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(54) METHOD OF FORMING SILICIDE FILM

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(57) ABSTRACT

A method of forming a silicide film including: disposing a semiconductor wafer containing silicon as a constituent element in a sputtering chamber; evacuating an inside of the sputtering chamber until a pressure reaches 9×10^{-5} Pa or less; introducing a sputtering gas into the sputtering chamber and sputtering a target in the sputtering chamber to deposit a metal film on the semiconductor wafer; and causing a laser beam to be incident into the metal film deposited on the semiconductor wafer to form a metal silicide film by a silicide reaction.

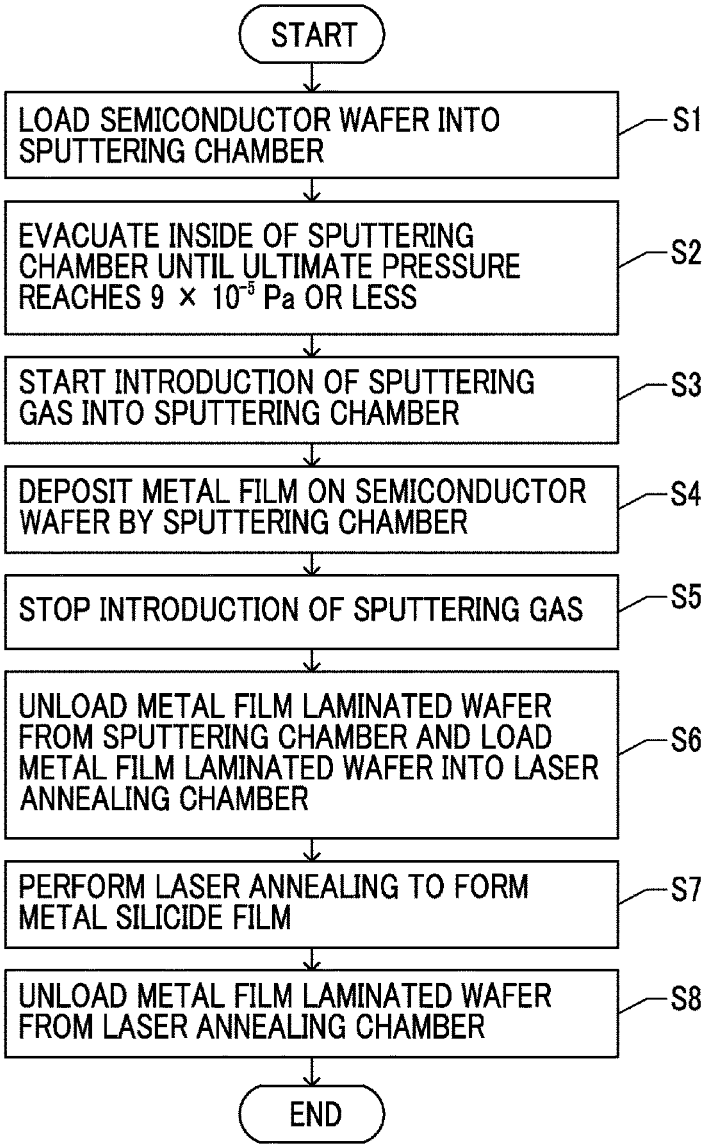


FIG. 1

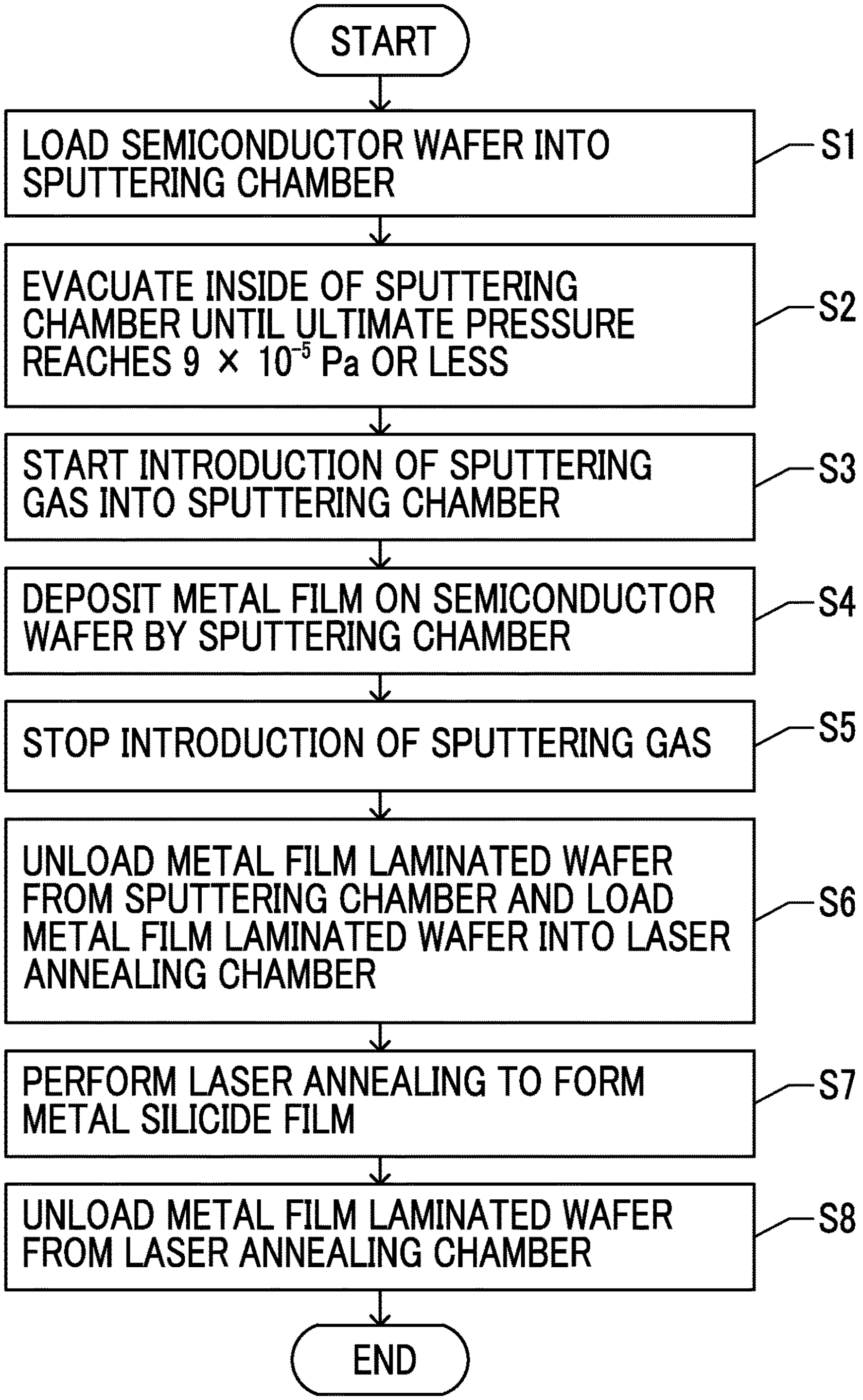

START
LOAD SEMICONDUCTOR WAFER INTO SPUTTERING CHAMBER
S1
EVACUATE INSIDE OF SPUTTERING CHAMBER UNTIL ULTIMATE PRESSURE REACHES 9 × 10^{-5} Pa OR LESS
S2
START INTRODUCTION OF SPUTTERING GAS INTO SPUTTERING CHAMBER
S3
DEPOSIT METAL FILM ON SEMICONDUCTOR WAFER BY SPUTTERING CHAMBER
S4
STOP INTRODUCTION OF SPUTTERING GAS
S5
UNLOAD METAL FILM LAMINATED WAFER FROM SPUTTERING CHAMBER AND LOAD METAL FILM LAMINATED WAFER INTO LASER ANNEALING CHAMBER
S6
PERFORM LASER ANNEALING TO FORM METAL SILICIDE FILM
S7
UNLOAD METAL FILM LAMINATED WAFER FROM LASER ANNEALING CHAMBER
S8
END

FIG. 2A

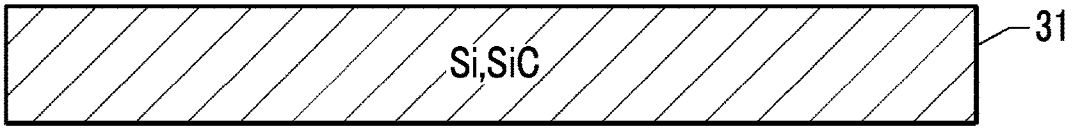


FIG. 2B

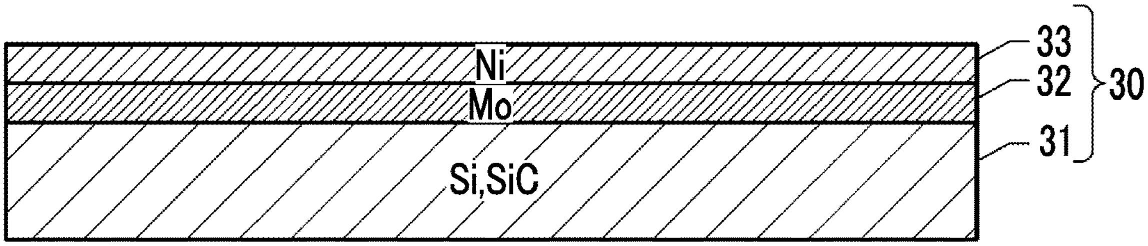


FIG. 2C

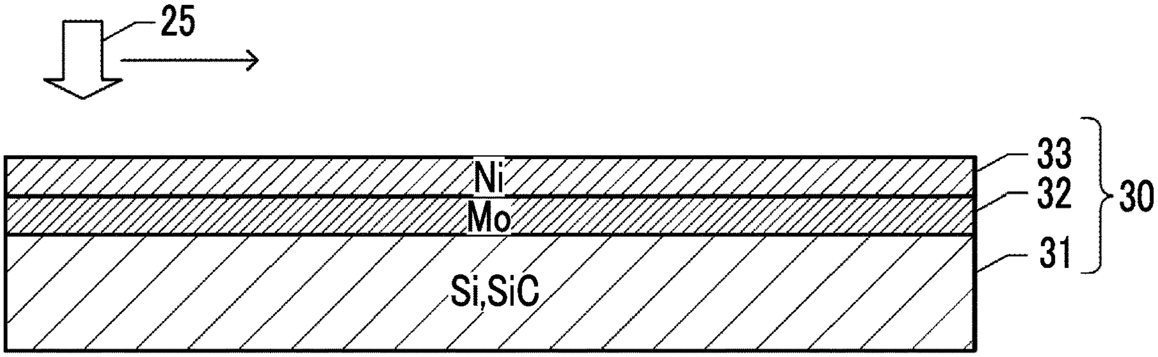


FIG. 2D

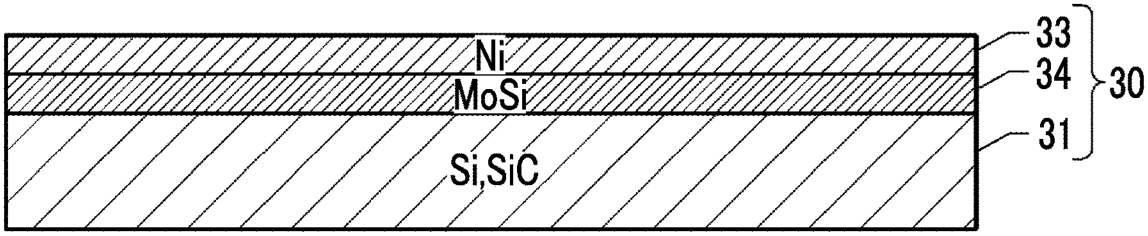


FIG. 3

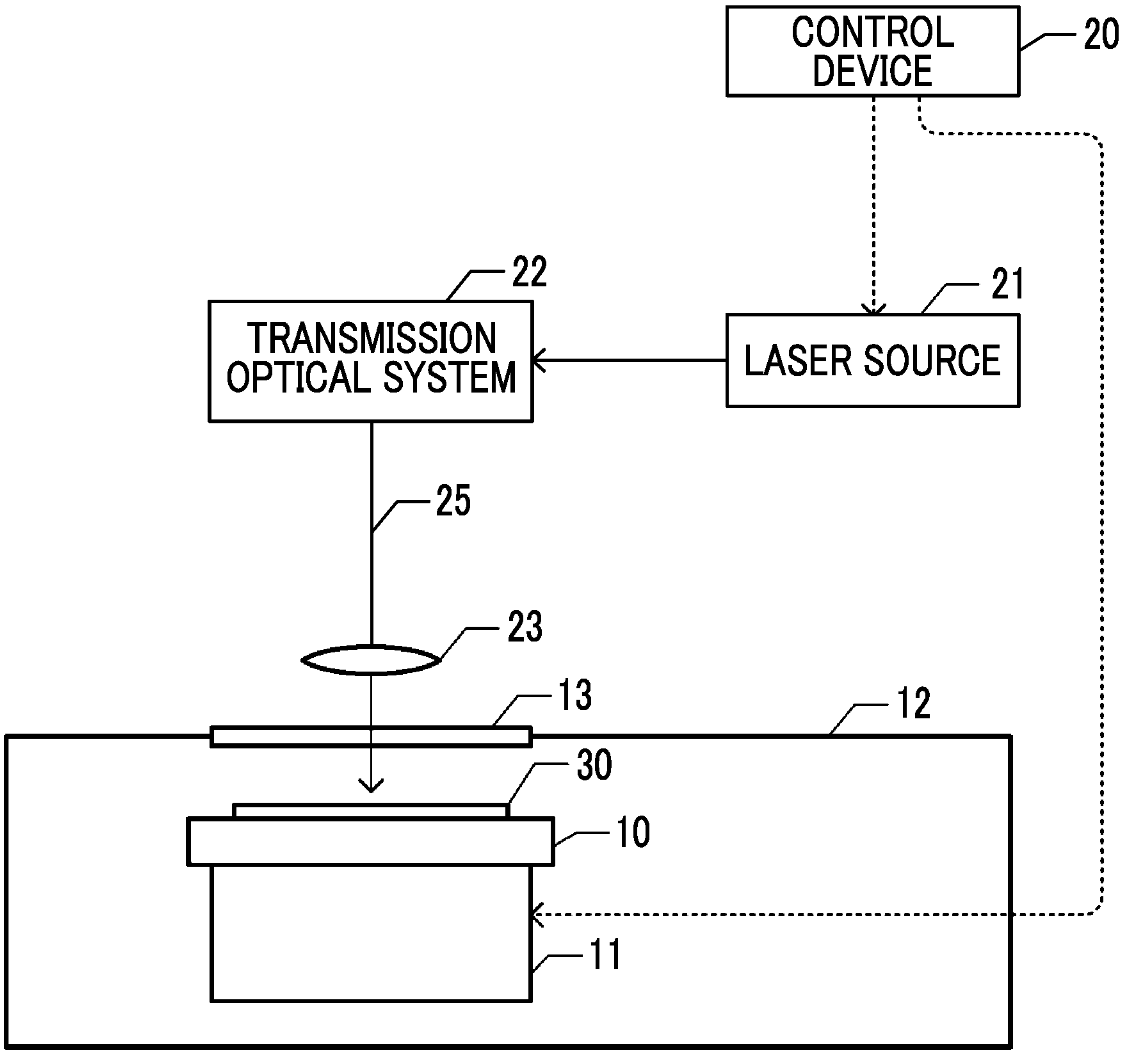

CONTROL DEVICE
20
22
21
TRANSMISSION OPTICAL SYSTEM
LASER SOURCE
25
23
13
12
30
10
11

FIG. 4A

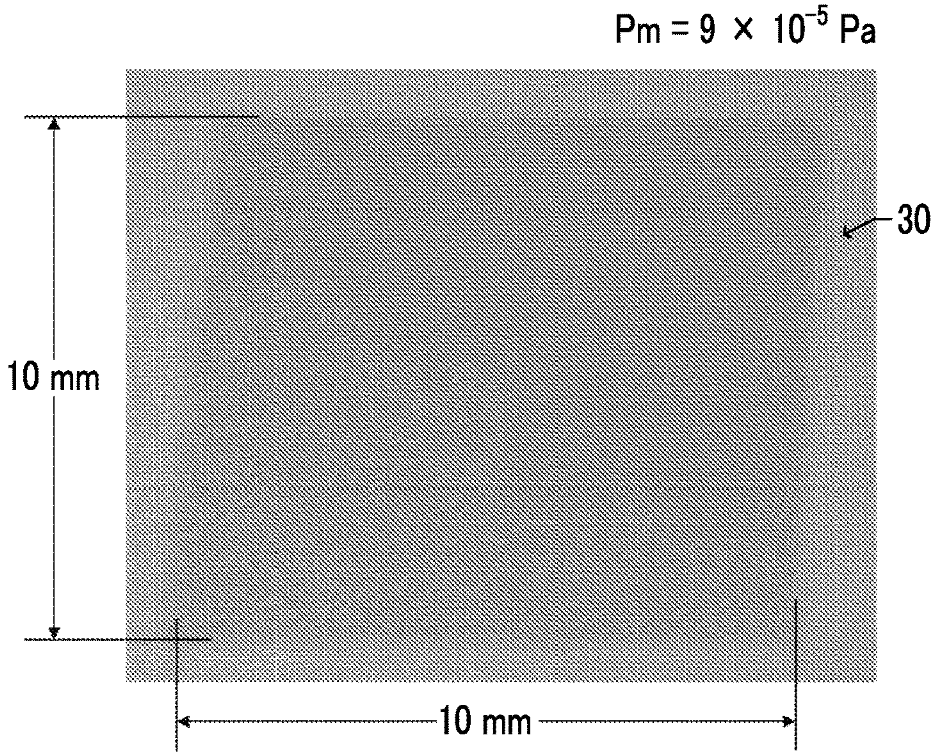


FIG. 4B

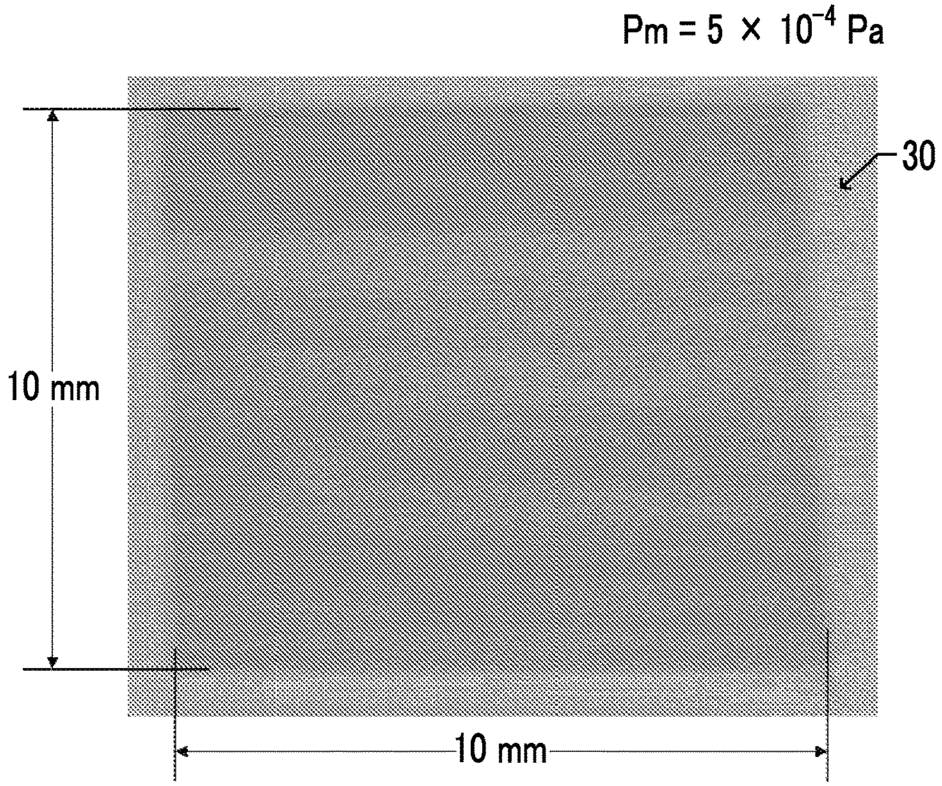


FIG. 5A

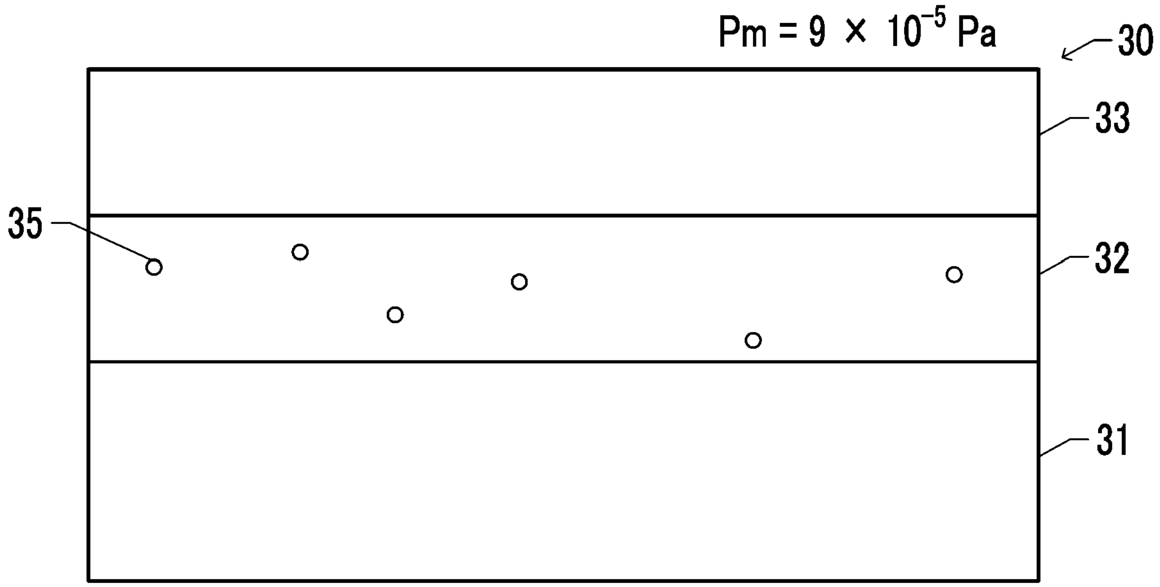
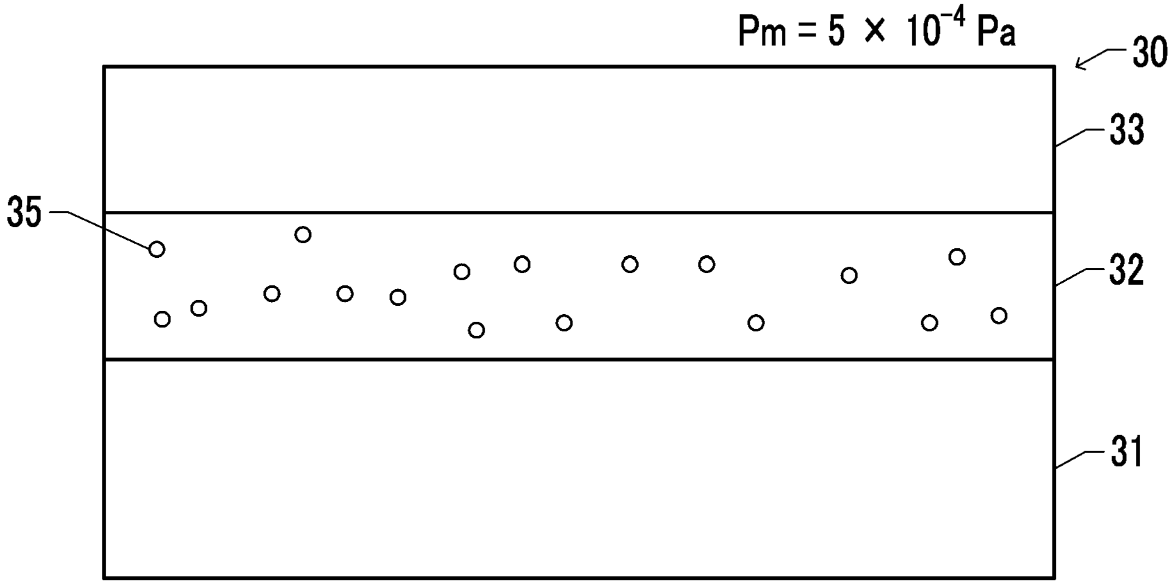


FIG. 5B



METHOD OF FORMING SILICIDE FILM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Japanese Patent Application No. 2021-203302, filed on Dec. 15, 2021, which is incorporated by reference herein in its entirety.

BACKGROUND

Technical Field

[0002] A certain embodiment of the present invention relates to a method of forming a silicide film.

Description of Related Art

[0003] A technique for forming a metal silicide film by depositing a metal film on a silicon-containing semiconductor wafer such as a silicon wafer or a silicon carbide (SiC) wafer and performing laser annealing thereon is known (related art). As the metal film, Ni, Ti, Mo, W, or the like is used.

SUMMARY

[0004] According to an aspect of the present invention, there is provided a method of forming a silicide film including: disposing a semiconductor wafer containing silicon as a constituent element in a sputtering chamber; evacuating an inside of the sputtering chamber until a pressure reaches 9×10^{-5} Pa or less; introducing a sputtering gas into the sputtering chamber and sputtering a target in the sputtering chamber to deposit a metal film on the semiconductor wafer; and causing a laser beam to be incident into the metal film deposited on the semiconductor wafer to form a metal silicide film by a silicide reaction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** is a flowchart showing a procedure of a method of forming a silicide film according to an embodiment.

[0006] FIGS. **2**A to **2**C are cross-sectional views of a wafer in an intermediate stage until a metal silicide film is formed, and FIG. **2**D is a cross-sectional view of the wafer on which the metal silicide film is formed.

[0007] FIG. **3** is a schematic view of a laser annealing apparatus used in the present embodiment.

[0008] FIGS. **4**A and **4**B are optical micrographs of metal silicide films produced by methods according to the embodiment and a comparative example, respectively.

[0009] FIGS. **5**A and **5**B are schematic views showing cross sections of metal film laminated wafers produced by the methods according to the embodiment and the comparative example, respectively.

DETAILED DESCRIPTION

[0010] It is desired to form a uniform metal silicide film on the entire surface of a semiconductor wafer. According to various evaluation experiments by the inventor of the present application, it has been confirmed that unevenness in appearance may occur in a metal silicide film formed by laser annealing. According to an embodiment of the present invention, it is desirable to provide a method of forming a silicide film capable of forming a uniform metal silicide film on a semiconductor wafer.

[0011] By evacuating the inside of the sputtering chamber until the pressure reaches 9×10^{-5} Pa or less before introducing the sputtering gas, the amount of oxygen atoms incorporated into the metal film is reduced. As a result, it is possible to suppress the occurrence of unevenness in appearance of the metal silicide film.

[0012] A method of forming a silicide film according to an embodiment will be described with reference to FIGS. **1** to **5**B. FIG. **1** is a flowchart showing a procedure of the method of forming a silicide film according to the present embodiment. FIGS. **2**A to **2**C are cross-sectional views of a wafer in an intermediate stage until a metal silicide film is formed, and FIG. **2**D is a cross-sectional view of the wafer on which the metal silicide film is formed.

[0013] First, a semiconductor wafer **31** (FIG. **2**A) is loaded into a sputtering chamber of a sputtering apparatus (step S**1**). The semiconductor wafer **31** is formed of a semiconductor containing silicon. For example, the semiconductor wafer **31** is a silicon wafer or a SiC wafer. As the sputtering apparatus, for example, an RF magnetron sputtering apparatus is used. As a target for sputtering, metal molybdenum (Mo) is used.

[0014] After the semiconductor wafer **31** is loaded, an inside of the sputtering chamber is evacuated (step S**2**). A pressure of the sputtering chamber at this time is set to 9×10^{-5} Pa. A pressure corresponding to the degree of vacuum in the sputtering chamber before the introduction of a sputtering gas is referred to as an ultimate pressure Pm. After evacuating the inside of the sputtering chamber, introduction of the sputtering gas is started (step S**3**). Furthermore, a molybdenum film **32** (FIG. **2**B) is deposited on the semiconductor wafer **31** by starting discharging in the sputtering chamber to perform sputtering, and the target is changed to deposit a nickel film **33** (FIG. **2**B) on the molybdenum film **32** (step S**4**). The wafer including the semiconductor wafer **31**, the molybdenum film **32**, and the nickel film **33** is referred to as a metal film laminated wafer **30**.

[0015] After depositing the nickel film **33**, the introduction of the sputtering gas is stopped (step S**5**). Thereafter, the metal film laminated wafer **30** is unloaded from the sputtering chamber and is loaded into an annealing chamber (step S**6**).

[0016] FIG. **3** is a schematic view of a laser annealing apparatus used in the present embodiment. A stage **10** is supported by a moving mechanism **11** in an annealing chamber **12**. The moving mechanism **11** can move the stage **10** in a horizontal plane in response to a command from a control device **20**. The metal film laminated wafer **30** (FIG. **2**B) in which the molybdenum film **32** and the nickel film **33** are formed is held on an upper surface of the stage **10** with the nickel film **33** facing upward.

[0017] A laser source **21** receives a command from the control device **20** and outputs a pulsed laser beam for annealing. As the laser source **21**, for example, a laser diode having an oscillation wavelength of about 800 nm is used. A pulsed laser beam **25** output from the laser source **21** passes through a transmission optical system **22** and a lens **23**, is transmitted by a laser transmission window **13** provided on a top plate of the annealing chamber **12**, and is incident into the metal film laminated wafer **30**. The transmission optical system **22** includes, for example, a beam homogenizer, an aperture, a lens, and a mirror. A beam spot on a surface of the metal film laminated wafer **30** is shaped by the beam homogenizer and the lens **23**, such that a beam profile is uniformized.

[0018] The control device **20** controls the moving mechanism **11** to move the stage **10** in a two-dimensional direction in the horizontal plane. The control device **20** further controls the laser source **21** to output the pulsed laser beam **25** from the laser source **21** based on current position information of the stage **10**. For example, the control device **20** controls the moving mechanism **11** and the laser source **21** to move the beam spot of the pulsed laser beam **25** (FIG. **2**C) on the surface of the metal film laminated wafer **30** in a main scanning direction and a sub-scanning direction. By repeating main scanning and sub-scanning, almost the entire surface of the metal film laminated wafer **30** can be annealed.

[0019] After step S**6**, laser annealing is performed on the metal film laminated wafer **30** to cause a silicide reaction to occur between the silicon contained in the semiconductor wafer **31** and the molybdenum film **32**, thereby forming a molybdenum silicide film **34** (FIG. **2**D) (step S**7**). The notation "MoSi" shown in FIG. **2**D does not mean that a composition ratio between Mo and Si is 1:1. When the laser annealing is ended, the metal film laminated wafer **30** is unloaded from the annealing chamber **12** (FIG. **3**) (step S**8**).

[0020] Next, excellent effects of the embodiment will be described with reference to FIGS. **4**A and **4**B. FIGS. **4**A and **4**B are optical micrographs of metal silicide films produced by methods according to the embodiment and a comparative example, respectively. A slightly dark region in FIGS. **4**A and **4**B is the metal film laminated wafer **30**. A shape of the metal film laminated wafer **30** is a square having a side length of 10 mm. In the comparative example shown in FIG. **4**B, the ultimate pressure Pm in step S**2** (FIG. **1**) is set to 5×10^{-4} Pa.

[0021] In the method according to the embodiment, as shown in FIG. **4**A, a uniform metal silicide film is formed in appearance. On the other hand, in the method according to the comparative example, it can be seen that color unevenness (a dark gray region and a light gray region in the photograph) occurs in appearance.

[0022] As described above, by applying the method according to the embodiment, it is possible to form the molybdenum silicide film **34** (FIG. **2**D) that is uniform without color unevenness in appearance.

[0023] Next, a cause of unevenness in appearance on the molybdenum silicide film produced by the method according to the comparative example will be described with reference to FIGS. **5**A and **5**B.

[0024] FIGS. **5**A and **5**B are schematic views showing cross sections of the metal film laminated wafers **30** produced by the methods according to the embodiment and the comparative example, respectively. The molybdenum film **32** is formed on the semiconductor wafer **31**, and the nickel film **33** is formed thereon. When the molybdenum film **32** is deposited by sputtering, oxygen atoms **35** are incorporated into the molybdenum film **32**. According to an evaluation experiment by the inventor of the present application, it has been found that when the ultimate pressure Pm in step S**2** is high (the degree of vacuum is low), the amount of oxygen atoms **35** incorporated into the molybdenum film **32** increases. In the embodiment (FIG. **5**A), the ultimate pressure Pm is set to 9×10^{-5} Pa, and in the comparative example (FIG. **5**B), the ultimate pressure Pm is set to 5×10^{-4} Pa. Therefore, the amount of oxygen incorporated into the molybdenum film **32** (FIG. **5**B) produced by the method according to the comparative example is larger than the amount of oxygen incorporated into the molybdenum film **32** (FIG. **5**A) produced by the method according to the embodiment.

[0025] The oxygen atoms **35** incorporated into the molybdenum film **32** reacts with molybdenum during the laser annealing (step S**7**). Due to an oxidation reaction of molybdenum during the laser annealing, color unevenness in appearance occurs on the molybdenum silicide film **34** (FIG. **2**D). By setting the ultimate pressure Pm in step S**2** to 9×10^{-5} Pa or less, the molybdenum silicide film **34** (FIG. **2**D) that is uniform without color unevenness in appearance can be formed.

[0026] Next, a modification example of the embodiment will be described. In the embodiment, the nickel film **33** (FIG. **2**B) is deposited on the molybdenum film **32** (FIG. **2**B), but the nickel film **33** can be omitted. In this case, the pulsed laser beam **25** (FIG. **2**C) for annealing is incident into the metal film laminated wafer **30** in which the molybdenum film **32** is exposed, thereby causing a silicide reaction.

[0027] In addition, although the metal film is deposited by using the RF magnetron sputtering method in the embodiment, other sputtering methods may also be used. For example, a DC magnetron sputtering method may be used.

[0028] In addition, in the embodiment, the molybdenum film **32** (FIG. **2**C) is used as the metal film that causes the silicide reaction. However, a film made of a metal other than molybdenum that causes the silicide reaction may also be used. Examples of such a metal include nickel, titanium, and tungsten. Even in a case where a metal film other than the molybdenum film is used as the metal film that causes the silicide reaction, when a large amount of oxygen is incorporated into the metal film, an oxidation reaction of the metal occurs during the laser annealing, which may cause color unevenness in appearance. Therefore, even in a case where a metal film other than the molybdenum film is used as the metal film that causes the silicide reaction, it is preferable to perform evacuation until the ultimate pressure Pm in step S**2** reaches 9×10^{-5} Pa or less.

[0029] Furthermore, in order to avoid an increase in the amount of oxygen incorporated into the metal film that causes the silicide reaction with silicon, a purity of argon gas used as the sputtering gas is preferably set to 99.9995% or higher.

[0030] It is needless to say that the embodiment is an example, and partial substitutions or combinations of the configurations shown in the embodiment and the modification examples can be made. The same actions and effects due to the same configurations of the embodiment and the modification examples are not sequentially mentioned for each of the embodiment and the modification examples. Furthermore, the present invention is not limited to the embodiment and the modification examples. For example, it is obvious to those skilled in the art that various changes, improvements, combinations, and the like can be made.

[0031] It should be understood that the invention is not limited to the above-described embodiment, but may be modified into various forms on the basis of the spirit of the invention. Additionally, the modifications are included in the scope of the invention.

What is claimed is:

1. A method of forming a silicide film comprising:
- disposing a semiconductor wafer containing silicon as a constituent element in a sputtering chamber;
- evacuating an inside of the sputtering chamber until a pressure reaches 9×10^{-5} Pa or less;
- introducing a sputtering gas into the sputtering chamber and sputtering a target in the sputtering chamber to deposit a metal film on the semiconductor wafer; and
- causing a laser beam to be incident into the metal film deposited on the semiconductor wafer to form a metal silicide film by a silicide reaction.

2. The method of forming a silicide film according to claim **1**, wherein the sputtering gas is an argon gas having a purity of 99.9995% or higher.

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