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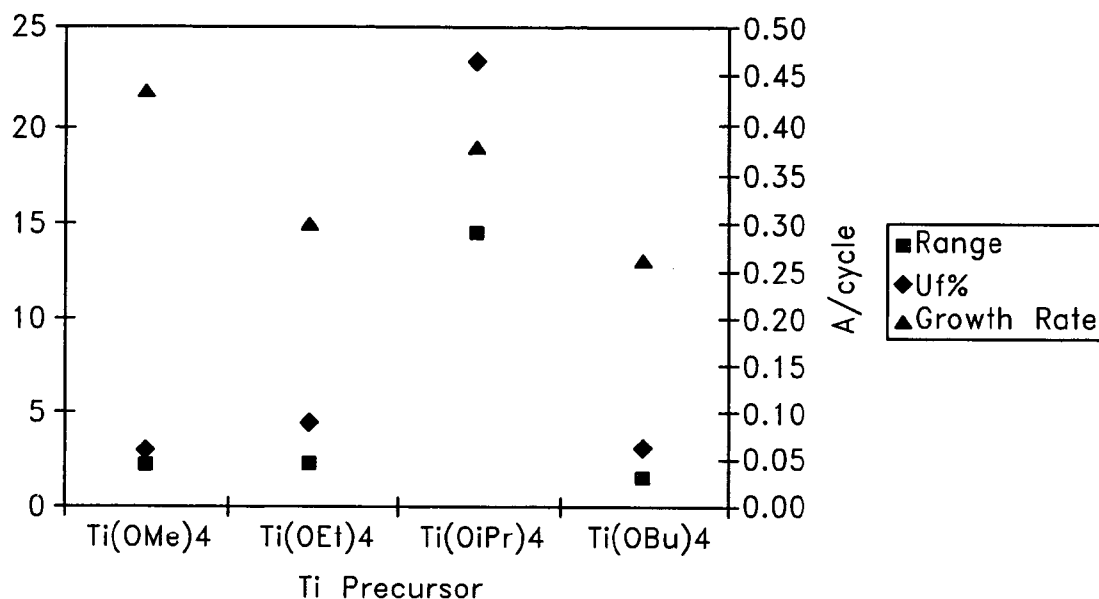
(19) **United States**(12) **Patent Application Publication**
Rahtu et al.(10) **Pub. No.: US 2006/0219157 A1**(43) **Pub. Date: Oct. 5, 2006**(54) **OXIDE FILMS CONTAINING TITANIUM****Publication Classification**(76) Inventors: **Antti Rahtu**, Helsinki (FI); **Raija Matero**, Vantaa (FI); **Markku Leskela**, Espoo (FI); **Mikko Ritala**, Espoo (FI); **Timo Hatanpaa**, Espoo (FI); **Timo Hanninen**, Helsinki (FI); **Marko Vehkamaki**, Helsinki (FI)(51) **Int. Cl.**
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IRVINE, CA 92614 (US)(57) **ABSTRACT**(21) Appl. No.: **11/317,656**(22) Filed: **Dec. 22, 2005****Related U.S. Application Data**

(63) Continuation-in-part of application No. 09/787,062, filed on Jun. 28, 2001.

Atomic layer deposition (ALD) type processes for producing titanium containing oxide thin films comprise feeding into a reaction space vapour phase pulses of titanium alkoxide as a titanium source material and at least one oxygen source material, such as ozone, capable of forming an oxide with the titanium source material. In preferred embodiments the titanium alkoxide is titanium methoxide.

Ti Alkoxides - H₂O @ 200C

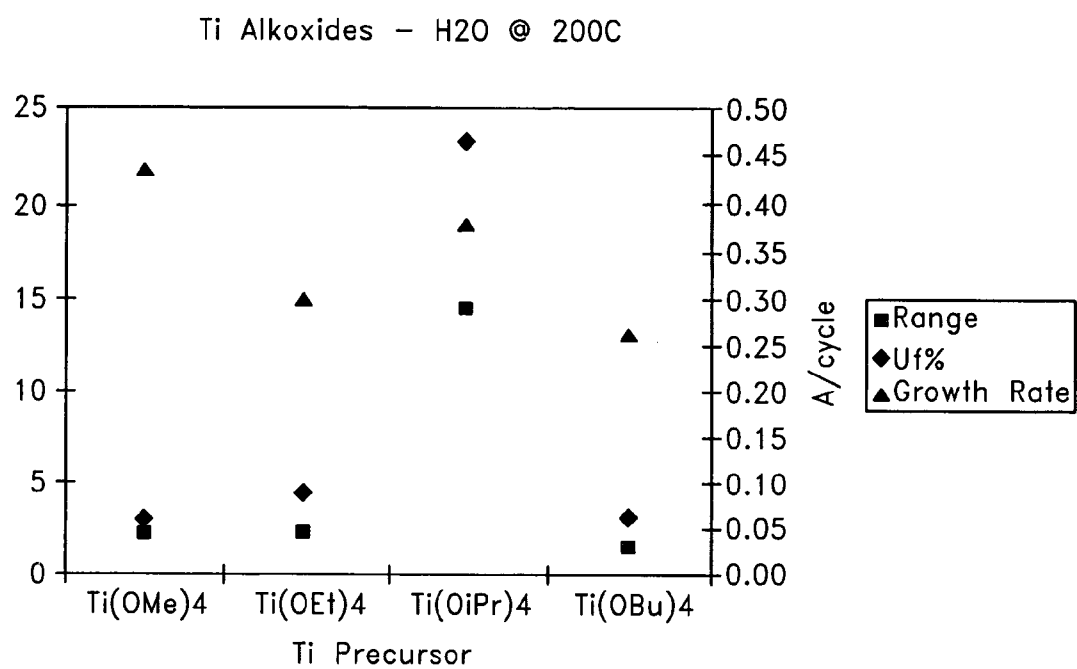


FIG. 1A

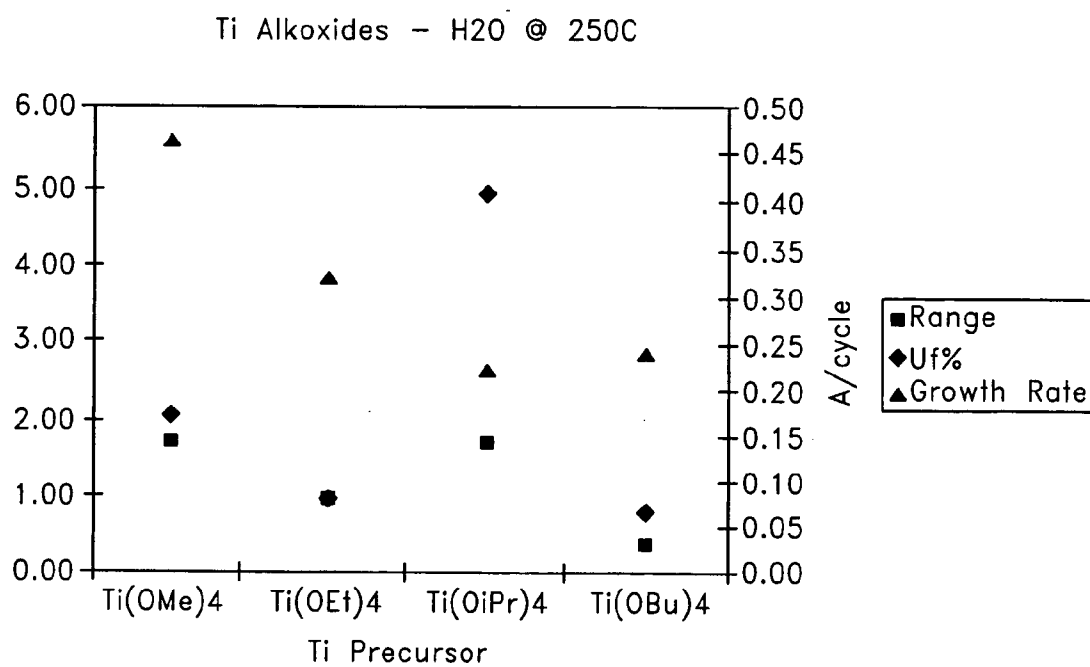


FIG. 1B

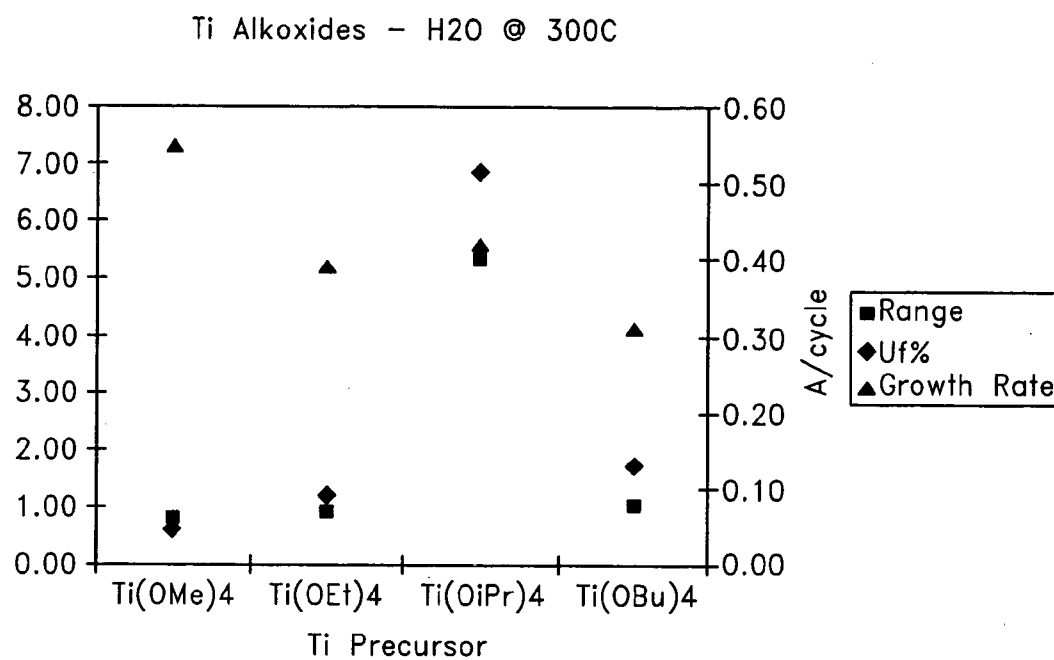


FIG. 1C

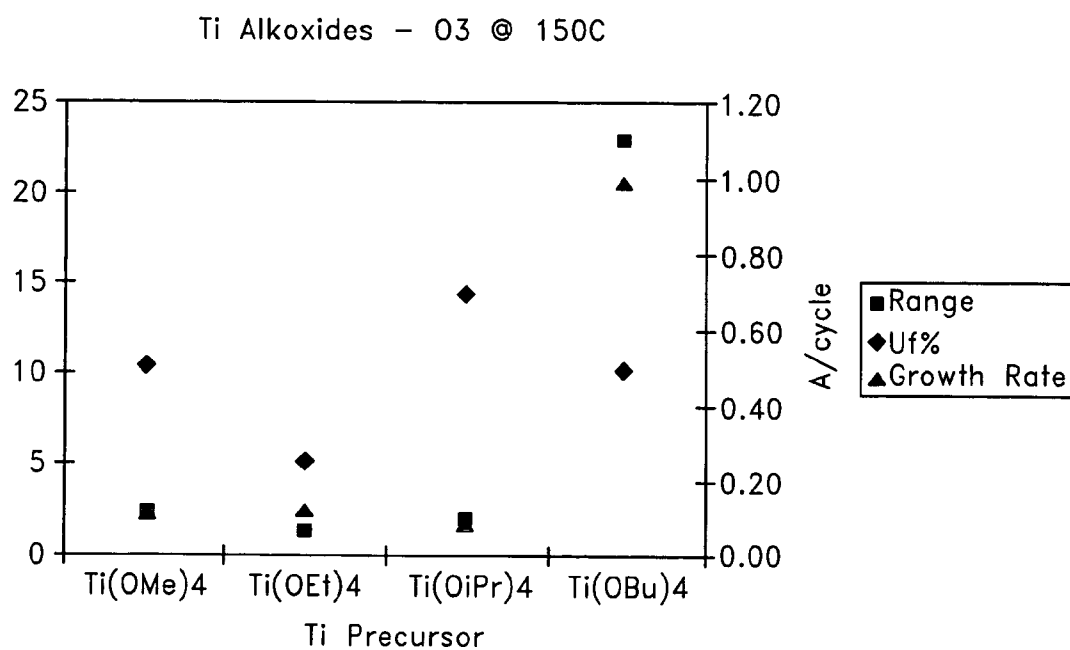


FIG. 1D

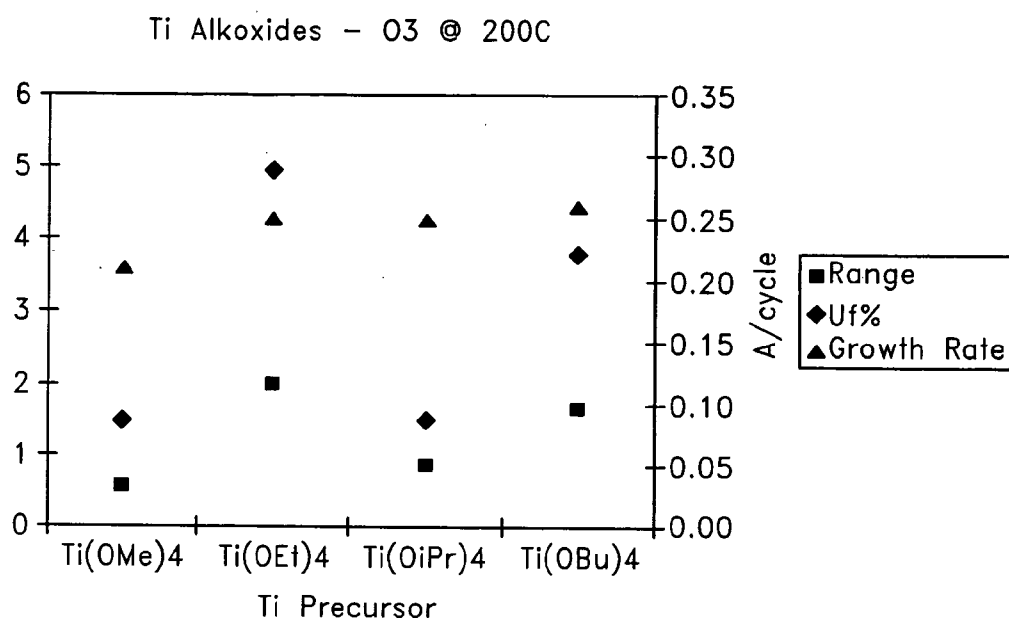


FIG. 1E

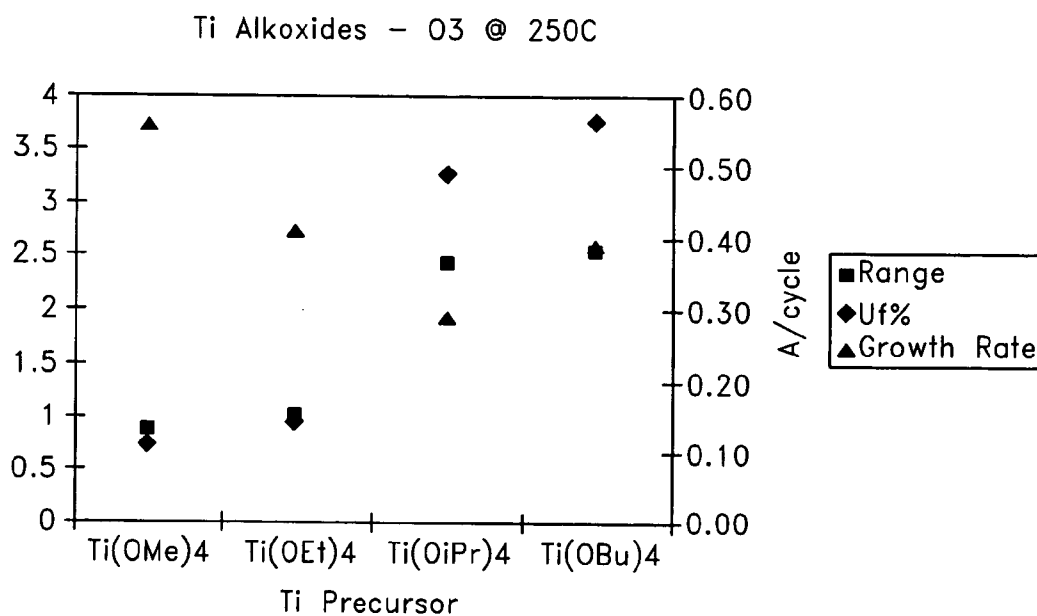


FIG. 1F

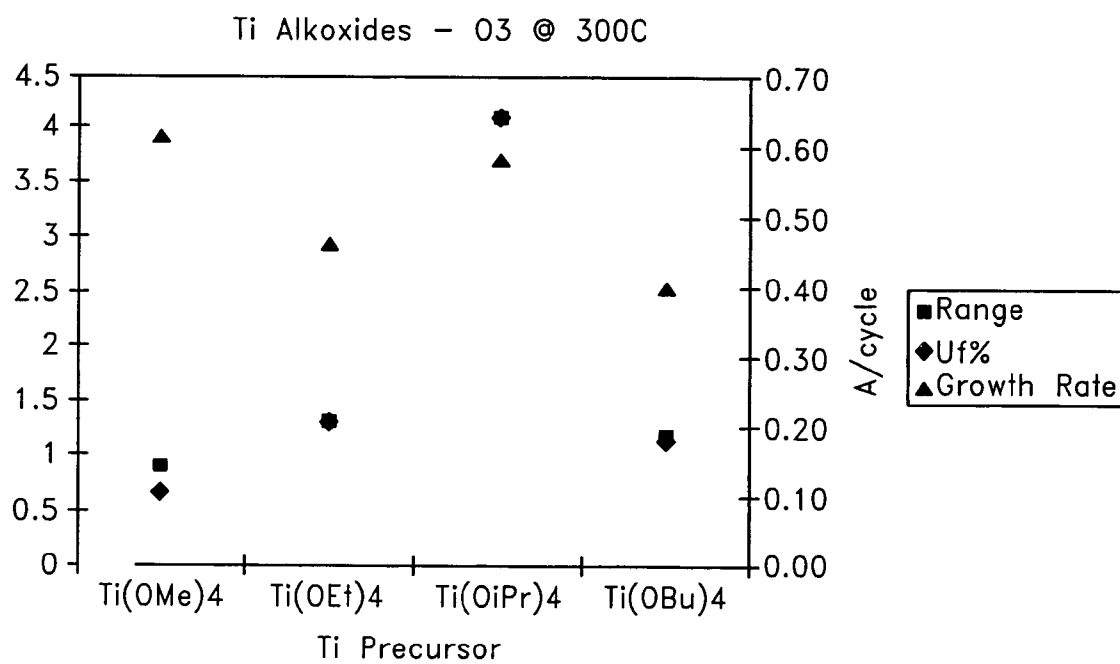


FIG. 1G

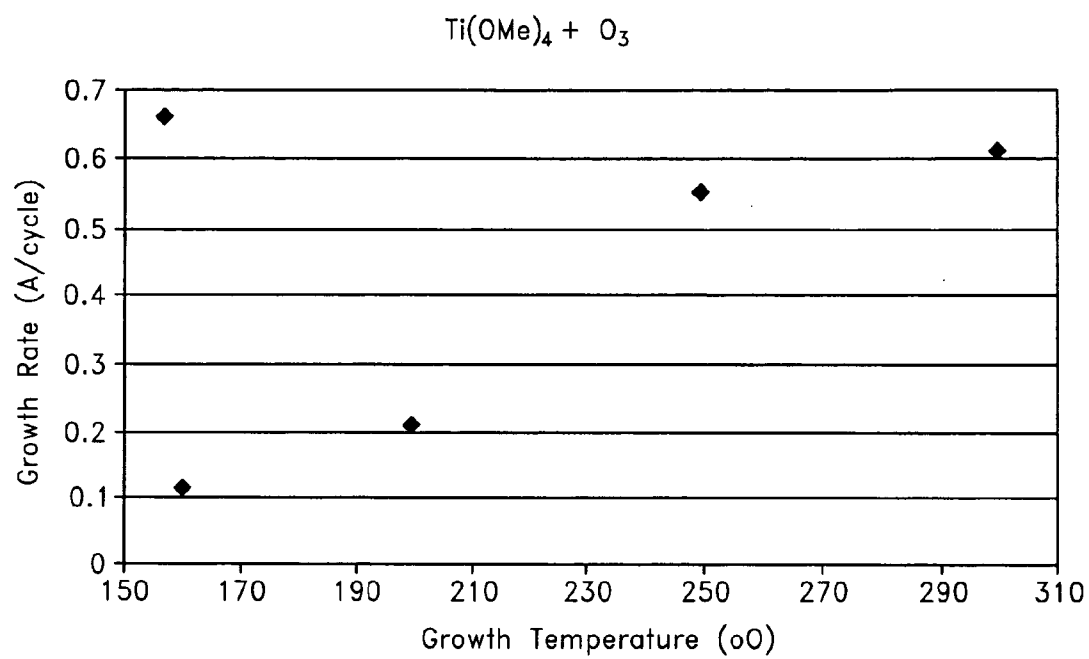


FIG. 2

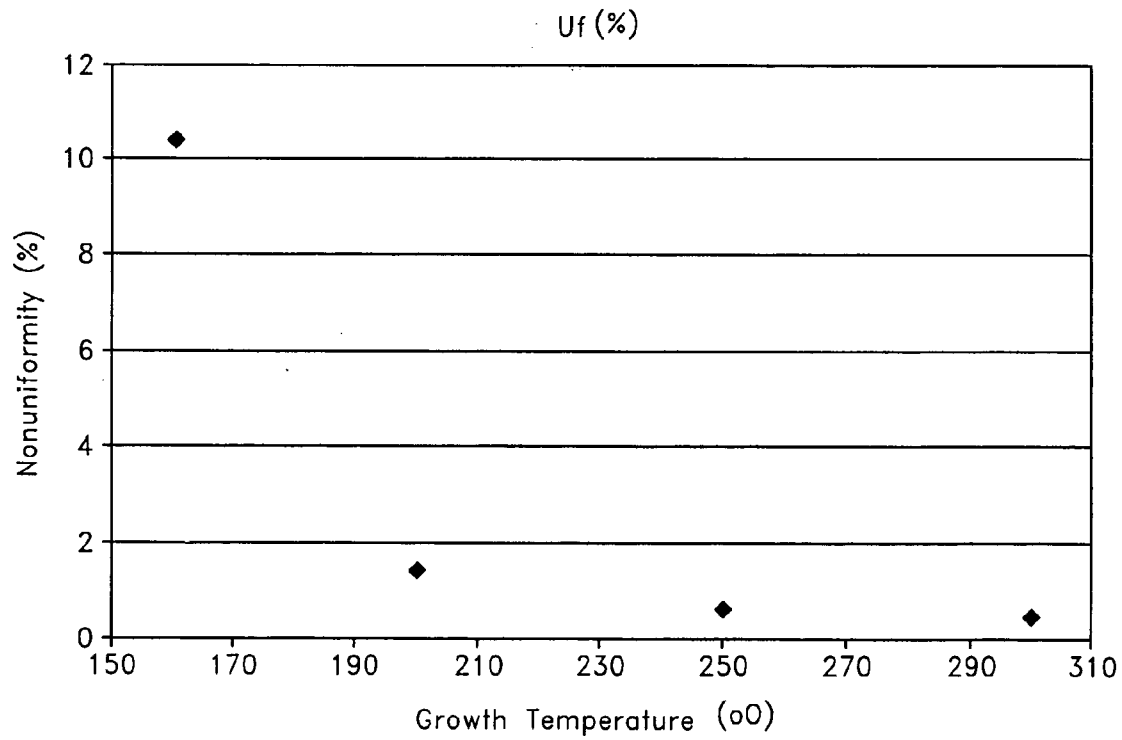


FIG. 3

OXIDE FILMS CONTAINING TITANIUM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority as a continuation in part of U.S. application Ser. No. 09/787,062, filed Jun. 28, 2001. The priority application is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates generally to processes for depositing titanium-containing oxide films. Certain embodiments relate to processes for manufacturing titanium-containing oxide thin films by atomic layer deposition using volatile titanium compounds as source materials.

[0004] 2. Description of the Related Art

[0005] Atomic layer deposition ("ALD") refers to vapour deposition-type methods in which a material, typically a thin film, is deposited on a substrate from vapour phase reactants. It is based on sequential self-saturating surface reactions. ALD is described in detail in U.S. Pat. Nos. 4,058,430 and 5,711,811, incorporated herein by reference. ALD reactors benefit from the use of inert carrier and purging gases, which makes the system fast.

[0006] According to the principles of ALD, the reactants (also referred to as "source chemicals" or "precursors") are separated from each other, typically by inert gas, to prevent gas-phase reactions and to enable the above-mentioned self-saturating surface reactions. Surplus chemicals and reaction by-products are removed from the reaction chamber by purging with an inert gas and/or evacuating the chamber before the next reactive chemical pulse is introduced. Undesired gaseous molecules can be effectively expelled from the reaction chamber by keeping the gas flow speeds high with the help of an inert purging gas. The purging gas pushes the extra molecules towards the vacuum pump used for maintaining a suitable pressure in the reaction chamber. ALD provides controlled film growth as well as outstanding conformality.

[0007] Titanium containing oxides are technologically very important and they have a variety of industrially useful properties. They function well, for example, as semiconductors, insulators and ferroelectrics. TiO_2 has a high permittivity of around 70. BaTiO_3 and SrTiO_3 have permittivities of several hundreds. Titanium also has several technologically important ternary compounds, such as BiTiO_3 and PbTiO_3 . Pure TiO_2 is usually oxygen deficient and thus semiconducting. Semiconducting TiO_2 has been used, for example, in solar cells and self-cleaning coatings.

[0008] Alkaline earth metals (such as Ba and Sr) easily form stable non-volatile halides. Therefore, halide-containing precursors of these metals are not generally useful in depositing oxides such as SrTiO_3 and BaTiO_3 by ALD. In addition, alkaline earth metals easily form hydroxides. As a result, ALD using water as an oxygen source can be problematic, requiring long purge times and/or high temperatures. However, long purge times effectively impair the productivity of these processes. Further, it can be difficult to find a deposition temperature that will not cause decompo-

sition of the precursors and will keep the thin film atoms intact, but will still keep the precursors in gaseous phase and provide the activation energy for the surface reactions.

SUMMARY OF THE INVENTION

[0009] In one aspect atomic layer deposition processes for producing titanium-containing oxide thin films are provided. The processes preferably comprise alternately contacting a substrate in a reaction space with vapor phase pulses of a titanium alkoxide reactant, such as a titanium methoxide compound and at least one oxygen source material capable of forming an oxide with the titanium. In some embodiments, the titanium methoxide is $\text{Ti}(\text{OMe})_4$. Preferably, the oxygen source material is ozone. However, in some embodiments the oxygen source material is selected from the group consisting of water, oxygen, hydrogen peroxide, aqueous solutions of hydrogen peroxide, ozone, oxides of nitrogen, halide-oxygen compounds, peracids ($-\text{O}-\text{O}-\text{H}$), alcohols, alkoxides, oxygen-containing radicals and mixtures thereof.

[0010] In some embodiments, ternary and other multicomponent oxide films are deposited by providing a second metal source material, preferably comprising at least one transition metal or main group metal, followed by provision of an oxygen source material.

[0011] In some embodiments, the deposition temperature is preferably between about 100°C . and about 300°C .

[0012] In another aspect, multicomponent oxide thin films comprising titanium are deposited by atomic layer deposition type processes. The processes preferably comprise contacting a substrate with alternate and sequential vapour phase pulses of a metal precursor and an oxygen source material, where the metal precursor is preferably a titanium alkoxide compound and the oxygen source material is preferably ozone. The titanium alkoxide compound may be, for example, a titanium methoxide compound. In some embodiments the multicomponent oxide film comprises titanium, barium and strontium.

[0013] In a further aspect, methods are provided for depositing a multicomponent oxide film comprising barium and strontium by repeating a first, second and third growth cycle. The first growth cycle preferably comprises contacting a substrate in a reaction chamber with a titanium methoxide compound, removing excess titanium methoxide, contacting the substrate with ozone and removing excess ozone from the reaction chamber. In the second and third deposition cycles, the substrate is alternately contacted with a barium or strontium compound, respectively, and an oxygen source material, such as ozone. The cycles may be repeated in equivalent numbers. In other embodiments, the ratio of cycles is varied to achieve the desired film composition, as will be apparent to the skilled artisan.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIGS. 1a-g** are graphical presentations of the range, uniformity and growth rate of titanium oxide films deposited at temperatures of 100 - 300°C . using titanium alkoxides as the titanium source material and water (**FIGS. 1a-1c**) or ozone (**FIGS. 1d-1g**) as the oxidant. Deposition was carried out at 200°C . in **FIG. 1a**, at 250°C . in **FIG. 1b**, at 300°C . in **FIG. 1c**, at 150°C . in **FIG. 1d**, at 200°C . in **FIG. 1e**, at 250°C . in **FIG. 1f** and at 300°C . in **FIG. 1g**.

[0015] FIG. 2 is a graphical presentation of the growth rate as a function of the growth temperature (deposition temperature). The titanium source chemical was $\text{Ti}(\text{OMe})_4$ and the oxidant was ozone. A 200 mm wafer was measured at 49 points.

[0016] FIG. 3 is a graphical presentation of the film nonuniformity as a function of growth temperature. The titanium source was $\text{Ti}(\text{OMe})_4$ and the oxidant was ozone. A 200 mm wafer was measured at 49 points.

DETAILED DESCRIPTION

[0017] In context of the present invention, “an ALD type process” generally refers to a process for depositing thin films on a substrate molecular layer by molecular layer. This controlled deposition is made possible by self-saturating chemical reactions on the substrate surface. Gaseous reactants are conducted alternately and sequentially into a reaction chamber and contacted with a substrate located in the chamber to provide a surface reaction. Typically, a pulse of a first reactant is provided to the reaction chamber where it chemisorbs to the substrate surface in a self-limiting manner. Excess first reactant is then removed and a pulse of a second reactant is provided to the reaction chamber. The second reactant reacts with the adsorbed first reactant, also in a self-limiting manner. Excess second reactant and reaction by-products, if any, are removed from the reaction chamber. Additional reactants may be supplied in each ALD cycle, depending on the composition of the thin film being deposited.

[0018] pressure and the temperature of the reaction chamber are adjusted to a range where physisorption (i.e. condensation of gases) and thermal decomposition of the precursors are avoided. Consequently, only up to one monolayer (i.e. an atomic layer or a molecular layer) of material is deposited at a time during each pulsing cycle. The actual

[0019] rate of the thin film, which is typically presented as Å/pulsing cycle, depends, for example, on the number of available reactive surface sites on the surface and bulkiness of the reactant molecules.

[0020] Gas phase reactions between precursors and any undesired reactions with by-products are preferably inhibited or prevented. Reactant pulses are separated from each other and the reaction chamber is purged with the aid of an inactive gas (e.g. nitrogen or

[0021] and/or evacuated between reactant pulses to remove surplus gaseous reactants and reaction by-products from the chamber. The principles of ALD type processes have been presented by the inventor of the ALD technology, Dr T. Suntola, e.g. in the Handbook of Crystal Growth 3, Thin Films and Epitaxy, Part B: Growth Mechanisms and Dynamics, Chapter 14, Atomic Layer Epitaxy, pp. 601-663, Elsevier Science B. V. 1994, the disclosure of which is incorporated herein by reference.

[0022] An extensive description of ALD precursors and ALD-grown materials has been presented by Prof. M. Ritala and Prof. M. Leskelä in a recent review article, Handbook of Thin Film Materials, Vol. 1: Deposition and Processing of Thin Films, Chapter 2 “Atomic Layer Deposition”, pp. 103-159, Academic Press 2002, incorporated by reference herein.

[0023] In context of the present application “a reaction space” designates generally a reaction chamber, or a defined volume therein, in which the conditions can be adjusted so that deposition of a thin film is possible.

[0024] In context of the present application, “an ALD type reactor” is a reactor where the reaction space is in fluid communication with an inactive gas source and at least one, preferably at least two precursor sources such that the precursors can be pulsed into the reaction space. The reaction space is also preferably in fluid communication with a vacuum generator (e.g. a vacuum pump), and the temperature and pressure of the reaction space and the flow rates of gases can be adjusted to a range that makes it possible to grow thin films by ALD type processes.

[0025] As is well known in the art, there are a number of variations of the basic ALD method, including PEALD (plasma enhanced ALD) in which plasma is used for activating reactants. Conventional ALD or thermal ALD refers to an ALD method where

[0026] is not used but where the substrate temperature is high enough for overcoming the

[0027] barrier (activation energy) during collisions between the chemisorbed species on the surface and reactant molecules in the gas phase so that up to a molecular layer of thin film grows on the substrate surface during each ALD pulsing sequence or cycle. For the purpose

[0028] present invention, the term “ALD” covers both PEALD and thermal ALD.

[0029] “Metal source material” and “metal precursor” are used interchangeably to designate a volatile or gaseous metal compound that can be used in an ALD process. Preferred metal source materials and metal precursors can be used as a starting compound for the corresponding metal oxide.

[0030] The term “multicomponent oxide” covers oxide materials comprising at least two different metal cations.

[0031] According to preferred embodiments, titanium oxide containing thin films are deposited by ALD using titanium alkoxide precursors, more preferably the specific alkoxide precursor $\text{Ti}(\text{OMe})_4$.

[0032] In a preferred ALD type process, a gas phase pulse of an evaporated titanium alkoxide compound, preferably an evaporated titanium methoxide compound, is introduced into the reaction space of an ALD reactor, where it is contacted with a suitable substrate. No more than a monolayer of the titanium alkoxide compound adsorbs to the substrate surface in a self-limiting manner. Excess titanium alkoxide compound is removed from the reaction space by purging and/or evacuating the chamber.

[0033] Subsequently, a gas phase pulse of an oxygen source material is introduced into the reaction space, where it reacts with the adsorbed titanium precursor in a self-limiting manner. The oxygen source material is preferably selected from the group consisting of water, oxygen, hydrogen peroxide, aqueous solution of hydrogen peroxide,

[0034] oxides of nitrogen, halide-oxygen compounds, peracids ($-\text{O}-\text{O}-\text{H}$), alcohols, alkoxides, oxygen-containing radicals and mixtures thereof. In preferred embodiments,

ozone is used as the oxygen source material, since it does not form hydroxides with the alkaline earth materials.

[0035] By alternating the provision of the titanium precursor and the oxygen

[0036] material, a titanium oxide thin film can be deposited. A growth rate of about 0.10 to 0.20 Å/cycle is typically achieved in ALD processes. However, when TiO₂ was grown from titanium methoxide and ozone a growth rate of 0.55 Å/c was achieved at 250° C.

[0037] Optionally, an inactive gas can be used as a carrier gas during deposition. Inactive gas may also be used to purge the reaction chamber of excess reactant and reaction by-products, if any, between reactant pulses.

[0038] The deposition can be carried out at normal pressure, but it is preferred to operate the process at reduced pressure. Thus, the pressure in the reactor is typically 0.01-20 mbar, preferably 0.1-5 mbar.

[0039] The reaction temperature can be varied depending on the evaporation temperature and the decomposition temperature of the precursor. In some embodiments the range is from about 100 to 400° C., in particular about 180 to 380° C. The substrate temperature is preferably low enough to keep the bonds between thin film atoms intact and to prevent thermal decomposition of the gaseous reactants. On the other hand, the substrate temperature is preferably high enough to keep the source materials in gaseous phase and avoid condensation. Further, the temperature is preferably sufficiently high to provide the activation energy for the surface reaction. In preferred embodiments the deposition temperature is preferably between about 100 and about 300° C. It is particularly preferred to grow titanium oxide films from titanium methoxide at temperatures of about 100-300° C., more preferably at about 250° C.

[0040] The titanium source temperature is preferably about 120 to 170° C., more preferably about 140° C. In preferred embodiments, the reaction temperature is somewhat higher than the titanium source temperature, typically about 20 to 160° C. higher. In the examples described below, maximum relative growth rates were obtained at 250 and 300° C. using titanium methoxide. The best values for the uniformity were also achieved at these temperatures. When the deposition temperature was increased from 160° C. to 250° C. the growth rate increases from 0.1 to 0.55 Å/cycle (see FIG. 2). From a temperature of 250° C. to 300° C. the growth rate stayed at a relatively constant level of about 0.55 to 0.6 Å/cycle. At 160° C. the non-uniformity was about 10%. This reaction temperature is already relatively close to the evaporation temperature of the Ti precursor. At a higher temperature the uniformity reaches lower values, i.e. about 1.5-0.6%.

[0041] For further details on the operation of a typical ALD process, reference is made to the documents cited above.

[0042] The substrate can be of various types. Examples include, without limitation, silicon, silica, coated silicon, germanium, silicon-germanium alloys, copper metal, noble and platinum metals group including silver, gold, platinum, palladium, rhodium, iridium and ruthenium, nitrides, such as transition metal nitrides, e.g. tantalum nitride TaN, carbides, such as transition metal carbides, e.g. tungsten carbide WC,

and nitride carbides, e.g. tungsten nitride carbide WN_xC_y. The preceding thin film layer deposited on the substrate, if any, will form the substrate surface for the next thin film.

[0043] In order to produce multicomponent oxide films, a second metal source material can be introduced to the ALD process. Additional metal source materials can also be used, depending on the number of metals desired in the thin film. For example, in some embodiments, a third, fourth, fifth etc. . . . metal compound is used. In some preferred embodiments, each additional metal source material is provided in a separate cycle, with each cycle comprising feeding a vapor phase pulse of a metal source material, removing excess metal source material, providing a vapor phase pulse of an oxygen source material and removing excess oxygen source material. The same oxygen source material may be provided after each metal reactant, or different oxidants may be used to oxidize the different metals. The number of cycles for each metal precursor may be approximately equivalent or may be different, depending on the composition of the film that is desired.

[0044] In other embodiments, a pulse of the second metal source reactant is the next reactant provided after the titanium source material in the same deposition cycle. An oxidant is then provided to convert the two metals to oxides. Additional metal reactants may also be provided prior to provision of the oxygen containing source material. In other embodiments, an oxidant is provided after each metal source reactant, as discussed above.

[0045] In addition, in some embodiments, the second (or additional) metal compound is provided in each ALD cycle. That is, a pulse of the second metal compound is provided for each pulse of the titanium reactant. However, in other embodiments the second metal reactant is provided intermittently in the deposition process. In still other embodiments, a nanolaminate structure is deposited by repeating a first cycle comprising provision of the titanium precursor and a first oxidant to deposit a thin film of titanium oxide, followed by repeating a second cycle comprising provision of the second metal precursor to deposit a thin film of the second metal oxide. The nanolaminate can start and end with either metal, and the thickness of each layer can be determined by the skilled artisan based on the particular circumstances.

[0046] Additional metal precursors can be metal compounds comprising a single metal or complex metal compounds comprising two or more metals. The metal compounds are preferably selected from the group of volatile or gaseous compounds of transition metals and main group metals, i.e., elements of groups 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and/or 14 (according to the system recommended by IUPAC) in the periodic table of elements.

[0047] Since the properties of the metal compounds vary, the suitability of each metal compound for use in the ALD processes disclosed herein has to be considered. The properties of the compounds can be found, e.g., in N. Greenwood and A. Earnshaw, *Chemistry of the Elements*, 1st edition, Pergamon Press, 1986. The suitability of any particular compound can readily be determined by a skilled artisan.

[0048] In some embodiments, preferred second metal source materials are halides, preferably fluorides, chlorides,

bromides or iodides, or metal organic compounds, preferably alkoxy, alkylamino, cyclopentadienyl, dithiocarbamate or betadiketonate compounds of the desired metal(s). Also double metal precursors, i.e. molecules containing two metals in a discrete ratio, may be used. In particular embodiments, cyclopentadienyl barium and/or cyclopentadienyl strontium compounds are used.

[0049] In some embodiments, barium, strontium, lanthanum and zirconium are used as sources of a second and/or third and/or fourth etc. . . . metal in ternary and other multicomponent oxides. As mentioned above, the second metal source material (and any additional metal reactants) can be oxidized using the same or another oxygen source material as for the titanium precursor.

[0050] In a particular embodiment a multicomponent oxide thin film comprises barium, strontium and titanium. The multicomponent oxide film may be BST. The multicomponent oxide is preferably deposited by alternating three deposition cycles, as described above. Thus, in one deposition cycle a vapour phase reactant pulse comprising a titanium compound, preferably a titanium alkoxide compound and more preferably a titanium methoxide compound, is fed into the reaction chamber. Excess titanium compound and reaction by products, if any, are removed from the reaction chamber, preferably with the aid of an inert gas. An oxygen source material, preferably ozone, is then provided to the reaction chamber where it reacts with the chemisorbed titanium compound. In the second cycle a barium compound, preferably a cyclopentadienyl compound, is provided in the reactant pulse. In the third cycle a strontium compound, preferably a cyclopentadienyl strontium compound, is provided in the first reactant pulse. The three cycles may be provided in any order and the deposition may begin and end with any of the cycles. In addition, one ratio of the cycles may be varied to provide the desired composition, as can be determined by the skilled artisan.

[0051] In theory, a stoichiometric oxide ABO_3 can be obtained simply by pulsing the two metal precursors and corresponding oxygen sources alternately and the growth rate of the ternary oxide can be predicted by summing the growth rates of the constituent oxides. In practice, however, both assumptions often fail due to the different reactivities of the precursors. The effect of surface chemistry usually causes changes in relative growth rate, which can be determined by comparing the observed film thickness with the theoretical thickness calculated from the growth rates of binary oxides.

[0052] The novel thin film oxide deposition processes will find extensive application as semiconductors, insulators and ferroelectrics. In addition, other applications will be apparent to the skilled artisan.

[0053] The following non-limiting example illustrates one embodiment of the invention.

EXAMPLE 1

[0054] Four different titanium alkoxides were tested as metal precursors in ALD reactions to deposit TiO_2 using H_2O and O_3 as oxygen sources. Films were deposited at temperatures of 100-300° C. (see FIGS. 1a-g).

[0055] Reactions Using H_2O as the Oxygen Source Material:

[0056] a) TiO_2 films were deposited at 200-300° C. by ALD using alternate pulses of $Ti(OEt)_4$ as the titanium

precursor and water as the oxidant. The growth rate increased from 0.30 to 0.39 Å/cycle with increasing temperature. The film uniformity ($Uf\% 1\sigma$) varied between 0.98 and 4.43, with the best uniformity being obtained at a deposition temperature of 250° C.

[0057] b) TiO_2 films were deposited by ALD at deposition temperatures of 200-300° C., using alternating pulses of $Ti(OiPr)_4$ as the titanium precursor and water as the oxidant. Growth rates were about 0.22-0.42 Å/cycle, with the lowest value being obtained at 250° C. and the highest at 300° C. Film uniformity ($Uf\% 1\sigma$) at these temperatures was 4.84 and 6.84 respectively. For an unknown reason the film deposited at 200° C. was very non-uniform, having a uniformity of 23.53%.

[0058] c) TiO_2 films were deposited by ALD at deposition temperatures of 200, 250 and 300° C., using alternating pulses of $Ti(OBu)_4$ as the titanium precursor and water as the oxidant. The growth rates at these temperatures were 0.26, 0.24 and 0.36 Å/cycle respectively. The most uniform films were obtained at 250° C. ($Uf\% 1\sigma 0.81$), while the $Uf\%$ were 3.33 and 1.73 at 200° C. and at 300° C. respectively.

[0059] d) For comparison, films were also deposited by ALD using $Ti(OMe)_4$ as the titanium source material. The growth rates, in this case, increased from 0.44 to 0.55 Å/cycle with increasing temperature (200-300° C.). At the same time the uniformity $Uf\% 1\sigma$ decreased from 2.26 to 0.80.

[0060] Reactions Using O_3 as the Oxygen Source Material:

[0061] a) TiO_2 films were deposited by ALD at 150-300° C., using alternating pulses of $Ti(OEt)_4$ and O_3 . The growth rate increased from 0.12 to 0.46 Å/cycle with increasing temperature. At the same time, the film uniformity ($Uf\% 1\sigma$) decreased from 5.21 to 1.33, with the highest uniformity being obtained at 250° C.

[0062] b) TiO_2 films were deposited by ALD at 100-300° C., using alternating pulses of $Ti(OiPr)_4$ and O_3 . The growth rate was 0.08-0.58 Å/cycle, the lowest value being obtained at 100° C. and the highest value at 300° C. The film uniformity ($Uf\% 1\sigma$) varied between 1.51 and 14.43, with the highest uniformity being obtained at 200° C. and the lowest at 100° C.

[0063] c) TiO_2 films were deposited by ALD at 150-300° C., using alternating pulses of $Ti(OBu)_4$ and O_3 . The growth rate at these temperatures was 0.26-0.99 Å/cycle. The best growth rate was obtained at 150° C. The lowest growth rate was therefore 0.26 Å/cycle, obtained at 200° C., and the highest growth rate was 0.39 Å/cycle, obtained at 300° C. The $Uf\% 1\sigma$ decreased with increasing temperature (200-300° C.) from 3.80 to 1.16, the value obtained at 150° C. being 10.30.

[0064] d) For comparison, the growth rate when using $Ti(OMe)_4$ increased with increasing temperature (160-300° C.) from 0.11 to 0.61 Å/cycle. At the same time the $Uf\% 1\sigma$ decreased from 10.43 to 0.65.

[0065] It will be appreciated by those skilled in the art that various omissions, additions and modifications may be made to the processes described above without departing from the scope of the invention, and all such modifications and

changes are intended to fall within the scope of the invention, as defined by the appended claims.

What is claimed is:

1. An atomic layer deposition process for producing titanium containing oxide thin films comprising alternately contacting a substrate in a reaction space with vapor phase pulses of a titanium alkoxide and at least one oxygen source material.

2. The process according to claim 1, wherein the oxygen source material is selected from the group of water, oxygen, hydrogen peroxide, aqueous solution of hydrogen peroxide, ozone, oxides of nitrogen, halide-oxygen compounds, peracids (—O—O—H), alcohols, alkoxides, oxygen-containing radicals and mixtures thereof.

3. The process according to claim 2, wherein the oxygen source material is ozone.

4. The process according to claim 1, wherein the titanium alkoxide source temperature is about 140°C .

5. The process according to claim 1, wherein the deposition temperature is in from about 100°C . to about 300°C .

6. The process according to claim 5, wherein the deposition temperature is about 250°C .

7. The process according to claim 1, additionally comprising contacting the substrate with alternating pulses of a second metal precursor.

8. The process according to claim 7, wherein the titanium containing oxide thin film is a multicomponent film.

9. The process according to claim 7, wherein the second metal precursor is a metal compound comprising a single metal or a complex metal compound comprising two or more metals.

10. The process according to claim 9, wherein the metal compound or the complex metal compound comprises titanium, lanthanum or zirconium.

11. A atomic layer deposition type process for depositing a multicomponent oxide thin film comprising titanium, the process comprising contacting a substrate with alternate and sequential vapor phase pulses of a metal precursor and an oxygen source material, wherein the metal precursor is a titanium alkoxide compound and the oxygen source material is ozone.

12. The process of claim 11, additionally comprising contacting the substrate with a vapor phase pulse of a second metal precursor.

13. The process of claim 11, wherein the titanium alkoxide compound is a titanium methoxide compound.

14. The process of claim 11, wherein the multicomponent oxide comprises barium and strontium.

15. A method for growing a thin film comprising barium, strontium and titanium on a substrate in a reaction chamber by atomic layer deposition, wherein a first growth cycle comprises:

feeding a first reactant pulse into the reaction chamber, wherein the first reactant is a titanium methoxide compound;

removing the first reactant from the reaction chamber with the aid of an inert gas;

feeding an oxygen source material into the reaction space, wherein the second reactant is ozone; and

removing excess second reactant from the reaction chamber with the aid of an inert gas.

16. The method of claim 15, additionally comprising a second growth cycle, the second growth cycle comprising:

feeding a second reactant pulse into the reaction chamber, wherein the third reactant pulse is a barium compound; and

removing excess second reactant from the reaction chamber with the aid of an inert gas;

feeding an oxygen source material into the reaction chamber; and

removing excess oxygen source material from the reaction chamber with the aid of an inert gas.

17. The method of claim 16, wherein the oxygen source material is ozone.

18. The method of claim 16, wherein the barium compound is a cyclopentadienyl compound.

19. The method of claim 16, additionally comprising a third growth cycle, the third growth cycle comprising:

feeding a third reactant pulse into the reaction chamber, wherein the third reactant pulse is a strontium compound; and

removing excess third reactant from the reaction chamber with the aid of an inert gas;

feeding an oxygen source material into the reaction chamber; and

removing excess oxygen source material from the reaction chamber with the aid of an inert gas.

20. The method of claim 18, wherein the oxygen source material is ozone.

21. The method of claim 18, wherein the strontium compound is a cyclopentadienyl compound.

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