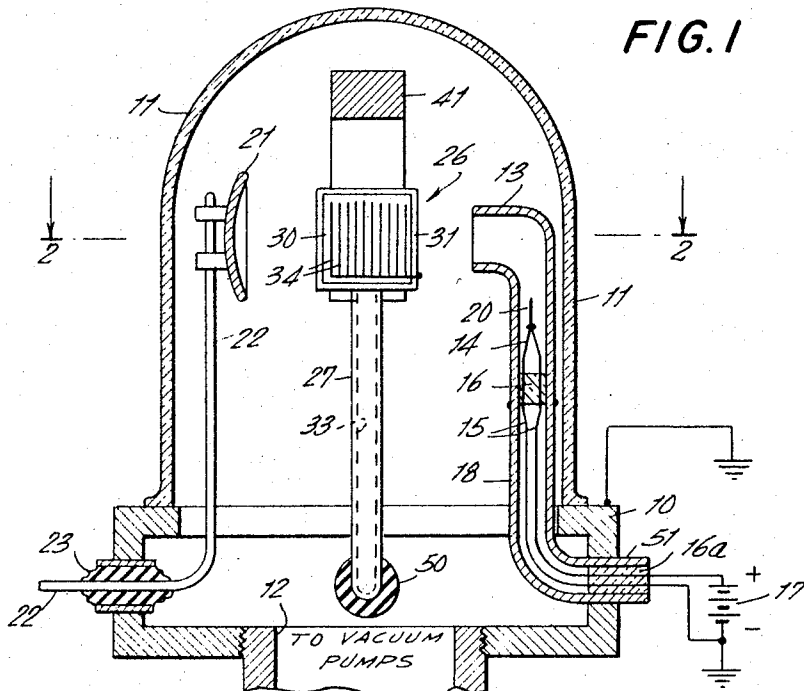


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TRIODE SPUTTERING APPARATUS AND METHOD USING SYNCHRONIZED PULSATING CURRENT

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ABSTRACT OF THE DISCLOSURE

A device and method for depositing molecules of a desired material on a substrate or base is described. Deposition is accomplished in a rarified atmosphere containing a noble gas. The initial discharge is created between an anode and a cathode which creates electrons and gas ions. An auxiliary target of the material to be deposited is biased with respect to the anode and attracts the gas ions which ions cause emission of the desired molecules. A substrate is mounted parallel to the target and the molecules are deposited on it. Both the main discharge between the anode and cathode and the auxiliary discharge between the anode and the target are pulsed by the application of high voltage.

Summary of the invention

This invention relates to an apparatus for depositing molecules on a substrate to form a thin film such as a semiconductive film. The invention has particular relationship to the application of high voltage pulses which are applied to both the main or plasma initiating discharge and the auxiliary discharge which transfers the molecules from the target to the substrate, however, the secondary discharge is one which is biased between the anode and the cathode. One feature of the invention is the use of a target in the form of a block of material to be deposited or a porous plug to one surface of which is a gas, as the gas molecules are drawn through the electron discharge beam, they are polymerized to form a solid polymer compound. This compound is deposited on the substrate. Another feature of the invention includes the use of a field emission cathode which employs a hot filament and a pointed discharge element often called a field emission cathode or point. Another feature of the invention includes the use of a magnetic field which may be movable to distribute or sweep the molecules evenly on the substrate.

Depositing molecules on a substrate by the use of a gas discharge is old in the art. While direct currents and alternating currents have been used for creating these discharges, it has been found that the application of sharp voltage pulses to the discharge electrodes produces an additional and unexpected rate of deposition, furthermore, this method also decreases the amount of heat generated during such deposition. This increased deposition is even more pronounced when the main discharge between the anode and cathode is turned on first and then a short time later the voltage between the target and the anode is applied. The target pulse is stopped before the plasma pulse is turned off. This method of pulsing produces a marked increase in deposition rate and lowers the integrated target current thus affording a reduction in the amount of heat generated.

Description of the drawings

FIGURE 1 is a cross-sectional view of the apparatus showing the anode, the cathode and the target. This view is taken along line 1—1 of FIGURE 2.

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FIGURE 2 is a cross sectional view of the apparatus shown in FIGURE 1, and is taken along line 2—2 of that figure. This view also shows the substrate.

Referring now to FIGURES 1 and 2, the device includes a ring-shaped base 10, on which a bell jar 11 is placed. The base 10 is connected to the conduit 12 of a pumping system (not shown). A plurality of electrodes 22, 51 and 52 are led into the base 10. The pumping system (not shown) must be particularly efficient in order to remove all traces of absorbed gasses and other undesirable hydrocarbon compounds from the interior of the bell jar 11. Such a pumping system may consist of either or all of a getter tantalum sublimation pump, a Vac-Ion pump or a cryogenetic absorption pump. In order to eliminate all undesirable substances from the bell jar, and associated pumping system, the entire apparatus is subjected to a temperature of at least 250° C. This may be done by local heating means or a furnace hood may be lowered over the entire system and heated in the usual manner. This part of the apparatus is not shown in the drawing because such equipment is old in the art and has been described before in books and other publications.

A field emission cathode 20 is carried within a conduit 13, mounted inside the bell jar 11. The field emission cathode 20 is in the form of a pointed tip 20, which is preferably made of tungsten. An associated filament 14 which is indirectly heated supports the cathode 20. Electrical insulation between the filament 14 and the conduit 13 is provided by a glass spacer 16. The lead-in wires 15, 15a, to the filament 14 are passed through a metal-to-glass seal 16a, and are connected to a source of current 17 which may be a battery or other DC potential source.

Because of the pulse nature of the discharge the pointed cathode wire 20 is welded to the top of the filament 14. The wire 20 increases the electric field at its tip and thereby permits the discharge to start with a rapid rise time. The shield 13 prevents direct evaporation of the tungsten tip 20 and filament 14 from reaching or contaminating the system.

An anode 21 is mounted in the bell jar 11, opposite the conduit 13, and is preferably made with a concave stainless steel surface. The anode 21 is supported on a vertical rod 22 which is also brought out through a hermetic seal 23, carried by a portion of the base 10. The end of the rod 22 acts as an electrode for the application of a high voltage pulse which is derived from an external power source. The external power source may be any source of pulsed potential such as the pulse amplifier 24, and generator 40. The pulse width and pulse repetition rate may be varied by means of the accompanying generator 40 for the power supply. The negative terminal of the source 24, 40, is connected to one of the cathode leads 15, which is grounded to create the main discharge. This in turn creates the desired plasma, when a gas such as argon or xenon is admitted into the bell jar 11 by means of the variable leak valve 53. This gas is preferably maintained at a pressure in the bell jar of below 10 microns.

A target 26 is carried by a combined conduit and support 27, which extends downwardly to the base and is supported by a portion of the base 10 through a hermetic seal or insulator 50. The target 26 includes a block 30 which may be a block of semiconductor material, metal or other solid material such as an insulator that is desired to be deposited on the substrate 35 across from it. Many forms of oxide and many types of mixtures of metals and oxides can be sputtered from the target to the substrate and any of these mixtures can be used for this apparatus.

Alternately, the target 26, as shown in the figures, may be in vapor form. By substituting for the block 30 a porous material, which has been formed by sintering, it is possible to direct a monomer gas therethrough as shown in FIGURES 1 and 2. The monomer gas is led through the conduit support 27 and then through the block. Porous porcelain or porous glass may be used instead of a sintered metallic powder for the block 30 in this embodiment. The porous block 30 is held by frame work 31 which grips the block on its sides but provides a space 32 at the rear of the block. This space 32 is in communication with the interior 33 of the conduit 27. When it is desired to deposit the polymer of a monomer on substrate 35, a monomer gas supply is connected to conduit 27 and permitted to slowly diffuse through the porous plug 30.

In order to provide a bias for an electrical charge, a grid or porous electrode 34 is placed on the front surface of the porous block 30. These wires 34 may be made of platinum or other noble metals of the high temperature class or any conductive material which sputters less easily than the target material. The electrode 34 is connected to the pulse power supply 40, 54.

The substrate 35 provides the support on which the semiconductor material or polymer is deposited. The substrate is supported by a rod 36 similar to rod 22 which is led out through an insulating connection 52. This substrate support may or may not be connected to ground potential, depending upon the material to be sputtered. It has been found that the deposition of molecules from the target 26 is not always spread uniformly over the surface of the substrate 35 or, spread completely over the entire surface when larger areas are to be covered. In order to make a deposit more uniform and complete a permanent magnet or electromagnet 41, may be installed inside the bell jar 11, and arranged for rotation and motion about a pivot axis 42. It is well known that moving ions will be deflected by a magnetic field. The amount of deflection and exact position of the magnet are functions of the ions and the voltages used to generate the discharge. The best arrangement for the magnet field for each material must be determined experimentally.

The operation of this device will be apparent from the foregoing. The substrate 35 is placed in its holder and the bell jar 11 slipped upon its base 10. The bell jar 11 may be either constructed from glass, stainless steel or similar metal. The vacuum pumps (not shown) are started and the interior space of the bell jar cleaned and flushed. The entire system is then baked out by the application of exterior heat of the order of 250° C. After these preliminary operations an inert gas such as argon is introduced into the evacuated bell jar at a pressure of 10 microns of mercury. This gas is ionized by the discharge between the cathode 20, 14, and the anode 21.

The material to be sputtered in this case a solid block 30, which has been placed in the holder 33, and may consist of a metal semiconductor or insulator is then biased negative with respect to the anode 21. Positive argon ions are accelerated to the target 26 and cause the target molecules to be sputtered onto the substrate 35.

The operation of this device for depositing a polymerized material includes the insertion of the substrate 35 into its holder and positioning of the bell jar 11 onto its base 10. The vacuum pumps are started and the interior space of the bell jar is cleaned and flushed and the entire system baked out while under the application of exterior heat of the order of 250° C. After these preliminary operations an inert gas such as argon is put into the evacuated space at a pressure of about 10 microns of mercury.

If a polymer is to be applied to the substrate 35, a monomer gas is applied to conduit 27 and diffused through the porous plug 30. The pulse generator which biases the target at a negative potential with respect to

the anode is started, however, pulses are first applied to the anode and cathode. After the material has been deposited to the required thickness, the discharges are stopped and the gas flow to conduit 27 is turned off. The gas which generates the plasma is also turned off and the bell jar is thoroughly evacuated of all gas. A neutral gas may also be used to backfill the bell jar if desired. However, in most instances air is admitted to the system and the substrate detached from its mounting.

Having thus fully described the invention, what is claimed as new and desired to be secured by Letters Patent of the United States is:

1. Apparatus for depositing a thin film of material on a substrate comprising a sealed envelope connected to a pumping system for exhausting and filling the envelope with an inert gas at reduced pressure, a cathode within said envelope having sealed lead-in conductors for connection to a first external circuit, an anode within said envelope having a sealed lead-in conductor for connection to a second external circuit, said anode and cathode bracketing a discharge path therebetween, a target within the bell jar adjacent to the discharge path, said target supporting the material for deposition, a first source of electrical power for applying a series of positive voltage direct current pulses to said anode to produce a pulse discharge between the anode and cathode, a second source of electrical power for applying a series of negative voltage direct current pulses to the target for attracting the ions which liberate the material from the target, and a substrate within the bell jar opposite to said target on the other side of the discharge path for receiving material from the target.

2. Apparatus as claimed in claim 1 wherein said cathode consists of a thermal emissive filament and a pointed electrode connected to said filament for the production of high intensity electric field and plasma.

3. Apparatus as claimed in claim 1, wherein said target includes a porous plug, a source of gas molecules in communication with the inside of said envelope adjacent the porous plug, whereby the gas is polymerized by the discharge between the anode and cathode.

4. Apparatus as claimed in claim 3 wherein a plurality of conductors are spaced on the surface of the porous block in the path of the gas.

5. Apparatus as claimed in claim 1 wherein the first and second sources of electrical power are derived from a pulse generator.

6. Apparatus as claimed in claim 1 wherein said first and second sources of electrical power are derived from direct current power sources connected in series with electronic switching means.

7. Apparatus as claimed in claim 1 wherein a source of magnetic flux is applied to said discharge between the cathode and anode to distribute and deposit molecules evenly on a substrate.

8. A process of depositing material on a substrate comprising the following steps of creating a direct current pulsed gaseous discharge between an anode and cathode within a sealed envelope, positioning a target containing material to be deposited adjacent to said discharge, positioning a substrate on which the material is to be deposited adjacent to said discharge but on the side opposite the target and applying negative voltage direct current pulses to the target for creating a pulse electric field between the target and the anode.

9. A process as claimed in claim 8, wherein in said electric pulses applied to the anode and cathode are in synchronism with the electric pulses applied between the electric target and anode.

10. A process as claimed in claim 9, wherein the said electric pulses applied to the anode and cathode overlap the pulses applied to the anode and cathode overlap the pulses applied to the target and anode in timed sequence.

11. A process as claimed in claim 9, wherein a magnetic

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field is applied to the discharge between the anode and the cathode by a source of magnetic flux.

12. A process as claimed in claim 11, wherein said magnet field is moved during the deposition sequence to spread the molecular discharge over a uniform area.

13. A process according to claim 8 in which the target material is a monomer gas and the material deposited is a polymer.

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