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[54] APPARATUS FOR FILM DEPOSITION

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[63] Continuation of Ser. No. 21,282, March 20, 1970, abandoned.

[52] **U.S. Cl.**..... **204/298;** 117/93.1 GD; 117/93.3; 219/121 EB

[51] **Int. Cl.**.. **C23c 15/00;** C23c 11/00; B23k 15/00

[58] **Field of Search** ..... 204/298; 118/49.1, 49.5; 117/93.3, 93.1 GD; 219/121 EB

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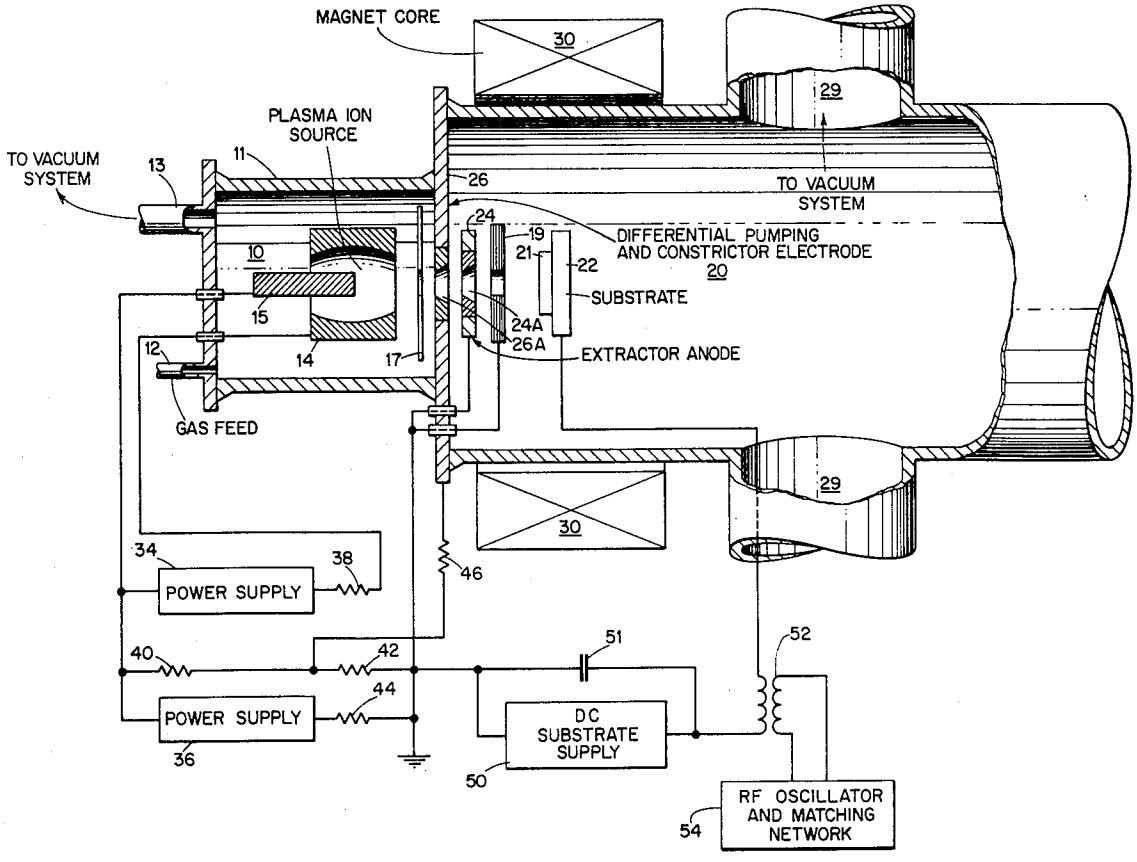
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[57] **ABSTRACT**

A method and apparatus for depositing a thin film of material upon a base substrate including a glow discharge ion source for generating the particular ions that will be subsequently deposited upon the base substrate, a vacuum deposition chamber wherein the substrate material is located, and, intermediate between the glow discharge ion source and the vacuum deposition chamber, a constrictor electrode for isolating the deposition chamber from the ion chamber and an anode electrode for extracting ions from the plasma ion source and directing them toward the target substrate. A magnetic field is also provided in the apparatus of the present invention by the use of an externally wound magnetic coil to permit the glow discharge ion source to operate at a lower pressure and to constrict the flow of ions toward the substrate.

18 Claims, 2 Drawing Figures



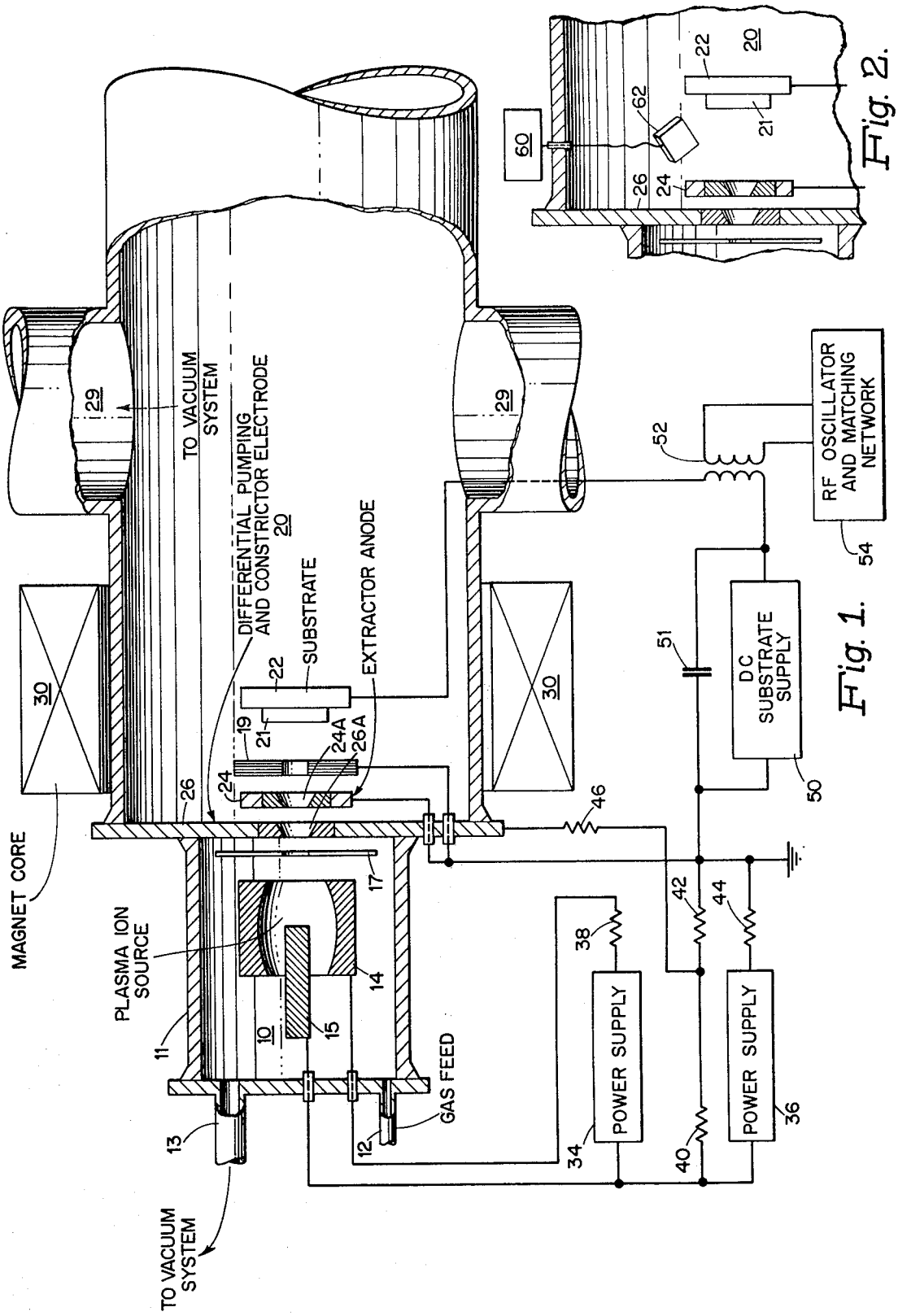

MAGNET CORE
PLASMA ION SOURCE
TO VACUUM SYSTEM
TO VACUUM SYSTEM
DIFFERENTIAL PUMPING AND CONSTRICTOR ELECTRODE
20
SUBSTRATE
EXTRACTOR ANODE
GAS FEED
POWER SUPPLY
POWER SUPPLY
DC SUBSTRATE SUPPLY
RF OSCILLATOR AND MATCHING NETWORK
29
30
10
11
12
13
14
15
17
19
21
22
24
24A
26
26A
34
36
38
40
42
44
46
50
51
52
54
60
62

Fig. 1.

Fig. 2.

APPARATUS FOR FILM DEPOSITION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation application of my previously filed application, Ser. No. 21,282 filed Mar. 20, 1970 now abandoned for FILM DEPOSITION.

BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for providing improved thin film deposition.

There have been numerous techniques employed for depositing thin film, most of which involve the use of a substrate, which is elevated to or maintained at a relatively high temperature. This high substrate temperature has been considered necessary during the deposition of the thin film for the purpose of increasing the mobility of the atoms being deposited. However, this high temperature substrate has certain problems associated with it. For example, one disadvantage of vapor deposition upon a hot substrate is that the impurities are caused to diffuse out from the substrate and thereby affect the composition of the thin film that is being deposited. Further, the excess temperatures cause a poor definition at the junction between the film and the base substrate material.

It is known that the necessary substrate atom mobility is obtained by heating the incident ions that are to be deposited on the substrate surface rather than the substrate itself. The apparatus of the present invention takes this fact into account and permits less heating of the substrate by isolating the substrate within a separate chamber adjacent to the plasma ion source chamber. Further, the apparatus is designed to control the energy of impinging ions by appropriate biasing means coupled to the substrate material.

It is an object of the present invention, therefore, to provide an improved method and means for the deposition of thin films.

It is another object of the present invention to provide film deposition apparatus wherein the substrate can be maintained at a relatively low temperature.

A further object of this invention is to provide a method for fabricating a thin film-substrate structure wherein the film can be deposited at a high rate and in a controllable manner.

Another object of the present invention is to provide a thin film upon a base substrate wherein there has been little or no impurity diffusion from the substrate affecting the thin film deposited thereon.

Still another object of the present invention is to provide a thin film-substrate structure wherein the junction between the two substances is well defined.

Other objects of the present invention will become apparent upon reading the detailed description in conjunction with the drawings and appended claims.

SUMMARY OF THE INVENTION

One embodiment of the apparatus of the present invention provides a means by which the thin film is formed on a substrate by ionizing and electrostatically accelerating a beam of atomic particles of a material which is to be deposited on the substrate as a thin film. A plasma ion source acts as a such source of atoms of the material to be deposited. An electrical discharge occurs within this source of ions, and the desired material is converted into a plasma form with the ions to be deposited in a mixture with high energy electrons. An

axial magnetic field may be used to constrain the orbits of the electrons and increase their likelihood of ionizing atoms of the material under consideration. This magnetic field permits the electrical discharge to operate at a lower gas pressure than could be used without the magnetic field. Thus, in the source discharge chamber, there is a plasma which contains a large concentration of ions of the species that are to be subsequently deposited.

A plasma discharge from this plasma ion source is generated into a vacuum deposition chamber where the substrate material is located. This can be accomplished by locating an extraction electrode in the vacuum deposition chamber and by the use of a constrictor means separating the higher pressure plasma ion chamber from the lower pressure vacuum deposition chamber. The ions are extracted through an aperture in the constrictor by means of the applied electric field which maintains a discharge between the plasma source, which functions as a cathode, and the extraction electrode, which is situated in the vacuum deposition chamber. The purpose of the constrictor means is to isolate the vacuum deposition chamber from the higher pressures present in the plasma ion chamber while the extractor electrode pulls the positive ions within the plasma source toward the target substrate. It is often desirable to surround the constrictor aperture with the same material as that to be deposited on the substrate.

In another embodiment of the invention the accelerated beam may be of an inert gas and the ions to be deposited may be supplied by an auxilliary source within the deposition chamber. The beam provides the energy necessary to deposit the ions from the source which coimpinge with the ion beam.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention will be more clearly understood when considered in conjunction with the accompanying drawings in which:

FIG. **1** is a cross-sectional diagram of one embodiment of the deposition system according to the invention.

FIG. **2** is a cross-sectional view of part of another embodiment of the deposition system similar to that shown in FIG. **1.**

DETAILED DESCRIPTION

As hereinbefore mentioned, the present invention permits the deposition of improved thin films by means of an ion beam source used in conjunction with a vacuum deposition chamber. FIG. **1** shows an embodiment for practicing the present invention. In one particular system, a silicon film **21** is deposited on a single crystal silicon substrate **22.** The film **21** is shown in an exaggerated thickness in FIG. **1.**

Plasma ion source **10** generally includes chamber structure **11** having vacuum line **13** and gas input line **12** connected thereto. Vacuum line **13** connects to a vacuum pump (not shown) which controls the pressure in source **10.** Also included in ion source **10** are silicon electrodes **14** and **15,** which connect externally to power supply **34** and resistor **38.** With an electrical discharge taking place within plasma ion source **10,** the material which is silicon in this particular case, is introduced into a plasma formed by the high energy electrons. A magnetic field set up by magnetic coil **30** influ-

ences the formation of the ions within plasma ion source **10** by constraining the orbits of the electrons and increasaing the likelihood of ionizing atoms of silicon. This external magnetic field permits the electrical discharge to operate at lower gas pressure than could be used without the magnetic field.

The generation of an ionized plasma usually can occur through a neutral gas such as argon, hydrogen, or helium, or through a more active gas, such as nitrogen or oxygen or a mixture thereof, introduced via line **12.** The ions produced in this source deposition chamber in turn bombard the cathode (electrodes **14** and **15**) and sputter or vaporize atoms of material into a discharge space where they can be ionized. Thus, in the plasma ion source **10,** there is produced a plasma which contains large concentrations of ions of the species that one wishes to deposit upon substrate **22.**

Many times it is desirous to obtain mixtures of ions, such as aluminum and oxygen, silicon and oxygen, or silicon and nitrogen, for the deposition of insulating layers, such as aluminum oxide, silicon dioxide, or silicon nitride. There are generally two different approaches. One approach is to use electrode material fabricated of silicon or aluminum and to introduce the necessary oxygen or nitrogen gas into the plasma by means of the appropriate gas feed line **12** for the maintenance of this ion plasma. There may be difficulty, however, with this approach since adjusting the partial pressures of the oxygen or nitrogen in order to obtain the correct film stochiometry appears to be difficult. An alternative way, which appears to be advantageous is to fabricate the electrode material of the necessary materials, such as silicon oxide or nitride. One then introduces the correct mixture into the plasma source by operating a glow discharge between the two electrodes in the ion source chamber **10.** Consideration of other types of films is taken up later after a discussion of the operation of the deposition chamber.

The next occurence in the operation of the apparatus is the extraction of the plasma discharge from the plasma ion source **10** into vacuum deposition chamber **20** where the substrate **22** is located. To facilitate this, an anode extraction electrode **24** is located in deposition chamber **20** along with a constrictor electrode **26.** The purpose of constrictor electrode **26** is basically to separate the higher pressure sputtering source chamber **10** from the lower pressure film deposition chamber **20.** The ions are extracted through the constrictor electrode **26** by means of the externally applied electric field, which maintains a discharge between the plasma source **10,** operated as a cathode, and the extractor anode **24,** located in deposition chamber **20.** Anode supply **36** facilitates the foregoing by biasing the anode positively with reference to the source **10.** The external electric field generated by power supply **36** is oriented along the external magnetic field caused by magnetic coil **30** so that the plasma is extracted along magnetic field lines. This serves to maintain the plasma in a constricted mode so that it is able to pass through the aperture **26A** in constrictor electrode **26** more efficiently. Anode electrode **24** acts to extract electrons from the plasma source, and the electric field generated by the extracted electron pulls the positive ions from plasma source **10** along with them. The anode **24** has an aperture **24A** in it located along the axis determined by the magnetic field produced by magnetic coil **30,** and this in turn serves to maintain the plasma constriction and permits a large fraction of the extracted positive ions to pass through the anode aperture, subsequently impinging on substrate **22.** The apertures in the electrodes **24** and **26** permits differential pumping to occur, thereby maintaining a good vacuum (about 10^{-6} Torr) in deposition chamber **20** (provided via vacuum line **29**), while somewhat higher pressure is maintained in plasma ion source **10.** It is often desirable to surround the apertures in electrodes **24** and **26** with the same material as that to be deposited on the substrate. Note that the magnetic field serves three purposes: In the plasma ion source it permits the source to operate at lower pressures; it aids in constricting the plasma through the constrictor electrode; and it helps to maintain the plasma in a constricted path on its way to the substrate.

The constrictor electrode **26** may be left essentially electrically floating through a high impedance resistor **46** to an appropriate potential such as the one determined by the resistors **40** and **42.** For the embodiment of FIG. **1,** this potential is intermediate between the potential of the cathode in source **10** and the anode in chamber **20.** Similarly, the insulating shield **17,** positioned between electrodes **14** and **26,** may be left floating. Shield **17** minimizes the tendency of the discharge to attach other than where desired. A focusing electrode **19** can also be used between anode **24** and substrate **22.** Electrode **19** is shown connected to anode **24,** but can be connected to a separate biasing supply if desired thereby controlling the final path of the ion beam.

The potential on substrate **22** relative to that of plasma ion source **10** and extractor anode **24** determines in large part of the kinetic energy with which the positive ions impinge on substrate **22.** Reference is directed to substrate supply **50** which connects via the secondary winding of transformer **52** to substrate **22.**

The combination of the DC power supply **50** with the by-pass capacitor **51** permits a DC bias to be applied to the substrate while maintaining the power supply at a low impedance relative to ground. An AC or RF voltage is superimposed on the DC bias voltage by means of oscillator **54** and transformer **52.** The use of the transformer permits the application of an additional AC voltage without modifying the DC bias voltage provided by the DC supply **50.**

As previously mentioned, the axial magnetic field helps maintain the ion beam in a columnated mode after it is extracted through the aperture in anode **24** and minimizes space charge spreading. In this way, one can achieve a higher deposition rate than would otherwise be expected in the absence of a magnetic columnating field.

There are some modifications of the deposition system of the present invention that will enable the deposition of either conducting films on insulating substrates or depositing insulating films on conducting or insulating substrates. The necessity for these modifications relates to the fact that when depositing an insulating substrate of film it is more difficult to control the energy of the ions impinging on the substrate **22,** and therefore is necessary to prevent the surface from building up to a positively charged repelling condition. In the present invention, as shown in FIG. **1,** this has been remedied by using an rf power supply **54.**

The AC or rf supply, which connects via transformer **52** to substrate **22,** operates at a high frequency (at about **15**Kc or **13** megacycles, for example) and is used

to alternately bias the substrate surface positive and negative by using the displacement current that flow through the insulating film or substrate. The alternating positive and negative potential applied to the substrate is used to extract positive ions and electrons from the plasma so that the net current to the surface is zero; but at the same time, during portions of the cycles, positive ions can be attracted to the surface. The rf amplitude applied to the substrate determines the energy of the positive ions attracted to the surface and can be used to control the deposition energy.

FIG. **2** shows a partial view of the system of FIG. **1** which has been adapted for practising another embodiment of the invention. A vaporizing source **62** and associated power source **60** are added to the configuration of FIG. **1.** Source **62** is located in chamber **20** near to substrate **22.** In practising this embodiment of the invention, the introduction of energy into the surface atoms of the vaporizing source is primarily to effect vaporization, with the energy to effect deposition on the substrate being primarily supplied by an energetic beam of gaseous ions. This can be accomplished by using an argon beam, for example, generated from the plasma source in conjunction with a source of atoms to be deposited and located in chamber **20.** Thus, an energetic beam of gaseous ions, such as argon or another inert gas, coimpinge on the substrate surface with atoms from source **62.** Within one or two collisions the high kinetic energy of the argon ion beam is transferred to the lower energy neutral film atoms to be deposited on the substrate surface and gives them the necessary mobility so that they can nucleate and form an improved film. For example, with the embodiment of FIG. **2** one could deposit silicon films on a substrate by means of thermal vaporization of silicon from source **62,** concurrently with impingement on the surface of a high energy argon beam, for example. This beam should provide the necessary kinetic energy to transfer to the silicon atoms by means of argon-silicon collisions on the surface.

Source **62** is shown schematically but can be any one of various types of sources of atoms. For example, source **62** may be a sputtering source, a crucible-type vaporization source or even a resistively heated ribbon.

There are other ways that a deposition material can be introduced into the source plasma. One is by sputtering of material from the electrodes **14** and **15** of FIG. **1.** Thus, a silicon electrode would be used for the deposition of silicon films, while a carbon electrode would be used for the deposition of carbon films. Metallic electrodes, of course, can be used for the deposition of metallic films. An alternatively way of introducing the deposition material into the plasma at a much faster rate is by the introduction of the deposition material in the vapor or gaseous form or as a component of a gaseous additive material and the subsequent decomposition of the gaseous additive material into the appropriate ions by means of the energy of the plasma. This is a form of plasma pyrolysis. The use of a hydrocarbon gas, for example, in chamber **10** can permit the deposition of carbon films on the substrate since the ions exiting from the ion source will consist of carbon ions and of hydrogen ions. The hydrogen ions incident on the substrate will help to remove residual oxygen ions that may be on the substrate and thus, enhance the subsequent deposition of the carbon ions.

The use of this ion beam deposition technique has shown, for example, that insulating films of carbon can be deposited with material properties very similar to that of carbon in the diamond form. The observed points of similarity between the ion beam deposited carbon form and a diamond-like material consists of the following: 1) high index of refraction, 2) high electrical resistivity, 3) transparency in the visible range, 4) high di-electric constant, 5) ability to scratch glass. These insulating carbon films also show a high resistance to hydrofluoric acid etching. One advantage of insulating carbon films is that such films are quite resistant to sodium ion diffusion through these films which occurs at elevated temperatures. This is in agreement with what would be expected for a densely packed diamond-like carbon structure which has densely packed grain boundaries and resists the motion of relatively large alkali ions. Stable insulating and semiconductor carbon films can therefore be produced by this technique and it is expected that the techniques of the invention will find widespread use in the semi-conductor field.

Mixtures of gases or vapors can also be used to deposit various film compounds. For example, tungsten and carbon mixtures or compounds thereof can be deposited in the tungsten carbide form by using either tungsten and carbon electrodes or, for more rapid deposition by introducing a tungsten compound in the gaseous form and a hydrocarbon compound in the gaseous form into the plasma ion source region.

Apparatus similar to that shown in FIg. **1** can be used to deposit a carbon-diamond film. The electrodes **14** and **15** may be made of carbon, and the mixture gas may be methane for example (a hydro-carbon gas). The carbon ions are introduced into a plasma from ion source **10** by sputtering from the electrodes themselves or from the gas.

By means of the acceleration potential applied to the substrate, it is possible to have the ions come in with a moderately high kinetic energy (about 100 electron volts for example). As a result of this large kinetic energy of the incident ions, these ions when they strike the deposition surface retain a very high surface mobility and can move about to nucleate into a single crystal structure. At the same time, the carbon atoms already on the deposition surface, in the process of scattering the incident ions themselves, will pick up kinetic energy and become mobile. Thus, the incident ion and the first few surface monolayers of the deposition surface are at a relatively high energy compared to that of the basic substrate. These surface atoms retain enough energy so that they can nucleate into a diamond-like single crystal structure.

Therefore, the apparatus of the present invention can be used to deposit various types of films or different substrates and does so by an ion beam technique, wherein the degree and uniformity of deposition are controlled. The apparatus can be also be implemented for use with a vapor source, which is uaually located in the deposition chamber. Such an arrangement has also been used to supplement the deposition from the ion beam. In other words a beam containing silicon ions could be used with a silicon vapor source. Another film so deposited was molybdenum.

Another feature of the invention is that relatively small layers of diamond-like carbon can be deposited. Usually for carbon to form into a diamond-like crystal-

lographic structure it is necessary that the carbon atoms be in a high temperature, high pressure, environment for a sufficiently long time so that the crystallization into a diamond form can occur. The technique used herein employs an energetic ion beam that does not require high pressures since only a small portion of the carbon is heated to a high temperature at one time.

Having described some of the features, objects and advantages of the invention, other modifications of and departures from the embodiments disclosed herein will become apparent to those skilled in the art of which are contemplated as falling within the spirit and scope of the invention and are to be limited solely by the appended claims.

What is claimed is:

1. A film deposition apparatus for depositing a film on a substrate comprising:

a. a deposition chamber having means for containing the substrate;

b. a source of deposition atoms to be deposited on the substrate, said source of atoms being located within said deposition chamber;

c. glow discharge ion source means for producing an energetic beam of gaseous ions, which may be of the same material to be deposited;

d. means disposed between said ion source and said deposition chamber for producing a pressure differential between the ion source and the deposition chamber; and,

e. means for directing said energetic beam of ions from the ion source to impinge upon the substrate, further wherein said energetic beam of ions and said source of deposition atoms are positioned with respect to each other and with respect to the substrate to provide for concurrent impingement of said ions and said atoms upon the substrate.

2. A film deposition apparatus as set forth in claim **1** wherein said source of ions includes ions of an inert gas.

3. A film deposition apparatus as set forth in claim **2** wherein said inert gas includes argon.

4. A film deposition apparatus as set forth in claim **1** wherein said source of deposition atoms includes silicon atoms.

5. Film deposition apparatus for depositing a film on a substrate comprising:

a. a deposition chamber having means for containing a base substrate;

b. a second chamber and means for maintaining at least one gas within said second chamber;

c. at least two spaced electrodes positioned within said second chamber with at least one of said electrodes being at least partly formed of the material which is to be deposited;

d. means for establishing a sufficient electrical potential between said spaced electrodes to cause a glow discharge therebetween which releases atoms of the material which is to be deposited from said electrode at least partly formed of said material and ionizes said released deposition material atoms to form ions thereof;

e. means disposed between said second chamber and said deposition chamber for producing a pressure differential between said second chamber and said deposition chamber;

f. extraction electrode means positioned within said deposition chamber for extracting the ions from said second chamber into said deposition chamber and through an aperture in the extraction electrode means;

g. accelerating means for causing at least some of said extracted ions to impinge upon said substrate thereby depositing a film on the substrate; and,

h. means for establishing an axial magnetic field between said second chamber and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture.

6. The apparatus of claim **5** further characterized by means for applying an electrical potential between at least one of said electrodes and the base substrate contained within said base substrate containing means.

7. The apparatus of claim **5** wherein said means for producing a pressure differential includes means for maintaining said second chamber at a higher pressure than said deposition chamber.

8. The apparatus of claim **5** wherein said ions are carbon ions and said film is a film of carbon having diamond-like characteristics.

9. The apparatus of claim **5** wherein said ions are carbon ions and said film is a carbon film having a high index of refraction, high electrical resistivity, transparency in the visual range, a high dielectric constant and the ability to scratch glass.

10. The apparatus of claim **5** wherein said means for producing a pressure differential comprises constrictor electrode means directly separating said second chamber from said deposition chamber and having an aperture disposed therein through which said ions flow from said second chamber into said deposition chamber.

11. An apparatus for depositing a relatively thin film upon a base substrate material comprising:

a. a source of energetic ions, at least some of said ions being of a normally solid deposition material;

b. a deposition chamber having means for containing a base substrate;

c. constrictor electrode means positioned between said source of ions and said deposition chamber and having an aperture disposed therein through which said ions flow from said source of ions into said deposition chamber;

d. extraction electrode means positioned between said constrictor electrode means and said means for containing the base substrate and having an aperture therein through which said ions flow; and, means for establishing an axial magnetic field between said source of energetic ions and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture; and

e. means for applying an electrical potential between said source of energetic ions and the base substrate as contained within the deposition chamber wherein said electrical potential is an AC voltage.

12. An apparatus for depositing a relatively thin film upon a base substrate material comprising:

a. a source of energetic ions, at least some of said ions being of a normally solid deposition material;

b. a deposition chamber having means for containing a base substrate;

c. constrictor electrode means positioned between said source of ions and said deposition chamber and having an aperture disposed therein through which said ions flow from said source of ions into

said deposition chamber wherein said constrictor electrode means aperture is lined with a material which is the same as the deposition material; and,

d. extraction electrode means positioned between said constrictor electrode means and said means for containing the base substrate and having an aperture therein through which said ions flow; and, means for establishing an axial magnetic field between said source of energetic ions and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture.

13. An apparatus for depositing a relatively thin film upon a base substrate material comprising:

a. a source of energetic ions, at least some of said ions being of a normally solid deposition material;

b. a deposition chamber having means for containing a base substrate;

c. constrictor electrode means positioned between said source of ions and said deposition chamber and having an aperture disposed therein through which said ions flow from said source of ions into said deposition chamber; and,

d. extraction electrode means positioned between said constrictor electrode means and said means for containing the base substrate and having an aperture therein through which said ions flow wherein said extraction electrode means aperture is lined with a material which is the same as the deposition material; and, means for establishing an axial magnetic field between said source of energetic ions and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture.

14. An apparatus for depositing a relatively thin film upon a base substrate material comprising:

a. a source of energetic ions, at least some of said ions being of a normally solid deposition material;

b. a deposition chamber having means for containing a base substrate;

c. constrictor electrode means positioned between said source of ions and said deposition chamber and having an aperture disposed therein through which said ions flow from said source of ions into said deposition chamber wherein said constrictor electrode means aperture is lined with a material which, is the same as the deposition material; and,

d. an extraction electrode means positioned between said constrictor electrode means and said means for containing the base substrate and having an aperture therein through which said ions flow wherein said extraction electrode means aperture is lined with a material which is the same as the deposition material; and, means for establishing an axial magnetic field between said source of energetic ions and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture.

15. Film deposition apparatus for depositing a film on a substrate comprising:

a. a deposition chamber having means for containing a base substrate;

b. a second chamber and means for maintaining at least one gas within said second chamber;

c. at least two spaced electrodes positioned within said second chamber with at least one of said electrodes being at least partly formed of the material which is to be deposited;

d. means for establishing a sufficient electrical potential between said spaced electrodes to cause a glow discharge therebetween which releases atoms of the material which is to be deposited from said electrode at least partly formed of said material and ionizes said released deposition material atoms to form ions thereof;

e. means disposed between said second chamber and said deposition chamber for producing a pressure differential between said second chamber and said deposition chamber;

f. extraction electrode means for extracting the ions from said second chamber into said deposition chamber through an aperture in the extraction electrode means wherein said extraction electrode means aperture is lined with a material which is the same as the material which is to be deposited;

g. accelerating means for causing at least some of said extracted ions to impinge upon said substrate thereby depositing a film on the substrate; and,

h. means for establishing an axial magnetic field between said second chamber and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture.

16. Film deposition apparatus for depositing a film on a substrate comprising:

a. a deposition chamber having means for containing a base substrate;

b. a second chamber and means for maintaining at least one gas within said second chamber;

c. at least two spaced electrodes positioned within said second chamber with at least one of said electrodes being at least partly formed of the material which is to be deposited,

d. means for establishing a sufficient electrical potential between said spaced electrodes to cause a glow discharge therebetween which releases atoms of the material which is to be deposited from said electrode at least partly formed of said material and which ionizes said released deposition material atoms to form ions thereof;

e. means for producing a pressure differential between said second chamber and said deposition chamber comprising constrictor electrode means positioned between said second chamber and said deposition chamber and having an aperture disposed therein through which said ions flow from said second chamber into said deposition chamber, said constrictor means aperture being lined with a material which is the same as the material which is to be deposited;

f. extraction electrode means for extracting the ions from said second chamber into said deposition chamber through an aperture in the extraction electrode means;

g. accelerating means for causing at least some of said extracted ions to impinge upon said substrate thereby depositing a film on the substrate; and,

h. means for establishing an axial magnetic field between said second chamber and said deposition chamber with the axis of the magnetic field being

substantially parallel to the axis of said extraction electrode means aperture.

17. Film deposition apparatus for depositing a film on a substrate comprising:

a. a deposition chamber having means for containing a base substrate;

b. a second chamber and means for maintaining at least one gas within said second chamber;

c. at least two spaced electrodes positioned within said second chamber with at least one of said electrodes being at least partly formed of the material which is to be deposited;

d. means for establishing a sufficient electrical potential between said spaced electrodes to cause a glow discharge therebetween which releases atoms of the material which is to be deposited from said electrode at least partly formed of said material and which ionizes said released deposition material atoms to form ions thereof;

e. means for producing a pressure differential between said second chamber and said deposition chamber comprising constrictor electrode means positioned between said second chamber and said deposition chamber and having an aperture disposed therein through which said ions flow from said second chamber into said deposition chamber, said constrictor means aperture being lined with a material which is the same as the material which is to be deposited;

f. extraction electrode means for extracting the ions from said second chamber into said deposition chamber through an aperture in the extraction electrode means wherein said extraction electrode means aperture is lined with a material which is the same as the material which is to be deposited;

g. accelerating means for causing at least some of said extracted ions to impinge upon said substrate thereby depositing a film on the substrate; and,

h. means for establishing an axial magnetic field between said second chamber and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture.

18. Film deposition apparatus for depositing a film on a substrate comprising:

a. a deposition chamber having means for containing a base substrate;

b. a second chamber and means for maintaining at least one gas within said second chamber;

c. at least two spaced electrodes positioned within said second chamber with at least one of said electrodes being at least partly formed of the material which is to be deposited;

d. means for establishing a sufficient electrical potential between said spaced electrodes to cause a glow discharge therebetween which releases atoms of the material which is to be deposited from said electrode at least partly formed of said material and ionizes said released deposition material atoms to form ions thereof;

e. means disposed between said second chamber and said deposition chamber for producing a pressure differential between said second chamber and said deposition chamber;

f. extraction electrode means for extracting the ions from said second chamber into said deposition chamber through an aperture in the extraction electrode means;

g. accelerating means for causing at least some of said extracted ions to impinge upon said substrate thereby depositing a film on the substrate;

h. means for establishing an axial magnetic field between said second chamber and said deposition chamber with the axis of the magnetic field being substantially parallel to the axis of said extraction electrode means aperture; and,

i. means for applying an electrical potential between at least one of said electrodes and the base substrate contained within said base substrate containing means, wherein said electrical potential is an AC voltage.

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