

TITLE OF THE INVENTION

METHOD AND APPARATUS FOR MANUFACTURING LOW REFLECTIVITY FILM

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to a method and an apparatus for manufacturing low reflectivity film to be used for optical filters of plasma displays and other flat panel displays.

Related Background Art

10 Conventionally, films of this type are mostly manufactured by means of a sputtering technique because the technique provides an advantage of excellent controllability of uniformly forming film on a substrate having a large surface area particularly from the viewpoint of flat display panels where the tendency of using
15 substrates having a large surface area is remarkable (see, inter alia, Patent Documents 1 and 2 listed below).

Low reflectivity film is conventionally formed by combining two or more than two layers prepared by reactive sputtering, using oxygen, nitrogen and/or carbon and a reflective
20 layer.

Generally, a technique (for example, magnetron sputtering method) of locally generating high density plasma, trapping electrons by a loop-shaped magnetic field formed on a target, is employed in the thin film forming process from the viewpoint
25 of improving the deposition rate (see, inter alia, Patent Documents 1 and 2 listed below). However, since high density plasma is locally generated by magnetron sputtering, the sputter generating region (erosion) is also localized on the target to

consequently reduce the efficiency of utilization of the target and hence raise the running cost.

To avoid this problem, a technique of swinging the magnetron magnetic circuit arranged at the back of the cathode relative to the latter and consequently moving the erosion on the target has been proposed. With this technique, however, a target having a large width needs to be used. Then, there arises a problem of high cost particularly in terms of target material and sputtering system.

10 If the magnetron magnetic circuit is made to swing, the extent of sputtering differs between the edges and the center of the target due the difference in the number of erosion strips that the circuit passes by. Then, the target erodes stepwise and also gives rise to a low efficiency of utilization of the target.

15 In an attempt to dissolve the above identified problems, the inventors of the present invention proposed in Japanese Patent Application No. 2002-37825 a method and an apparatus for forming thin film at low cost with an enhanced level of productivity by increasing the number of magnetron magnetic circuits that are
20 arranged at the back of the cathode. More specifically, two magnetron magnetic circuits are arranged at the back of the cathode showing a same electric potential in a proposed apparatus in order to generate two closed loops of plasma. Then, the magnetron magnetic circuits arranged at the back of the cathode
25 are made to swing relative to the back of the cathode so that consequently the plasma that is obtained by generating magnetron plasma moves on the surface of the target.

[Patent Document 1]

Japanese Patent Application Laid-Open Publication No.
10-140345

[Patent Document 2]

5 Japanese Patent Application Laid-Open Publication No.
07-310181

When forming thin film by sputtering, the rate at which the layer is formed by reactive sputtering and the optical constants of the layer greatly vary depending on the ratio of the flow rate of oxygen, that of nitrogen and that of carbon dioxide. With the proposed method, the swinging speed of the magnetron magnetic circuits has to be rigorously defined when the rate and the optical constants vary rapidly by reactive sputtering because the swinging direction of the magnetron magnetic circuits and the direction of conveying the substrate are opposite to each other.

SUMMARY OF THE INVENTION

20 Therefore, it is the object of the present invention to provide a method and an apparatus for manufacturing low reflectivity film, in which the problems mentioned above could be overcome.

In the first aspect of the invention, the above object is achieved by providing a method for continuously forming low reflectivity film on a substrate disposed opposite to and moving relative to a cathode arranged in a sputtering chamber by sputtering a target material for forming the low reflectivity

film onto the substrate comprising the steps of:

generating closed loops magnetron plasma on the surface of the target arranged on the cathode showing a same electric potential by respectively means of two magnetron magnetic
5 circuits arranged at the back of the cathode; and

swinging the magnetron magnetic circuits showing a same electric potential and arranged at the back of the cathode at a speed of not higher than $1/50$ relative to the moving speed of the substrate, thereby moving the plasma obtained as a result
10 of the generation of magnetron plasma along the surface of the target accordingly.

The target material arranged on the surface of the cathode may be made of Cr, Mo, Fe or Ni or an alloy containing one or more than one of the above listed elements.

15 Gas containing one or more of oxygen, nitrogen and carbon may be used as reactive gas in a method according to the invention.

In the second aspect of the invention, there is provided an apparatus for continuously forming low reflectivity film on a substrate disposed opposite to and moving relative to a cathode
20 arranged in a sputtering chamber by sputtering a target material for forming the low reflectivity film onto the substrate comprising:

two magnetron magnetic circuits arranged at the back of the cathode showing a same electric potential so as to generate
25 respective closed loops of magnetron plasma;

magnetic circuit swinging means for respectively swinging the magnetron magnetic circuits relative to the back surface of the cathode, thereby moving the plasma obtained as a result of

the generation of magnetron plasma along the surface of the target accordingly; and

a control means for controlling the swinging speed of the magnetron magnetic circuits relative to the moving speed of the
5 substrate.

With a method according to the invention, two closed loops of magnetron plasma are generated on the surface of a target arranged on the surface of a cathode showing a same electric potential by means of two magnetron magnetic circuits arranged
10 at the back of the cathode and the generated magnetron plasma is moved along the surface of the target by swinging the magnetron magnetic circuits arranged at the back of the cathode at a speed of not higher than $1/50$ relative to the moving speed of the substrate. Thus, the efficiency of using the target can be
15 remarkably improved to reduce the film forming cost. Additionally, low reflectivity film can be uniformly formed on the substrate.

An apparatus according to the invention comprises two magnetron magnetic circuits arranged at the back of the cathode
20 showing a same electric potential so as to generate respective closed loops of magnetron plasma, magnetic circuit swinging means for respectively swinging the magnetron magnetic circuits relative to the back surface of the cathode, thereby moving the generated magnetron plasma along the surface of the target
25 accordingly, and a control means for controlling the swinging speed of the magnetron magnetic circuits relative to the moving speed of the substrate. Thus, the film forming rate of the apparatus can be twice as high as that of a comparable conventional

apparatus having a single magnetic circuit so that it is possible to remarkably improve the efficiency of the use of the target. As a result, the number of cathodes, that of power sources and that of pumps can be reduced significantly to consequently reduce
5 the overall length and the cost of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of an embodiment of apparatus for forming low reflectivity film according to the
10 invention;

FIGS. 2A and 2B are schematic plan views of two-layered low reflectivity films formed on respective substrates by using the apparatus of FIG. 1;

FIG. 3 is a graph illustrating the reflectivity
15 characteristic of the substrate of FIG. 2A; and

FIG. 4 is a graph illustrating the distribution of reflectivity along the moving direction of the substrate, which is obtained by changing the swinging speed of the magnetic circuits.

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DETAILED DESCRIPTION OF THE INVENTION

Now, the present invention will be described by referring to the accompanying drawings that illustrate a preferred embodiment of method and apparatus for manufacturing low
25 reflectivity film according to the invention.

FIG. 1 is a schematic block diagram of an embodiment of apparatus for forming low reflectivity film according to the invention, showing the overall configuration thereof. The

illustrated apparatus comprises a feed-in/feed-out chamber 1 and a sputtering chamber 2, which are separated from each other by a partition valve 3. The feed-in/feed-out chamber 1 can be evacuated to a desired vacuum level by means of a vacuum/exhaust pump 5 by way of a valve 4. Similarly, the sputtering chamber 2 can also be evacuated to a desired vacuum level by means of a vacuum/exhaust pump 7 by way of a valve 6. Mixture gas is introduced into the sputtering chamber 2 at a desired rate by means of an Ar gas introducing system 8 and a reactive gas introducing system 9 having respective mass flow controllers.

A cathode 11 is arranged in the sputtering chamber 2 with an electrically insulating plate 10. A target material 12 is mounted on the surface of the cathode 11. Two magnetron magnetic circuits 13 are arranged below the cathode in order to form two looped magnetic fields on the target material 12. The two magnetron magnetic circuits 13 are mounted on respective swinging mechanisms 14 in such a way that they can be made to swing simultaneously by a magnetic circuit swinging drive unit 15.

The cathode 11 is connected to a DC power source 16 so that high density plasma 17 is generated along the looped magnetic fields on the target material 12 by feeding power from the DC power source 16 and an RF power source (not shown) and the target material 12 is sputtered at and around centers of sputtering, which are in the regions where plasma is generated.

A substrate holder 18 is also arranged in the sputtering chamber 2 and a substrate 19 is mounted on the substrate holder 18. The substrate holder 18 is supported by a conveying mechanism (not shown) so as to move between the feed-in/feed-out chamber

1 and the sputtering chamber 2. The substrate holder 18 can be heated by a sheath heater 20 that is arranged at the right end of the sputtering chamber 2.

A control unit 21 to be used for defining the swinging speed
5 of the magnetron magnetic circuits 13 is connected to the magnetic circuit swinging drive unit 15 for driving the swinging mechanisms 14 of the magnetron magnetic circuits 13. The control unit 21 operates to limit the swinging speed M of the magnetron magnetic circuits 13 arranged at the back of the cathode at a speed of
10 not higher than $1/50$ relative to the moving speed S of the substrate 19. The swinging mechanism 14 makes the magnetic circuits to swing in positive and negative directions relative to the direction in which the substrate holder 17 passes.

The illustrated apparatus operates in the following way.
15 After evacuating the feed-in/feed-out chamber 1 to a desired vacuum level by means of the vacuum/exhaust pump 5 by way of the valve 4, the substrate holder 18 on which a substrate 19 is mounted is brought into the sputtering chamber 2 by way of the partition valve 3. The sputtering chamber 2 is firstly evacuated to a high
20 degree of vacuum by means of the vacuum/exhaust pump 7 by way of the valve 6 and subsequently mixture gas is introduced into it at a predetermined rate by means of the Ar gas introducing system 8 and the reactive gas introducing system 9 having respective mass flow controllers. On the other hand, as power
25 is supplied to the cathode 11 from the DC power source 16 and the RF power source, high density plasma 17 is formed along the looped magnetic fields on the target material 12 and the target material 12 is sputtered at and around the centers of sputtering,

which are in the region where plasma is generated. In this way, the substrate 19 mounted on the substrate holder 18 that is heated by the sheath heater 20 is brought into the region where the target material 12 is being sputtered. As a result, oxide film, nitride
5 film and carbide film are formed on the substrate 19 that is mounted on the substrate holder 18 by the sputtered target material. During the operation, the substrate 19 has a temperature that is controlled by the sheath heater 20.

EXAMPLE

10 Now, the present invention will be described further with reference to an example. In the illustrated embodiment, a Cr target was used as the target material 12 in the apparatus as shown in FIG. 1 and oxygen, carbon dioxide and nitrogen gas were used for the reactive gas introducing system 9. At the same time,
15 sputtering pressure of 0.7Pa and power of 15kW were used. The magnetic circuit swinging drive unit 15 was controlled by means of the control unit 21 in such a way that the swinging speed M of the magnetron magnetic circuits 13 was 1/50 and 1/7 relative to the moving speed of the substrate 19 mounted on the respective
20 substrate holder 18 when the substrate holder 18 was made to pass over the surface of the corresponding Cr target material 12. As a result, a 45nm reactive sputtering layer and a 130nm reflective layer were formed on each of the substrates. FIGS. 2A and 2B show the substrates 19 observed in the example.

25 FIG. 2A shows the substrate 19 whose speed ratio (the moving speed S of the substrate 19 : the swinging speed M of the magnetron magnetic circuits 13) was 1 : 50 and FIG. 2B shows the substrate 19 whose speed ratio was 1 : 7. A low reflectivity film was

uniformly formed on the substrate 19 of FIG. 2A as indicated by a, whereas stripes were produced on the substrate 19 of FIG. 2B as indicated by b and c. Since film is formed on the substrate under the condition of a swinging speed of +M and that of -M of the magnetic circuits relative to the moving speed S of the substrate, the relative speed of the substrate as viewed from plasma is S+M and S-M. In other words, stripes are produced unless M is sufficiently large or small. It is easier to eliminate stripes by selecting a sufficiently small value for M because
10 M has an upper limit due to hardware-related reasons.

FIG. 3 is a graph illustrating the reflectivity characteristic of the substrate of FIG. 2A. Referring to FIG. 3, the wavelength for the lowest reflectivity value B is expressed by λ_B . For the purpose of the present invention, the wavelength
15 is made to be found between 550nm and 600nm that is about at the center of the wavelength range of visible light in order to cover the entire visible light range.

FIG. 4 is a graph illustrating the distribution of reflectivity along the moving direction of the substrate, which is obtained by changing the swinging speed M of the magnetic
20 circuits. As seen from FIG. 4, when the speed ratio (which is equal to the reciprocal number of the swinging speed M of the magnetic circuits) is not less than 50, the width $\Delta\lambda_B$ of the wavelength λ_B is stabilized to show a uniform distribution of
25 reflectivity.

What is claimed is:

1. A method for continuously forming low reflectivity film on a substrate disposed opposite to and moving relative to a cathode arranged in a sputtering chamber by sputtering a target material for forming the low reflectivity film onto the substrate comprising the steps of:

generating closed loops magnetron plasma on the surface of the target arranged on the cathode showing a same electric potential by respectively means of two magnetron magnetic circuits arranged at the back of the cathode; and

swinging the magnetron magnetic circuits arranged at the back of the cathode showing a same electric potential at a speed of not higher than 1/50 relative to the moving speed of the substrate, thereby moving the plasma obtained as a result of the generation of magnetron plasma along the surface of the target accordingly.

2. A method according to claim 1, wherein the target material arranged on the surface of the cathode is made of Cr, Mo, Fe or Ni or an alloy containing one or more than one of the above listed elements.

3. A method according to claim 1, wherein a target made of Cr, Mo, Fe or Ni or an alloy containing one or more than one of the above listed elements is used as target and gas containing one or more than one of oxygen, nitrogen and carbon is used as reactive gas.

4. An apparatus for continuously forming low reflectivity film on a substrate disposed opposite to and moving relative to a cathode arranged in a sputtering chamber by

sputtering a target material for forming the low reflectivity film onto the substrate comprising:

two magnetron magnetic circuits arranged at the back of the cathode showing a same electric potential so as to generate
5 respective closed loops of magnetron plasma;

magnetic circuit swinging means for respectively swinging the magnetron magnetic circuits relative to the back surface of the cathode, thereby moving the plasma obtained as a result of the generation of magnetron plasma along the surface of the target
10 accordingly; and

a control means for controlling the swinging speed of the magnetron magnetic circuits relative to the moving speed of the substrate.