exposure light is ArF excimer laser light,

the light-shielding film is formed in a single layer, the layer is composed of a single composition layer having a constant composition in a thickness direction,

a reflectance to the exposure light of the light-shielding film on a side remote from the substrate is 40% or less, and

the refractive index n of the light-shielding film to the exposure light is 2.3 or less and the extinction coefficient k to the exposure light is 1.3 or more, and the thickness of the light-shielding film is 80 nm or less.

As disclosed, in a case where the light-shielding film is a single layer composed of the composition gradient layer in which the composition continuously varies in the thickness direction, a difference of refractive indexes n to the exposure light between a surface on the substrate side and a surface on a side remote from the substrate is 0.2 or less and a difference of extinction coefficients k to the exposure light between a surface on the substrate side and a surface on a side remote from the substrate is 0.5 or less, and

As disclosed, in a case where the light-shielding film is a multilayer, among the refractive indexes n to the exposure light at the surface on the substrate side and at the surface on the side remote from the substrate of all layers of the multilayer, a difference between the highest refractive index n and the lowest refractive index n is 0.2 or less, and among the extinction coefficients k to the exposure light at the surface on the substrate side and at the surface on the side remote from the substrate of all layers of the multilayer, a difference between the highest extinction coefficient k and the lowest extinction coefficient k is 0.5 or less.

In a preferred embodiment, the light-shielding film is a single layer composed of the single composition layer in which the composition is constant in the thickness direction, the refractive index n of the light-shielding film to the exposure light is 2.3 or less and the extinction coefficient k to the exposure light is 1.3 or more, and the thickness of the light-shielding film is 80 nm or less.

In a preferred embodiment, the light-shielding film is a single layer composed of the composition gradient layer in which the composition continuously varies in the thickness direction, in the light-shielding film, the refractive index n at the surface on the substrate side is lower than the refractive index n at the surface on the side remote from the substrate, and the extinction coefficient k at the surface on the substrate side is higher than the extinction coefficient k at the surface on the side remote from the substrate. Typically, the refractive index n of the light-shielding film to the exposure light is 2.3 or less and the

extinction coefficient k to the exposure light is 1.3 or more, and the thickness of the light-shielding film is 80 nm or less.

In a preferred embodiment, the light-shielding film is a multilayer, in the light-shielding film, the refractive index n of a layer on a side closest to the substrate is lower than the refractive index n at a layer on a side remotest from the substrate, and the extinction coefficient k of the layer on the side closest to the substrate is higher than the extinction coefficient k of the layer on the side remotest from the substrate. Typically, i) the multilayer is composed of only the single composition layer in which the composition is constant in the thickness direction, ii) in the light-shielding film, the refractive index n at the face closest to the substrate is the lowest, and the layer closest to the substrate has the highest extinction coefficient k and has a thickness of 50 nm or less, or iii) any of the refractive indexes n is 2.3 or less and any of the extinction coefficients k is 1.3 or more, and the thickness of the light-shielding film is 80 nm or less.

In a preferred embodiment, in any of the compositions of respective layers of the light-shielding film, the total content of molybdenum and silicon is 55 to 75 atom%, the content of nitrogen is 25 to 45 atom%, and the ratio of molybdenum to the total of molybdenum and silicon is 20 atom% or less.

In a preferred embodiment, the light-shielding film is formed in contact with the substrate and an optical density OD with respect to a wavelength of the exposure light is 2.8 or more, or the light-shielding film is formed on the substrate with one or two or more of other films interposed, and the optical density OD of the whole of the light-shielding film and the other films with respect to the wavelength of the exposure light is 2.8 or more. Typically, the other films include only an etching stopper film having an etching characteristic different from that of the light-shielding film, only a phase shift film having an etching characteristic same as that of the light-shielding film, or both of the etching stopper film and the phase shift film.

In a preferred embodiment, the photomask blank including a hard mask film having an etching characteristic different from that of the light-shielding film in contact with the light-shielding film on a side remote from the substrate.

In another aspect, the invention is to provide a photomask produced by using the photomask blank.

In a second aspect, the invention is to provide a photomask blank comprising:

a transparent substrate; and

a light-shielding film comprising molybdenum, silicon, and nitrogen, wherein

an exposure light is ArF excimer laser light,

the light-shielding film is formed in a single layer, the single layer is composed of a composition gradient layer having a continuously varying composition in the thickness direction,

a reflectance to the exposure light of the light-shielding film on a side remote from the substrate is 40% or less,

in the light-shielding film, the refractive index n at the surface on the substrate side is lower than the refractive index n at the surface on the side remote from the substrate, and the extinction coefficient k at the surface on the substrate side is higher than the extinction coefficient k at the surface on the side remote from the substrate, and

a difference of refractive indexes n to the exposure light between a surface on the substrate side and a surface on a side remote from the substrate is 0.2 or less and a difference of extinction coefficients k to the exposure light between a surface on the substrate side and a surface on a side remote from the substrate is 0.5 or less.

In a third aspect, the invention is to provide a photomask blank comprising:

a transparent substrate; and

a light-shielding film comprising molybdenum, silicon, and nitrogen, wherein

an exposure light is ArF excimer laser light,

the light-shielding film is formed in a multilayer consisting of two or more layers, the layer is composed of a single composition layer having a constant composition in a thickness direction or a composition gradient layer having a continuously varying composition in the thickness direction,

a reflectance to the exposure light of the light-shielding film on a side remote from the substrate is 40% or less,

in the light-shielding film, the refractive index n of a layer on a side closest to the substrate is lower than the refractive index n at a layer on a side remotest from the substrate, and the extinction coefficient k of the layer on the side closest to the substrate is higher than the extinction coefficient k of the layer on the side remotest from the substrate, and

among the refractive indexes n to the exposure light at the surface on the substrate side and at the surface on the side remote from the substrate of all layers of the multilayer, a difference between the highest refractive index n and the lowest refractive index n is 0.2 or less, and among the extinction coefficients k to the exposure light at the surface on the

substrate side and at the surface on the side remote from the substrate of all layers of the multilayer, a difference between the highest extinction coefficient k and the lowest extinction coefficient k is 0.5 or less.

CLAIMS:

1. A photomask blank comprising:

a transparent substrate; and

a light-shielding film comprising molybdenum, silicon, and nitrogen, wherein

an exposure light is ArF excimer laser light,

the light-shielding film is formed in a single layer, the layer is composed of a single composition layer having a constant composition in a thickness direction,

a reflectance to the exposure light of the light-shielding film on a side remote from the substrate is 40% or less, and

the refractive index n of the light-shielding film to the exposure light is 2.3 or less and the extinction coefficient k to the exposure light is 1.3 or more, and the thickness of the light-shielding film is 80 nm or less.

2. The photomask blank of claim 1, wherein in any of the compositions of respective layers of the light-shielding film, the total content of molybdenum and silicon is 55 to 75 atom %, the content of nitrogen is 25 to 45 atom %, and the ratio of molybdenum to the total of molybdenum and silicon is 20 atom % or less.

3. The photomask blank of claim 1 or 2, wherein the light-shielding film is formed in contact with the substrate and an optical density OD with respect to a wavelength of the exposure light is 2.8 or more, or the light-shielding film is formed on the substrate with one or two or more of other films interposed, and the optical density OD of the whole of the light-shielding film and the other films with respect to the wavelength of the exposure light is 2.8 or more.

4. The photomask blank of claim 3, wherein the other films include only an etching stopper film having an etching characteristic different from that of the light-shielding film, only a phase shift film having an etching characteristic same as that of the light-shielding film, or both of the etching stopper film and the phase shift film.

5. The photomask blank of any one of claims 1 to 4, comprising a hard mask film having an etching characteristic different from that of the light-shielding film in contact with the light-shielding film on a side remote from the substrate.

6. A photomask produced by using the photomask blank of any one of claims 1 to 5.

7. A photomask blank comprising:

a transparent substrate; and

a light-shielding film comprising molybdenum, silicon, and nitrogen, wherein

an exposure light is ArF excimer laser light,

the light-shielding film is formed in a single layer, the single layer is composed of a composition gradient layer having a continuously varying composition in the thickness direction,

a reflectance to the exposure light of the light-shielding film on a side remote from the substrate is 40% or less,

in the light-shielding film, the refractive index n at the surface on the substrate side is lower than the refractive index n at the surface on the side remote from the substrate, and the extinction coefficient k at the surface on the substrate side is higher than the extinction coefficient k at the surface on the side remote from the substrate, and

a difference of refractive indexes n to the exposure light between a surface on the substrate side and a surface on a side remote from the substrate is 0.2 or less and a difference of extinction coefficients k to the exposure light between a surface on the substrate side and a surface on a side remote from the substrate is 0.5 or less.

8. The photomask blank of claim 7, wherein the refractive index n of the light-shielding film to the exposure light is 2.3 or less and the extinction coefficient k to the exposure light is 1.3 or more, and the thickness of the light-shielding film is 80 nm or less.

9. The photomask blank of claim 7 or 8, wherein in any of the compositions of respective layers of the light-shielding film, the total content of molybdenum and silicon is 55 to 75 atom %, the content of nitrogen is 25 to 45 atom %, and the ratio of molybdenum to the total of molybdenum and silicon is 20 atom % or less.

10. The photomask blank of any one of claims 7 to 9, wherein the light-shielding film is formed in contact with the substrate and an optical density OD with respect to a wavelength of the exposure light is 2.8 or more, or the light-shielding film is formed on the substrate with one or two or more of other films interposed, and the optical density OD of the whole of the light-shielding film and the other films with respect to the wavelength of the exposure light is 2.8 or more.

11. The photomask blank of claim 10, wherein the other films include only an etching stopper film having an etching characteristic different from that of the light-shielding film, only a phase shift film having an etching characteristic same as that of the light-shielding film, or both of the etching stopper film and the phase shift film.

12. The photomask blank of any one of claims 7 to 11, comprising a hard mask film having an etching characteristic different from that of the light-shielding film in contact with the light-shielding film on a side remote from the substrate.

13. A photomask produced by using the photomask blank of any one of claims 7 to 12.

14. A photomask blank comprising:

a transparent substrate; and

a light-shielding film comprising molybdenum, silicon, and nitrogen, wherein an exposure light is ArF excimer laser light,

the light-shielding film is formed in a multilayer consisting of two or more layers, the layer is composed of a single composition layer having a constant composition in a thickness direction or a composition gradient layer having a continuously varying composition in the thickness direction,

a reflectance to the exposure light of the light-shielding film on a side remote from the substrate is 40% or less,

in the light-shielding film, the refractive index n of a layer on a side closest to the substrate is lower than the refractive index n at a layer on a side remotest from the substrate, and the extinction coefficient k of the layer on the side closest to the substrate is

higher than the extinction coefficient k of the layer on the side remotest from the substrate, and

among the refractive indexes n to the exposure light at the surface on the substrate side and at the surface on the side remote from the substrate of all layers of the multilayer, a difference between the highest refractive index n and the lowest refractive index n is 0.2 or less, and among the extinction coefficients k to the exposure light at the surface on the substrate side and at the surface on the side remote from the substrate of all layers of the multilayer, a difference between the highest extinction coefficient k and the lowest extinction coefficient k is 0.5 or less.

15. The photomask blank of claim 14, wherein the multilayer is composed of only the single composition layer in which the composition is constant in the thickness direction.

16. The photomask blank of claim 14 or 15, wherein in the light-shielding film, the refractive index n at the face closest to the substrate is the lowest, and the layer closest to the substrate has the highest extinction coefficient k and has a thickness of 50 nm or less.

17. The photomask blank of any one of claims 14 to 16, wherein any of the refractive indexes n is 2.3 or less and any of the extinction coefficients k is 1.3 or more, and the thickness of the light-shielding film is 80 nm or less.

18. The photomask blank of any one of claims 14 to 17, wherein in any of the compositions of respective layers of the light-shielding film, the total content of molybdenum and silicon is 55 to 75 atom %, the content of nitrogen is 25 to 45 atom %, and the ratio of molybdenum to the total of molybdenum and silicon is 20 atom % or less.

19. The photomask blank of any one of claims 14 to 18, wherein the light-shielding film is formed in contact with the substrate and an optical density OD with respect to a wavelength of the exposure light is 2.8 or more, or the light-shielding film is formed on the substrate with one or two or more of other films interposed, and the optical density OD of the whole of the light-shielding film and the other films with respect to the wavelength of the exposure light is 2.8 or more.

20. The photomask blank of claim 19, wherein the other films include only an etching stopper film having an etching characteristic different from that of the light-shielding film, only a phase shift film having an etching characteristic same as that of the light-shielding film, or both of the etching stopper film and the phase shift film.

21. The photomask blank of any one of claims 14 to 20, comprising a hard mask film having an etching characteristic different from that of the light-shielding film in contact with the light-shielding film on a side remote from the substrate.

22. A photomask produced by using the photomask blank of any one of claims 14 to 21.