

MAGNETRON SPUTTERING METHOD AND MAGNETRON SPUTTERING APPARATUS

Technical Field

The present invention generally relates to magnetron
5 sputtering methods and magnetron sputtering apparatuses, and
more particularly, the present invention relates to magnetron
sputtering methods and magnetron sputtering apparatuses having
a plurality of targets in a vacuum chamber.

10 Background Art

Conventionally, a magnetron sputtering apparatus shown in
Fig. 6 is known as a type of magnetron sputtering apparatus.

As shown in Fig. 6, a magnetron sputtering apparatus 101
has a vacuum chamber 102 that is connected to a prescribed
15 evacuation system 103 and a prescribed gas introduction pipe
104, and a substrate 106, on which films are to be formed, is
disposed in an upper portion inside the vacuum chamber 102.

In a lower portion inside the vacuum chamber 102, a
plurality of targets 107 are disposed that respectively have a
20 magnetic circuit forming member 105. Each target 107 is
configured such that a predetermined voltage is applied to the
target 107 from a power supply 109 via a backing plate 108.

Then, a shield 110 that is set to a ground potential is
disposed between the targets 107 in order to stably generate
25 plasma on each of the targets 107 to form a uniform film on the

substrate 106.

Disclosure of the Invention

Problems to be Solved by the Invention

5 However, in such a conventional system or process, plasma is absorbed by the shield 110 disposed between the targets 107 during film formation so that a non-erosion region that has not been eroded remains in a region located in the vicinity of the shield 110 of each target 107.

10 The presence of this non-erosion region causes an abnormal electrical discharge on the surface of the target 107, or invites deterioration of the film quality by deposition of the target materials in the non-erosion region.

 The present invention was achieved to solve such problems
15 of the conventional system or process, and the present invention is directed to magnetron sputtering methods and magnetron sputtering apparatuses that can significantly reduce the non-erosion region so as to prevent an abnormal electrical discharge caused by the non-erosion region present on the
20 surface of the target, and deposition of target materials that causes deterioration of the film quality.

Means to Solve the Problems

 In order to solve the above-described problems, the present invention provides a magnetron sputtering method
25 comprises performing sputtering by generating magnetron

discharges in the vicinity of a plurality of targets, the targets being disposed close to each other in order to be directly opposed to the adjacent targets and each of the targets is electrically independent in a vacuum atmosphere, and
5 applying voltages having a phase difference of 180 degrees to the adjacent targets at a prescribed timing during the sputtering.

In the above-described magnetron sputtering method, the voltages having a phase difference of 180 degrees can be
10 periodically and alternately applied to the adjacent targets.

In the above-described magnetron sputtering method, the voltages applied to the adjacent targets may be pulsed DC voltages.

In the above-described magnetron sputtering method,
15 frequencies of the voltages applied to the adjacent targets may be equal.

In the above-described magnetron sputtering method, voltages applied to the adjacent targets are always exclusive to each other.

20 The present invention provides a magnetron sputtering apparatus including a plurality of targets electrically independent to each other disposed in a vacuum chamber, wherein adjacent targets are disposed close to each other so as to directly oppose to each other, and a voltage supply portion is
25 further provided that has a power supply capable of applying to

each target voltage having a phase difference of 180 degrees respectively at a predetermined timing.

In the above-described magnetron sputtering apparatus, a space between the adjacent targets may be set to a distance
5 such that an abnormal electrical discharge does not occur between the adjacent targets; and also, plasma is not generated between the adjacent targets.

In the method of the present invention, by applying voltages having a phase difference of 180 degrees to the
10 adjacent targets that are disposed close to each other at a prescribed timing during sputtering, it becomes possible to stably generate a uniform plasma on each target even in a state in which a shield is not provided between the targets.

As a result, according to the present invention, the non-
15 erosion region can be significantly reduced; and consequently, it is possible to prevent an abnormal electrical discharge on the surface of the target, as well as to prevent deposition of target materials in the non-erosion region as much as possible.

In addition, with the apparatus of the present invention,
20 the above-described method of the present invention can be easily performed with good efficiency.

Effects of the Invention

According to the present invention, it is possible to
25 stably generate uniform plasma on each target even in a state

in which a shield is not provided between the targets.
Consequently, it is possible to prevent an abnormal electrical
discharge on the surface of the target, as well as to prevent
deposition of target materials in the non-erosion region as
5 much as possible.

Brief Description of the Drawings

Fig. 1 is a cross-sectional view showing a configuration
of a magnetron sputtering apparatus according to an embodiment
10 of the present invention.

Fig. 2 is a timing chart showing an example of waveforms
of voltages applied to targets of the present invention.

Fig. 3 shows timing charts showing the relationships
between frequencies and waveforms of the voltages applied to
15 the targets.

Figs. 4(a) and 4(b) are timing charts showing another
example of waveforms of voltages applied to the targets.

Fig. 5(a) is an explanatory diagram showing a state of
targets of a comparative example.

20 Fig. 5(b) is an explanatory diagram showing a state of
targets of a working example.

Fig. 6 is a cross-sectional view showing a configuration
of a magnetron sputtering apparatus according to conventional
techniques.

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Description of Reference Numerals

1: magnetron sputtering apparatus, 2: vacuum chamber, 6:
substrate, 8(8A, 8B, 8C and 8D): target, 10: voltage supply
portion, 11A, 11B, 11C and 11D: power supply, 12: voltage
5 control portion

Best Mode for Carrying Out the Invention

A preferred embodiment of the present invention is
described below in detail with reference to accompanying
10 drawings.

Fig. 1 is a cross-sectional view showing a configuration
of a magnetron sputtering apparatus according to an embodiment
of the present invention.

As shown in Fig. 1, a magnetron sputtering apparatus 1 of
15 the present embodiment has a vacuum chamber 2 to which a
prescribed evacuation system 3 and a prescribed gas
introduction pipe 4 are connected and to which a vacuum gauge 5
is also attached.

In an upper portion inside the vacuum chamber 2, a
20 substrate 6 that is connected to a power supply (not shown) is
disposed while being held by a substrate holder 7.

In the present invention, while it is possible to fix the
substrate 6 at a prescribed position in the vacuum chamber 2,
with a view to securing a uniform film thickness, it is
25 preferable to adopt a configuration in which the substrate 6 is

moved by way of swaying, rotation or shifting.

In a lower portion inside the vacuum chamber 2, a plurality of targets 8 (in the present embodiment, 8A, 8B, 8C and 8D) are respectively placed on backing plates 9A, 9B, 9C and 9D, being electrically independent of one another.

In the present invention, the number of targets 8 is not particularly limited. However, with a view to achieving more stable electrical discharge, it is preferable to provide an even number of targets 8.

In the present embodiment, the targets 8A, 8B, 8C and 8D are formed in, for example, a rectangular shape, and are provided at the same height. With a view to securing a uniform film thickness (film quality), the targets 8A, 8B, 8C and 8D are disposed close to each other such that side face portions in the longitudinal direction of the respective adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D directly opposed to each other.

In this case, with a view to securing a uniform film thickness (film quality), it is preferable to adopt a configuration in which a region for disposing the targets 8A, 8B, 8C and 8D is larger than the size of the substrate 6.

In the present invention, a spacing between the adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D is not limited to a particular distance. However, it is preferable to set the spacing to a distance at which an abnormal electrical discharge

(arc discharge) does not occur between the adjacent targets, and further plasma is not generated between the adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D based on Paschen's law.

5 In the present embodiment, it is confirmed by the present inventors that when the spacing between the adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D is less than 1 mm, an abnormal electrical discharge (arc discharge) occurs between the adjacent targets, whereas plasma is generated when the spacing
10 exceeds 60 mm (pressure: 0.3 Pa, supplied power: 10 W/cm²).

Also, taking a drawback that a film adheres to the side face portion or the like in the longitudinal direction of the targets 8A to 8D into account, it is more preferable to set the spacing to 1 mm or more and 3 mm or less.

15 On the other hand, a voltage supply portion 10 for applying a prescribed voltage to the targets 8A, 8B, 8C and 8D is provided on the outside of the vacuum chamber 2.

The voltage supply portion 10 of the present embodiment has power supplies 11A, 11B, 11C and 11D that respectively
20 correspond to the targets 8A, 8B, 8C and 8D. These power supplies 11A, 11B, 11C and 11D are connected to a voltage control portion 12 such that the magnitude and timing of output voltages are controlled; and thus, prescribed voltages described below are applied respectively to the targets 8A, 8B,
25 8C and 8D via the backing plates 9A, 9B, 9C and 9D.

Below the backing plates 9A, 9B, 9C and 9D, namely, on the side of the backing plates 9A, 9B, 9C and 9D opposite to the targets 8A, 8B, 8C and 8D, magnetic circuit forming members 13A, 13B, 13C and 13D are provided including, for example, a
5 permanent magnet.

In the present invention, although it is possible to fix the magnetic circuit forming members 13A, 13B, 13C and 13D at prescribed positions, with a view to achieving uniformity in formed magnetic circuits, it is preferable to adopt, for
10 example, a configuration in which the magnetic circuit forming members 13A, 13B, 13C and 13D reciprocally move in a horizontal direction.

It should be noted that it is preferable to configure the magnetic circuit such that the leakage magnetic field produced on the surface of each of the targets 8A, 8B, 8C and 8D is such
15 that the horizontal magnetic field is 100 to 2000 G at the position with a vertical magnetic field of 0.

A preferred embodiment of a magnetron sputtering method according to the present invention is described below.

20 In the present embodiment, when sputtering is performed under a prescribed pressure after a sputtering gas is introduced to the inside of the vacuum chamber 2, voltages having a phase difference of 180 degrees are applied at a prescribed timing to the adjacent targets 8A and 8B, 8B and 8C,
25 and 8C and 8D.

Fig. 2 is a timing chart showing an example of waveforms of voltages applied to the targets of the present invention.

As shown in Fig. 2, in this example, voltages having a phase difference of 180 degrees as described below, for example,
5 are periodically and alternately applied to the adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D.

More particularly, in this example, pulsed DC voltages are applied to the targets 8A to 8D.

In this case, in view of reliably generating plasma on
10 the targets 8A to 8D, it is preferable that the voltages applied to the adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D have waveforms that are exclusive to each other that include no period in which the voltages applied to the adjacent targets are at the same potential; i.e. waveforms that do not
15 overlap each other.

In the present invention, it is preferable that the frequency of the voltages applied to the targets 8A to 8D is as low as possible in a range in which charged electrical charges escape (specifically, e.g. 1 Hz or more).

20 The upper limit of the frequency of the voltages applied to the targets 8A to 8D is set as described below.

Fig. 3 shows timing charts showing the relationships between the frequencies and the waveforms of the voltages applied to the targets.

25 A case is described in which the above-described pulsed

DC voltages are applied to adjacent targets A and B that have the configuration described above. As shown in Fig. 3, it is confirmed in this invention that up to 10 kHz, an effect of the capacitance of the target A and B and their circuits is small, and therefore the waveform (rectangular shape) is not deformed. As a result, by applying voltages exclusively to the adjacent targets A and B, plasma can be reliably generated on the targets A and B.

On the other hand, it is confirmed in the present invention that when the frequency of the applied voltage exceeds 10 kHz (12 kHz in Fig. 3), an effect of the capacitance of the target A and B and their circuits cannot be neglected; and therefore, the waveform is deformed so as to be similar to a sine wave. As a result, in the waveforms of the voltages applied to the adjacent targets A and B, a period appears in which the voltages have the same potential, and thus it becomes impossible to reliably generate plasma on the targets A and B as described above.

Accordingly, in the present embodiment, the frequency of the voltages applied to the targets 8A to 8D is preferably 1 Hz to 10 kHz.

In the present invention, although the adjacent targets 8A to 8D may be applied with the voltages of different frequencies, in view of securing a uniform film thickness, it is preferable to apply voltages of the same frequency to the

adjacent targets 8A to 8D.

The magnitude of the voltages (electric power) applied to the adjacent targets 8A to 8D is not particularly limited.

However, in view of securing a uniform film thickness, it is
5 preferable to apply voltages of the same magnitude to the adjacent targets 8A to 8D.

In this case, in view of stably generating plasma on the targets 8A to 8D, it is preferable to set the maximum value in the positive (+) direction of the applied voltage to be equal
10 to the ground potential.

Figs. 4(a) and 4(b) are timing charts showing another example of waveforms of voltages applied to the targets.

As shown in Figs. 4(a) and 4(b), in the present invention, instead of the above-described pulsed DC voltage, AC
15 (alternation) voltages having a phase difference of 180 degrees can be periodically and alternately applied to the adjacent targets.

In this example as well, in view of reliably generating plasma on the targets 8A to 8D, it is preferable that the
20 voltages applied to the adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D have waveforms exclusive to each other that include no period in which the voltages applied to the adjacent targets are at the same potential, i.e. waveforms that do not mutually overlap.

25 Also, it is preferable that the frequency of the voltages

applied to the targets 8A to 8D is as low as possible in a range in which charged electrical charges escape (specifically, e.g. 1 Hz or more).

On the other hand, with respect to the upper limit of the frequency of the voltages applied to the target 8A to 8D, it is confirmed by the present inventors that the extent of deformation of the waveform due to an increase of the frequency is small compared with the case of the above-described pulsed DC voltage; and thus, it is possible to apply a voltage having a frequency of up to about 60 kHz.

Accordingly, in this example, the frequency of the voltages applied to the targets 8A to 8D is preferably 1 Hz to 40 kHz.

According to the present embodiment described above, by applying voltages having a phase difference of 180 degrees to the adjacent targets 8A and 8B, 8B and 8C, and 8C and 8D that are disposed close to each other during sputtering, it is possible to reliably generate uniform plasma on the targets 8A to 8D even in a state in which shields are not provided between the targets 8A to 8D. As a result, the non-erosion region in the targets 8A to 8D can be significantly reduced; and therefore, it is possible to prevent an abnormal electrical discharge on the surface of the targets 8A to 8D, as well as to prevent deposition of target materials in the non-erosion region as much as possible.

Also, with the magnetron sputtering apparatus 1 of the present embodiment, the above-described method of the present invention can be easily performed with good efficiency.

The present invention can be applied to an unprescribed
5 number of various types of targets; and there is no restriction to the type of a sputtering gas that can be introduced.

Working Example

A working example of the present invention is described below.

10 <Working example>

The magnetron sputtering apparatus shown in Fig. 1 is used and six sheets of targets obtained by adding 10 wt% of SnO_2 to In_2O_3 are disposed in the vacuum chamber.

Then, a sputtering gas including Ar and O_2 was introduced
15 to the inside of the vacuum chamber. Under a pressure of 0.7 Pa, voltages that have pulsed rectangular waves with the opposite phases (frequency: 50 Hz, supplied power: 6.0 kW) as shown in Fig. 2 are applied to the targets to perform sputtering.

<Comparative Example>

20 Sputtering is performed under the same process conditions as those of the working example, using the magnetron sputtering apparatus of the conventional techniques shown in Fig. 6.

While a non-erosion region 80 with a width of approximately 10 mm is present on the rim portion of the target
25 8 in the comparative example as shown Fig. 5(a), and almost no

non-erosion region is present in the rim portion of the target 8 in the working example as shown in Fig. 5(b).

SCOPE OF CLAIMS

1. A magnetron sputtering method, comprising;
performing sputtering by generating a magnetron discharge
5 in the vicinity of a plurality of targets, the targets being
disposed in close each other in order to be directly opposed to
the adjacent targets, wherein each of the targets is
electrically independent in a vacuum atmosphere; and
applying voltages having a phase difference of 180
10 degrees to the adjacent targets at a prescribed timing during
the sputtering.
2. The magnetron sputtering method according to claim 1,
wherein the voltages having a phase difference of 180 degrees
15 are periodically and alternately applied to the adjacent
targets.
3. The magnetron sputtering method according to claim 1,
wherein the voltages applied to the adjacent targets are pulsed
20 DC voltages.
4. The magnetron sputtering method according to claim 1,
wherein frequencies of the voltages applied to the adjacent
targets are equal.

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5. The magnetron sputtering method according to claim 1, wherein voltages applied to the adjacent targets are always exclusive to each other.

5 6. A magnetron sputtering apparatus, comprising:
a plurality of targets electrically independent to each other disposed in a vacuum chamber, wherein the targets are disposed close to each other in order to be directly opposed to the adjacent targets; and
10 a voltage supply member having a power supply capable of applying voltage having a phase difference of 180 degrees to each target respectively at a predetermined timing.

7. The magnetron sputtering apparatus according to claim 6,
15 wherein a space between the adjacent targets is set to a distance that an abnormal electrical discharge does not occur between the adjacent targets, and also plasma is not generated between the adjacent targets.

20