"METHOD OF MANUFACTURING SEMICONDUCTOR DEVICES"

Background of the Invention

The present invention relates to a method of manufacturing semiconductor devices and, more particularly, to an improvement on forming an interlayered insulating layer of semiconductor devices having a multi-layered wiring layer structure.

With an increase in packing density of semiconductor devices, a multi-layered wiring structure in which a number of wiring layers are formed on a semiconductor substrate has been developed, and the number of steps of structuring such multi-layered wiring layers has increased.

In particular, a large part of manufacturing cost is occupied by the steps of forming multi-layered wiring layers. In order to reduce the cost of semiconductor devices, a reduction of the steps of forming multi-layered wiring layers has been demanded.

Conventional steps of forming multi-layered wiring layers will be described below. A first wiring material for lower wiring layers is deposited on a semiconductor substrate, and then, the deposited wiring material layer is patterned to form a plurality of lower wirings. A first insulating layer is formed on the lower wiring layers to bury the gaps between the lower wirings. At this time, step configuration is present on the surface of the first insulating film

depending on the lower wiring pattern. The step configuration adversely affects to deposition of a second wiring material for an upper wiring layer and patterning of the upper wiring material layer, which are carried out in the following steps, so that serious defects such as disconnection or short circuit of the upper wirings may occur.

In general, before the second wiring material is deposited on the first insulating layer serving as an underlying layer, the surface of the first insulating film is flattened by etch back to remove the step configuration, and the second insulating material is deposited on the flattened surface of the first insulating layer.

Therefore, the conventional method of forming the interlayered insulating layer structure in which the first and second insulating films are superposed include an increased number of steps, i.e., formation of the first insulating film, flattening of the surface of the first insulation film, and formation of the second insulating film. This is a large hindrance to the demand for the reduction of the steps of forming the multi-layered wiring layers.

In place of the method of flattening the surface of the first insulating film, a method of moderating the step configuration on the surface of the first insulating film by forming an SOG (Spin on Glass) film

of an insulating material on the first insulating film is available.

However, this method requires an increased number of annealing steps of forming of the SOG film. Furthermore, an undesired portion of the SOG film must be removed by etch back to assure the reliability of the upper wiring layer. As a result, the method requires an increased number of steps, and does not sufficiently cope with the demand for the reduction of the steps of forming multi-layered wiring layers.

Recently, as one of techniques coping with the reduction of the steps of forming multi-layered wiring layers, the following method has attracted attention. That is, in formation of an interlayered insulating layer on the lower wiring layers, an SiH_4 gas reacts to H_2O_2 (hydrogen peroxide water) serving as an oxidant at a low temperature (e.g., about 0°C) in a vacuum state to form a self-flow type (reflow) insulating film (to be referred to as a reflow insulating film hereinafter) on the lower wiring layer.

According to this method, the formation of an insulating film (reflow insulating film) and flattening of the surface of the insulating film can be simultaneously achieved. That is, in the step of forming the insulating film, film formation and flattening can be simultaneously achieved. For this reason, a reduction of the steps of forming multi-

layered wiring layers can be realized.

However, in the method of forming the reflow insulating film, as is apparent from its reaction manner, moisture (H_2O) is generated during formation of the insulating film, and thus the insulating film has a high moisture content. The reflow insulating film tends to crack mainly when it is subjected to annealing (e.g., at 450°C for 30 minutes) at a later step.

FIG. 6 shows data obtained by actually measuring the state wherein cracks are formed in the reflow SiO_2 film formed by the conventional method. In this case, the thickness of the reflow SiO_2 film and the thickness of an SiO film (to be referred to as a cap film hereinafter) formed on the reflow SiO_2 film by a general plasma CVD (Chemical Vapor Deposition) method are used as parameters. Upon completion of the film formation, these films are annealed at 450°C for 30 minutes.

As is apparent from FIG. 6, regardless of the presence/absence of the cap film, cracks are formed when the thickness of the reflow SiO_2 film is 1.1 μm or more. In other words, the allowable thickness of the reflow SiO_2 film has an upper limit from the view point of crack resistance. The upper limit is as low as 1.0 μm.

However, in order to form a reflow SiO_2 film which

is sufficiently flattened, the reflow SiO_2 requires a thickness of a considerable extent.

When the cap film is formed on the reflow SiO_2 film by a general plasma CVD, a semiconductor wafer is not still sufficiently heated up. For this reason, a cap film having a low wet etching rate is formed. Since the etching rate of the cap film is low, an abnormal configuration is formed between the cap film and the reflow SiO_2 film in an etching step performed upon completion of the step of forming a cap film, for forming a through-hole or a via-hole in the reflow SiO_2 film and the cap film. The abnormal configuration degrades the coverage of an upper wiring layer formed in the following step, and causes a connection failure of the upper wiring layer.

As described above, the thickness of a reflow SiO_2 film obtained when a reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer of the conventional steps of forming multi-layered wiring layers is to be increased to flatten the reflow SiO_2 film, however, the upper limit of the thickness is inadvantageously suppressed to a low level from a viewpoint of crack resistance.

In addition, an abnormal configuration is formed between the cap film and the reflow SiO_2 film in an etching step for forming a through-hole or a via-

hole in the reflow SiO_2 film and the cap film formed thereon. The abnormal configuration degrades the coverage of the upper wiring layer, and causes a connection failure of the upper wiring layer.

Summary of the Invention

The present invention has been made in consideration of the above problem, and has as its object to provide a method of manufacturing a semiconductor device in which the crack resistance of a reflow insulating film obtained when a reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer of the steps of forming multi-layered wiring layers of semiconductor devices is improved to obtain a desirable thickness capable of flattening the reflow insulating film, and the reliability of an upper wiring layer formed after the interlayered insulating layer is formed can be improved.

According to the present invention, there is provided a method of manufacturing a semiconductor device, characterized by comprising the steps of supplying an SiH_4 gas and H_2O_2 into a reaction chamber in which a semiconductor substrate having an insulating film formed thereon is placed to cause the SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film having a thickness of 0.4 μm

to 1.4 μm on the semiconductor substrate; putting the semiconductor substrate in the reaction chamber in vacuum for more than 30 seconds; and putting the semiconductor substrate at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds.

The step of forming the insulating film to the step of forming the reflow SiO_2 film may be continuously performed in vacuum.

In the method of the present invention, a reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer of the steps of forming multi-layered wiring layers to form a reflow SiO_2 film, and the semiconductor substrate is put in a vacuum of a predetermined pascal for a predetermined time or more. In addition, the semiconductor substrate is put at a predetermined high temperature for a predetermined time or more to reduce the moisture content contained in the reflow SiO_2 film, so that crack resistance can be improved.

Since, in this way, the clack resistance of the reflow SiO_2 film is improved, the reflow insulating film can assure a desired thickness capable of flattening the reflow insulating film. Thus, the flatness of the surface of the interlayered insulating layer can be improved, and the upper wiring layer formed on the interlayered insulating layer can be micropatterned.

In addition, an abnormal configuration is not formed between the cap film and the reflow SiO_2 film in an etching step for forming a through-hole or a via-hole in the insulating layers. Therefore, degradation of coverage of an upper wiring layer formed in the following steps or a conduction failure of the upper wiring layer are not caused, and the reliability of the upper wiring layer can be improved.

According to the present invention, there is further provided a method of manufacturing a semiconductor device, comprising the steps of: causing a gas to react with H_2O_2 in vacuum to form an insulating film having a substantially flat surface on a semiconductor substrate; putting the semiconductor substrate in a first condition; and putting the semiconductor substrate in a second condition.

The thickness of the insulating film may be substantially 0.4 μm to 1.4 μm.

The step of causing the gas to react with H_2O_2 is carried out in substantially below than 650, at a predetermined temperature range of -10°C to +10°C, an SiO_4 gas being used as the gas.

The first condition may be such that the semiconductor substrate is put in vacuum for substantially more than 30 seconds.

The second condition is such that the semiconductor substrate is put at a temperature

of substantially 300°C to 450° for substantially 120 seconds to 600 seconds.

The method may further comprise a step performed after the putting step of the semiconductor substrate at the high temperature, for forming an insulating film on the reflow SiO_2 film.

The method may further comprise a step carried out carried out after the insulating film forming step, of annealing the semiconductor substrate at a temperature of 450°C for 30 minutes.

According to the present invention, there is still further provided a method of manufacturing a semiconductor device, comprising the steps of: placing a semiconductor substrate with wirings thereon into a reaction chamber of a plasma CVD device of a manufacturing device; forming a plasma SiO_2 film on the semiconductor substrate having a thickness of more than 0.1 μm in the reaction chamber of the plasma CVD device; moving the semiconductor substrate from the reaction chamber of the plasma CVD device into a reaction chamber of a pressure-reduced CVD device of the manufacturing device; supplying an SiH_4 gas and H_2O_2 into the reaction chamber of the pressure-reduced CVD device in which the semiconductor substrate is placed to cause the SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film

having a thickness of 0.4 μm to 1.4 μm on the semiconductor substrate; putting the semiconductor substrate, still retained in the reaction chamber of the pressure-reduced CVD device, in vacuum for more than 30 seconds; moving the semiconductor substrate from the reaction chamber of the pressure-reduced CVD device to the reaction chamber of the plasma CVD device; and putting the semiconductor substrate, in the reaction chamber of the plasma CVD device, at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds.

The moving steps may be carried out by an arm provided in the manufacturing device.

The method may further comprise a step performed after the putting step of the semiconductor substrate at the high temperature, for forming an insulating film on the reflow SiO_2 film.

The method may further comprise a step after the insulating film forming step, of annealing the semiconductor substrate at a temperature of 450°C for 30 minutes.

Brief Description of the Drawings

FIGS. 1A to 1C are schematic view showing an arrangement of a semiconductor manufacturing apparatus used in an embodiment of a method of manufacturing semiconductor devices according to the present invention;

FIGS. 2A to 2E are sectional views showing semiconductor structures in the steps of forming multi-layered wiring layers when a reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer according to an embodiment of the method of manufacturing semiconductor devices of the present invention;

FIG. 3 is a flow chart showing the steps of the embodiment;

FIG. 4 is a flow chart showing the steps of the embodiment;

FIG. 5 is a graph showing crack formation when the thickness of a reflow SiO_2 film obtained in the steps of the embodiment of the present invention and the thickness of a cap SiO film formed on the reflow SiO_2 film are used as parameters; and

FIG. 6 is a graph showing crack formation when the thickness of a reflow SiO_2 film obtained in the steps of forming multi-layered wiring layers when a reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer in manufacture of a conventional semiconductor device and the thickness of a cap SiO film formed on the reflow SiO_2 film are used as parameters.

Detailed Description of the Preferred Embodiments

An embodiment of the present invention will be described with reference to the accompanying drawings.

FIG. 1A schematically shows an arrangement of a semiconductor manufacturing apparatus used in an embodiment of a method of manufacturing semiconductor devices according to the present invention.

Referring to FIG. 1A, reference numeral 10 denotes a plasma CVD device; 20, a reduced-pressure CVD device; 1, a cassette loader chamber in which a semiconductor substrate is set; and 2, a robot arm for conveying (i.e., loading/unloading) the semiconductor substrate between the cassette loader chamber 1 and the reaction chamber of the plasma CVD device 10 or the reaction chamber of the reduced-pressure CVD device 20.

The plasma CVD device 10 has a general arrangement. This arrangement is schematically shown in FIG. 1B. Referring to FIG. 1B, reference numeral 11 denotes a reaction chamber (chamber); 12, an upper electrode (shower head); 13, a lower electrode (table); 14, an exhaust port; 15, a process gas supply path; and 16, a high frequency power supply path.

The reduced-pressure CVD device has a general arrangement. This arrangement is schematically shown in FIG. 1C. Referring to FIG. 1C, reference numeral 21 denotes a reaction chamber (chamber); 22, an upper electrode (shower head); 23, a lower electrode (table); 24, an exhaust port; 25, an SiH_4 gas supply path; and 26, an H_2O_2 supply path.

FIGS. 2A to 2E show the cross-sections of semiconductor structures in the steps of forming multi-layered wiring layers when a reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer according to an embodiment of a method of manufacturing semiconductor devices of the present invention.

The steps of forming multi-layered wiring layers when the reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer according to an embodiment of a method of manufacturing semiconductor devices of the present invention will be described hereinafter with reference to FIGS. 1A to 1C, FIGS. 2A to 2E.

As shown in FIG. 2A, a first wiring material (e.g., aluminum) for a lower wiring layer is deposited on an insulating film 31 on a semiconductor substrate 30 by, e.g., a sputtering method, and the first wiring material layer is patterned by using a photolithography technique and a reactive ion etching (RIE) technique to form a plurality of lower wiring layers 32.

An insulating film is buried between the lower wiring layers 32 and deposited on the upper surfaces of the lower wiring layers using the semiconductor manufacturing apparatus as shown in FIG. 1A, to form an interlayered insulating layer formed on the semiconductor substrate 30.

More specifically, in the step of forming the interlayered insulating layer, the semiconductor substrate 30 on which the lower wiring layers 32 are formed is set on, e.g., a quartz board (not shown) in the cassette loader chamber 1.

The cassette loader chamber 1 is set in vacuum by using a vacuum pump (not shown), and the semiconductor substrate 30 is loaded into the reaction chamber 11 of the plasma CVD device 10 by the robot arm 2. The temperature in the reaction chamber 11 of the plasma CVD device 10 is set to about 300°C in advance, and a first plasma SiO_2 film 33 having a thickness of 0.1 μm or more (100 nm in this embodiment) is formed by a general plasma CVD method on the surface of the semiconductor substrate 30, i.e., on the exposed surface of the lower wiring layers 32 and the exposed surface of the insulating film 31 between the lower wiring layers 32.

The semiconductor substrate 30 is moved from the reaction chamber 11 of the plasma CVD device 10 into the reaction chamber 21 of the reduced-pressure CVD device 20 by the robot arm 2. An SiH_4 gas and H_2O_2 are supplied from an SiH_4 gas supply source and an H_2O_2 supply source into the reaction chamber 21 of the reduced-pressure CVD device 20 through the SiH_4 gas supply path 25 and the H_2O_2 supply path 26, respectively, and react to each other in a vacuum of 650 Pa or less

in a temperature range of -10°C to +10°C (e.g., 0°C). As a result, as shown in FIG. 2B, a reflow SiO_2 film 34 having a thickness falling within the range of 0.4 μm to 1.4 μm is formed on the semiconductor substrate 30, i.e., on the first plasma SiO_2 film 33. The thickness of the reflow SiO_2 film 34 means a thickness of that portion of the reflow SiO_2 film 34 which portion is formed on that layer formed on the semiconductor substrate 30, which layer has a flat surface and has a large size of e.g. about 100 μm long × 100 μm wide. The flat surface layer is typically bonding pads formed on the semiconductor substrate, though not shown.

As shown in FIG. 2C, the semiconductor substrate 30 still retained in the reaction chamber 21 of the reduced-pressure CVD device is put in a vacuum of 6.5 Pa or less for 30 seconds or more (30 seconds in this embodiment).

The semiconductor substrate 30 is then moved from the reaction chamber 21 of the reduced-pressure CVD device 20 into the reaction chamber 11 of the plasma CVD device 10 by the robot arm 2. As shown in FIG. 2D, the semiconductor substrate 30 is put in the reaction chamber 11 of the plasma CVD device 10 at a high temperature falling within the range of 300°C to 450°C (300°C in this embodiment) for a time falling within the range of 120 seconds to 600 seconds (120 seconds in this embodiment).

Thereafter, in the reaction chamber 11 of the plasma CVD device 10, as shown in FIG. 2E, a second plasma SiO_2 film 35 serving as a cap film having a thickness of 0.3 μm or more (300 nm in this embodiment) is formed by a plasma CVD method on the surface of the semiconductor substrate 30, i.e., on the reflow SiO_2 film 34.

Thereafter, the semiconductor substrate 30 is removed from the semiconductor manufacturing apparatus, and furnace annealing is performed at 450°C for 30 minutes by using another semiconductor manufacturing apparatus.

Thereafter, an etching step is carried out to form a contact-hole or via-hole (not shown) in these insulating films. Then, a second wiring material for an upper wiring layer is deposited on the semiconductor substrate 30, i.e., on the second plasma SiO_2 film 35 and the exposed portion of the substrate 30. The second wiring material layer (not shown) is patterned to form the upper wiring layer.

The following table shows a comparison data between the prior art and the embodiment the present invention, of the change of moisture contents (%) in reflow SiO_2 film 34 in the following steps.

Table

	Moisture contents (%) in reflow SiO_2 film 34.	
	Prior art	Present invention
When reflow SiO_2 film 34 has been formed (FIG. 2B)	100	100
After semiconductor substrate 30 has been put in vacuum below 6.5 Pa for 30 seconds (FIG. 2C)	--	70
After semiconductor substrate 30 has been put at 300°C for 120 seconds (FIG. 2D)	50	50
When cap film 35 has been formed (FIG. 2E)	20	20
After semiconductor substrate 30 has been annealed at 450°C for 30 minutes	5	5

As is understood from the table, in the embodiment of the present invention, moisture contained in the reflow SiO_2 film 34 was gently changed in the following steps, while in the prior art it was sharply changed. To describe more specific, in the embodiment of the present invention, the semiconductor substrate 30 was first put in vacuum below 6.5 for 30 seconds. With this step, the contained moisture in the reflow SiO_2 film 34 was changed from 100 % to 70 %. Then, the semiconductor substrate 30 was put at 300° C for 120 seconds. With this step, the contained moisture in the reflow SiO_2 film 34 was changed from 70 % to 50 %. Thereafter, the cap SiO_2 film 35 was formed on the semiconductor substrate 30, i.e. on the reflow SiO_2 film 34. With this step, the contained moisture in the reflow SiO_2 film 34 was changed from 50 % to 20 %. After that the semiconductor substrate 30 was annealed at 450° C for 30 minutes. With this step, the contained moisture in the reflow SiO_2 film 34 was changed from 20 % to 5 %. In this way, since in the present invention the moisture contained in the reflow SiO_2 film 34 was changed in the four steps, i.e., stepwise to 70 %, 50 %, 20 % and 5 %. That is, according to the present invention, the moisture contained in the reflow SiO_2 film 34 was gently reduced. In particular, according to the present invention, there is added a step performed after the step in which reflow SiO_2

film 34 was formed, of putting the semiconductor substrate 30 vacuum, so that the moisture contained in the reflow SiO_2 film 34 was prevented from being abruptly reduced from 100 % to 50 % as conventional, resulting in minimum possibility of the reflow SiO_2 film 34 being cracked when the semiconductor substrate 30 was annealed after the cap SiO_2 film was formed.

In the prior art, a step corresponding to the step of putting the semiconductor in vacuum below 6.5 Pa for 30 seconds was not carried out. Thus, the contained moisture in the reflow SiO_2 film 34 was changed from 100 % to 50 % at one step. This abrupt change of the contained moisture in the reflow SiO_2 film 34 will cause cracks in the reflow SiO_2 film 34 when the semiconductor substrate 30 is annealed after the cap SiO_2 film was formed.

The above advantage of the present invention will not be obtained if the step of putting the semiconductor substrate 34 in the high temperature is first carried out, and then, the step of putting the semiconductor substrate 34 in vacuum is carried out, as the moisture contained in the reflow SiO_2 film 34 will be abruptly changed from 100 % to 50 % at the step in which the semiconductor substrate is put at the high temperature. FIGS. 3 and 4 are charts showing the flows of the steps of the embodiment. FIG. 3 shows manufacturing procedures themselves, and FIG. 4 shows

the manufacturing procedures with reference to the relationship between the plasma CVD device and the reduce-pressure CVD device.

Assume that the thickness of the reflow SiO_2 film 34 and the thickness of the plasma SiO_2 film (cap film) on the reflow SiO_2 after annealing is performed at 450°C for 30 minutes are used as parameters. In this case, the results obtained by actually measuring the state wherein cracks are formed are shown in FIG. 5.

As is apparent from FIG. 5, the reflow SiO_2 film 34 obtained in this embodiment has the same crack characteristics of a reflow SiO_2 film on which no cap film is formed. However, when the reflow SiO_2 film 34 has the cap film formed thereon, the upper limit of the thickness of the film free from cracks increases from about 1.0 μm (prior art) to 2.0 μm. Therefore, the crack resistance of the reflow SiO_2 film 34 is improved.

According to the above embodiment, after the reflow insulating film forming technique is applied to the steps of forming an interlayered insulating layer of the steps of forming multi-layered wiring layers to form the reflow SiO_2 film 34, the reflow SiO_2 film 34 is put in a vacuum of a predetermined pascal for a predetermined time or more, and the reflow SiO_2 film 34 is put at a high temperature for a predetermined time or more.

In this manner, even if moisture is generated during formation of the insulating film in the step of forming the reflow SiO_2 film 34 to cause the insulating film to contain moisture, the moisture in the insulating film is reduced in content. Therefore, the reflow SiO_2 film 34 having high crack resistance can be obtained.

In this manner, when the crack resistance of the reflow SiO_2 film is improved, a desired thickness capable of flattening the reflow SiO_2 film can be assured.

Therefore, the flatness of the surface of the interlayered insulating layer can be improved, and serious defects such as disconnection or short circuit of the upper wiring layer can be prevented without adversely affecting the deposition of the upper wiring material on the interlayered insulating layer and patterning the upper wiring material layer.

According to this embodiment, before the cap film 35 is formed on the reflow SiO_2 film by a plasma CVD method, a semiconductor wafer is already sufficiently heated up. For this reason, the wet etching rage of the formed film 35 increases. Therefore, in the etching step of forming a through-hole or via-hole in the interlayered insulating layer constituted by the reflow SiO_2 film 34 and the cap film 35, an abnormal configuration is not formed at the interface between the cap film and the reflow SiO_2 film, the coverage of

the upper wiring layer formed in the following steps is not degraded, and a connection failure of the upper wiring layer does not occur.

As described above, according to the method of manufacturing a semiconductor device of the present invention, the crack resistance of a reflow insulating film obtained when the reflow insulating film forming technique is applied to the steps of forming an inter-layered insulating layer of the steps of forming multi-layered wiring layers can be improved, a desired thickness capable of flattening the reflow insulating film can be assured. For this reason, the flatness of the surface of the interlayered insulating layer can be improved, and an upper wiring layer formed after the interlayered insulating layer is formed can be micropatterned.

In addition, abnormal configuration of the interface of the insulating layers in an etching step for forming a through-hole or a via-hole can be prevented. Therefore, the reliability of the upper wiring layer can be improved without degradation of coverage of an upper wiring layer formed in the following steps or a conduction failure of the upper wiring layer.

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Claims:

1. A method of manufacturing a semiconductor device, comprising the steps of:

supplying an SiH_4 gas and H_2O_2 into a reaction chamber in which a semiconductor substrate having an insulating film formed thereon is placed to cause the SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film having a thickness of 0.4 μm to 1.4 μm on said semiconductor substrate;

putting said semiconductor substrate, retained in said reaction chamber, in vacuum for more than 30 seconds; and

putting said semiconductor substrate at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds.

2. A method of manufacturing a semiconductor device according to claim 1, wherein the step of forming said insulating film to the step of forming said reflow SiO_2 film are continuously performed in vacuum.

3. A method of manufacturing a semiconductor device, comprising the steps of:

causing a gas to react with H_2O_2 in vacuum to form an insulating film having a substantially flat surface on a semiconductor substrate;

putting said semiconductor substrate in a first

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condition; and

putting the semiconductor substrate in a second condition;

4. A method of manufacturing a semiconductor device according to claim 3, wherein the thickness of said insulating film is substantially 0.4 μm to 1.4 μm.

5. A method of manufacturing a semiconductor device according to claim 3, wherein the step of causing the gas to react with H_2O_2 is carried out in substantially below than 650, at a predetermined temperature range of -10°C to +10°C, an SiO_4 gas being used as the gas.

6. A method of manufacturing a semiconductor device according to claim 3, wherein said first condition is such that said semiconductor substrate is put in vacuum for substantially more than 30 seconds.

7. A method of manufacturing a semiconductor device according to claim 3, wherein said second condition is such that said semiconductor substrate is put at a temperature of substantially 300°C to 450° for substantially 120 seconds to 600 seconds.

8. A method of manufacturing a semiconductor device according to claim 1, further comprising a step performed after the putting step of the semiconductor substrate at the high temperature, for forming an insulating film on said reflow SiO_2 film.

9. A method of manufacturing a semiconductor

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device according to claim 8, further comprising a step carried out after the insulating film forming step, of annealing said semiconductor substrate at a temperature of 450°C for 30 minutes.

10. A method of manufacturing a semiconductor device, comprising the steps of:

placing a semiconductor substrate with wirings thereon into a reaction chamber of a plasma CVD device of a manufacturing device;

forming a plasma SiO_2 film on said semiconductor substrate having a thickness of more than 0.1 μm in the reaction chamber of said plasma CVD device;

moving the semiconductor substrate from the reaction chamber of said plasma CVD device into a reaction chamber of a pressure-reduced CVD device of the manufacturing device;

supplying an SiH_4 gas and H_2O_2 into the reaction chamber of the pressure-reduced CVD device in which the semiconductor substrate is placed to cause the SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film having a thickness of 0.4 μm to 1.4 μm on said semiconductor substrate;

putting said semiconductor substrate, still retained in said reaction chamber of the pressure-reduced CVD device, in vacuum for more than 30 seconds;

moving the semiconductor substrate from the

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reaction chamber of the pressure-reduced CVD device to the reaction chamber of the plasma CVD device; and

putting said semiconductor substrate, in the reaction chamber of the plasma CVD device, at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds.

11. A method of manufacturing a semiconductor device according to claim 1, wherein said moving steps are carried out by an arm provided in the manufacturing device.

12. A method of manufacturing a semiconductor device according to claim 10, further comprising a step performed after the putting step of the semiconductor substrate at the high temperature, for forming an insulating film on said reflow SiO_2 film.

13. A method of manufacturing a semiconductor device according to claim 12, further comprising a step after the insulating film forming step, of annealing said semiconductor substrate at a temperature of 450°C for 30 minutes.

14. A method of manufacturing semiconductor devices, substantially as hereinbefore described with reference to FIG. 1A to FIG. 5 of the accompanying drawings.

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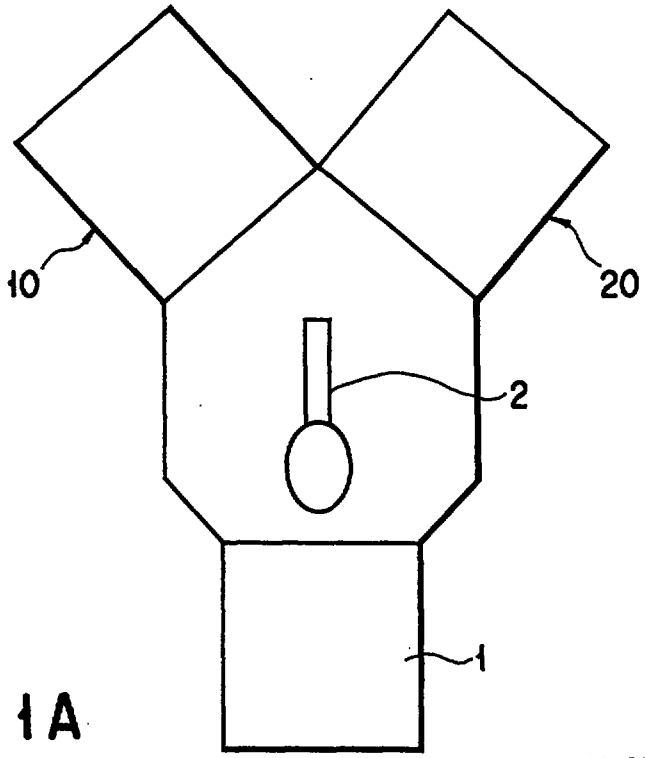


FIG. 1A

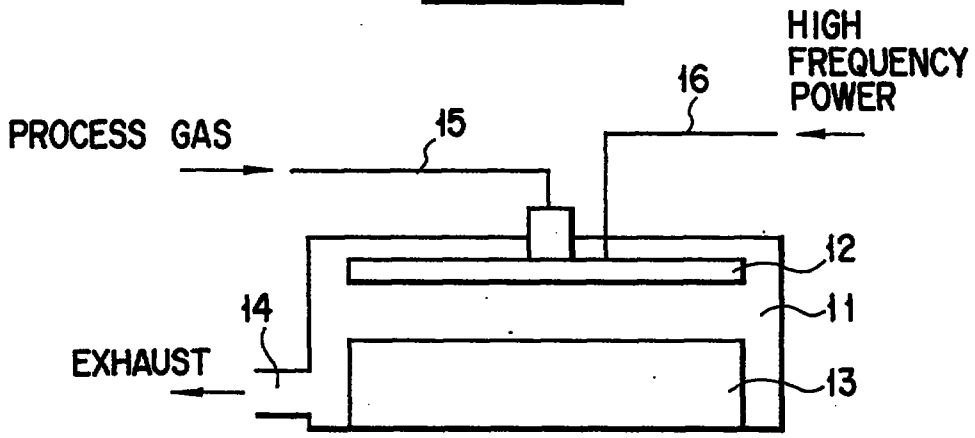


FIG. 1B

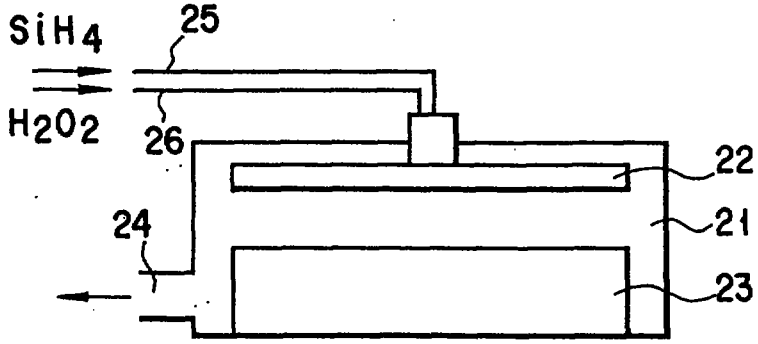
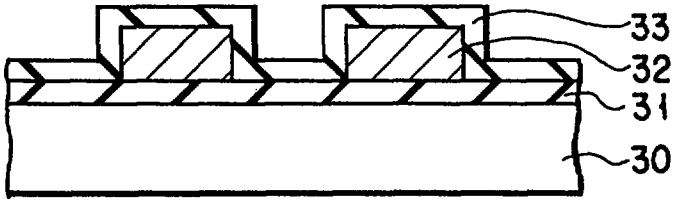


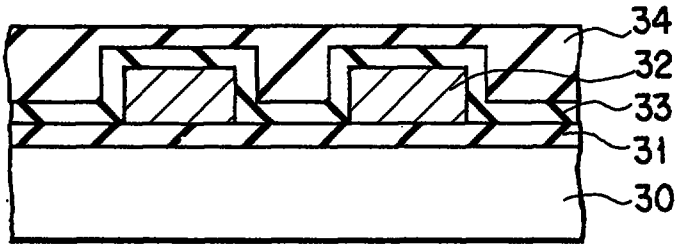
FIG. 1C

FIG. 2A



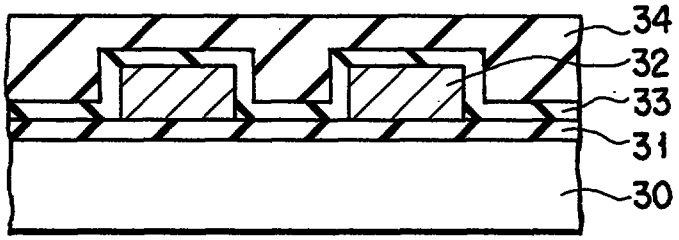
(PLASMA CVD DEVICE)

FIG. 2B



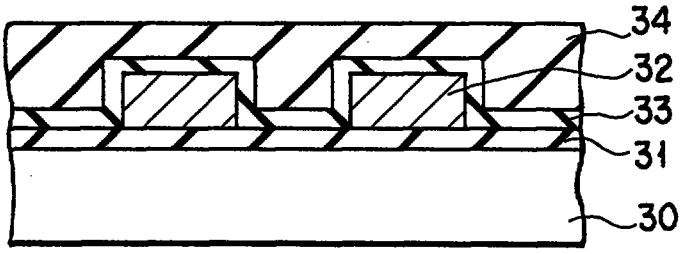
(REDUCED-PRESSURE CVD DEVICE)

FIG. 2C



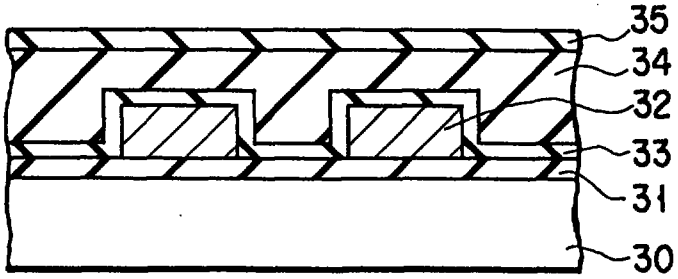
(REDUCED-PRESSURE CVD DEVICE)

FIG. 2D



(PLASMA CVD DEVICE)

FIG. 2E



(PLASMA CVD DEVICE)

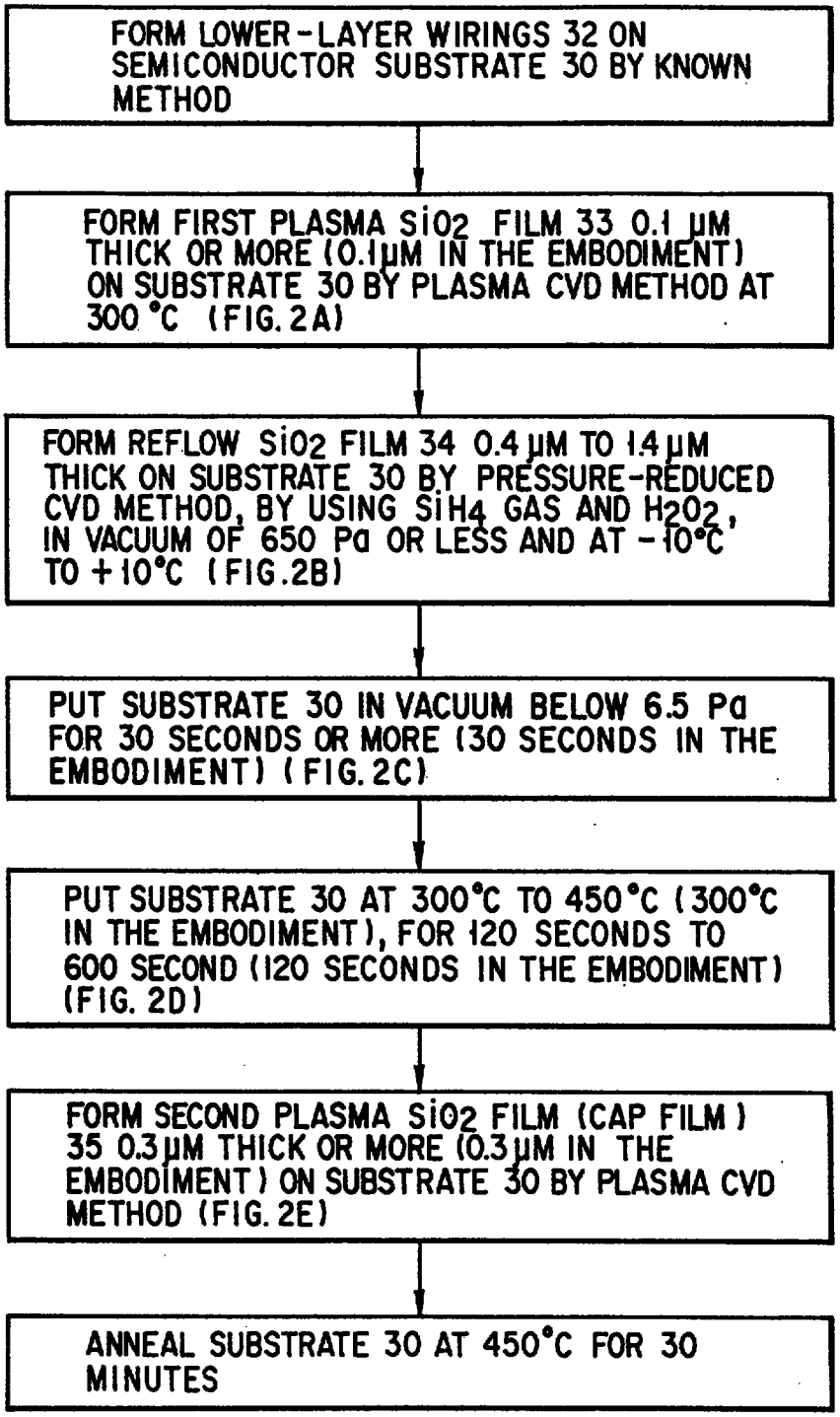

FORM LOWER-LAYER WIRINGS 32 ON SEMICONDUCTOR SUBSTRATE 30 BY KNOWN METHOD
FORM FIRST PLASMA SiO2 FILM 33 0.1 μM THICK OR MORE (0.1μM IN THE EMBODIMENT) ON SUBSTRATE 30 BY PLASMA CVD METHOD AT 300 °C (FIG. 2A)
FORM REFLOW SiO2 FILM 34 0.4 μM TO 1.4 μM THICK ON SUBSTRATE 30 BY PRESSURE-REDUCED CVD METHOD, BY USING SiH4 GAS AND H2O2, IN VACUUM OF 650 Pa OR LESS AND AT -10°C TO +10°C (FIG. 2B)
PUT SUBSTRATE 30 IN VACUUM BELOW 6.5 Pa FOR 30 SECONDS OR MORE (30 SECONDS IN THE EMBODIMENT) (FIG. 2C)
PUT SUBSTRATE 30 AT 300°C TO 450°C (300°C IN THE EMBODIMENT), FOR 120 SECONDS TO 600 SECOND (120 SECONDS IN THE EMBODIMENT) (FIG. 2D)
FORM SECOND PLASMA SiO2 FILM (CAP FILM) 35 0.3 μM THICK OR MORE (0.3 μM IN THE EMBODIMENT) ON SUBSTRATE 30 BY PLASMA CVD METHOD (FIG. 2E)
ANNEAL SUBSTRATE 30 AT 450°C FOR 30 MINUTES

FIG. 3

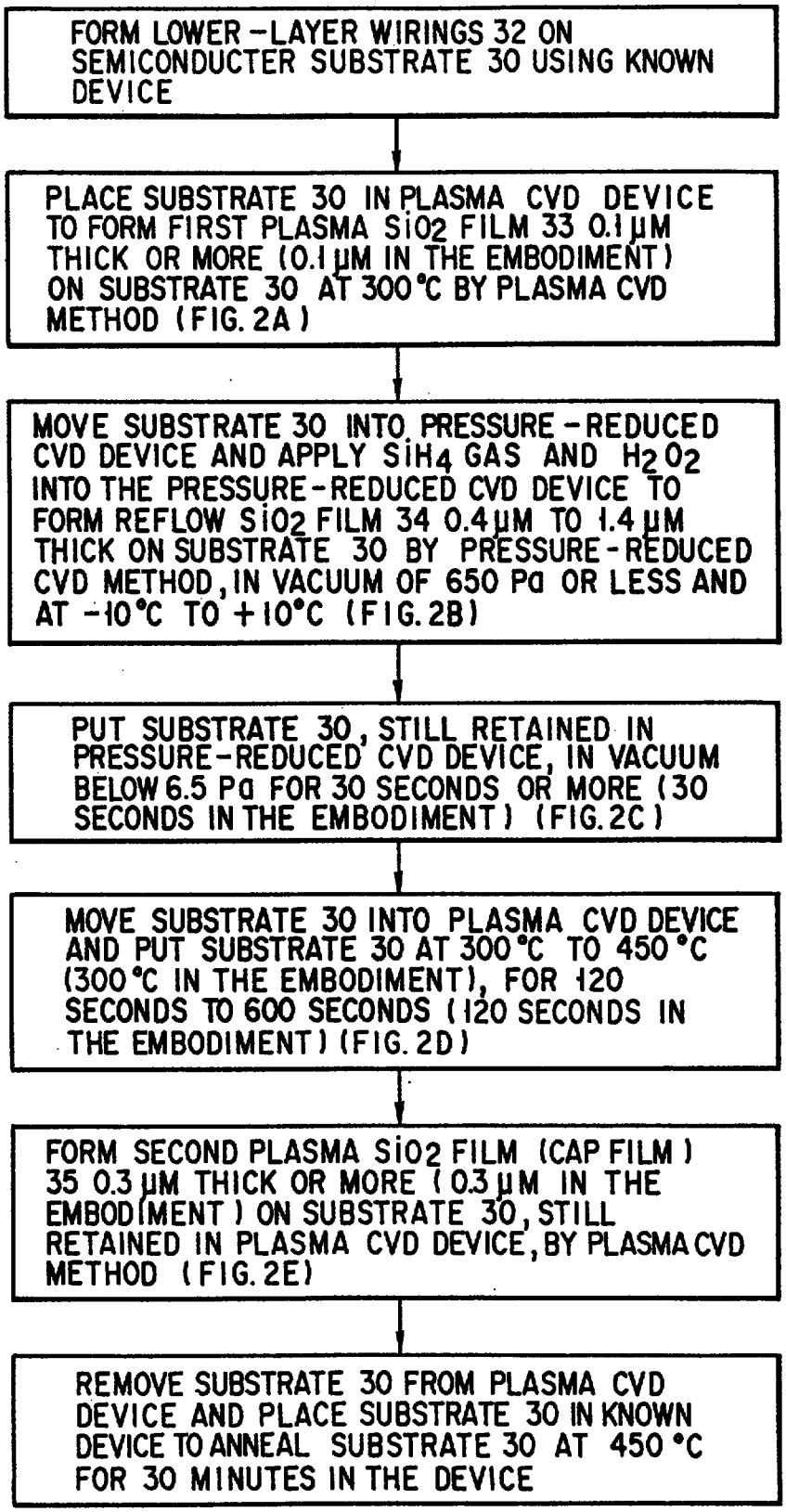

FORM LOWER-LAYER WIRINGS 32 ON SEMICONDUCTER SUBSTRATE 30 USING KNOWN DEVICE
PLACE SUBSTRATE 30 IN PLASMA CVD DEVICE TO FORM FIRST PLASMA SiO2 FILM 33 0.1 μM THICK OR MORE (0.1 μM IN THE EMBODIMENT) ON SUBSTRATE 30 AT 300 °C BY PLASMA CVD METHOD (FIG. 2A)
MOVE SUBSTRATE 30 INTO PRESSURE-REDUCED CVD DEVICE AND APPLY SiH4 GAS AND H2O2 INTO THE PRESSURE-REDUCED CVD DEVICE TO FORM REFLOW SiO2 FILM 34 0.4 μM TO 1.4 μM THICK ON SUBSTRATE 30 BY PRESSURE-REDUCED CVD METHOD, IN VACUUM OF 650 Pa OR LESS AND AT -10 °C TO +10 °C (FIG. 2B)
PUT SUBSTRATE 30, STILL RETAINED IN PRESSURE-REDUCED CVD DEVICE, IN VACUUM BELOW 6.5 Pa FOR 30 SECONDS OR MORE (30 SECONDS IN THE EMBODIMENT) (FIG. 2C)
MOVE SUBSTRATE 30 INTO PLASMA CVD DEVICE AND PUT SUBSTRATE 30 AT 300 °C TO 450 °C (300 °C IN THE EMBODIMENT), FOR 120 SECONDS TO 600 SECONDS (120 SECONDS IN THE EMBODIMENT) (FIG. 2D)
FORM SECOND PLASMA SiO2 FILM (CAP FILM) 35 0.3 μM THICK OR MORE (0.3 μM IN THE EMBODIMENT) ON SUBSTRATE 30, STILL RETAINED IN PLASMA CVD DEVICE, BY PLASMA CVD METHOD (FIG. 2E)
REMOVE SUBSTRATE 30 FROM PLASMA CVD DEVICE AND PLACE SUBSTRATE 30 IN KNOWN DEVICE TO ANNEAL SUBSTRATE 30 AT 450 °C FOR 30 MINUTES IN THE DEVICE

FIG. 4

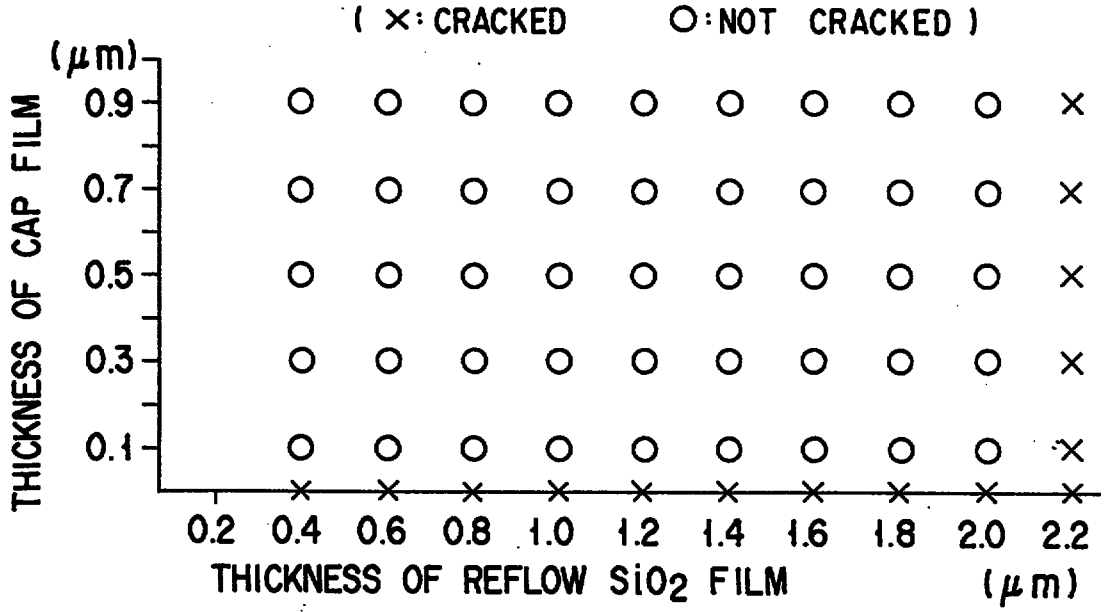

(×: CRACKED ○: NOT CRACKED)
(μm)
THICKNESS OF CAP FILM
0.9
0.7
0.5
0.3
0.1
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
THICKNESS OF REFLOW SiO2 FILM
(μm)

FIG. 5

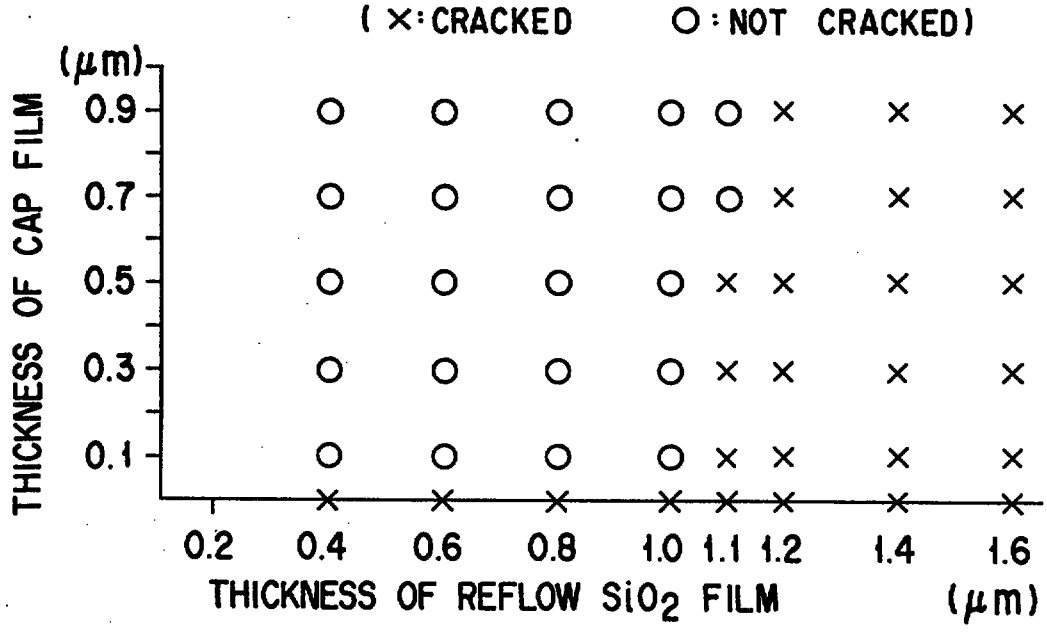

(×: CRACKED ○: NOT CRACKED)
(μm)
THICKNESS OF CAP FILM
0.9
0.7
0.5
0.3
0.1
0.2 0.4 0.6 0.8 1.0 1.1 1.2 1.4 1.6
THICKNESS OF REFLOW SiO2 FILM
(μm)

FIG. 6

Abstract of the Disclosure

"METHOD OF MANUFACTURING SEMICONDUCTOR DEVICES"

In a method of manufacturing a semiconductor device, a first plasma insulating film (33) having a thickness of 0.1 μm or more is formed on the semiconductor substrate (30) with lower-surface wirings (32) thereon. The semiconductor substrate is moved into a pressure-reduced CVD device, and then an SiH_4 gas and H_2O_2 are supplied into the pressure-reduced CVD device to react them to each other in a vacuum of 650 Pa or less within the temperature range of -10°C to +10°C to form a reflow SiO_2 film (34) having a thickness of 0.4 μm to 1.4 μm on the semiconductor substrate. The semiconductor substrate is put in a vacuum of 6.5 pascal for 30 seconds or more. Thereafter, the semiconductor substrate is put at a high temperature of 300°C to 450°C for 120 to 600 seconds. A second plasma insulating film (35) having a thickness of 0.3 μm or more and serving as a cap film is formed on the semiconductor substrate. The crack resistance of the reflow insulating film formed in the above steps is improved, and the flatness of the reflow insulating film is improved.

(Please note that Figure 2C should accompany the abstract when published)

REPLACEMENT SHEET
Date : 14 FEB 1997

Claims:

1. A method of manufacturing a semiconductor device, comprising the steps of:

supplying an SiH_4 gas and H_2O_2 into a first reaction chamber in which a semiconductor substrate having ~~an~~ a first insulating film formed thereon is placed to cause the SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film having a thickness of 0.4 μm to 1.4 μm on said semiconductor substrate;

putting said semiconductor substrate, retained in said reaction chamber, in vacuum for more than 30 seconds; and

putting said semiconductor substrate in a second chamber, at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds.

2. A method of manufacturing a semiconductor device according to claim 1, wherein the step of forming said insulating film to the step of forming said reflow SiO_2 film are continuously performed in vacuum.

~~3.~~ A method of manufacturing a semiconductor device, comprising the steps of:

causing a gas to react with H_2O_2 in vacuum to form an insulating film having a substantially flat surface on a semiconductor substrate;

putting said semiconductor substrate in a first

REPLACEMENT SHEET
Date : 14 FEB 1997

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condition; and

putting the semiconductor substrate in a second condition;

4. A method of manufacturing a semiconductor device according to claim 3, wherein the thickness of said insulating film is substantially 0.4 μm to 1.4 μm.

5. A method of manufacturing a semiconductor device according to claim 3, wherein the step of causing the gas to react with H_2O_2 is carried out in substantially below than 650, at a predetermined temperature range of -10°C to +10°C, an SiO_4 gas being used as the gas.

6. A method of manufacturing a semiconductor device according to claim 3, wherein said first condition is such that said semiconductor substrate is put in vacuum for substantially more than 30 seconds.

7. A method of manufacturing a semiconductor device according to claim 3, wherein said second condition is such that said semiconductor substrate is put at a temperature of substantially 300°C to 450° for substantially 120 seconds to 600 seconds.

8. A method of manufacturing a semiconductor device according to claim 1, further comprising a step performed after the putting step of the semiconductor substrate at the high temperature, for forming ~~an~~ a second insulating film on said reflow SiO_2 film.

9. A method of manufacturing a semiconductor

REPLACEMENT SHEET
14 FEB 1997
Date .....



device according to claim 8, further comprising a step carried out after ~~the~~ said second insulating film forming step, of annealing said semiconductor substrate at a temperature of 450°C for 30 minutes.

10. A method of manufacturing a semiconductor device, comprising the steps of:

placing a semiconductor substrate with wirings thereon into a reaction chamber of a plasma CVD device of a manufacturing device;

forming a plasma SiO_2 film on said semiconductor substrate having a thickness of more than 0.1 μm in the reaction chamber of said plasma CVD device;

moving the semiconductor substrate from the reaction chamber of said plasma CVD device into a reaction chamber of a pressure-reduced CVD device of the manufacturing device;

supplying an SiH_4 gas and H_2O_2 into the reaction chamber of the pressure-reduced CVD device in which the semiconductor substrate is placed to cause the SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film having a thickness of 0.4 μm to 1.4 μm on said semiconductor substrate;

putting said semiconductor substrate, still retained in said reaction chamber of the pressure-reduced CVD device, in vacuum for more than 30 seconds;

moving the semiconductor substrate from the

REPLACEMENT SHEET
14 FEB 1997
Date :.....

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reaction chamber of the pressure-reduced CVD device to the reaction chamber of the plasma CVD device; and

putting said semiconductor substrate, in the reaction chamber of the plasma CVD device, at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds.

11. A method of manufacturing a semiconductor device according to claim 1, wherein said moving steps are carried out by an arm provided in the manufacturing device.

12. A method of manufacturing a semiconductor device according to claim 10, further comprising a step performed after the putting step of the semiconductor substrate at the high temperature, for forming an insulating film on said reflow SiO_2 film.

13. A method of manufacturing a semiconductor device according to claim 12, further comprising a step after the insulating film forming step, of annealing said semiconductor substrate at a temperature of 450°C for 30 minutes.

14. A method of manufacturing semiconductor devices, substantially as hereinbefore described with reference to FIG. 1A to FIG. 5 of the accompanying drawings.

REPLACEMENT SHEET
14 FEB 1997
Date .....

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--15. A method of manufacturing a semiconductor device, comprising the step of:

supplying an SiH_4 gas and H_2O_2 into a reaction chamber in which a semiconductor substrate having an insulating film formed thereon is placed to cause SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film having a thickness of 0.4 μm to 1.4 μm on said semiconductor substrate;

putting said semiconductor substrate, retained in said reaction chamber, in vacuum of below 6.5 Pa for 30 seconds; and

putting said semiconductor substrate in an another chamber, at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds .--

--16. A method of manufacturing a semiconductor device, comprising the steps of:

placing a semiconductor substrate with wirings thereon into a reaction chamber of a plasma CVD device of a manufacturing device;

forming a plasma SiO_2 film on said semiconductor substrate having a thickness of more than 0.1 μm in the reaction chamber of said plasma CVD device;

moving the semiconductor substrate from the reaction chamber of said plasma CVD device into a reaction chamber of a pressure-reduced CVD device of the manufacturing device;

supplying an SiH_4 gas and H_2O_2 into the reaction chamber of the pressure-reduced CVD device in which the semiconductor substrate is placed to cause the SiH_4 gas and H_2O_2 to react to each other in a vacuum below 650 Pa within the temperature range of -10°C to +10°C to form a reflow SiO_2 film having a thickness of 0.4 μm to 1.4 μm on said semiconductor substrate;

REPLACEMENT SHEET
Date : 14 FEB 1997

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putting said semiconductor substrate, still retained in said reaction chamber of the pressure-reduced CVD device, in vacuum of below 6.5 Pa for 30 seconds;

moving the semiconductor substrate from the reaction chamber of the pressure-reduced CVD device to the reaction chamber of said plasma CVD device; and

putting said semiconductor substrate, in the reaction chamber of the plasma CVD device, at a high temperature of 300°C to 450°C for 120 seconds to 600 seconds.--

17. A method of manufacturing a semiconductor device according to claim 1, wherein the pressure in said first chamber is reduced after said reflow SiO_2 film is formed, but prior to said step of putting said semiconductor substrate, retained in said first reaction chamber, in vacuum for more than 30 seconds so as to gradually reduce a moisture content in said reflow SiO_2 film.

18. A method of manufacturing a semiconductor device according to claim 10, wherein the pressure in said reaction chamber of the pressure-reduced CVD device is reduced after said reflow SiO_2 film is formed, but prior to said step of putting said semiconductor substrate, still retained in said reaction chamber of the pressure-reduced CVD device, in vacuum for more than 30 seconds so as to gradually reduce a moisture content in said reflow SiO_2 film.--