with EUV light using the mask, the interdiffusion layer becomes thicker or changes its nature, resulting further decrease of reflectance.

The present invention has been made to solve the above problems, and an object of the present invention is to provide a substrate with a multilayer reflection film for an EUV mask blank including the multilayer reflection film that has high reflectance, and is hard to be decreased reflectance when the multilayer reflection film is heated, a manufacturing method of the substrate, and an EUV mask blank including the substrate.

The inventors have been found that in a multilayer reflection film used for an EUV mask blank which is constructed by a Si/Mo laminated portion in which Si layers and Mo layers are alternately laminated, when a layer containing Si and N intervenes at one or more portions between the Si layer and the Mo layer of the Si/Mo laminated portion, and is contact with both of the Si layer and the Mo layer, preferably, when the multilayer reflection film is constructed by such a Si/Mo laminated portion and a protection layer containing Ru formed in contact with the Si/Mo laminated portion, as the uppermost layer of the multilayer reflection film, a substrate with a multilayer reflection film for an EUV mask blank, and an EUV mask blank have high reflectance, and is hard to be decreased reflectance when the multilayer reflection film is heated.

In one aspect, the invention provides a substrate with a multilayer reflection film for an EUV mask blank including a substrate, and a multilayer reflection film formed on the substrate, wherein

the multilayer reflection film includes a Si/Mo laminated portion in which Si layers and Mo layers are alternately laminated, and

a layer containing Si and N intervenes at one or more portions between the Si layer and the Mo layer of the Si/Mo laminated portion, and is contact with both of the Si layer and the Mo layer.

In yet another aspect, the present disclosure provides substrate with a multilayer reflection film for an EUV mask blank comprising a substrate, and a multilayer reflection film formed on the substrate, wherein

the multilayer reflection film comprises a Si/Mo laminated portion in which Si layers and Mo layers are alternately laminated, and

a layer containing Si and N intervenes at one or more portions between the Si layer and the Mo layer of the Si/Mo laminated portion, and is contact with both of the Si layer and the Mo layer,

the multilayer reflection film further comprises a protection layer containing Ru formed in contact with the Si/Mo laminated portion, as the uppermost layer,

the protection layer is contact with the Mo layer of the Si/Mo laminated portion,

the uppermost part of the multilayer reflection film consists of, from the side remote from the substrate, the protection layer, the Mo layer, a layer containing Si and N, and the Si layer, and

in the uppermost part, the Mo layer has a thickness of not more than 1 nm

Preferably, the layer containing Si and N has a thickness of not more than 2 nm.

Preferably, the multilayer reflection film further includes a protection layer containing Ru formed in contact with the Si/Mo laminated portion, as the uppermost layer.

Preferably, the protection layer is contact with the Mo layer of the Si/Mo laminated portion.

CLAIMS:

1. A substrate with a multilayer reflection film for an EUV mask blank comprising a substrate, and a multilayer reflection film formed on the substrate, wherein

the multilayer reflection film comprises a Si/Mo laminated portion in which Si layers and Mo layers are alternately laminated, and

a layer containing Si and N intervenes at one or more portions between the Si layer and the Mo layer of the Si/Mo laminated portion, and is contact with both of the Si layer and the Mo layer,

the multilayer reflection film further comprises a protection layer containing Ru formed in contact with the Si/Mo laminated portion, as the uppermost layer,

the protection layer is contact with the Mo layer of the Si/Mo laminated portion,

the uppermost part of the multilayer reflection film consists of, from the side remote from the substrate, the protection layer, the Mo layer, a layer containing Si and N, and the Si layer, and

in the uppermost part, the Mo layer has a thickness of not more than 1 nm.

2. The substrate of claim 1, wherein the layer containing Si and N has a thickness of not more than 2 nm.

3. The substrate of claim 1 or 2, wherein in the uppermost part, the protection layer has a thickness of not more than 4 nm, the layer containing Si and N has a thickness of not more than 2 nm, and the Si layer has a thickness of not more than 4 nm.

4. The substrate of any one of claims 1 to 3, wherein the Si/Mo laminated portion comprises not less than 30 of three-layer laminated structure units, and the three-layer laminated structure unit consists of, from the substrate side,

i) the Si layer, a layer containing Si and N formed in contact with the Si layer, and the Mo layer formed in contact with the layer containing Si and N, or;

ii) the Mo layer, a layer containing Si and N formed in contact with the Mo layer, and the Si layer formed in contact with the layer containing Si and N.

5. The substrate of any one of claims 1 to 3, wherein the Si/Mo laminated portion comprises not less than 30 of four-layer laminated structure units, and the four-layer laminated structure unit consists of, from the substrate side, the Si layer, a layer containing Si and N formed in contact with the Si layer, the Mo layer formed in contact with the layer containing Si and N, and a layer containing Si and N formed in contact with the Mo layer.

6. The substrate of any one of claims 1 to 5, wherein the multilayer reflection film has a peak reflectance of not less than 65% with respect to EUV light of the wavelength range of 13.4 to 13.6 nm at an incident angle of 6°.

7. A manufacturing method for the substrate with a multilayer reflection film for an EUV mask blank of any one of claims 1 to 6, the method comprising the step of

(A) forming the Si/Mo laminated portion by sputtering, wherein

the sputtering is performed by a magnetron sputtering apparatus comprising a chamber, wherein in the chamber,

one or more Mo targets and one or more Si targets are attachable;

powers are individually appliable to the Mo target and the Si target;

the substrate and each of the targets are disposed in offset arrangement;

none of shield members are disposed between the substrate and each of the targets;

the substrate is rotatable along its main surface; and

nitrogen-containing gas is introducible.

8. A manufacturing method for the substrate with a multilayer reflection film for an EUV mask blank of any one of claims 1 to 6, the method comprising the steps of

(A) forming the Si/Mo laminated portion by sputtering, and

(B) forming the protection layer by sputtering, wherein

after the step (A), the Si/Mo laminated portion is provided to the step (B) without contacting to gases reactable to the Si/Mo laminated portion that has been formed in the step (A).

9. The manufacturing method of claim 8, wherein the step (A) is performed in one sputter chamber, the substrate on which the Si/Mo laminated portion has been formed is transferred to the other sputter chamber, and then, the step (B) is performed in the other sputter chamber.

10. The manufacturing method of claim 9, wherein a transfer chamber is provided between said one and other sputter chambers, the transfer chamber is capable of communicating with each of the sputter chambers individually or with both of the sputter chambers at the same time, and the substrate on which the Si/Mo laminated portion has been formed is transferred from said one sputter chamber via the transfer chamber to said other sputter chamber.

11. The manufacturing method of claim 10, wherein the substrate is transferred under vacuum both in the transfer from said one sputter chamber to the transfer chamber, and the transfer from the transfer chamber to said other sputter chamber.

12. The manufacturing method of any one of claims 8 to 11, wherein the Si/Mo laminated portion comprises not less than 30 of three-layer laminated structure units, and the three-layer laminated structure unit consists of, from the substrate side,

i) the Si layer, a layer containing Si and N formed in contact with the Si layer, and the Mo layer formed in contact with the layer containing Si and N, or;

ii) the Mo layer, a layer containing Si and N formed in contact with the Mo layer, and the Si layer formed in contact with the layer containing Si and N.

13. The manufacturing method of any one of claims 8 to 11, wherein the Si/Mo laminated portion comprises not less than 30 of four-layer laminated structure units, and the four-layer laminated structure unit consists of, from the substrate side, the Si layer, a layer containing Si and N formed in contact with the Si layer, the Mo layer formed in contact with the layer containing Si and N, and a layer containing Si and N formed in contact with the Mo layer.

14. The manufacturing method of any one of claims 8 to 13, wherein the multilayer reflection film has a peak reflectance of not less than 65% with respect to EUV light of the wavelength range of 13.4 to 13.6 nm at an incident angle of 6°.

15. An EUV mask blank comprising the substrate with a multilayer reflection film for an EUV mask blank of any one of claims 1 to 6, and an absorber film containing Ta or Cr formed on the multilayer reflection film.

16. An EUV mask blank comprising the substrate with a multilayer reflection film for an EUV mask blank of any one of claims 1 to 6, an absorber film containing Ta and being free of Cr formed on the multilayer reflection film, and a hard mask film which contains Cr and acts as an etching mask in dry etching for the absorber film.