(D) forming a pattern of the first inorganic film by etching the first inorganic film by fluorine -based dry etching with using the pattern of the second inorganic film as an etching mask.

In yet another aspect, there is provided a method for manufacturing a photomask from a photomask blank comprising a transparent substrate, a first inorganic film which comprises silicon and is free of chromium, and a second inorganic film which comprises chromium and is free of silicon, the first inorganic film and the second inorganic film being contacted, the first inorganic film being formed on the transparent substrate via two or more another inorganic films, wherein

the photomask blank comprises a third inorganic film which comprises chromium and is free of silicon, and a fourth inorganic film which comprises silicon and is free of chromium, as said other films, the third inorganic film is in contact with the transparent substrate side of the first inorganic film, and the fourth inorganic film is in contact with the transparent substrate side of the third inorganic film, wherein

the method comprising the steps of:

(A) forming a resist film in contact with the second inorganic film;

(B) patterning the resist film to form a resist pattern;

(C) forming a pattern of the second inorganic film by etching the second inorganic film by fluorine-based dry etching with using the resist pattern as an etching mask; and

(D) forming a pattern of the first inorganic film by etching the first inorganic film by fluorine -based dry etching with using the pattern of the second inorganic film as an etching mask.

In a further aspect, there is provided a method for manufacturing a photomask from a photomask blank comprising a transparent substrate, a first inorganic film which comprises silicon and is free of chromium, a second inorganic film which comprises chromium and is free of silicon, and a resist film, the first inorganic film, the second inorganic film and the resist film being contacted in this order, the first inorganic film being formed on the transparent substrate via two or more another inorganic films, wherein

the photomask blank comprises a third inorganic film which comprises chromium and is free of silicon, and a fourth inorganic film which comprises silicon and is free of chromium, as said other films, the third inorganic film is in contact with the transparent

substrate side of the first inorganic film, and the fourth inorganic film is in contact with the transparent substrate side of the third inorganic film, wherein

the method comprising the steps of:

(B) patterning the resist film to form a resist pattern;

(C) forming a pattern of the second inorganic film by etching the second inorganic film by fluorine-based dry etching with using the resist pattern as an etching mask; and

(D) forming a pattern of the first inorganic film by etching the first inorganic film by fluorine -based dry etching with using the pattern of the second inorganic film as an etching mask.

Preferably, steps (C) and (D) are continuously performed by the fluorine-based dry etching.

Preferably, the fluorine-based dry etching in step (C) and the fluorine-based dry etching in step (D) are performed under the same condition, and a ratio of an etching rate of the second inorganic film by the fluorine-based dry etching applied in step (C) to an etching rate of the first inorganic film by the fluorine-based dry etching applied in step (D) is not less than 0.3.

Preferably, the second inorganic film has a chromium content of not less than 25 at% and not more than 40 at%.

Preferably, the second inorganic film has a thickness of not less than 1 nm and not more than 10 nm.

Preferably, in the method, the photomask blank includes a third inorganic film which comprises chromium and is free of silicon, as said other film, and the third inorganic film is in contact with the transparent substrate side of the first inorganic film.

Preferably, a ratio of an etching rate of the third inorganic film by the fluorine-based dry etching applied in step (D) to an etching rate of the first inorganic film by the fluorine-based dry etching applied in step (D) is less than 0.3.

Preferably, in the method, the photomask blank includes a fourth inorganic film which comprises silicon and is free of chromium, as said other film, and the fourth inorganic film is in contact with the transparent substrate side of the third inorganic film.

Preferably, the first inorganic film is a hard mask film for the third inorganic film, the second inorganic film is a processing aid film for the first inorganic film, the third inorganic film is a light-shielding film, and the fourth inorganic film is a phase shift film.

In the other aspect, the invention provides a photomask blank including a transparent substrate, a first inorganic film which contains silicon and is free of chromium, and a second inorganic film which contains chromium and is free of silicon, the first inorganic film and the second inorganic film being contacted, the first inorganic film being formed on the substrate directly or via one or more another inorganic films, wherein

when fluorine-based dry etching is performed under the same condition, a ratio of an etching rate of the second inorganic film to an etching rate of the first inorganic film is not less than 0.3.

In yet another aspect, there is provided a photomask blank comprising a transparent substrate, a first inorganic film which comprises silicon and is free of chromium, and a second inorganic film which comprises chromium and is free of silicon, the first inorganic film and the second inorganic film being contacted, the first inorganic film being formed on the substrate via two or more another inorganic films, wherein

the photomask blank comprises a third inorganic film which comprises chromium and is free of silicon, and a fourth inorganic film which comprises silicon and is free of chromium, as said other films, the third inorganic film is in contact with the transparent substrate side of the first inorganic film, and the fourth inorganic film is in contact with the transparent substrate side of the third inorganic film, and

when fluorine-based dry etching is performed under the same condition, a ratio of an etching rate of the second inorganic film to an etching rate of the first inorganic film is not less than 0.3

Preferably, the second inorganic film has a chromium content of not less than 25 at% and not more than 40 at%.

Preferably, the second inorganic film has a thickness of not less than 1 nm and not more than 10 nm.

Preferably, the photomask blank includes a third inorganic film which contains chromium and is free of silicon, as said other film, and the third inorganic film is in contact with the transparent substrate side of the first inorganic film.

Preferably, when fluorine-based dry etching is performed under the same condition, a ratio of an etching rate of the third inorganic film to an etching rate of the first inorganic film is less than 0.3.

Preferably, the photomask blank includes a fourth inorganic film which contains silicon and is free of chromium, as said other film, and the fourth inorganic film is in contact with the substrate side of the third inorganic film.

Preferably, the first inorganic film is a hard mask film for the third inorganic film, the second inorganic film is a processing aid film for the first inorganic film, the third inorganic film is a light-shielding film, and the fourth inorganic film is a phase shift film.

Preferably, the photomask blank includes a resist film being in contact with the side remote form the transparent substrate of the second inorganic film.

ADVANTAGEOUS EFFECTS OF THE INVENTION

According to the invention, adhesion of a resist film is ensured regardless of properties of a film containing silicon by forming the re resist film via a second inorganic film containing chromium and being free of silicon to a first inorganic film containing silicon and being free of chromium. Moreover, by forming the second inorganic film containing chromium and being free of silicon, as a film that can be etched by fluorine-based dry etching, and patterning both of the second inorganic film and the first inorganic film by fluorine-based dry etching in this order, a photomask in which defects are reduced can be manufactured with avoiding problem of resist residues generated after development when forming a resist pattern from a resist film, which is a problem in the silylation

CLAIMS:

1. A method for manufacturing a photomask from a photomask blank comprising a transparent substrate, a first inorganic film which comprises silicon and is free of chromium, and a second inorganic film which comprises chromium and is free of silicon, the first inorganic film and the second inorganic film being contacted, the first inorganic film being formed on the transparent substrate via two or more another inorganic films, wherein

the photomask blank comprises a third inorganic film which comprises chromium and is free of silicon, and a fourth inorganic film which comprises silicon and is free of chromium, as said other films, the third inorganic film is in contact with the transparent substrate side of the first inorganic film, and the fourth inorganic film is in contact with the transparent substrate side of the third inorganic film, wherein

the method comprising the steps of:

(A) forming a resist film in contact with the second inorganic film;

(B) patterning the resist film to form a resist pattern;

(C) forming a pattern of the second inorganic film by etching the second inorganic film by fluorine-based dry etching with using the resist pattern as an etching mask; and

(D) forming a pattern of the first inorganic film by etching the first inorganic film by fluorine -based dry etching with using the pattern of the second inorganic film as an etching mask.

2. A method for manufacturing a photomask from a photomask blank comprising a transparent substrate, a first inorganic film which comprises silicon and is free of chromium, a second inorganic film which comprises chromium and is free of silicon, and a resist film, the first inorganic film, the second inorganic film and the resist film being contacted in this order, the first inorganic film being formed on the transparent substrate via two or more another inorganic films, wherein

the photomask blank comprises a third inorganic film which comprises chromium and is free of silicon, and a fourth inorganic film which comprises silicon and is free of chromium, as said other films, the third inorganic film is in contact with the transparent

substrate side of the first inorganic film, and the fourth inorganic film is in contact with the transparent substrate side of the third inorganic film, wherein

the method comprising the steps of:

(B) patterning the resist film to form a resist pattern;

(C) forming a pattern of the second inorganic film by etching the second inorganic film by fluorine-based dry etching with using the resist pattern as an etching mask; and

(D) forming a pattern of the first inorganic film by etching the first inorganic film by fluorine -based dry etching with using the pattern of the second inorganic film as an etching mask.

3. The method of claim 1 or 2, wherein steps (C) and (D) are continuously performed by the fluorine-based dry etching.

4. The method of any one of claims 1 to 3, wherein the fluorine-based dry etching in step (C) and the fluorine-based dry etching in step (D) are performed under the same condition, and a ratio of an etching rate of the second inorganic film by the fluorine-based dry etching applied in step (C) to an etching rate of the first inorganic film by the fluorine-based dry etching applied in step (D) is not less than 0.3.

5. The method of any one of claims 1 to 4, wherein the second inorganic film has a chromium content of not less than 25 at% and not more than 40 at%.

6. The method of any one of claims 1 to 5, wherein the second inorganic film has a thickness of not less than 1 nm and not more than 10 nm.

7. The method of any one of claims 1 to 6, wherein a ratio of an etching rate of the third inorganic film by the fluorine-based dry etching applied in step (D) to an etching rate of the first inorganic film by the fluorine-based dry etching applied in step (D) is less than 0.3.

8. The method of any one of claims 1 to 7, wherein the first inorganic film is a hard mask film for the third inorganic film, the second inorganic film is a processing aid film for the first inorganic film, the third inorganic film is a light-shielding film, and the fourth inorganic film is a phase shift film.

9. A photomask blank comprising a transparent substrate, a first inorganic film which comprises silicon and is free of chromium, and a second inorganic film which comprises chromium and is free of silicon, the first inorganic film and the second inorganic film being contacted, the first inorganic film being formed on the substrate via two or more another inorganic films, wherein

the photomask blank comprises a third inorganic film which comprises chromium and is free of silicon, and a fourth inorganic film which comprises silicon and is free of chromium, as said other films, the third inorganic film is in contact with the transparent substrate side of the first inorganic film, and the fourth inorganic film is in contact with the transparent substrate side of the third inorganic film, and

when fluorine-based dry etching is performed under the same condition, a ratio of an etching rate of the second inorganic film to an etching rate of the first inorganic film is not less than 0.3.

10. The photomask blank of claim 9, wherein the second inorganic film has a chromium content of not less than 25 at% and not more than 40 at%.

11. The photomask blank of claim 9 or 10, wherein the second inorganic film has a thickness of not less than 1 nm and not more than 10 nm.

12. The photomask blank of any one of claims 9 to 11, wherein when fluorine-based dry etching is performed under the same condition, a ratio of an etching rate of the third inorganic film to an etching rate of the first inorganic film is less than 0.3.

13. The photomask blank of any one of claims 9 to 12, wherein the first inorganic film is a hard mask film for the third inorganic film, the second inorganic film is a processing aid film for the first inorganic film, the third inorganic film is a light-shielding film, and the fourth inorganic film is a phase shift film.

14. The photomask blank of any one of claims 9 to 13 comprising a resist film being in contact with the side remote form the transparent substrate of the second inorganic film.