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,

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,

the mixed region has a thickness of 1nm or more and 2nm or less, and

the mixed region has higher abundance ratio of an amorphous structure of silicon compared to the high

transmitting layer.

[Claim 2]

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

[Claim 3]

The mask blank according to claim 1 or claim 2, wherein the high transmitting layer and the low transmitting layer are made of same constituent elements.

[Claim 4]

The mask blank according to any one of claims 1 to 3, wherein the high transmitting layer and the low transmitting layer are made of a material consisting of silicon and nitrogen.

[Claim 5]

The mask blank according to any one of claims 1 to 4, wherein the low transmitting layer has a thickness of 1/2 or less than a thickness of the high transmitting layer.

[Claim 6]

The mask blank according to any one of claims 1 to 5, wherein the stacked structure has the high transmitting layer and the low transmitting layer stacked in this order from the transparent substrate side.

[Claim 7]

The mask blank according to any one of claims 1 to 6, 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 8]

The mask blank according to any one of claims 1 to 7 comprising a light shielding film on the phase shift film.

[Claim 9]

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,

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,

the mixed region has a thickness of 1nm or more and 2nm or less, and

the mixed region has higher abundance ratio of an amorphous structure of silicon compared to the high transmitting layer.

[Claim 10]

The phase shift mask according to claim 9, wherein the mixed region has lower abundance ratio of a microcrystalline structure made of Si-N bond compared to the high transmitting layer.

[Claim 11]

The phase shift mask according to claim 9 or claim 10, wherein the high transmitting layer and the low transmitting layer made of same constituent elements.

[Claim 12]

The phase shift mask according to any one of claims 9 to 11, wherein the high transmitting layer and the low transmitting layer are made of a material consisting of silicon and nitrogen.

[Claim 13]

The phase shift mask according to any one of claims 9 to 12, wherein the low transmitting layer has a thickness of 1/2 or less than a thickness of the high transmitting layer.

[Claim 14]

The phase shift mask according to any one of claims 9 to 13, wherein the stacked structure has the high transmitting layer and the low transmitting layer stacked in this order from the transparent substrate side.

[Claim 15]

The phase shift mask according to any one of claims 9 to 14, 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 16]

The phase shift mask according to any one of claims 9 to 15 comprising a light shielding film having a pattern comprising a light shielding band on the phase shift film.

[Claim 17]

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 16.