[DOCUMENT] Claims

[Claim 1]

A mask blank comprising a phase shift film on a transparent substrate, wherein:

the phase shift film has a function to transmit an exposure light of an ArF excimer laser at a transmittance of 1% or more, and a function to generate a phase difference of 150 degrees or more and 200 degrees or less between the exposure light transmitted through the phase shift film and the exposure light transmitted through air for a same distance as a thickness of the phase shift film,

the phase shift film has a structure comprising three sets or more of a set of a stacked structure comprising a high transmitting layer and a low transmitting layer,

the high transmitting layer and the low transmitting layer are made of a material consisting of silicon and nitrogen, or a material consisting of silicon, nitrogen, and one or more elements selected from a metalloid element and a non-metallic element,

the high transmitting layer comprises 50 atom% or more nitrogen content and has a thickness of 11 nm or less,

the low transmitting layer comprises less than 50 atom% nitrogen content and has a thickness less than the high transmitting layer, and

a mixed region including a mixture of constituent elements of the low transmitting layer and constituent elements of the high transmitting layer is formed between the low transmitting layer and the high transmitting layer.

[Claim 2]

The mask blank according to claim 1, wherein the mixed region has a thickness of 0.1nm or more and 2nm or less.

[Claim 3]

The mask blank according to claim 1 or 2, wherein the mixed region has higher abundance ratio of an amorphous structure of silicon compared to the high transmitting layer.

[Claim 4]

The mask blank according to any one of claims 1 to 3, wherein the mixed region has lower abundance ratio of a microcrystalline structure made of Si-N bond compared to the high transmitting layer.

[Claim 5]

The mask blank according to any one of claims 1 to 4, wherein the high transmitting layer and the low transmitting layer are made of same constituent elements.

[Claim 6]

The mask blank according to any one of claims 1 to 5, wherein the high transmitting layer and the low transmitting layer are made of a material consisting of silicon and nitrogen.

[Claim 7]

The mask blank according to any one of claims 1 to 6, wherein the low transmitting layer has a thickness of 1/2 or less than a thickness of the high transmitting layer.

[Claim 8]

The mask blank according to any one of claims 1 to 7, wherein the stacked structure has the high transmitting layer and the low transmitting layer stacked in this order from the transparent substrate side.

[Claim 9]

The mask blank according to any one of claims 1 to 8, wherein the phase shift film has an uppermost layer at a position that is farthest from the transparent substrate, and the uppermost layer is made of a material consisting of silicon, nitrogen, and oxygen, or a material consisting of silicon, nitrogen, oxygen, and one or more elements selected from a

metalloid element and a non-metallic element.

[Claim 10]

The mask blank according to any one of claims 1 to 9 comprising a light shielding film on the phase shift film.

[Claim 11]

A phase shift mask comprising a phase shift film having a transfer pattern on a transparent substrate, wherein:

the phase shift film has a function to transmit an exposure light of an ArF excimer laser at a transmittance of 1% or more, and a function to generate a phase difference of 150 degrees or more and 200 degrees or less between the exposure light transmitted through the phase shift film and the exposure light transmitted through air for a same distance as a thickness of the phase shift film,

the phase shift film has a structure comprising three sets or more of a set of a stacked structure comprising a high transmitting layer and a low transmitting layer,

the high transmitting layer and the low transmitting layer are made of a material consisting of silicon and nitrogen, or a material consisting of silicon, nitrogen, and one or more elements selected from a metalloid element and a non-metallic element,

the high transmitting layer comprises 50 atom% or more nitrogen content and has a thickness of 11 nm or less,

the low transmitting layer comprises less than 50 atom% nitrogen content and has a thickness less than the high transmitting layer, and

a mixed region including a mixture of constituent elements of the low transmitting layer and constituent elements of the high transmitting layer is formed between the low transmitting layer and the high transmitting layer.

[Claim 12]

The phase shift mask according to claim 11, wherein the mixed region has a thickness of 0.1nm or more and 2nm or less.

[Claim 13]

The phase shift mask according to claim 11 or 12, wherein the mixed region has higher abundance ratio of an amorphous structure of silicon compared to the high transmitting layer.

[Claim 14]

The phase shift mask according to any one of claims 11 to 13, wherein the mixed region has lower abundance ratio of a microcrystalline structure made of Si-N bond compared to the high transmitting layer.

[Claim 15]

The phase shift mask according to any one of claims 11 to 14, wherein the high transmitting layer and the low transmitting layer made of same constituent elements.

[Claim 16]

The phase shift mask according to any one of claims 11 to 15, wherein the high transmitting layer and the low transmitting layer are made of a material consisting of silicon and nitrogen.

[Claim 17]

The phase shift mask according to any one of claims 11 to 16, wherein the low transmitting layer has a thickness of 1/2 or less than a thickness of the high transmitting layer.

[Claim 18]

The phase shift mask according to any one of claims 11 to 17, wherein the stacked structure has the high transmitting layer and the low transmitting layer stacked in this order from the transparent substrate side.

[Claim 19]

The phase shift mask according to any one of claims 11 to 18, wherein the phase shift film has an uppermost layer at

a position that is farthest from the transparent substrate, and the upper most layer is made of a material consisting of silicon, nitrogen, and oxygen, or a material consisting of silicon, nitrogen, oxygen, and one or more elements selected from a metalloid element and a non-metallic element.

[Claim 20]

The phase shift mask according to any one of claims 11 to 19 comprising a light shielding film having a pattern comprising a light shielding band on the phase shift film.

[Claim 21]

A method for manufacturing a semiconductor device comprising the step of exposure-transferring a transfer pattern on a resist film on a semiconductor substrate using the phase shift mask according to claim 20.