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(54) **METHOD FOR PRODUCING THIN FILM, THIN FILM, AND SUBSTRATE PROCESSING APPARATUS**

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(57) **ABSTRACT**

The present inventive concept relates to: a method for producing a thin film, the method comprising a first forming step for forming a first thin film layer on a substrate by spraying a first source gas comprising a high dielectric constant (High-k) material, a second forming step for forming a second thin film layer on the substrate by spraying a second source gas comprising a high dielectric constant material, and a crystallization step for crystallizing at least one among the first thin film layer and the second thin film layer by using plasma; a thin film; and a substrate processing apparatus.

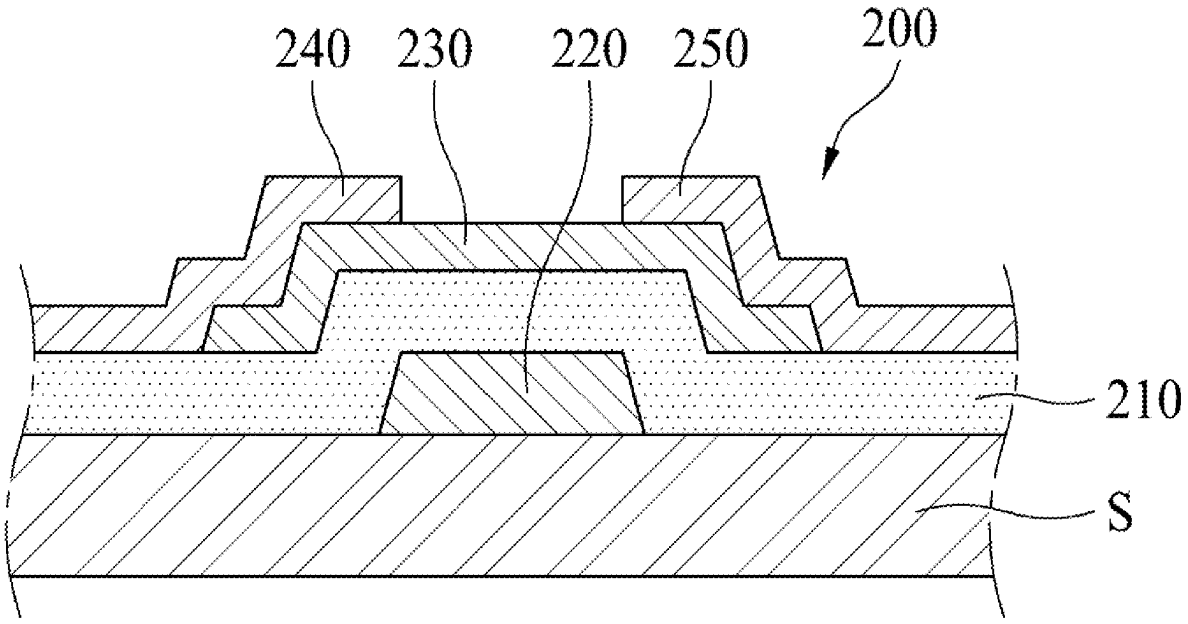


FIG. 1

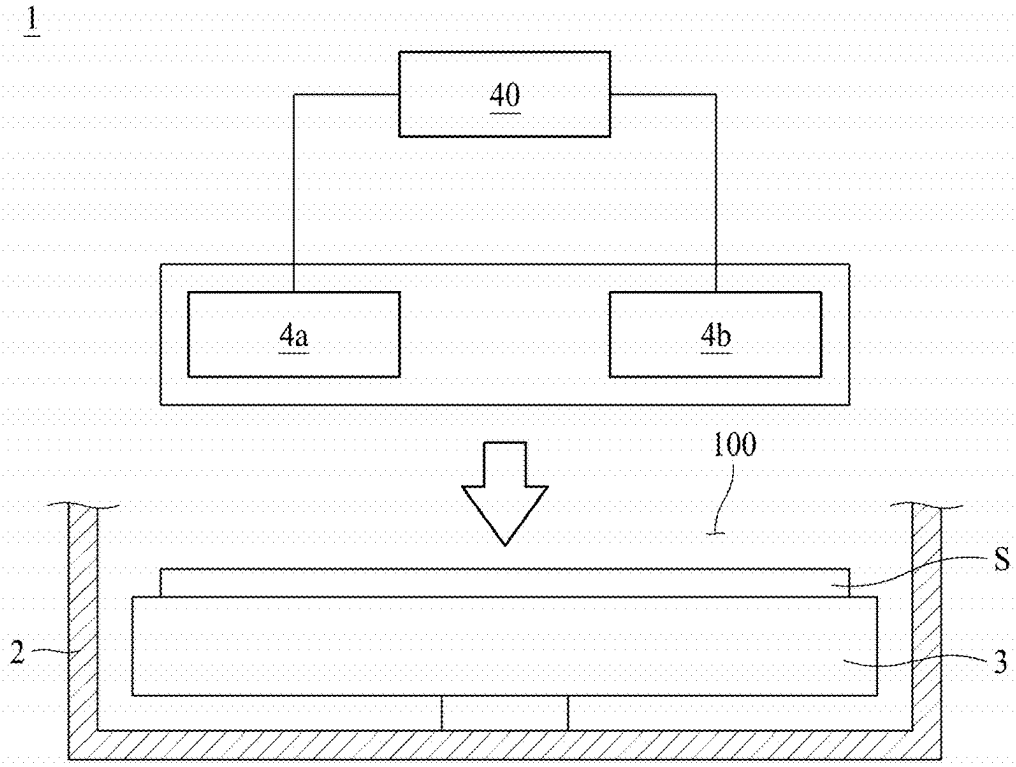


FIG. 2

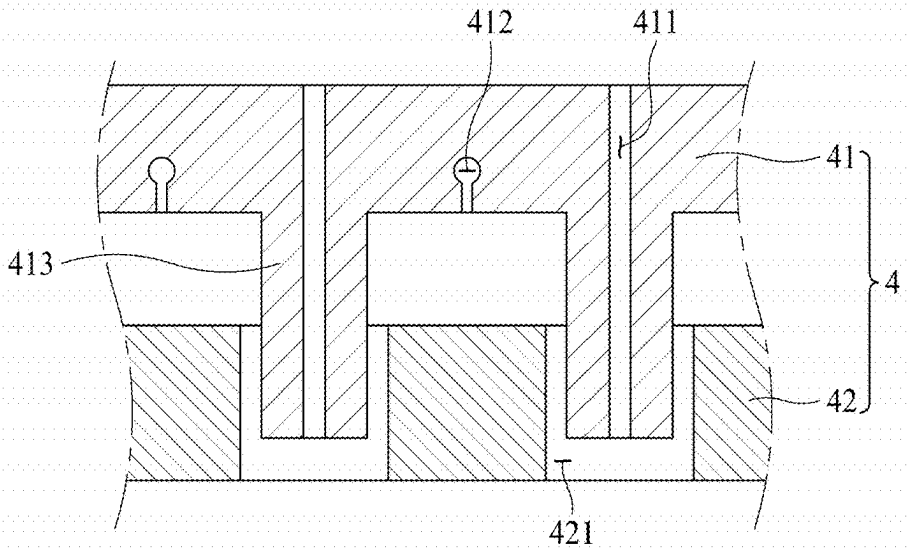


FIG. 3

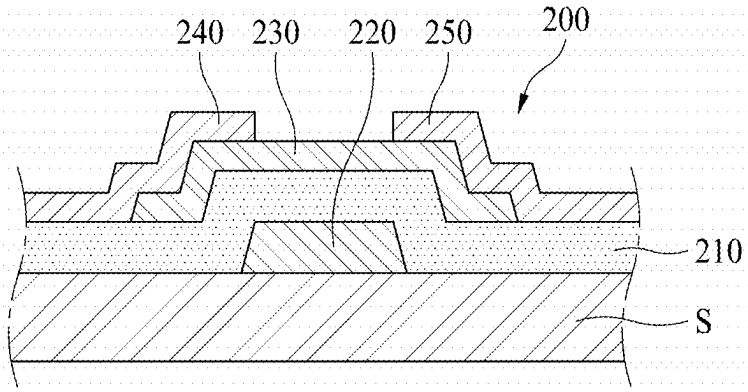


FIG. 4

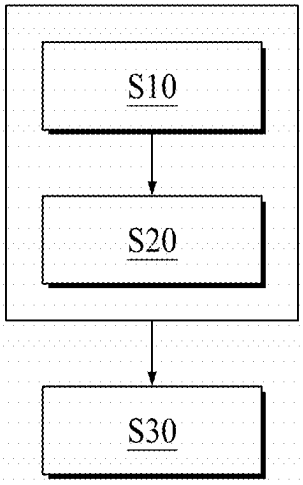


FIG. 5

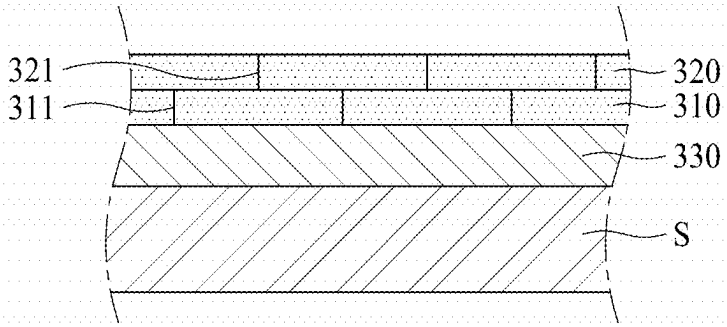


FIG. 6

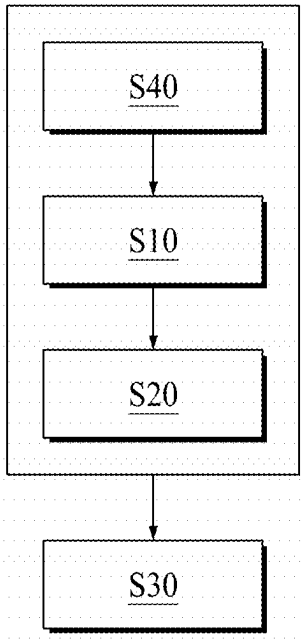


FIG. 7

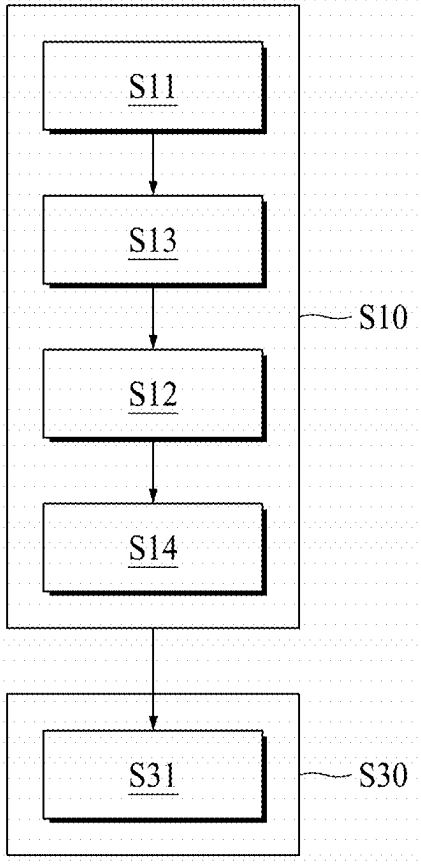


FIG. 8

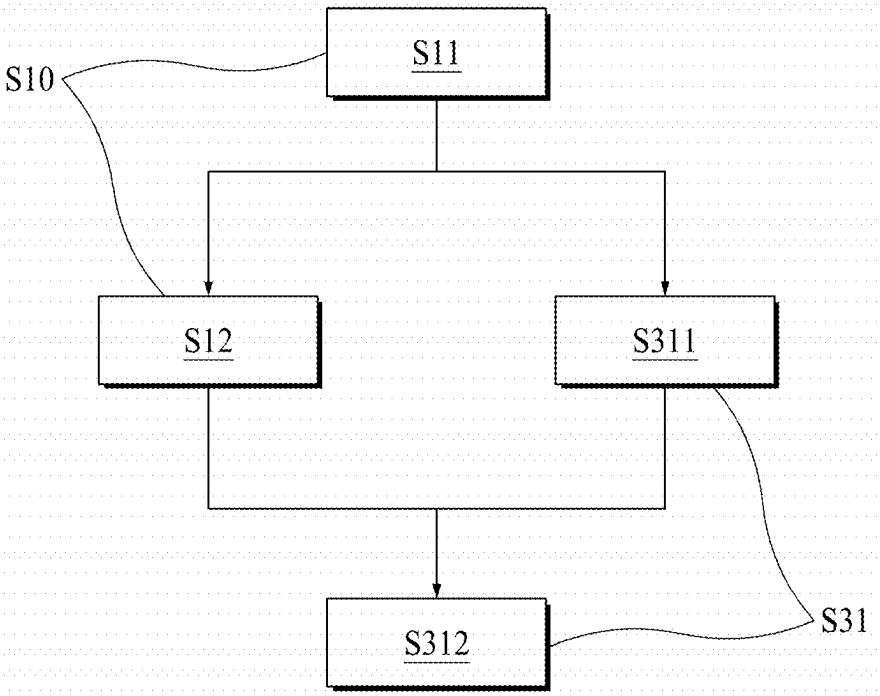


FIG. 9

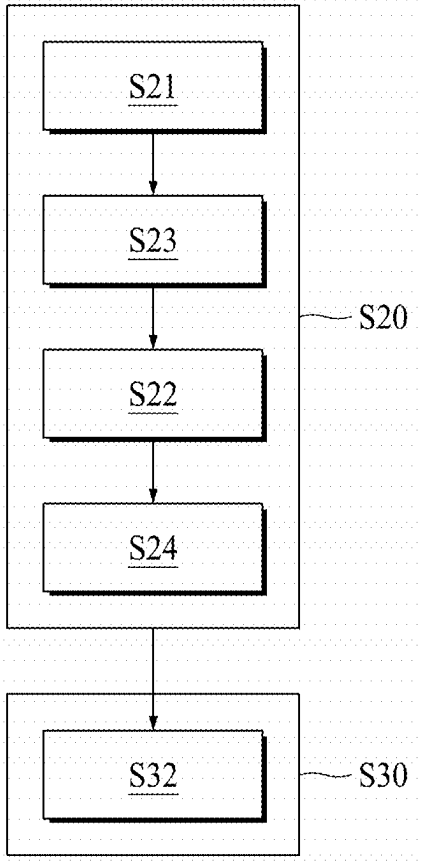


FIG. 10

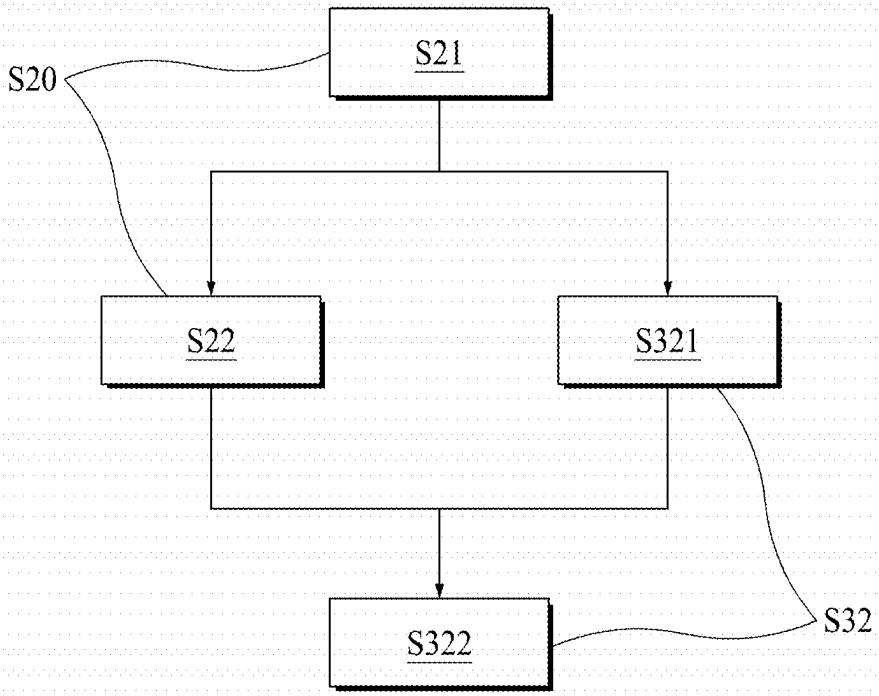


FIG. 11

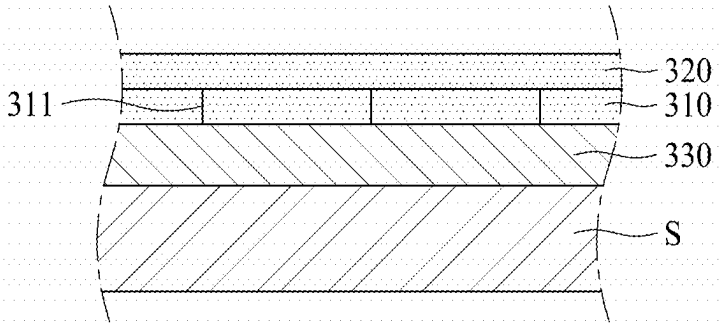


FIG. 12

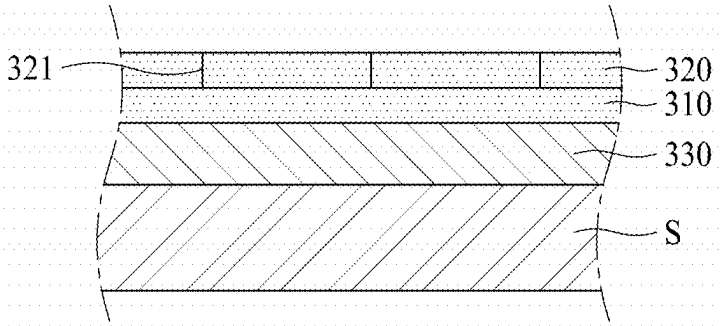


FIG. 13

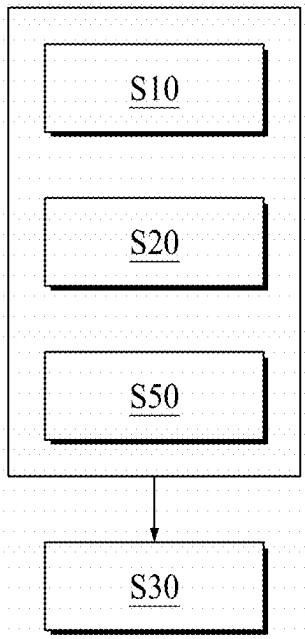


FIG. 14

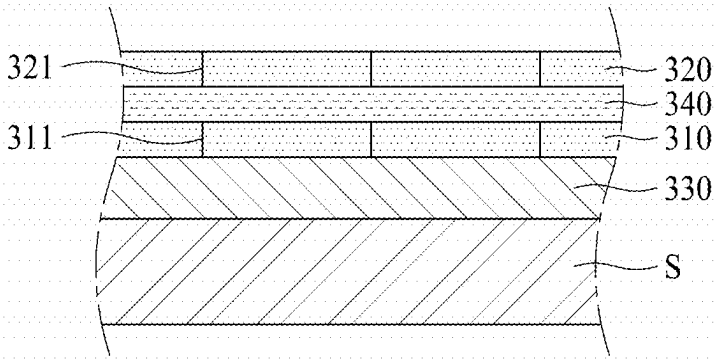
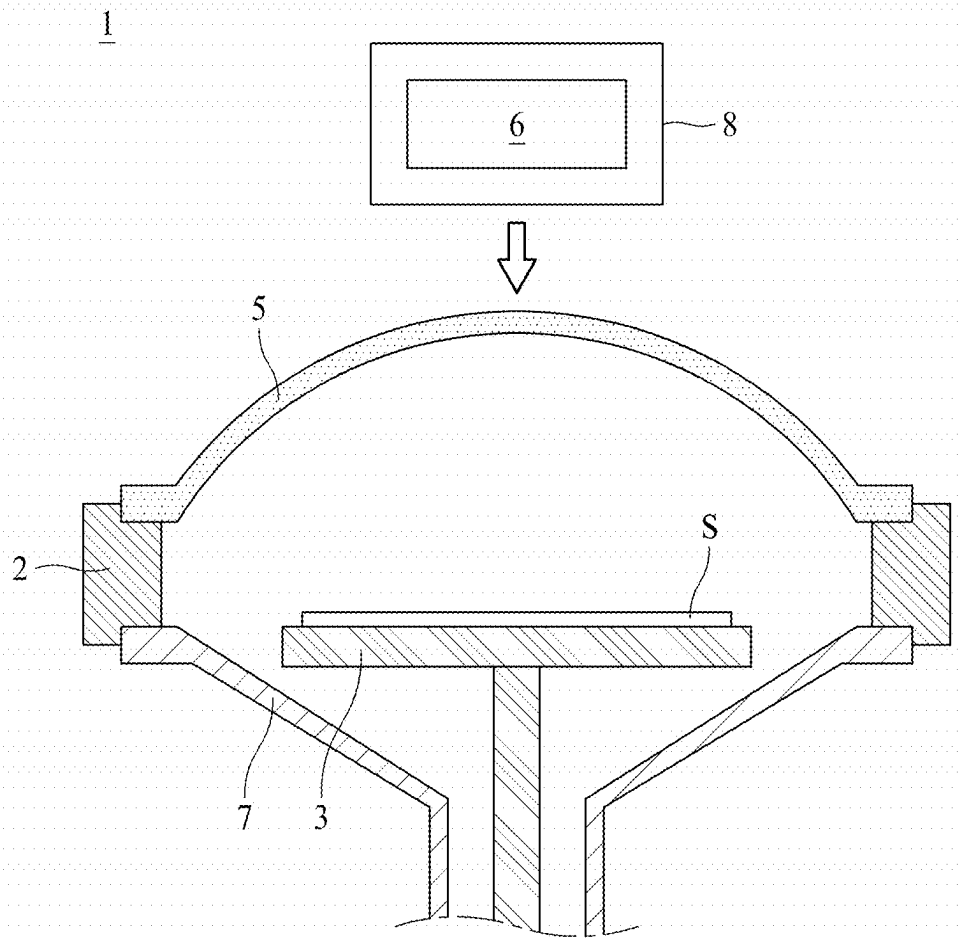


FIG. 15



METHOD FOR PRODUCING THIN FILM, THIN FILM, AND SUBSTRATE PROCESSING APPARATUS

TECHNICAL FIELD

[0001] The present inventive concept relates to a method of manufacturing a thin film on a substrate through a processing process such as a deposition process on the substrate, a thin film, and a substrate processing apparatus.

BACKGROUND ART

[0002] Generally, a thin film layer, a thin film circuit pattern, or an optical pattern should be formed on a substrate for manufacturing a semiconductor device, a display device, a solar cell, etc. To this end, a processing process is performed on a substrate, and examples of the processing process include a deposition process of depositing a thin film including a specific material on the substrate, a photo process of selectively exposing a portion of a thin film by using a photosensitive material, an etching process of removing the selectively exposed portion of the thin film to form a pattern, etc. Through such a processing process on a substrate, a thin film may be manufactured on the substrate.

[0003] Recently, a semiconductor device, a display device, and a solar cell have been more miniaturized and have also been developed to have a thinner thickness, and to this end, a thickness of a thin film should be thinned. However, in a thin film which is implemented as an insulation layer between a semiconductor layer and a gate layer in a thin film transistor (TFT), there is a problem where the leakage of a current occurs due to a tunneling phenomenon as a thickness of the thin film is thinned.

[0004] Therefore, it is required to develop a thin film for reducing the leakage of a current despite that a thickness of the thin film is implemented to be thin.

DISCLOSURE

Technical Problem

[0005] The present inventive concept is devised to solve the above-described problem and is for providing a method of manufacturing a thin film and a thin film, which may reduce the leakage of a current despite having a thin thickness.

Technical Solution

[0006] To accomplish the above-described objects, the present inventive concept may include the following elements.

[0007] A method of manufacturing a thin film, according to the present inventive concept, may include: a first formation step of injecting a first source gas including a high-k dielectric material to form a first thin film layer on a substrate; a second formation step of injecting a second source gas including a high-k dielectric material to form a second thin film layer on the substrate; and a crystallization step of crystallizing at least one of the first thin film layer and the second thin film layer by using plasma.

[0008] A thin film according to the present inventive concept may include: a first thin film layer formed on a substrate by using a high-k dielectric material and crystallized by plasma; and a second thin film layer formed on the substrate by using a high-k dielectric material.

[0009] A substrate processing apparatus according to the present inventive concept may include: a chamber; a substrate supporting unit supporting a substrate in the chamber; an upper dome provided on an upper surface of the chamber; and an antenna disposed over the upper dome to generate inductively-coupled plasma, wherein the upper dome may be formed of ceramic.

Advantageous Effect

[0010] According to the present inventive concept, the following effects may be realized.

[0011] The present inventive concept may be implemented so that all of a first thin film layer and a second thin film layer are formed of a high-k dielectric material and at least one of the first thin film layer and the second thin film layer is crystallized, and thus, may more decrease the leakage of a current despite being formed to have a thinner thickness. Accordingly, the present inventive concept may manufacture a thin film transistor and the like, which are finer and have a thinner thickness, and may more decrease the leakage of a current, thereby contributing to more enhancing the performance of a thin film transistor and the like.

DESCRIPTION OF DRAWINGS

[0012] FIG. **1** is a schematic block diagram illustrating an embodiment of a substrate processing apparatus which performs a method of manufacturing a thin film according to the present inventive concept.

[0013] FIG. **2** is a schematic side cross-sectional view of an injection unit injecting a gas in an example of a substrate processing apparatus which performs a method of manufacturing a thin film according to the present inventive concept.

[0014] FIG. **3** is a schematic side cross-sectional view illustrating an example of a thin film transistor.

[0015] FIG. **4** is a schematic flowchart of a method of manufacturing a thin film according to the present inventive concept.

[0016] FIG. **5** is a schematic side cross-sectional view of a thin film manufactured through a method of manufacturing a thin film according to the present inventive concept.

[0017] FIG. **6** is a schematic flowchart of an embodiment including a removal step in a method of manufacturing a thin film according to the present inventive concept.

[0018] FIGS. **7** and **8** are schematic flowcharts of a first formation step and a first crystallization step in a method of manufacturing a thin film according to the present inventive concept.

[0019] FIGS. **9** and **10** are schematic flowcharts of a second formation step and a second crystallization step in a method of manufacturing a thin film according to the present inventive concept.

[0020] FIG. **11** is a schematic side cross-sectional view of an embodiment where only a first thin film layer is crystallized in a thin film manufactured through a method of manufacturing a thin film according to the present inventive concept.

[0021] FIG. **12** is a schematic side cross-sectional view of an embodiment where only a second thin film layer is crystallized in a thin film manufactured through a method of manufacturing a thin film according to the present inventive concept.

[0022] FIG. **13** is a schematic flowchart of an embodiment including a third formation step in a method of manufacturing a thin film according to the present inventive concept.

[0023] FIG. **14** is a schematic side cross-sectional view of an embodiment where a thin film manufactured through a method of manufacturing a thin film according to the present inventive concept includes a first thin film layer, a second thin film layer, and a third thin film layer.

[0024] FIG. **15** is a schematic block diagram illustrating another embodiment of a substrate processing apparatus which performs a method of manufacturing a thin film according to the present inventive concept.

MODE FOR INVENTIVE CONCEPT

[0025] Hereinafter, an embodiment of a method of manufacturing a thin film according to the present inventive concept will be described in detail with reference to the accompanying drawings. In describing an embodiment of the present inventive concept, when an arbitrary structure is described as being formed "on" or "under" another structure, this description should be construed as including a case, where a third structure is disposed between the structures, as well as a case where the structures contact each other.

[0026] Referring to FIGS. **1** to **4**, the method of manufacturing a thin film according to the present inventive concept performs a processing process on a substrate S to manufacture a thin film on the substrate S. The substrate S may be a silicon substrate, a glass substrate, a metal substrate, or the like.

[0027] The method of manufacturing a thin film according to the present inventive concept may be performed by a substrate processing apparatus **1**. Before describing an embodiment of the method of manufacturing a thin film according to the present inventive concept, the substrate processing apparatus **1** will be described below in detail.

[0028] Referring to FIGS. **1** and **2**, the substrate processing apparatus **1** may include a chamber **2**, a susceptor **3**, and an injection unit **4**.

[0029] The chamber **2** provides a processing space **100**. A process of performing a processing process on the substrate S to manufacture a thin film on the substrate S may be performed in the processing space **100**. The processing space **100** may be disposed in the chamber **2**. An exhaust port (not shown) which exhausts a gas from the processing space **100** may be coupled to the chamber **2**. The susceptor **3** and the injection unit **4** may be disposed in the chamber **2**.

[0030] The susceptor **3** supports the substrate S. The susceptor **3** may support one substrate S, or may support a plurality of substrates S. In a case where the plurality of substrates S are supported by the susceptor **3**, a process of performing a processing process on the plurality of substrates S at a time to manufacture a thin film on each of the substrates S may be performed. The susceptor **3** may be coupled to the chamber **2**. The susceptor **3** may be disposed in the chamber **2**.

[0031] The injection unit **4** injects a gas toward the susceptor **3**. The injection unit **4** may be connected with a gas storage unit **40**. In this case, the injection unit **4** may inject a gas, supplied from the gas storage unit **40**, toward the susceptor **3**. The injection unit **4** may be disposed in the chamber **2**. The injection unit **4** may be disposed to be opposite to the susceptor **3**. The injection unit **4** may be disposed over the susceptor **3**. The processing space **100** may be disposed between the injection unit **4** and the susceptor **3**. The injection unit **4** may be coupled to a lid (not shown). The lid may be coupled to the chamber **2** to cover an upper portion of the chamber **2**.

[0032] The injection unit **4** may include a first gas flow path **4***a* and a second gas flow path **4***b*.

[0033] The first gas flow path **4***a* is for injecting a first gas. One side of the first gas flow path **4***a* may be connected with the gas storage unit **40** through a pipe, a hose, or the like. The other side of the first gas flow path **4***a* may communicate with the processing space **100**. Accordingly, the first gas supplied from the gas storage unit **40** may flow along the first gas flow path **4***a*, and then, may be injected into the processing space **100** through the first gas flow path **4***a*. The first gas flow path **4***a* may function as a flow path for enabling the first gas to flow and may function as an injection port for injecting the first gas into the processing space **100**.

[0034] The second gas flow path **4***b* is for injecting a second gas. The second gas and the first gas may be different gases. For example, when the first gas is a source gas, the second gas may be a reactant gas. One side of the second gas flow path **4***b* may be connected with the gas storage unit **40** through a pipe, a hose, or the like. The other side of the second gas flow path **4***b* may communicate with the processing space **100**. Accordingly, the second gas supplied from the gas storage unit **40** may flow along the second gas flow path **4***b*, and then, may be injected into the processing space **100** through the second gas flow path **4***b*. The second gas flow path **4***b* may function as a flow path for enabling the second gas to flow and may function as an injection port for injecting the second gas into the processing space **100**.

[0035] The second gas flow path **4***b* and the first gas flow path **4***a* may be disposed to be spatially separated from each other. Therefore, the second gas supplied from the gas storage unit **40** to the second gas flow path **4***b* may be injected into the processing space **100** without passing through the first gas flow path **4***a*. The first gas supplied from the gas storage unit **40** to the second gas flow path **4***b* may be injected into the processing space **100** without passing through the second gas flow path **4***b*. The second gas flow path **4***b* and the first gas flow path **4***a* may inject a gas toward different portions of the processing space **100**.

[0036] For example, the injection unit **4** may include a first plate **41** and a second plate **42**.

[0037] The first plate **41** is disposed over the second plate **42**. The first plate **41** and the second plate **42** may be disposed apart from each other. A plurality of first gas holes **411** may be formed in the first plate **41**. Each of the first gas holes **411** may function as a path for enabling the first gas to flow. The first gas holes **411** may be included in the first gas flow path **4***a*. A plurality of second gas holes **412** may be formed in the second plate **42**. Each of the second gas holes **412** may function as a path for enabling the second gas to flow. The second gas holes **412** may be included in the second gas flow path **4***b*. A plurality of protrusion members **413** may be coupled to the first plate **41**. The protrusion members **413** may protrude toward the second plate **42** from a lower surface of the first plate **41**. Each of the first gas holes **411** may be formed to pass through the first plate **41** and the protrusion member **413**.

[0038] A plurality of openings **421** may be formed in the second plate **42**. The openings **421** may be formed to pass through the second plate **42**. The openings **421** may be disposed at position respectively corresponding to the pro-

trusion members **413**. Therefore, as illustrated in FIG. **2**, the protrusion members **413** may be formed by a length which enables the protrusion members **413** to be respectively inserted into the openings **421**. Although not shown, the protrusion members **413** may be formed by a length which enables the protrusion members **413** to be respectively disposed over the openings **421**. The protrusion members **413** may be formed by a length which protrudes downward from the second plate **42**. The second gas holes **412** may be disposed to inject a gas toward an upper surface of the second plate **42**.

[0039] The injection unit **4** may generate plasma by using the second plate **42** and the first plate **41**. In this case, a plasma power such as radio frequency (RF) power may be applied to the first plate **41**, and the second plate **42** may be grounded. The first plate **41** may be grounded, and the plasma power may be applied to the second plate **42**.

[0040] The method of manufacturing a thin film according to the present inventive concept may be performed by using the substrate processing apparatus **1**.

[0041] Referring to FIGS. **1** to **4**, as illustrated in FIG. **3**, the method of manufacturing a thin film according to the present inventive concept may manufacture a thin film implemented as an insulation layer **210** in a thin film transistor (TFT) **200**. The insulation layer **210** may be disposed between a gate electrode **220** and a semiconductor layer **230**. The gate electrode **220** may be formed on the substrate S. The semiconductor layer **230** may be formed on the insulation layer **210**. A source electrode **240** and a drain electrode **250** may be formed on the semiconductor layer **230**. When the thin film transistor **200** is manufactured to be more miniaturized and have a thinner thickness, the insulation layer **210** may be thinned, and the leakage of a current may occur due to a tunneling phenomenon as a thickness of the insulation layer **210** is thinned.

[0042] To decrease the leakage of a current, the method of manufacturing a thin film according to the present inventive concept is implemented to manufacture a thin film including a high-k dielectric material. Furthermore, the method of manufacturing a thin film according to the present inventive concept is implemented to manufacture a thin film by crystallizing a high-k dielectric material. Accordingly, the method of manufacturing a thin film according to the present inventive concept may manufacture a thin film for more reducing the leakage of a current, thereby contributing to manufacturing the thin film transistor **200** which is finer and has a thinner thickness.

[0043] To this end, the method of manufacturing a thin film according to the present inventive concept may include a first formation step S**10**, a second formation step S**20**, and a crystallization step S**30**.

[0044] Referring to FIGS. **1** to **5**, the first formation step S**10** injects a first source gas including a high-k dielectric material to form a first thin film layer **310** on the substrate S. In the first formation step S**10**, the first source gas may be injected through the first gas flow path **4***a* included in the injection unit **4**. The first source gas may include at least one of hafnium (Hf) and zirconium (Zr). All of hafnium and zirconium correspond to a high-k dielectric material. In a case where the first source gas includes all of hafnium and zirconium, a source gas including hafnium and a source gas including zirconium may be mixed with each other in a buffer tank disposed apart from the injection unit **4** to generate a mixed gas, and then, the mixed gas may be supplied to the injection unit **4** and may be injected into the processing space **100**. Therefore, the method of manufacturing a thin film according to the present inventive concept may manufacture a thin film where a step coverage is enhanced, and moreover, may manufacture a thin film where the uniformity of a composition is enhanced.

[0045] The first formation step S**10** may inject the first source gas to adsorb a high-k dielectric material included in the first source gas onto the substrate S, and then, may inject a first reactant gas to form the first thin film layer **310** on the substrate S. In this case, the first formation step S**10** may form the first thin film layer **310** on the substrate S by using an atomic layer deposition (ALD) process. The first reactant gas may react with the first source gas and may be injected through the second gas flow path **4***b* included in the injection unit **4**. For example, the first reactant gas may be ozone (**03**).

[0046] Referring to FIGS. **1** to **5**, the second formation step S**20** injects a second source gas including a high-k dielectric material to form a second thin film layer **320** on the substrate S. In the second formation step S**20**, the second source gas may be injected through the first gas flow path **4***a* included in the injection unit **4**. The second source gas may include at least one of hafnium and zirconium. The second formation step S**20** may inject the second source gas to adsorb a high-k dielectric material included in the second source gas onto the substrate S, and then, may inject a second reactant gas to form the second thin film layer **320** on the substrate S. In this case, the second formation step S**20** may form the second thin film layer **320** on the substrate S by using an atomic layer deposition (ALD) process. The second reactant gas may react with the second source gas and may be injected through the second gas flow path **4***b* included in the injection unit **4**. For example, the second reactant gas may be ozone (O_3). Furthermore, in FIG. **5**, the second thin film layer **320** is illustrated as being formed directly on the first thin film layer **310**, but is not limited thereto and another thin film layer may be disposed between the second thin film layer **320** and the first thin film layer **310**. Also, in FIG. **5**, the first thin film layer **310** is illustrated as being formed on a lower film **330** formed on the substrate S, but is not limited thereto and the first thin film layer **310** may be formed directly on the substrate S.

[0047] Referring to FIGS. **1** to **5**, the crystallization step S**30** crystallizes at least one of the first thin film layer **310** and the second thin film layer **320** by using plasma. Because a thin film is manufactured by crystallizing a high-k dielectric material by using plasma through the crystallization step S**30**, the method of manufacturing a thin film according to the present inventive concept may realize the following effects.

[0048] First, a comparative example, which is manufactured as a thin film where all of the first thin film layer **310** and the second thin film layer **320** include a high-k dielectric material and all of the first thin film layer **310** and the second thin film layer **320** are not crystallized, represents a leakage current value which is greater in the same thickness than that of a thin film where all of the first thin film layer **310** and the second thin film layer **320** include a high-k dielectric material and at least one of the first thin film layer **310** and the second thin film layer **320** is crystallized, based on the method of manufacturing a thin film according to the present inventive concept. Therefore, the method of manufacturing a thin film according to the present inventive concept may be implemented to manufacture a thin film where all of the first

thin film layer **310** and the second thin film layer **320** include a high-k dielectric material and at least one of the first thin film layer **310** and the second thin film layer **320** is crystallized, and thus, may manufacture a thin film for more decreasing a leakage current despite being formed to have a thickness which is thinner than the thin film according to the comparative example. Therefore, the method of manufacturing a thin film according to the present inventive concept may manufacture the thin film transistor **200** and the like, which are finer and have a thinner thickness and may more decrease the leakage of a current, thereby contributing to more enhancing the performance of the thin film transistor **200** and the like.

[0049] Second, in a comparative example which crystallizes a high-k dielectric material through a thermal process, the high-k dielectric material is not crystallized when not formed to have a certain thickness or more. For example, a high-k dielectric material including at least one of hafnium and zirconium may be crystallized only when formed to have a thickness of 100 Å or more, through the thermal process. On the other hand, the method of manufacturing a thin film according to the present inventive concept is implemented to crystallize a high-k dielectric material by using plasma, and thus, may crystallize the high-k dielectric material despite being formed to have a thickness which is thinner than the comparative example which crystallizes the high-k dielectric material through the thermal process. For example, a high-k dielectric material including at least one of hafnium and zirconium may be crystallized only when formed to have a thickness of 60 Å or less, based on plasma. Accordingly, the method of manufacturing a thin film according to the present inventive concept is implemented to crystallize a high-k dielectric material by using plasma, and thus, may manufacture a thin film for more reducing the leakage of a current despite being formed to have a thinner thickness.

[0050] The crystallization step S**30** may generate plasma by using a plasma gas including at least one of helium (He), argon (Ar), ammonia (NH_3), oxygen (O_2), and hydrogen (H_2). In this case, the first source gas may include at least one of hafnium and zirconium, and the first reactant gas may be ozone (O_3). The first source gas may include at least one of hafnium, zirconium, and aluminum (Al).

[0051] Referring to FIGS. **1** to **6**, the method of manufacturing a thin film according to the present inventive concept may include a removal step S**40**.

[0052] The removal step S**40** removes an oxide film from the lower film **330** formed on the substrate S. The removal step S**40** may be performed before the first formation step S**10** is performed. Therefore, the first formation step S**10** may be performed by forming the first thin film layer **310** on the lower film **330** from which the oxide film is removed through the removal step S**40**. Therefore, the method of manufacturing a thin film according to the present inventive concept may form the first thin film layer **310** having film quality which is more enhanced. An oxide film formed on the lower film **330** may be exposed to an atmosphere, and due to this, may occur. For example, the oxide film may be formed on the lower film **330** in a process where the substrate S is transferred between process chambers. Undesired pollutants may be removed together through the removal step S**40** in a process of removing the oxide film. The removal step S**40** may be performed by using an oxide elimination chamber (OEC).

[0053] Referring to FIGS. **1** to **7**, in the method of manufacturing a thin film according to the present inventive concept, the first formation step S**10** may include a first adsorption step S**11** and a first deposition step S**12**.

[0054] The first adsorption step S**11** injects the first source gas to adsorb the high-k dielectric material onto the substrate S. The first adsorption step S**11** may be performed by injecting the first source gas onto the substrate S through the first gas flow path **4***a* included in the injection unit **4**. The source gas may include at least one of hafnium (Hf) and zirconium (Zr). The first adsorption step S**11** may inject the first source gas including hafnium or zirconium. The first adsorption step S**11** may inject the first source gas including all of hafnium and zirconium. In this case, in the first adsorption step S**11**, a source gas including hafnium and a source gas including zirconium may be mixed with each other in the buffer tank to generate a mixed gas, and then, the mixed gas may be injected. The first adsorption step S**11** may first inject a source gas including one of hafnium and zirconium, and then, may inject a source gas including the other of hafnium and zirconium. The first source gas may include at least one of hafnium, zirconium, and aluminum (Al). For example, the first source gas may be one of HfO_2, ZrO_2, Al_2O_3, and HfZrO.

[0055] The first deposition step S**12** injects the first reactant gas to deposit a thin film including a high-k dielectric material on the substrate S. The first deposition step S**12** may be performed by injecting the first reactant gas onto the substrate S through the second gas flow path **4***b* included in the injection unit **4**. Through the first adsorption step S**11** and the first deposition step S**12**, the first thin film layer **310** may be formed on the substrate S by an atomic layer deposition (ALD) process. The first deposition step S**12** may be performed by injecting ozone as the first reactant gas onto the substrate S.

[0056] The first formation step S**10** may include a first adsorption purge step S**13** and a first deposition purge step S**14**.

[0057] The first adsorption purge step S**13** may be performed by injecting a purge gas onto the substrate S after the first adsorption step S**11** is performed. The first adsorption purge step S**13** may be performed by injecting the purge gas onto the substrate S through at least one of the first gas flow path **4***a* and the second gas flow path **4***b* of the injection unit **4**. The first adsorption purge step S**13** may be performed by injecting the purge gas onto the substrate S through a purge gas flow path (not shown) of the injection unit **4**. The purge gas flow path, the first gas flow path **4***a*, and the second gas flow path **4***b* may be implemented to be spatially apart from one another. After the first adsorption purge step S**13** is performed, the first deposition step S**12** may be performed.

[0058] The first deposition purge step S**14** may be performed by injecting the purge gas onto the substrate S after the first deposition step S**12** is performed. The first deposition purge step S**14** may be performed by injecting the purge gas onto the substrate S through at least one of the first gas flow path **4***a* and the second gas flow path **4***b* of the injection unit **4**. The first deposition purge step S**14** may be performed by injecting the purge gas onto the substrate S through the purge gas flow path (not shown). After the first deposition purge step S**14** is performed, the crystallization step S**30** may be performed.

[0059] Here, the first formation step S**10** and the crystallization step S**30** may be performed in the processing space

100 having an ultra-vacuum state. For example, the first formation step S**10** and the crystallization step S**30** may be performed in a state where the processing space **100** has an ultra-vacuum of several mtorr to tens mtorr. Undesired impurities of the first source gas may be more smoothly exhausted in the ultra-vacuum state, and thus, the method of manufacturing a thin film according to the present inventive concept may arrange first source materials included in the first source gas in a uniform lattice structure. Accordingly, the method of manufacturing a thin film according to the present inventive concept may be implemented to be favorable for growing the first source materials, arranged in the uniform lattice structure, as crystallization arrangement having a high-k dielectric constant.

[0060] In a case where the first formation step S**10** includes the first deposition step S**12** and the first adsorption step S**11**, the crystallization step S**30** may include a first crystallization step S**31**.

[0061] The first crystallization step S**31** crystallizes the first thin film layer **310**. The first crystallization step S**31** may be performed after the first deposition step S**12** is performed. In this case, the method of manufacturing a thin film according to the present inventive concept may deposit the first thin film layer **310** on the substrate S through the first adsorption step S**11** and the first deposition step S**12**, and then, may crystallize the high-k dielectric material of the first thin film layer **310** by using plasma through the first crystallization step S**31**. After the first crystallization step S**31** is performed, each step may be again performed from the first adsorption step S**11**. Furthermore, in a case where the first crystallization step S**31** is performed after the first deposition step S**12** is performed, the method of manufacturing a thin film according to the present inventive concept may perform each step along with the thermal process. The thermal process may be continuously or intermittently performed while the first adsorption step S**11**, the first deposition step S**12**, and the first crystallization step S**31** are being performed. In a case where the first formation step S**10** includes the first deposition purge step S**14**, the first crystallization step S**31** may be performed after the first deposition purge step S**14** is performed.

[0062] Referring to FIGS. **1** to **8**, in the method of manufacturing a thin film according to the present inventive concept, the first deposition step S**12** and the first crystallization step S**31** may be performed together. In this case, the first reactant gas injected onto the substrate S through the first deposition step S**12** may be activated by using plasma generated by the first crystallization step S**31** and may reach the substrate S. Accordingly, because the first deposition step S**12** and the crystallization step S**30** are performed together, the method of manufacturing a thin film according to the present inventive concept may deposit the first thin film layer **310** including a high-k dielectric material onto the substrate S and may crystallize the first thin film layer **310** by using plasma. After the first deposition step S**12** and the first crystallization step S**31** are performed together, each step may be again performed from the first adsorption step S**11**. Although not shown, the first deposition step S**12** may use oxygen (O**2**) plasma as the first reactant gas, and thus, may performed deposition and crystallization together.

[0063] Referring to FIGS. **1** to **8**, in the method of manufacturing a thin film according to the present inventive concept, the first crystallization step S**31** may include a first parallel crystallization step S**311** and a first subsequent crystallization step S**312**.

[0064] The first parallel crystallization step S**311** crystallizes the high-k dielectric material by using plasma. The first parallel crystallization step S**311** may be performed along with the first deposition step S**12**. In this case, the first reactant gas injected onto the substrate S through the first deposition step S**12** may be activated by using plasma generated by the first parallel crystallization step S**311** and may reach the substrate S. Accordingly, because the first deposition step S**12** and the first parallel crystallization step S**311** are performed together, the method of manufacturing a thin film according to the present inventive concept may deposit the first thin film layer **310** onto the substrate S and may crystallize the first thin film layer **310** by using plasma.

[0065] The first subsequent crystallization step S**312** crystallizes the first thin film layer **310** by using plasma. After the first deposition step S**12** and the first parallel crystallization step S**311** are performed, the first subsequent crystallization step S**312** may be performed. Therefore, the method of manufacturing a thin film according to the present inventive concept may be implemented to primarily crystallize the first thin film layer **310** through the first parallel crystallization step S**311** and then secondarily crystallize the first thin film layer **310** through the first subsequent crystallization step S**312**. Therefore, the method of manufacturing a thin film according to the present inventive concept may increase a crystallization rate of the first thin film layer **310**, and thus, may manufacture a thin film for more reducing the leakage of a current despite being formed to have a thinner thickness. Accordingly, the method of manufacturing a thin film according to the present inventive concept may contribute to manufacturing the thin film transistor **200** which is finer and has a thinner thickness. After the first subsequent crystallization step S**312** is performed, each step may be again performed from the first adsorption step S**11**.

[0066] Referring to FIGS. **1** to **9**, in the method of manufacturing a thin film according to the present inventive concept, the second formation step S**20** may include a second adsorption step S**21** and a second deposition step S**22**.

[0067] The second adsorption step S**21** injects the second source gas to adsorb the high-k dielectric material onto the substrate S. The second adsorption step S**21** may be performed by injecting the second source gas onto the substrate S through the first gas flow path **4***a* included in the injection unit **4**. The second adsorption step S**21** may inject the second source gas including hafnium or zirconium. The second adsorption step S**21** may inject the second source gas including all of hafnium and zirconium. In this case, in the second adsorption step S**21**, a source gas including hafnium and a source gas including zirconium may be mixed with each other in the buffer tank to generate a mixed gas, and then, the mixed gas may be injected. The second adsorption step S**21** may first inject a source gas including one of hafnium and zirconium, and then, may inject a source gas including the other of hafnium and zirconium. The first source gas may include at least one of hafnium, zirconium, and aluminum (Al). The second source gas may include at least one of hafnium, zirconium, and aluminum (Al). For example, the second source gas may be one of HfO_2, ZrO_2, Al_2O_3, and HfZrO.

[0068] The second deposition step S**22** injects the second reactant gas to deposit a thin film including a high-k dielectric material on the substrate S. The second deposition step S**22** may be performed by injecting the second reactant gas onto the substrate S through the second gas flow path **4***b* included in the injection unit **4**. Through the second adsorption step S**21** and the second deposition step S**22**, the second thin film layer **320** may be formed on the substrate S by an atomic layer deposition (ALD) process. The second deposition step S**22** may be performed by injecting ozone as the second reactant gas onto the substrate S.

[0069] The second formation step S**20** may include a second adsorption purge step S**23** and a second deposition purge step S**24**.

[0070] The second adsorption purge step S**23** may be performed by injecting a purge gas onto the substrate S after the second adsorption step S**21** is performed. The second adsorption purge step S**23** may be performed by injecting the purge gas onto the substrate S through at least one of the first gas flow path **4***a* and the second gas flow path **4***b* of the injection unit **4**. The second adsorption purge step S**23** may be performed by injecting the purge gas onto the substrate S through a purge gas flow path (not shown) of the injection unit **4**. The purge gas flow path, the first gas flow path **4***a*, and the second gas flow path **4***b* may be implemented to be spatially apart from one another. After the second adsorption purge step S**23** is performed, the second deposition step S**22** may be performed.

[0071] The second deposition purge step S**24** may be performed by injecting the purge gas onto the substrate S after the second deposition step S**22** is performed. The second deposition purge step S**24** may be performed by injecting the purge gas onto the substrate S through at least one of the first gas flow path **4***a* and the second gas flow path **4***b* of the injection unit **4**. The second deposition purge step S**24** may be performed by injecting the purge gas onto the substrate S through the purge gas flow path (not shown). After the second deposition purge step S**24** is performed, the crystallization step S**30** may be performed.

[0072] Here, the second formation step S**20** and the crystallization step S**30** may be performed in the processing space **100** having an ultra-vacuum state. For example, the second formation step S**20** and the crystallization step S**30** may be performed in a state where the processing space **100** has an ultra-vacuum of several mtorr to tens mtorr. Undesired impurities of the second source gas may be more smoothly exhausted in the ultra-vacuum state, and thus, the method of manufacturing a thin film according to the present inventive concept may arrange second source materials included in the second source gas in a uniform lattice structure. Accordingly, the method of manufacturing a thin film according to the present inventive concept may be implemented to be favorable for growing the second source materials, arranged in the uniform lattice structure, as crystallization arrangement having a high-k dielectric constant.

[0073] In a case where the second formation step S**20** includes the second deposition step S**22** and the second adsorption step S**21**, the crystallization step S**30** may include a second crystallization step S**32**.

[0074] The second crystallization step S**32** crystallizes the second thin film layer **320**. The second crystallization step S**32** may be performed after the second deposition step S**22** is performed. In this case, the method of manufacturing a thin film according to the present inventive concept may deposit the second thin film layer **320** on the substrate S through the second adsorption step S**21** and the second deposition step S**22**, and then, may crystallize the high-k dielectric material of the second thin film layer **320** by using plasma through the second crystallization step S**32**. After the second crystallization step S**32** is performed, each step may be again performed from the second adsorption step S**21**. Furthermore, in a case where the second crystallization step S**32** is performed after the second deposition step S**22** is performed, the method of manufacturing a thin film according to the present inventive concept may perform each step along with the thermal process. The thermal process may be continuously or intermittently performed while the second adsorption step S**21**, the second deposition step S**22**, and the second crystallization step S**32** are being performed. In a case where the second formation step S**20** includes the second deposition purge step S**24**, the second crystallization step S**32** may be performed after the second deposition purge step S**24** is performed.

[0075] Referring to FIGS. **1** to **10**, in the method of manufacturing a thin film according to the present inventive concept, the second deposition step S**22** and the second crystallization step S**32** may be performed together. In this case, the second reactant gas injected onto the substrate S through the second deposition step S**22** may be activated by using plasma generated by the second crystallization step S**32** and may reach the substrate S. Accordingly, because the second deposition step S**22** and the crystallization step S**30** are performed together, the method of manufacturing a thin film according to the present inventive concept may deposit the second thin film layer **320** including a high-k dielectric material onto the substrate S and may crystallize the second thin film layer **320** by using plasma. After the second deposition step S**22** and the second crystallization step S**32** are performed together, each step may be again performed from the second adsorption step S**21**. Although not shown, the second deposition step S**22** may use oxygen (O_2) plasma as the second reactant gas, and thus, may performed deposition and crystallization together.

[0076] Referring to FIGS. **1** to **10**, in the method of manufacturing a thin film according to the present inventive concept, the second crystallization step S**32** may include a second parallel crystallization step S**321** and a second subsequent crystallization step S**322**.

[0077] The second parallel crystallization step S**321** crystallizes the high-k dielectric material by using plasma. The second parallel crystallization step S**321** may be performed along with the second deposition step S**22**. In this case, the second reactant gas injected onto the substrate S through the second deposition step S**22** may be activated by using plasma generated by the second parallel crystallization step S**321** and may reach the substrate S. Accordingly, because the second deposition step S**22** and the second parallel crystallization step S**321** are performed together, the method of manufacturing a thin film according to the present inventive concept may deposit the second thin film layer **320** onto the substrate S and may crystallize the second thin film layer **320** by using plasma.

[0078] The second subsequent crystallization step S**322** crystallizes the second thin film layer **320** by using plasma. After the second deposition step S**22** and the second parallel crystallization step S**321** are performed, the second subsequent crystallization step S**322** may be performed. Therefore, the method of manufacturing a thin film according to

the present inventive concept may be implemented to primarily crystallize the second thin film layer **320** through the second parallel crystallization step S**321** and then secondarily crystallize the second thin film layer **320** through the second subsequent crystallization step S**322**. Therefore, the method of manufacturing a thin film according to the present inventive concept may increase a crystallization rate of the second thin film layer **320**, and thus, may manufacture a thin film for more reducing the leakage of a current despite being formed to have a thinner thickness. Accordingly, the method of manufacturing a thin film according to the present inventive concept may contribute to manufacturing the thin film transistor **200** which is finer and has a thinner thickness. After the second subsequent crystallization step S**322** is performed, each step may be again performed from the second adsorption step S**21**.

[0079] Here, when the first thin film layer **310** is crystallized, a first grain boundary **311** (illustrated in FIG. **5**) may be formed in the first thin film layer **310**. The first grain boundary **311** may be formed to pass through the first thin film layer **310** in a direction in which the first thin film layer **310** is deposited. The first grain boundary **311** may be formed in plurality in the first thin film layer **310**. When the second thin film layer **320** is crystallized, a second grain boundary **321** (illustrated in FIG. **5**) may be formed in the second thin film layer **320**. The second grain boundary **321** may be formed to pass through the second thin film layer **320** in a direction in which the second thin film layer **320** is deposited.

[0080] In this case, when the first thin film layer **310** and the second thin film layer **320** are deposited by using the same high-k dielectric material and are crystallized under the same process condition, the first grain boundary **311** and the second grain boundary **321** may be connected with each other. Accordingly, the leakage of a current may occur through the first grain boundary **311** and the second grain boundary **321**.

[0081] To prevent this, the first source gas and the second source gas may include different high-k dielectric materials. Therefore, in the method of manufacturing a thin film according to the present inventive concept, even when the first thin film layer **310** and the second thin film layer **320** are crystallized under the same process condition, the first grain boundary **311** and the second grain boundary **321** may not be connected with each other. That is, as illustrated in FIG. **5**, the first grain boundary **311** and the second grain boundary **321** may be formed at staggered positions. Therefore, the method of manufacturing a thin film according to the present inventive concept may decrease the leakage of a current through the first grain boundary **311** and the second grain boundary **321**. In this case, the first formation step S**10** and the second formations step S**20** may deposit the first thin film layer **310** and the second thin film layer **320** by using the first source gas and the second source gas which differ. Subsequently, in the crystallization step S**30**, even when the first thin film layer **310** and the second thin film layer **320** are crystallized under the same process condition, the first grain boundary **311** and the second grain boundary **321** may be formed at staggered positions.

[0082] Furthermore, the crystallization step S**30** may crystallize the first thin film layer **310** and the second thin film layer **320** under different conditions. In this case, even when the first source gas and the second source gas include the same high-k dielectric material, the method of manufacturing a thin film according to the present inventive concept may form the first grain boundary **311** and the second grain boundary **321** at staggered positions, based on a difference between process conditions for crystallization. Accordingly, the method of manufacturing a thin film according to the present inventive concept may decrease the leakage of a current through the first grain boundary **311** and the second grain boundary **321**. The crystallization step S**30** may crystallize the first thin film layer **310** and the second thin film layer **320** at different crystallization rates, and thus, may form the first grain boundary **311** and the second grain boundary **321** at staggered positions.

[0083] Furthermore, the method of manufacturing a thin film according to the present inventive concept may be implemented so that the first source gas and the second source gas include different high-k dielectric materials and the first thin film layer **310** and the second thin film layer **320** are crystallized under different process conditions. Accordingly, a distance by which the first grain boundary **311** and the second grain boundary **321** are staggered with each other may increase, and thus, the method of manufacturing a thin film according to the present inventive concept may more decrease the leakage of a current through the first grain boundary **311** and the second grain boundary **321**. For example, the first crystallization step S**31** and the second crystallization step S**32** may generate plasma by using different plasma gases, and thus, may perform crystallization under different process conditions.

[0084] Referring to FIGS. **1** to **12**, the method of manufacturing a thin film according to the present inventive concept may be implemented to crystallize only one of the first thin film layer **310** and the second thin film layer **320**. For example, the crystallization step S**30** may be implemented to crystallize only the first thin film layer **310** and not to crystallize the second thin film layer **320**. In this case, as illustrated in FIG. **11**, the first grain boundary **311** is formed in only the first thin film layer **310**, and the second grain boundary **321** is not formed in the second thin film layer **320**. For example, the crystallization step S**30** may be implemented to crystallize only the second thin film layer **320** and not to crystallize the first thin film layer **310**. In this case, as illustrated in FIG. **12**, the second grain boundary **321** is formed in only the second thin film layer **320**, and the first grain boundary **311** is not formed in the first thin film layer **310**. As described above, the method of manufacturing a thin film according to the present inventive concept may be implemented to crystallize only one of the first thin film layer **310** and the second thin film layer **320**, and thus, may prevent the leakage of a current from occurring through a grain boundary.

[0085] Referring to FIGS. **1** to **14**, the method of manufacturing a thin film according to the present inventive concept may include a third crystallization step S**50**.

[0086] The third formation step S**50** forms a third thin film layer **340** on the substrate S. The third formation step S**50** may form an amorphous third thin film layer **340**. Therefore, a grain boundary is not formed in the third thin film layer **340**. Accordingly, even when the first source gas is the same as the second source gas and the first thin film layer **310** and the second thin film layer **320** crystallized under the same process condition are formed, the third thin film layer **340** may prevent the occurrence of current leakage through the first grain boundary **311** and the second grain boundary **321**. The third formation step S**50** may form the third thin film

layer **340** which is lower in crystallization rate than each of the first thin film layer **310** and the second thin film layer **320**. Therefore, a grain boundary may not be formed in the third thin film layer **340**, or fewer grain boundaries than the first thin film layer **310** and the second thin film layer **320** may be formed therein. Accordingly, even when the first source gas is the same as the second source gas and the first thin film layer **310** and the second thin film layer **320** crystallized under the same process condition are formed, the third thin film layer **340** may prevent the occurrence of current leakage through the first grain boundary **311** and the second grain boundary **321**.

[0087] As illustrated in FIG. **14**, the third thin film layer **340** may be disposed between the first thin film layer **310** and the second thin film layer **320**. In this case, the third formation step S**50** may be performed after the first formation step S**10** is performed. The second formation step S**20** may be performed after the third formation step S**50** is performed. Although not shown, the third thin film layer **340** may be disposed between the first thin film layer **310** and the lower film **330**. In this case, the first formation step S**10** may be performed after the third formation step S**50** is performed. The third thin film layer **340** may be disposed on the second thin film layer **320**. In this case, the third formation step S**50** may be performed after the second formation step S**20** is performed. Although not shown, the method of manufacturing a thin film according to the present inventive concept may perform the third formation step S**50** a plurality of times, and thus, may form a plurality of third thin film layers **340**. In this case, the third thin film layers **340** may be disposed apart from one another. Accordingly, the third thin film layers **340** may prevent the occurrence of current leakage through a grain boundary at different positions.

[0088] The third formation step S**50** may inject a third source gas to adsorb a third source material of the third source gas onto the substrate S, and then, may inject a third reactant gas to form the third thin film layer **340** on the substrate S. In this case, the third formation step S may form the third thin film layer **340** on the substrate S by using an atomic layer deposition (ALD) process. The third source gas may include a high-k dielectric material, but is not limited thereto and may include a material capable of preventing the leakage of a current through a grain boundary, instead of a high-k dielectric material. The third source gas may be injected through the first gas flow path **4***a* included in the injection unit **4**. The third reactant gas may react with the third source gas and may be injected through the second gas flow path **4***b* included in the injection unit **4**. The third formation step S**50** may be performed by injecting the third source gas and the third reactant gas. In this case, the third formation step S**50** may form the third thin film layer **340** by using a chemical vapor deposition (CVD) process.

[0089] Hereinafter, an embodiment of a thin film according to the present inventive concept will be described in detail.

[0090] Referring to FIGS. **1** to **14**, a thin film according to the present inventive concept may be manufactured by the method of manufacturing a thin film according to the present inventive concept described above. The thin film according to the present inventive concept may be implemented as the insulation layer **210** disposed between the gate electrode **220** and the semiconductor layer **230**, in the thin film transistor **200**.

[0091] The thin film according to the present inventive concept may include the first thin film layer **310** and the second thin film layer **320**.

[0092] The first thin film layer **310** may be formed on the substrate S by using a mixed material including a high-k dielectric material. The first thin film layer **310** may be crystallized by plasma. Therefore, the thin film according to the present inventive concept may be implemented to have a dielectric constant capable of decreasing the leakage of a current despite that the first thin film layer **310** is formed to have a thin thickness, thereby contributing to manufacturing the thin film transistor **200** which is finer and has a thinner thickness. The first thin film layer **310** may also be formed on the lower film **330**. Although not shown, the thin film according to the present inventive concept may include a plurality of first thin film layers **310**. The first thin film layers **310** may be disposed apart from one another.

[0093] The first thin film layer **310** may be formed of a mixed material including at least one of hafnium and zirconium. The first thin film layer **310** may be formed of a mixed material including at least one of hafnium, zirconium, and aluminum. The first thin film layer **310** may be deposited on the substrate S through the first formation step S**10** and may be crystallized through the crystallization step S**30**.

[0094] The first thin film layer **310** may be formed to have a thickness of **30** Å or less and may be crystallized to have a dielectric constant of 30 K or more. The first thin film layer **310** may be crystallized on a whole surface of a deposition surface, and thus, may be formed to have a thickness of 30 Å or less and a dielectric constant of 30 K or more. Accordingly, the first thin film layer **310** may be implemented to decrease the leakage of a current despite being formed to have a thin thickness.

[0095] Furthermore, a dielectric constant of the first thin film layer **310** may be determined based on the following Equation 1.

$$Cox \times \left(\frac{D}{A}\right) \quad \text{[Equation 1]}$$

[0096] In the Equation 1, Cox may be an oxide capacitance of the thin film layer, D may be a thickness of the thin film layer, and A may be an area of the thin film layer. The dielectric constant of the first thin film layer **310** calculated through the Equation 1 may be implemented to 30 K or more.

[0097] The first thin film layer **310** may be formed to have an equivalent oxide thickness (EOT) of 6.5 Å or less. EOT represents a certain degree to which a high-k dielectric material shows a thickness effect, compared to silicon dioxide (SiO_2). That is, an EOT denotes a thickness of the high-k dielectric material when having the same capacitance as that of to silicon dioxide (SiO_2). As the first thin film layer **310** is formed to have an EOT of 6.5 Å or less, the first thin film layer **310** may be implemented to have a thin thickness and decrease the leakage of a current.

[0098] Referring to FIGS. **1** to **14**, the second thin film layer **320** may be formed on the substrate S by using a mixed material including a high-k dielectric material. The second thin film layer **320** may be formed on the first thin film layer **310**. Although not shown, the first thin film layer **310** may be formed on the second thin film layer **320**. The second thin film layer **320** may be formed of a mixed material including

at least one of hafnium and zirconium. The second thin film layer **320** may be formed of a mixed material including at least one of hafnium, zirconium, and aluminum. The second thin film layer **320** may be deposited on the substrate S through the second formation step S**20**. Although not shown, the thin film according to the present inventive concept may include a plurality of second thin film layers **320**. The second thin film layers **320** may be disposed apart from one another.

[0099] The second thin film layer **320** may be formed of an amorphous material. In this case, as illustrated in FIG. **11**, the first grain boundary **311** is formed in only the first thin film layer **310**, and the second grain boundary **321** is not formed in the second thin film layer **320**. Accordingly, the method of manufacturing a thin film according to the present disclosure may be implemented to crystallize only the first thin film layer **310**, thereby preventing the occurrence of current leakage through a grain boundary.

[0100] The second thin film layer **320** may be crystallized by plasma. Accordingly, the thin film according to the present inventive concept may be formed to have a thin thickness and may be implemented to have a dielectric constant capable of decreasing the leakage of a current, thereby contributing to manufacturing the thin film transistor **200** which is finer and has a thinner thickness. The second thin film layer **320** may be crystallized through the crystallization step S**30**.

[0101] The second thin film layer **320** may be crystallized at a crystallization rate which differs from that of the first thin film layer **310**. Therefore, the second grain boundary **321** formed in the second thin film layer **320** and the first grain boundary **311** formed in the first thin film layer **310** may be formed at staggered positions, and thus, may not be connected with each other. Therefore, the thin film according to the present inventive concept may decrease the leakage of a current through the first grain boundary **311** and the second grain boundary **321**. In this case, the second thin film layer **320** and the first thin film layer **310** may be formed of different high-k dielectric materials. Therefore, even when the second thin film layer **320** and the first thin film layer **310** are crystallized under the same process condition, the second grain boundary **321** and the first grain boundary **311** may be formed at staggered positions. The second thin film layer **320** and the first thin film layer **310** may be crystallized under different process conditions. Accordingly, even when the second thin film layer **320** and the first thin film layer **310** are formed of the same high-k dielectric material, the second grain boundary **321** and the first grain boundary **311** may be formed at staggered positions. The second thin film layer **320** and the first thin film layer **310** may be formed of different high-k dielectric materials and may also be crystallized under different process conditions.

[0102] The second thin film layer **320** may be formed to have a thickness of 40 Å or more and 70 Å or less and may be crystallized to have a dielectric constant of 20 K or more and 30 K or less. Here, when the second thin film layer **320** is formed to have a thickness of less than 40 Å, the leakage of a current may increase, and when the second thin film layer **320** is formed to have a thickness of more than 70 Å, thinness is difficult. When the second thin film layer **320** is crystallized to have a dielectric constant of less than 20 K, it is difficult to decrease the leakage of a current, and when the second thin film layer **320** is crystallized to have a dielectric constant of more than 30 K, the second thin film layer **320** has conductivity and is difficult to function as an insulation layer. Based thereon, the thin film according to the present inventive concept may be formed to have a thickness of 40 Å or more and 70 Å or less and may be implemented to have a dielectric constant of 20 K or more and 30 K or less. Furthermore, a dielectric constant of the second thin film layer **320** may be determined based on the Equation 1.

[0103] The second thin film layer **320** may be partially crystallized, and thus, may be formed to have a thickness of 40 Å or more and 70 Å or less and may be formed to have a dielectric constant of 20 K or more and 30 K or less. In this case, comparing with that all of the second thin film layer **320** is crystallized, the thin film according to the present inventive concept may be implemented to have a dielectric constant and a thickness sufficient to be used as the insulation layer **210** and reduce a process time, thereby increasing productivity.

[0104] The second thin film layer **320** may be formed to have an EOT of 6.5 Å or more and 9.7 Å or less. When an EOT of the second thin film layer **320** is less than 6.5 Å, the leakage of a current increases, and when an EOT of the second thin film layer **320** is more than 9.7 Å, thinness is difficult. Based thereon, the second thin film layer **320** may be formed to have an EOT of 6.5 Å or more and 9.7 Å or less, and thus, may be implemented to decrease the leakage of a current despite being formed to have a thin thickness.

[0105] Referring to FIGS. **1** to **14**, the thin film according to the present inventive concept may include a third thin film layer **340**.

[0106] The third thin film layer **340** may be formed on the substrate S by using a mixed material including a high-k dielectric material. The third thin film layer **340** may be formed on the substrate S through the third formation step S**50**. The third thin film layer **340** may be formed of a mixed material including at least one of hafnium and zirconium. The third thin film layer **340** may be formed of a mixed material including at least one of hafnium, zirconium, and aluminum. As illustrated in FIG. **14**, the third thin film layer **340** may be disposed between the first thin film layer **310** and the second thin film layer **320**. Although not shown, the third thin film layer **340** may be disposed between the first thin film layer **310** and the lower film **330**. The third thin film layer **340** may be formed on the second thin film layer **320**. Although not shown, the thin film according to the present inventive concept may include a plurality of third thin film layers **340**. The third thin film layers **340** may be disposed apart from one another.

[0107] The third thin film layer **340** may be formed of an amorphous material. Therefore, a grain boundary is not formed in the third thin film layer **340**. Accordingly, even when the first thin film layer **310** and the second thin film layer **320** are formed by using the same source gas and are crystallized under the same process condition, the third thin film layer **340** may prevent the occurrence of current leakage through the first grain boundary **311** and the second grain boundary **321**.

[0108] The third thin film layer **340** may be crystallized at a crystallization rate which is lower than that of each of the first thin film layer **310** and the second thin film layer **320**. Therefore, a grain boundary is not formed in the third thin film layer **340**, or fewer grain boundaries than the first thin film layer **310** and the second thin film layer **320** may be formed. Accordingly, even when the first thin film layer **310** and the second thin film layer **320** are formed by using the same source gas and are crystallized under the same process

condition, the third thin film layer **340** may prevent the occurrence of current leakage through the first grain boundary **311** and the second grain boundary **321**.

[0109] Hereinafter, an embodiment of a substrate processing apparatus according to the present inventive concept will be described in detail with reference to the accompanying drawings.

[0110] Referring to FIGS. **1** to **15**, the substrate processing apparatus **1** according to the present inventive concept may be implemented to deposit a thin film by using a plasma chemical vapor deposition (PCVD) process and crystallize the thin film. The method of manufacturing a thin film according to the present inventive concept described above may be performed by the substrate processing apparatus **1**. The thin film according to the present inventive concept described above may be manufactured by using the substrate processing apparatus **1**.

[0111] The substrate processing apparatus **1** according to the present inventive concept may include a chamber **2**, a susceptor **3**, an upper dome **5**, and an antenna **6**.

[0112] The chamber **2** may include a sidewall. The chamber **2** may be formed of a conductor. An internal space of the chamber **2** may have a cylindrical shape. An outer shape of the chamber **2** may be a cuboid shape. The chamber **2** may be cooled by cooling water. The chamber **2**, the upper dome **5**, and a lower dome **7** may be combined to provide a sealed space. A substrate entrance (not shown) may be provided in a side surface of the chamber **2**. The chamber **2** may include an exhaust port (not shown) which is formed in a side surface facing the substrate entrance. The exhaust portion may be connected with a high vacuum pump (not shown). The high vacuum pump may be a turbo molecular pump. The high vacuum pump may maintain a low base pressure and may maintain a pressure of several mtorr or less even in performing a process. An upper surface of the exhaust port may be lower than or equal to an upper surface of the substrate entrance.

[0113] The susceptor **3** supports the substrate S. The susceptor **3** may support one substrate S, or may support a plurality of substrates S. In a case where the plurality of substrates S are supported by the susceptor **3**, a process of performing a processing process on the plurality of substrates S at a time to manufacture a thin film on each of the substrates S may be performed. The susceptor **3** may be disposed in the chamber **2**.

[0114] The upper dome **5** covers an upper surface of the chamber **2**. The upper dome **5** may be formed of a transparent dielectric material. For example, the upper dome **5** may be formed of quartz or sapphire. The upper dome **5** may be inserted into or coupled to a jaw which is formed on the upper surface of the chamber **2**. A coupling portion, coupled to the chamber **2**, of the upper dome **5** may be formed in a washer shape for vacuum sealing. The upper dome **5** may also be formed in an arc shape or an oval shape. The upper dome **5** may allow infrared light incident from a lower portion to pass through the upper dome **5**. The upper dome **5** may be formed of ceramic which is better in corrosion resistance and anti-corrosion than quartz.

[0115] The antenna **6** is disposed over the upper dome **5**. The antenna **6** may form inductively-coupled plasma. The antenna **6** may include two one-turn unit antennas. In this case, the two one-turn unit antennas may be disposed to overlap each other on an upper surface and a lower surface. The two one-turn unit antennas may be connected in parallel with an RF power source **140**. A width direction of the two one-turn unit antennas may be disposed to vertically stand. In the method of manufacturing a thin film according to the present inventive concept described above, plasma may be generated by the antenna **6**. Furthermore, in the method of manufacturing a thin film according to the present inventive concept described above, a source gas and a reactant gas may be injected through an injector (not shown) which is provided to extend long toward the processing space in the upper dome **5** and the lower dome **7**. The injector may function as the injection unit described above. The substrate processing apparatus **1** according to the present inventive concept may include a plurality of injectors.

[0116] The lower dome **7** may be coupled to the chamber **2** to cover a lower surface of the chamber **2**. The lower dome **7** may be formed of a transparent dielectric material. For example, the lower dome **7** may be formed of quartz or sapphire. The lower dome **7** may include a lower dome body having a funnel shape, a washer-shaped coupling portion which is coupled to a jaw formed in the lower surface of the chamber **2**, and a cylindrical-shaped cylindrical pipe which is connected with a center of the lower dome body. The lower dome **7** may be inserted into and coupled to the jaw formed in the lower surface of the chamber **2**. A coupling portion **158***a*, coupled to the chamber **2**, of the chamber **2** may be formed in a washer shape for vacuum sealing. A driving shape for moving the susceptor **3** may be inserted into and disposed in the cylindrical pipe. A purge gas may be supplied through the lower dome **7**. In this case, the purge gas may be supplied through the cylindrical pipe.

[0117] The substrate processing apparatus **1** according to the present inventive concept may include an electric wave shield housing **8**. The electric wave shield housing **8** may be disposed to surround the antenna **6**. The electric wave shield housing **8** may be heated by a heater. Infrared light reflected by the electric wave shield housing **8** may pass through the upper dome **5** and may be incident on the substrate S.

[0118] The present inventive concept described above are not limited to the above-described embodiments and the accompanying drawings and those skilled in the art will clearly appreciate that various modifications, deformations, and substitutions are possible without departing from the scope and spirit of the inventive concept.

1. A method of manufacturing a thin film, comprising:

a first formation step of injecting a first source gas including a high-k dielectric material to form a first thin film layer on a substrate;

a second formation step of injecting a second source gas including a high-k dielectric material to form a second thin film layer on the substrate; and

a crystallization step of crystallizing at least one of the first thin film layer and the second thin film layer by using plasma.

2. The method of manufacturing a thin film of claim **1**, further comprising a removal step of removing an oxide film from a lower film formed on the substrate before the first formation step is performed,

wherein the first formation step forms the first thin film layer on the lower film from which the oxide film is removed.

3. The method of manufacturing a thin film of claim **1**, wherein the first source gas and the second source gas comprise different high-k dielectric materials.

4. The method of manufacturing a thin film of claim **1**, wherein the first formation step forms the first thin film layer by using a first source gas including at least one high-k dielectric material of hafnium (Hf) and zirconium (Zr), and

the second formation step forms the second thin film layer by using a second source gas including at least one high-k dielectric material of hafnium (Hf) and zirconium (Zr).

5. The method of manufacturing a thin film of claim **1**, wherein the first formation step comprises:

a first adsorption step of injecting the first source gas to adsorb a high-k dielectric material onto the substrate; and

a first deposition step of injecting a first reactant gas reacting with the first source gas to deposit the first thin film layer including a high-k dielectric material on the substrate.

6. The method of manufacturing a thin film of claim **5**, wherein the crystallization step comprises a first crystallization step of crystallizing the first thin film layer, and

the first crystallization step is performed after the first deposition step is performed, or is performed along with the first deposition step.

7. The method of manufacturing a thin film of claim **5**, wherein the first deposition step performs deposition and crystallization together by using oxygen (O**2**) plasma as the first reactant gas.

8. The method of manufacturing a thin film of claim **5**, wherein the first deposition step injects ozone (O_3) as the first reactant gas.

9. The method of manufacturing a thin film of claim **5**, wherein the crystallization step comprises a first crystallization step of crystallizing the first thin film layer, and

the first crystallization step comprises:

a first parallel crystallization step performed along with the first deposition step; and

a first subsequent crystallization step performed after the first deposition step and the first parallel crystallization step are performed.

10. The method of manufacturing a thin film of claim **1**, wherein the crystallization step generates plasma by using a plasma gas including at least one of helium (He), argon (Ar), ammonia (NH_3), oxygen (O_2), and hydrogen (H_2).

11. The method of manufacturing a thin film of claim **1**, wherein the crystallization step crystallizes the first thin film layer and the second thin film layer at different crystallization rates.

12. The method of manufacturing a thin film of claim **1**, wherein the crystallization step crystallizes only the first thin film layer.

13. The method of manufacturing a thin film of claim **1**, further comprising a third formation step of forming a third thin film layer on the substrate,

wherein the third formation step forms an amorphous third thin film layer, or forms a third thin film layer which is lower in crystallization rate than each of the first thin film layer and the second thin film layer.

14. A thin film comprising:

a first thin film layer formed on a substrate by using a high-k dielectric material and crystallized by plasma; and

a second thin film layer formed on the substrate by using a high-k dielectric material.

15. The thin film of claim **14**, wherein the second thin film layer is crystallized at a crystallization rate which differs from a crystallization rate of the first thin film layer, or is formed of an amorphous material.

16. The thin film of claim **14**, wherein the first thin film layer and the second thin film layer are formed by using different high-k dielectric materials.

17. The thin film of claim **14**, wherein the first thin film layer is formed by using at least one high-k dielectric material of hafnium (Hf) and zirconium (Zr), and the second thin film layer is formed by using at least one high-k dielectric material of hafnium (Hf) and zirconium (Zr).

18. The thin film of claim **14**, further comprising a third thin film layer formed on the substrate, and

the third thin film layer is formed of an amorphous material, or is crystallized at a crystallization rate which is lower than a crystallization rate of each of the first thin film layer and the second thin film layer.

19. A substrate processing apparatus comprising:

a chamber;

a substrate supporting unit supporting a substrate in the chamber;

an upper dome provided on an upper surface of the chamber; and

an antenna disposed over the upper dome to generate inductively-coupled plasma,

wherein the upper dome is formed of ceramic.

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