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(54) **PLASMA GENERATOR APPARATUS**

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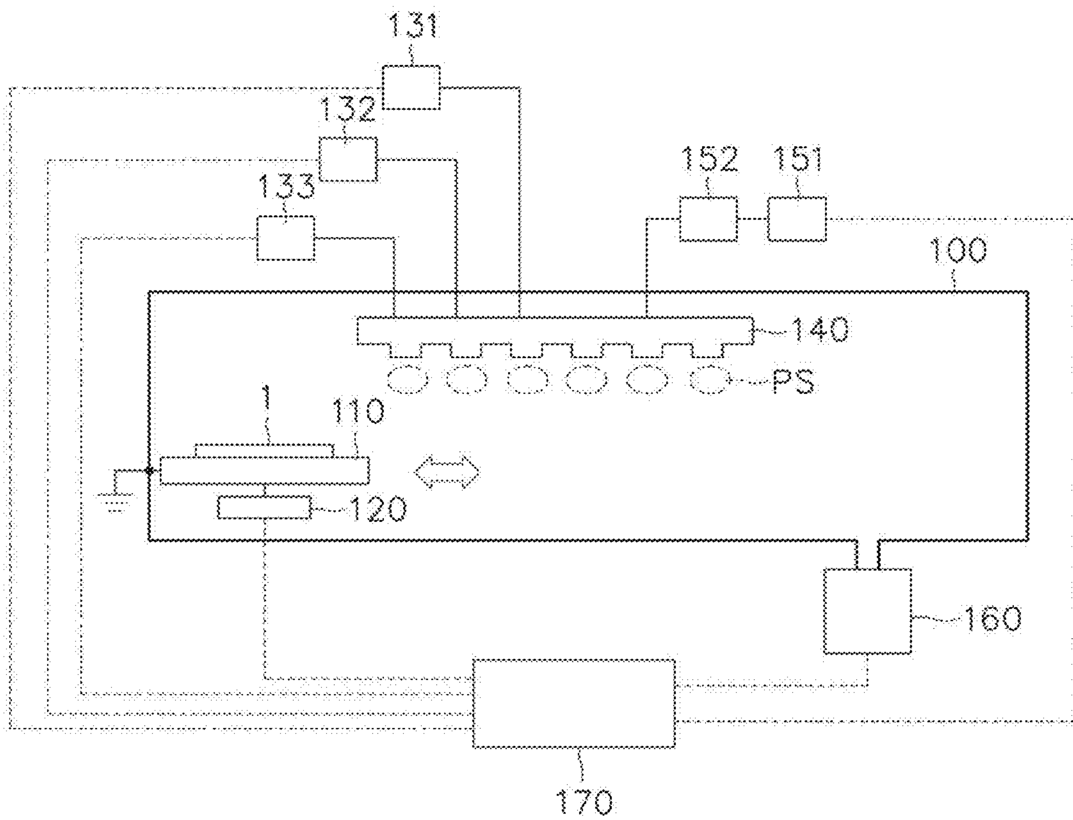
(57) **ABSTRACT**

Provided is a plasma generator apparatus for forming a thin film in local plasma atmosphere at a predetermined spatial period. The plasma generator apparatus includes an electrode body part **141**, a plurality of gas supply ports **142** which protrude from the electrode body part **141** at predetermined pitch intervals to direct the substrate and have nozzle holes h**1** electing the reaction gas, and a plurality of purge ports **143** which are dented with steps between the gas supply ports **142** and have exhaust holes h**2** exhausting the reaction gas.



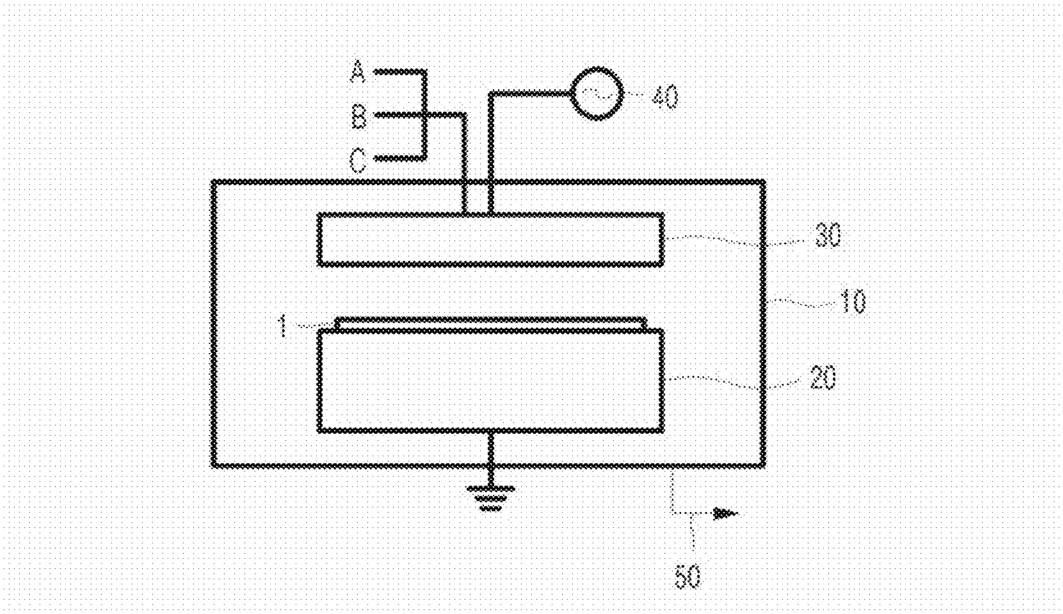

A
B
C
40
30
10
1
20
50

FIG. 1A

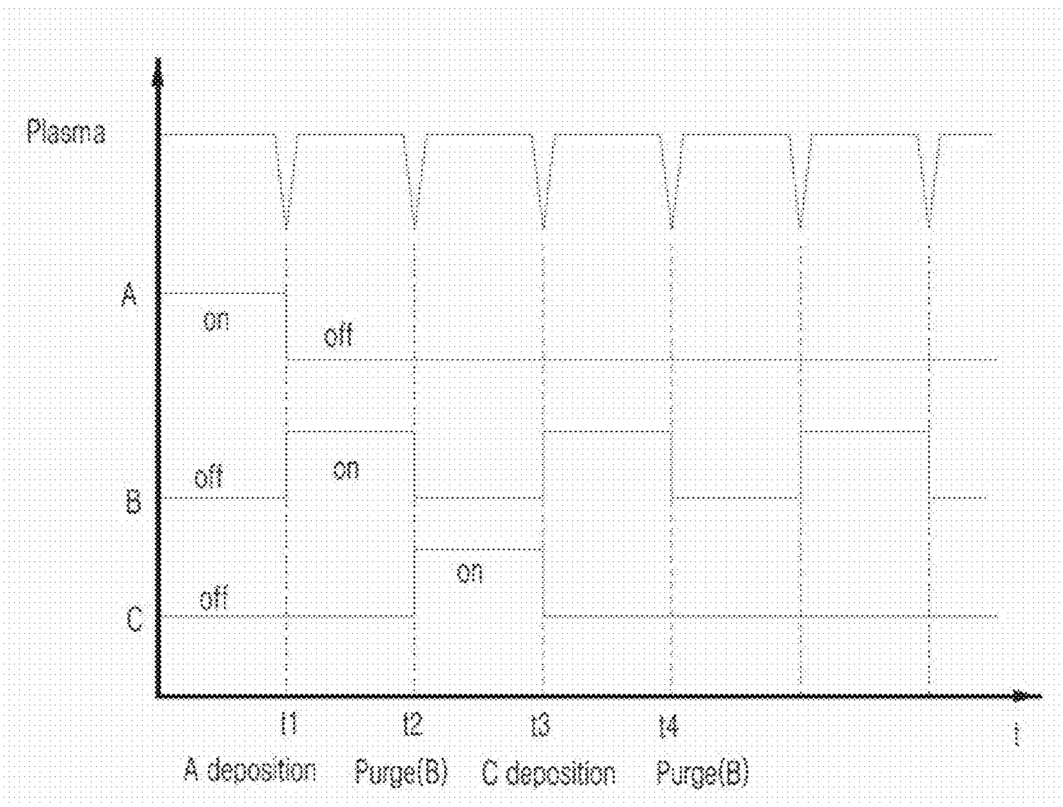

Plasma
A
on
off
B
off
on
C
off
on
t1
t2
t3
t4
t
A deposition
Purge(B)
C deposition
Purge(B)

FIG. 1B

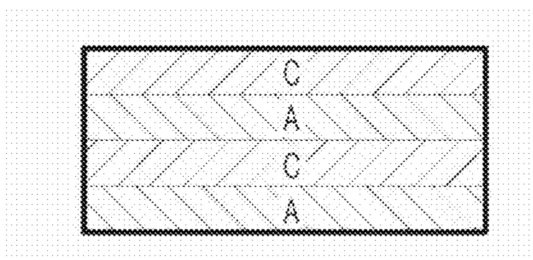


FIG. 1C

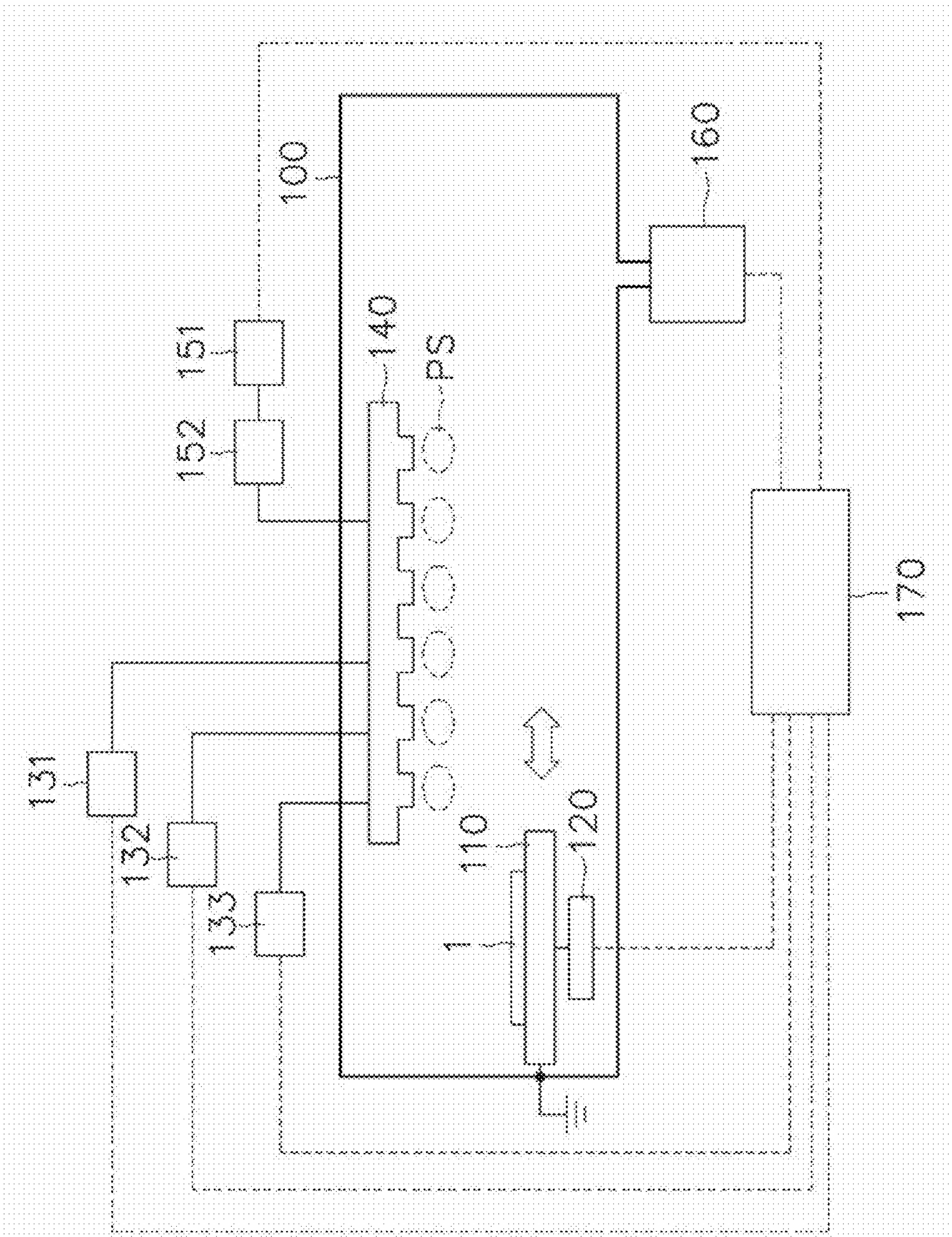


FIG. 2

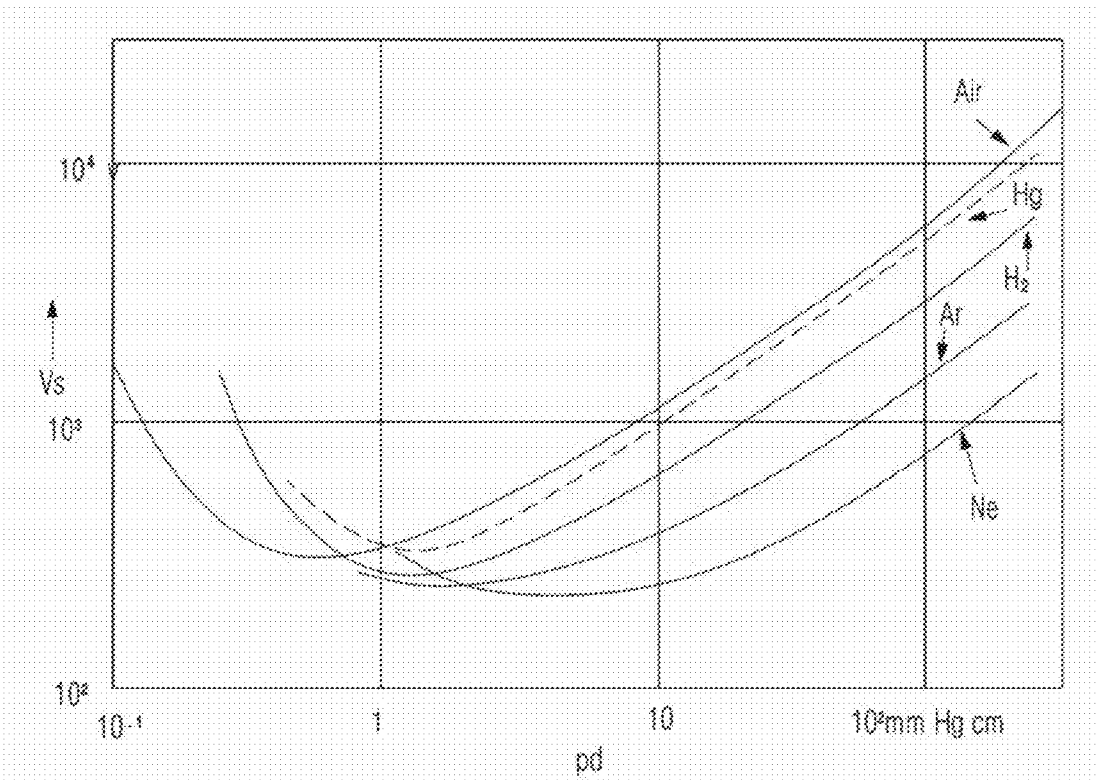


FIG. 3

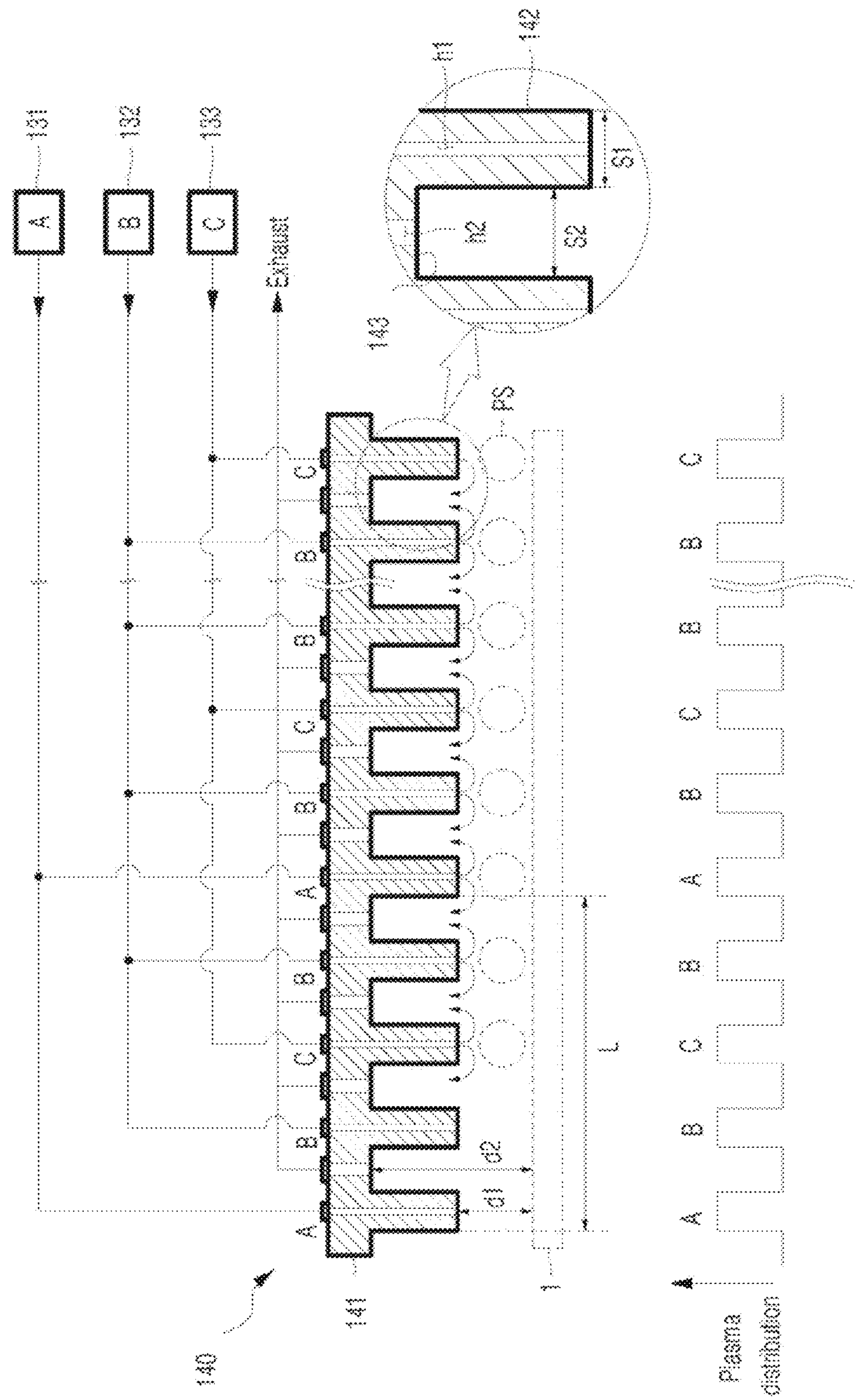

131
132
133
A
B
C
Exhaust
142
h1
h2
S1
S2
143
PS
140
141
1
d1
d2
L
Plasma distribution

FIG. 4

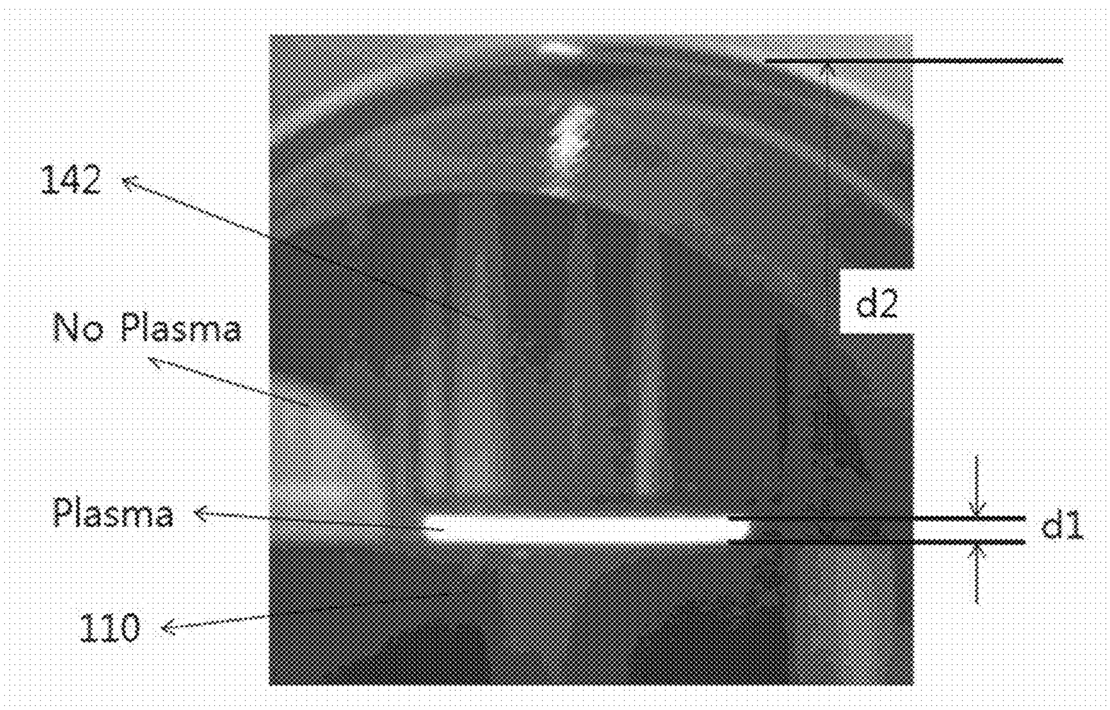


FIG. 5

PLASMA GENERATOR APPARATUS

RELATED APPLICATIONS

[0001] This application claims the priority of Korean Patent Application No. 10-2016-0076416 filed on Jun. 20, 2016, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a plasma generator apparatus, and a thin film deposition apparatus and an atomic layer deposition (ALD) apparatus using the plasma.

Description of the Related Art

[0003] Recently, in order to manufacture a flexible display, an organic light-emitting diode (OLED) has received much attention, a flexible substrate has been used in manufacturing of the flexible display, and polyethylene terephthalate (PET) has been mainly used as a flexible substrate material.

[0004] For deposit on the flexible substrate, the deposition needs to be made at a low temperature to prevent damage to an organic emission layer and generally, a recommended deposition temperature is within 100° C.

[0005] Particularly, one of the most important processes of the OLED process is an encapsulation (encap) process of laminating and forming an inorganic material, an organic material, and an inorganic material so as to delay oxygen and moisture to reach the organic emission layer, and a high-quality thin film deposition at a low temperature is required.

[0006] Recently, as a method for depositing a high-quality thin film at a low temperature, an atomic layer deposition (ALD) method has been frequently researched, and the ALD method is a method of depositing atoms sequentially layer by layer in atomic units and thus, the characteristics of the deposited thin film are excellent, but there is a disadvantage in that a deposition speed is low and mass productivity is deteriorated.

[0007] Recently, in order to overcome the low deposition speed of the ALD method, a plasma enhanced atomic layer deposition (PEALD) method using plasma has been proposed.

[0008] FIG. **1**A is a configuration diagram of a PEALD apparatus in the related art, and a substrate holder **20** is provided in a reaction chamber **10**, and a shower head **30** for injecting gas is provided at the inner top of the reaction chamber **10**. The shower head **30** is connected with an RF power generator **40** and the reaction chamber **10** and the substrate holder **20** are grounded. Reference numeral **50** represents a pumping port for exhausting the gas.

[0009] After a substrate **1** is loaded on the substrate holder **20**, reaction gas and purge gas are sequentially supplied into the reaction chamber **10** through the shower head **30**, and in this case, the plasma is formed between the shower head **30** and the substrate **1** by applying RF voltage to the shower head **30** through the RF power generator **40** to form a thin film on the substrate **1**.

[0010] FIG. **1**B is a graph illustrating a process of supplying gas for laminating an A/C thin film structure in the PEALD apparatus in the related art, and the process includes a gas supply step constituted by one period of four steps in which first reaction gas A is supplied for t**1**, purge gas B is supplied for t**2**, second reaction gas C is supplied for t**3**, and purge gas B is supplied for t**4**. FIG. **1**C is a cross-sectional configuration diagram illustrating the thin film structure manufactured by the process.

[0011] In the PEALD method, because the deposition of the thin film is made by sequential supply of the gases A, B, and C, a pumping speed of the gases is very important, and in the gas supply process, because the on/off of the gases are sequentially repeated, instability of the plasma occurs. Further, the thin film deposition is made by sequentially injecting a plurality of reaction gases and thus there is a problem in that a lot of deposition process time is required.

SUMMARY OF THE INVENTION

[0012] In order to solve the above-mentioned problems, an aspect of the present invention provides a plasma generator apparatus and an atomic layer deposition apparatus having advantages of providing a stable plasma atmosphere and improving a process speed through continuous film deposition.

[0013] According to an aspect of the present invention, there is provided a plasma generator apparatus for forming a thin film in a local plasma atmosphere at a predetermined spatial period including: a electrode body part; a plurality of gas supply ports which protrude from the electrode body part at predetermined pitch intervals to face the substrate and have nozzle holes ejecting reaction gas; and a plurality of purge ports which are dented with steps between the gas supply ports and have exhaust holes exhausting reaction byproducts.

[0014] Preferably, two kinds or more of reaction gases and purge gases may be supplied at a predetermined spatial period to correspond to the plurality of gas supply ports, respectively.

[0015] Preferably, a distance d**1** (cm) between the electrode body part and the substrate and process pressure p (Torr) may be $0<p\cdot d1\leq 300$ Torr-cm, and more preferably, a range of the process pressure p (Torr) may be $0<p\leq 1000$ Torr.

[0016] Preferably, a depth d**2**−d**1** of the purge port with respect to the electrode body part may be 10 times greater than the distance d**1** between the electrode body part and the substrate.

[0017] According to another aspect of the present invention, there is provided an atomic layer deposition apparatus including: a reaction chamber; a transfer unit for transferring horizontally a substrate in the reaction chamber; and a plasma generating unit for supplying reaction gas to the top of the substrate in a local plasma atmosphere at a predetermined spatial period on the substrate transferred by the transfer unit.

[0018] According to the exemplary embodiment of the present invention, in the plasma generator apparatus, the thin-film deposition is possible by injecting reaction gas and purge gas to the substrate in a local plasma atmosphere at a predetermined spatial period. Accordingly, the injection of different reaction gases is sequentially turned on/off, and as a result, the deposition may be made in a stable plasma state without the need of the injection. Particularly, in the local plasma atmosphere, while the plurality of reaction gases are injected with the purge gas, the thin-film deposition is possible, and as a result, as compared with a PEALD method in the related art, a deposition speed can be significantly increased.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The above and other aspects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0020] FIG. **1**A is a configuration diagram of a PEALD apparatus in the related art;

[0021] FIGS. **1**B and **1**C are graphs illustrating a process of supplying gas and a cross-sectional configuration diagram of a manufactured thin film structure in the PEALD apparatus in the related art, respectively;

[0022] FIG. **2** is a configuration diagram of an atomic layer deposition (ALD) apparatus according to an exemplary embodiment of the present invention;

[0023] FIG. **3** is a graph illustrating Pashcen's curves for each reaction gas;

[0024] FIG. **4** is a cross-sectional configuration diagram of a plasma generating unit in the ALD apparatus of the present invention; and

[0025] FIG. **5** is a photograph obtained by capturing plasma generated locally in the plasma generating unit in the ALD apparatus of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0026] Specific structural or functional descriptions presented in exemplary embodiments of the present invention are made only for the purposes of describing the exemplary embodiments according the concept of the present invention and the exemplary embodiments according the concept of the present invention may be carried out in various forms. Further, it should not be interpreted that the exemplary embodiments are limited to the exemplary embodiments described in the present specification and it should be understood that the present invention covers all the modifications, equivalents and replacements within the idea and technical scope of the present invention.

[0027] Meanwhile, terms such as first and/or second, and the like may be used for describing various components, but the components are not limited by the terms. The terms may be used only for distinguishing one component from other components, for example, a first component may be referred to as a second component, and similarly, a second component may be referred to as a first component within the scope without departing from the claims according to the concept of the present invention.

[0028] It should be understood that, when it is described that a component is "connected to" or "accesses" another component, the component may be directly connected to or access the other component or a third component may be present therebetween. In contrast, it should be understood that, when it is described that an element is "directly connected to" or "directly contact" another element, it is understood that no element is present between the element and another element. Meanwhile, other expressions for describing the relationship of the components, that is, "between" and "directly between" or "adjacent to" and "directly adjacent to" should be similarly analyzed.

[0029] Terms used in the present specification are used only to describe specific embodiments, and are not intended to limit the present invention. Singular expressions used herein include plural expressions unless they have definitely opposite meanings in the context. In the present specification, it should be understood that the term "include" or "have" indicates that a feature, a number, a step, an operation, a component, a part or the combination thereof which are implemented, but does not exclude a possibility of presence or addition of one or more other features, numbers, steps, operations, components, parts or combinations thereof, in advance.

[0030] Hereinafter, exemplary embodiments of the present invention will be described with reference to the accompanying drawings.

[0031] Referring to FIG. **2**, an atomic layer deposition apparatus includes a reaction chamber **100** in a vacuum state, and the reaction chamber **100** includes a substrate holder **110** on which a substrate for depositing a thin film is seated, a transfer unit **120** for transferring horizontally the substrate holder **110** and a plasma generating unit **140** which is connected with a plurality gas supply units **131**, **132**, and **133** to inject the gas and generates local plasma (PS) with a predetermined pitch.

[0032] The plasma generating unit **140** may be connected with a power supply unit **151** for supplying RF power and an impedance matching unit **152** for optimizing and transferring the RF power, and the power supply unit may be provided by DC power.

[0033] The gas supply units **131**, **132**, and **133** supply a precursor of a material to be deposited on the substrate **1** or purge gas, and the precursor may be solid, liquid or gas and may be transferred as the gas when transferred to the reaction chamber **100**, and in this case, carrier gas may be used. In the exemplary embodiment, the gas supply units **131**, **132**, and **133** may be configured by a first reaction gas supply unit **131** for supplying first reaction gas, a second reaction gas supply unit **133** for supplying second reaction gas, and a purge gas supply unit **132** for supplying purge gas.

[0034] Further, although not illustrated, the gas supply units **131**, **132**, and **133** and the plasma generating unit **140** may be added with well-known flow meters for controlling well-known. valves or flow rates that may control the flow of the gases.

[0035] The reaction chamber **100** may include a well-known vacuum pump **160** for maintaining the inside in a vacuum.

[0036] Reference numeral **170** represents a controller and the controller is connected with the transfer unit **120**, the gas supply units **131**, **132**, and **133**, and the vacuum pump **160** to perform a control for each driving.

[0037] Meanwhile, although not illustrated, a well-known temperature control means such as a heating lamp capable of controlling the temperature in the reaction chamber may be added, and the temperature control means may be controlled by the controller **170**.

[0038] Particularly, the present invention is characterized in that the plasma generating unit generates local plasma P with a predetermined pitch interval on the substrate **1** to perform deposition of the thin film by the reaction gas.

[0039] Generally, according to a Paschen's law, among plasma generating voltage Vb, pressure p in the chamber, and a distance d between electrodes, the following Equation is established [ref. Alfred Grill, Cold Plasma in Material Fabrication, IEEE Press, 1993, P(27)].

$$V_b = \frac{C_2(p \cdot d)}{[C_2 + \ln(p \cdot d)]};\quad \text{[Equation]}$$

[0040] C_1 and C_2 are constants determined by gas.

[0041] According to Equation, when a (p·d) value is too large, V_b is increased and thus it is difficult to maintain the plasma, and meanwhile, even when the (p·d) value is too small, V_b is increased and thus it is difficult to generate and maintain the plasma.

[0042] FIG. **3** is a graph illustrating Pashcen's curves for each reaction gas, and it can be seen that at approximately 1 Torr (mmHg), DC voltage at about 100 V needs to be applied to an electrode at an interval of 1 cm, and it can be seen that when the pressure is increased to 10 Torr at the same voltage, the interval for generating the plasma is 0.1 cm.

[0043] The present invention is characterized to include a plasma generating unit having a plasma generating space at a predetermined spatial period by an electrode structure constituted by a gas supply port and a purge port which have an unevenness structure at a constant pitch interval by using the Pashcen's law.

[0044] FIG. **4** is a cross-sectional configuration diagram of the plasma generating unit in the ALD apparatus of the present invention.

[0045] Specifically referring to FIG. **4**, the plasma generating unit **140** includes an electrode body part **141**, a plurality of gas supply ports **142** which protrude from the electrode body part **141** at predetermined pitch intervals to direct the substrate and have nozzle holes h**1** which elect the reaction gas, and a plurality of purge ports **143** which are dented with steps in the gas supply port **142** and have exhaust holes h**2** which exhaust the reaction gas.

[0046] The electrode body part **141** is connected with the power supply unit to supply the power and has a plurality of gas supply ports **142** and purge ports **143** which are formed on one surface facing the substrate **1** at predetermined pitch intervals.

[0047] The gas supply port **142** has a predetermined width S**1**, and is formed to protrude from the electrode body part **141** and formed so that the nozzle hole h**1** which ejects the reaction gas pass through the electrode body part **141** and in this case, a predetermined distance d**1** is provided between the electrode body part **141** and the substrate **1**.

[0048] The purge port **143** is dented with a predetermined width S**2** between the gas supply ports **142** and has an exhaust hole h**2** which exhausts the reaction gas, and in this case, a predetermined distance d**2**>d1 is provided between the purge port **143** and the substrate **1**. The exhaust hole h**2** of the purge port **143** may be connected with an external vacuum pump and exhausts reaction byproducts and the like in the reaction chamber **100** through the purge port **143**.

[0049] Preferably, at an Ar gas atmosphere, when the pressure in the reaction chamber is about 10 Torr, the distance between the electrode body part **141** and the substrate **1** is 0.1 mm<d**1**<100 mm and a distance d**2** between the purge port **143** and the substrate **1** is equal to or greater than 100 mm, and in this case, the voltage applied to the electrode body part **141** is 1000 V or less.

[0050] That is, a depth d**2**<d**1** of the purge port **143** with respect to the electrode body part **141** may be 10 times greater than the distance d**1** between the electrode body part **141** and the substrate **1**.

[0051] Preferably, in the present invention, the distance d**1** (cm) between the electrode body part **141** and the substrate **1** and process pressure p (Torr) are 0<p·d**1**≤300 Torr-cm, and more preferably, the range of the process pressure p (Torr) is 0<p≤1000 Torr.

[0052] Under such a condition, in the gas supply port **142**, the plasma PS is locally generated, while in the purge port **143**, the plasma is not generated. Accordingly, spatially periodic plasma may be generated on the substrate **1** at a predetermined pitch interval. FIG. **5** is a photograph obtained by capturing the plasma generated locally in the plasma generating unit in the ALD apparatus of the present invention.

[0053] Meanwhile, each gas supply port **142** is connected with the gas supply units **131**, **132**, and **133** to supply the reaction gas and the purge gas, and in the exemplary embodiment, the first reaction gas supply unit **131** supplying the first reaction gas A, the second reaction gas supply unit **133** supplying the second react on gas B, and the purge gas supply unit **132** supplying the purge gas B are exemplified.

[0054] In the following description, when the gas supply units need to be divided according to a type of gas supplied to each gas supply port **142**, the gas supply units are written with 'A', 'B', and 'C' at the ends of the reference numerals and referred to as 'a first reaction gas supply unit **142**A', 'a purge gas supply port **142**B' and 'a second reaction gas supply port **143**C'.

[0055] In the plasma generating unit **140**, the first reaction gas supply unit **142**A, the purge gas supply port **142**B, the second reaction gas supply port **143**C, and the purge gas supply port **142**B sequentially disposed from the gas supply port positioned at the leftmost side of the electrode body part **141** is configured as one unit module having a predetermined length L and the unit modules may be repeatedly configured.

[0056] In the plasma generating unit **140** configured as such, when the substrate **1** is transferred at a predetermined speed in the horizontal direction in the state where the power is supplied from the power supply unit and the first reaction gas A, the purge gas B, and the second reaction gas C are supplied through the gas supply ports **142**A, **142***b*, and **142**C, respectively, the deposition is made on the top of the substrate **1** by the corresponding reaction gas and the purge gas sequentially while passing through the respective gas supply ports **142**A, **142***b*, and **142**C, and as a result, an AC thin film structure may be acquired.

[0057] For example, as an example of thin-film deposition, in the case of Al_2O_3 thin-film deposition generally adopting an encapsulation material during a solar cell manufacturing process or an OLED manufacturing process, the first reaction gas A may be trimethylaluminum (TMA) gas and the second reaction gas C may be N_2O gas or O_2 gas. As the purge gas B, inert gas such as Ar or He may be used.

[0058] Meanwhile, as another example, the plasma generating unit **140** periodically reciprocates on the substrate **1** at a distance corresponding to a length L of one period (A-B-C) of the deposition, and as a result, the AC thin film structure may be similarly acquired.

[0059] The aforementioned present invention is not limited to the aforementioned exemplary embodiments and the accompanying drawings, and it will be obvious to those skilled in the technical field to which the present invention pertains that various substitutions, modifications, and changes may be made within the scope without departing from the technical spirit of the present invention.

What is claimed is:

1. A plasma generator apparatus for forming a thin film in a local plasma atmosphere at a predetermined spatial period, the plasma generator apparatus comprising:

a electrode body part;

a plurality of gas supply ports which protrude from the electrode body part at predetermined pitch intervals to face the substrate and have nozzle holes electing reaction gas; and

a plurality of purge ports which are dented with steps between the gas supply ports and have exhaust holes exhausting reaction byproducts.

2. The plasma generator apparatus of claim **1**, wherein two kinds or more of reaction gases and purge gases are supplied at a predetermined spatial period to correspond to the plurality of gas supply ports, respectively.

3. The plasma generator apparatus of claim **1**, wherein a distance d**1** (cm) between the electrode body part and the substrate and process pressure p (Torr) are $0<p \cdot d1 \leq 300$ Torr-cm.

4. The plasma generator apparatus of claim **3**, wherein a range of the process pressure p (Torr) is $0<p\leq 1000$ Torr.

5. The plasma generator apparatus of claim **1**, wherein a depth d**2**−d**1** of the purge port with respect to the electrode body part is 10 times greater than the distance d**1** between the electrode body part and the substrate.

6. An atomic layer deposition apparatus, comprising:

a reaction chamber;

a transfer unit for horizontally transferring a substrate in the reaction chamber; and

a plasma generating unit for supplying reaction gas to the top of the substrate in a local plasma atmosphere at a predetermined spatial period on the substrate transferred by the transfer unit.

7. The atomic layer deposition apparatus of claim **6**, wherein the plasma generating unit includes a electrode body part, a plurality of gas supply ports which protrude from the electrode body part at predetermined pitch intervals to face the substrate and have nozzle holes ejecting reaction gas, and a plurality of purge ports which are dented with steps between the gas supply ports and have exhaust holes exhausting reaction byproducts.

8. The atomic layer deposition apparatus of claim **7**, wherein two kinds or more of gas supply units are connected to the plasma generating unit and supply the reaction gas at a predetermined spatial period to correspond to the plurality of gas supply ports, respectively.

9. The atomic layer deposition apparatus of claim **8**, wherein a depth d**2**−d**1** of the purge port with respect to the electrode body part is 10 times greater than the distance d**1** between the electrode body part and the substrate.

* * * * *