low melting point, and are outstandingly stable in air and to heat and light. Consequently, the indium compounds in Application Example 7 to Application Example 13 above are liquids at the desired indium compound supply temperature, and are easily supplied to the film-forming process.

Formation of indium-containing films can be carried out by ALD with the present invention, and in order to ensure a broad ALD window and obtain high quality it is necessary to be able to form a film at high temperatures. The indium compounds in Application Example 7 to Application Example 13 above have high heat stability, and therefore the film-forming process can be carried out at high temperature. Moreover, a high GPC is obtained by employing the indium compounds in Application Example 7 to Application Example 13 above. Consequently, they are ideal materials having a broad ALD window, for obtaining high quality films with a high throughput.

In one aspect, there is provided a process for forming an indium-containing film on at least part of the surface of a substrate wherein the process for forming an indium containing film includes

(a) a step of placing an aforementioned substrate inside a chamber, and

(b) a step of introducing a gas which includes an indium compound having a structure with a hydrocarbon group as a substituent group on a cyclopentadienyl group represented by general formula (I) below into the aforementioned chamber, and

(c) a first purging step after carrying out the aforementioned step (b), in which the aforementioned chamber is purged with a first purge gas, and

(d) a step in which an oxygen-containing gas is introduced into the aforementioned chamber, and

(e) a second purging step after carrying out the aforementioned step (d), in which the aforementioned chamber is purged with a second purge gas,

wherein steps (b) to (e) are repeated at a temperature of 225°C or higher and 400°C or lower until a desired thickness of the indium-containing film is obtained,

In $(C_5R^1_xH_{(5-x)})$ ・・・・・ (1)

wherein in general formula (1), x is an integer 1-5, and each R^1 is independently a C_{5-8} hydrocarbon group.

In another aspect, there is provided an indium compound having a structure with a hydrocarbon group as a substituent group on a cyclopentadienyl group for forming the indium-containing film, represented by general formula (2) below:

$In(C_5R^1_xH_{(5-x)})$ ・・・・・ (2)

wherein in general formula (2), x is an integer 1-5, and each R^1 is independently a C_{5-8} hydrocarbon group which includes a secondary carbon.

Simplified Description of the Drawings

[0041]

[Figure 1] Figure 1 is a graph showing the result of thermal analysis of In(^{s}BuCp) obtained in Example 1.

[Figure 2] Figure 2 is a graph showing the result of thermal analysis of In(^{s}PenCp) obtained in Example 2.

[Figure 3] Figure 3 is a graph showing the result of thermal analysis of In(^{i}PenCp) obtained in Example 3.

Modes for Carrying Out the Invention

[0042]

Modes for carrying out the present invention are described in detail below. It should be understood that the present invention is not restricted only to the embodiments described below, and includes various other different examples within a scope which does not alter the essential substance of the present invention.

[0043]

<Indium compounds>

The indium compound according to one embodiment of the present invention is a compound represented by general formula (1) to (8) below.

[0044]

Compounds represented by general formula (1)

$In(C_5R^1_xH_{(5-x)})$ ・・・・・ (1)

CLAIMS

1. A process for forming an indium-containing film on at least part of the surface of a substrate wherein the process for forming an indium containing film includes

(a) a step of placing an aforementioned substrate inside a chamber, and

(b) a step of introducing a gas which includes an indium compound having a structure with a hydrocarbon group as a substituent group on a cyclopentadienyl group represented by general formula (1) below into the aforementioned chamber, and

(c) a first purging step after carrying out the aforementioned step (b), in which the aforementioned chamber is purged with a first purge gas, and

(d) a step in which an oxygen-containing gas is introduced into the aforementioned chamber, and

(e) a second purging step after carrying out the aforementioned step (d), in which the aforementioned chamber is purged with a second purge gas,

wherein steps (b) to (e) are repeated at a temperature of 225°C or higher and 400°C or lower until a desired thickness of the indium-containing film is obtained,

In $(C_5R^1_xH_{(5-x)})$ ・・・・・ (1)

wherein in general formula (1), x is an integer 1-5, and each R^1 is independently a C_{5-8} hydrocarbon group.

2. The process for forming the indium-containing film as claimed in claim 1, wherein the aforementioned indium-containing film is a film containing indium oxide, and the aforementioned oxygen-containing gas includes at least ozone.

3. The process for forming the indium-containing film as claimed in claim 1 or claim 2, wherein the aforementioned indium containing film is an insulating material with a relative permittivity (k value) of ≥7.

4. The process for forming the indium-containing film as claimed in claim 2, wherein the aforementioned oxygen-containing gas further includes water, hydrogen peroxide, oxygen, nitric oxide, nitrous oxide, nitrogen dioxide, a sulfur oxide or a gas comprising a combination thereof.

5. The process for forming the indium-containing film according to any of claim 1 to claim 4, wherein the substrate is glass, silicon, silica or a polymer.

6. The process for forming the indium-containing film as claimed in any of claim 1 to claim 5, characterized in that the speed of film formation in one cycle of steps (a)-(e) above is ≥0.7Å/cycle.

7. An indium compound, having a structure with a hydrocarbon group as a substituent group on a cyclopentadienyl group, for forming an indium-containing film, represented by general formula (2) below:

$In(C_5R^1{}_xH_{(5-x)})$ ・・・・・ (2)

wherein in general formula (2), x is an integer 1-5, and each R^1 is independently a C_{5-8} hydrocarbon group which includes a secondary carbon.

8. The compound as claimed in claim 7 wherein the aforementioned indium compound represented by general formula (2) is $In(C_5{}^sPenH_4)$ or $In(C_5{}^iPenH_4)$.

9. The indium compound as claimed in any of claim 7 to claim 8, wherein the compound has a melting point of ≤80ºC.

10. The indium compound as claimed in any of claim 7 to claim 8, wherein the compound is material for forming an indium-containing film for producing a semiconductor device.

11. The indium compound as claimed in any of claim 7 to claim 8, which is material for forming an indium-containing film by a film-forming process selected from a set comprising chemical vapor deposition (CVD), atomic layer deposition (ALD), plasma-enhanced chemical vapor deposition (PECVD), plasma-enhanced atomic layer deposition (PEALD), pulsed chemical vapor deposition (PCVD), low pressure chemical vapor deposition (LPCVD), subatmospheric chemical vapor deposition (SACVD), atmospheric pressure chemical vapor deposition (APCVD), spatial ALD, radical-assisted deposition, supercritical fluid deposition, spi*n*-on deposition and combinations thereof.

12. A process for forming an indium-containing film on at least part of the surface of a substrate, wherein the process for forming an indium containing film includes

(a) a step of placing an aforementioned substrate inside a chamber, and

(b) a step of introducing a gas which includes an indium compound of any one of claims 7 to 8 into the aforementioned chamber, and

(c) a first purging step after carrying out the aforementioned step (b), in which the aforementioned chamber is purged with a first purge gas, and

(d) a step in which an oxygen-containing gas is introduced into the aforementioned chamber, and

(e) a second purging step after carrying out the aforementioned step (d), in which the aforementioned chamber is purged with a second purge gas and

and steps (b)-(e) are repeated, at a temperature of ≥225ºC and ≤400ºC, until the desired thickness of the aforementioned indium-containing film is obtained.

13. The process for forming the indium-containing film according to claim 2, wherein the indium-containing film is an insulator with a relative permittivity (k value) of 7 or more material.