of the phase difference adjustment layer to uniformize the transition metal and N content in the mixture of the surface of the phase difference adjustment layer in the in-plane direction.

By using a light source having a power of 2 to 10 mW/cm^2, a light with a wavelength of 200 nm or less is irradiated to the surface of the phase difference adjustment layer for 5 to 20 minutes, and thereby the surface of the phase difference adjustment layer may be treated.

The phase difference adjustment layer 21 may be heat-treated together with or separately from the UV light irradiation process. The heat treatment may be applied by utilizing the heat generated by UV irradiation or may be performed as separated processes.

The phase difference adjustment layer 21 formed through the sputtering process may have an internal stress. The internal stress may be a compressive stress or a tensile stress depending on the conditions of sputtering. The internal stress of the phase difference adjustment layer may cause warpage of the substrate, and as a result, the resolution of the photomask to which the phase difference adjustment layer is applied may be reduced. In the embodiment, the warpage of the substrate may be reduced by applying a heat treatment to the phase difference adjustment layer.

The protective layer may be formed through a heat treatment process after sputtering process of the phase difference adjustment layer. During the heat treatment process, an atmospheric gas in the chamber may be introduced to form a protective layer on the surface of the phase difference adjustment layer 21. A protective layer may be formed by reacting the surface of the phase difference adjustment layer with atmospheric gas in the heat treatment process. However, the manufacturing method of the protective layer is not limited thereto.

The heat treatment process may comprise a temperature increasing operation, a temperature maintaining operation, a cooling operation, and a protective layer forming operation. The heat treatment process may be performed by disposing a blank mask having

CLAIMS

1. A blank mask comprising:

a transparent substrate;

a phase shift film disposed on the transparent substrate; and

a light shielding film disposed on at least some of the phase shift film, wherein the light shielding film disposed on the at least some of the phase shift film is removed before an XRD analysis is performed,

wherein the blank mask is analyzed by normal mode XRD (X-Ray Diffraction),

wherein the phase shift film has a XRD maximum peak at 2θ of 15° to 30° when the normal mode XRD analysis is performed on an upper surface of the phase shift film,

wherein the transparent substrate has a XRD maximum peak at 2θ of 15° to 30° when the normal mode XRD analysis is performed on a lower surface of the transparent substrate, and

wherein the blank mask has AI1 value of 0.9 to 1.1 expressed by Equation 1 below;

[Equation 1]

$$AI1 = \frac{XM1}{XQ1}$$

where in the Equation 1,

the XM1 is a maximum value of measured X-ray intensity when the normal mode XRD analysis is performed on the upper surface of the phase shift film, and

the XQ1 is a maximum value of measured X-ray intensity when the normal mode XRD analysis is performed on the lower surface of the transparent substrate, and

wherein the phase shift film comprises a phase difference adjustment layer and a

protective layer disposed on the phase difference adjustment layer,

the phase difference adjustment layer and the protective layer comprise a transition metal, silicon, oxygen, and nitrogen,

the phase difference adjustment layer comprises a transition metal of 3 to 10 atom%, silicon in an amount of 20 to 50 atom%, oxygen in an amount of 2 to 10 atom%, and nitrogen in an amount of 40 to 60 atom%, and

the protective layer comprises a transition metal in an amount of 0.5 to 5 atom%, silicon in an amount of 10 to 50 atom%, oxygen in an amount of 10 to 50 atom%, and nitrogen in an amount of 20 to 40 atom%.

2. The blank mask of claim 1,

which is analyzed by fixed mode XRD,

wherein the phase shift film has a first peak, which is the XRD maximum peak at 2θ of 15° to 25° when the fixed mode XRD analysis is performed on the upper surface of the phase shift film,

wherein the transparent substrate has a second peak, which is the XRD maximum peak at 2θ of 15° to 25° when the fixed mode XRD analysis is performed on the lower surface of the transparent substrate, and

wherein AI2 value expressed by Equation 2 below is 0.9 to 1.1;

[Equation 2]

$$AI2 = \frac{XM2}{XQ2}$$

wherein in the Equation 2,

the XM2 is the intensity value of the first peak, and

the XQ2 is the intensity value of the second peak.

3. The blank mask of claim 1,

wherein AI3 value expressed by Equation 3 below is 0.9 to 1.1;

[Equation 3]

$$AI3 = \frac{AM1}{AQ1}$$

wherein in the Equation 3,

the AM1 is an area of the region where 2θ is 15 ° to 30 ° in the X-ray intensity graph measured when the normal mode XRD analysis is performed on the upper surface of the phase shift film, and

the AQ1 is an area of the region where 2θ is 15 ° to 30 ° in an X-ray intensity graph measured when the normal mode XRD analysis is performed on the lower surface of the transparent substrate.

4. The blank mask of claim 3,

wherein AI4 value expressed by Equation 4 below is 0.9 to 1.1;

[Equation 4]

$$AI4 = \frac{XM4}{XQ4}$$

wherein in the Equation 4,

the XM4 is the X-ray intensity where 2θ is 43° when the normal mode XRD analysis is performed on the upper surface of the phase shift film, and

the XQ4 is the X-ray intensity where 2θ is 43 ° when the normal mode XRD analysis is performed on the lower surface of the transparent substrate.

5. The blank mask of claim 1,

wherein a photon energy of incident light at the point where the Del_1 value according to Equation 7 below is 0 is 1.8 to 2.14 eV when PE_1 is 1.5 eV and PE_2 is 3 eV;

[Equation 7]

$$Del_1 = \lim_{\Delta PE \to 0} \left(\frac{\Delta DPS}{\Delta PE} \right)$$

wherein in the Equation 7, the DPS is a phase difference between the P wave and the S wave of reflected light if the phase difference between the P wave and the S wave of the reflected light is 180° or less or a value obtained by subtracting the phase difference between the P wave and the S wave of the reflected light from 360 ° if the phase difference between the P wave and the S wave of the reflected light is more than 180 °, when the phase shift film is measured with a spectroscopic ellipsometer by applying an incident angle of 64.5 °,

the PE is the photon energy of the incident light within the range of the PE_1 value to the PE_2 value,

the ΔDPS is a difference of the DPS, and

the ΔPE is a difference of the PE.

6. The blank mask of claim 1,

wherein the photon energy of incident light at the point where the Del_1 value

according to Equation 7 below is 0 is 3.8 to 4.64 eV when the PE_1 value is 3.0 eV and the PE_2 value is 5.0 eV;

[Equation 7]

$$Del_1 = \lim_{\Delta PE \to 0} \left(\frac{\Delta DPS}{\Delta PE} \right)$$

where in the Equation 7, the DPS is the phase difference between the P wave and the S wave of reflected light if the phase difference between the P wave and the S wave of the reflected light is 180° or less, or a value obtained by subtracting the phase difference between the P wave and the S wave of the reflected light from 360 ° if the phase difference between the P wave and the S wave of the reflected light is more than 180 °, when the phase shift film is measured with a spectroscopic ellipsometer by applying an incident angle of 64.5 °,

the PE is the photon energy of the incident light within the range of the PE_1 value to the PE_2 value,

the ΔDPS is a difference of the DPS, and

the ΔPE is a difference of the PE.

7. The blank mask of claim 1,

wherein the protective layer comprises a region in which the ratio of nitrogen content to oxygen content in the thickness direction is 0.4 to 2, and the region has a thickness of 30 to 80% compared to a total thickness of the protective layer.

8. A photomask comprising:

a transparent substrate; a phase shift film disposed on the transparent substrate; and a light shielding film disposed on at least some of the phase shift film, wherein the light shielding

film disposed on the at least some of the phase shift film is removed before an XRD analysis is performed,

wherein the photomask is analyzed by normal mode XRD,

wherein the phase shift film has a XRD maximum peak at 2θ of 15° to 30° when the normal mode XRD analysis is performed on an upper surface of the phase shift film,

wherein the transparent substrate has a XRD maximum peak at 2θ of 15° to 30° when the normal mode XRD analysis is performed on a lower surface of the transparent substrate, and

wherein the photomask has AI1 value of 0.9 to 1.1 expressed by Equation 1 below is;

[Equation 1]

$$AI1 = \frac{XM1}{XQ1}$$

where in the Equation 1,

the XM1 is the maximum value of the measured X-ray intensity when the normal mode XRD analysis is performed on the phase shift film, and

the XQ1 is the maximum value of the measured X-ray intensity when the normal mode XRD analysis is performed on the lower surface of the transparent substrate, and

wherein the phase shift film comprises a phase difference adjustment layer and a protective layer disposed on the phase difference adjustment layer,

the phase difference adjustment layer and the protective layer comprise a transition metal, silicon, oxygen, and nitrogen,

the phase difference adjustment layer comprises a transition metal of 3 to 10 atom%, silicon in an amount of 20 to 50 atom%, oxygen in an amount of 2 to 10 atom%, and nitrogen

in an amount of 40 to 60 atom%, and

the protective layer comprises a transition metal in an amount of 0.5 to 5 atom%, silicon in an amount of 10 to 50 atom%, oxygen in an amount of 10 to 50 atom%, and nitrogen in an amount of 20 to 40 atom%.