portion in the photomask pattern region should have a degree of light shielding enough to substantially shield exposure light, these portions are typically formed of a chromium-containing light shielding film.

Commonly used is a halftone phase shift photomask blank including a transparent substrate and a two-layer film including a halftone phase shift film and a chromium-containing light shielding film deposited in order on the substrate. When a halftone phase shift photomask is prepared from this photomask blank, the surface of the chromium-containing film is exposed where light shielding is necessary. Also used is a halftone phase shift photomask blank including a transparent substrate and a three-layer film including a halftone phase shift film, a chromium-containing light shielding film, and a silicon-containing hard mask film. When a halftone phase shift photomask is prepared from this photomask blank having the hard mask film, the surface of the chromium-containing film is exposed where light shielding is necessary, because the hard mask film is finally removed. If the surface of the chromium-containing film is exposed on the halftone phase shift photomask, there is a likelihood of chromium migration upon irradiation of ArF excimer laser light. During continuous use of the halftone phase shift photomask, defects in the form of foreign particles will generate.

Embodiments of the invention seek to provide a halftone phase shift photomask blank having deposited thereon a hard mask film from which a finer size pattern can be formed by applying a thinner resist film, such that a halftone phase shift photomask may be prepared from the blank at a high accuracy and with a minimized possibility of defect generation, while a silicon-containing film is left on a chromium-containing film (formed for ensuring a high degree of light shielding) via a simple pattern forming step, at the outer periphery of the photomask whereby the surface of the chromium-containing film is not exposed outside.

The inventors have found that a halftone phase shift photomask blank is constructed as comprising a transparent substrate, a first film serving as a halftone phase shift film on the substrate, a second film formed contiguous to the first film, a third film formed contiguous to the second film, and a fourth film formed contiguous to the third film, wherein the first and third films are formed of silicon-containing materials which are resistant to chlorine base dry etching and removable by fluorine base dry etching, the second and fourth films are formed of silicon-free, chromium-containing materials which

are resistant to fluorine base dry etching and removable by chlorine base dry etching; that a halftone phase shift photomask may be prepared from the blank (having the hard mask film) at a high accuracy and with a minimized possibility of defect generation, while a silicon-containing film is left on a chromium-containing film (formed for providing a high degree of light shielding) via a simple pattern forming step, at the outer periphery of the photomask; and that in the resulting halftone phase shift photomask, the surface of the chromium-containing film is not exposed at the top thereof.

In one aspect, the invention provides a halftone phase shift photomask blank comprising a transparent substrate, a first film serving as a halftone phase shift film on the substrate, a second film serving as a light shielding film formed contiguous to the first film, a third film serving as a hard mask film formed contiguous to the second film, and a fourth film formed contiguous to the third film. The first and third films are formed of silicon-containing materials which are resistant to chlorine base dry etching and removable by fluorine base dry etching. The second and fourth films are formed of silicon-free, chromium-containing materials which are resistant to fluorine base dry etching and removable by chlorine base dry etching, the fourth film has a thickness of 30 to 120 nm, and the second and fourth films are constructed such that an etching clear time of the fourth film on chlorine base dry etching under one set of conditions is longer than an etching clear time of the second film on chlorine base dry etching under said one set of conditions.

Preferably, the second film has a sheet resistance of up to 10,000 Ω/□; the third film has a thickness of 1 to 20 nm; the third film is thinner than the second film; the fourth film has a thickness of 30 to 120 nm; the first, second and third films have a total optical density of at least 2 relative to exposure light.

In a preferred embodiment, the second and fourth films are constructed such that an etching clear time of the fourth film on chlorine base dry etching under one set of conditions is longer than an etching clear time of the second film on chlorine base dry etching under the one set of conditions.

ADVANTAGEOUS EFFECTS OF INVENTION

From the halftone phase shift photomask blank of the invention, a halftone phase shift photomask may be prepared at a high accuracy and with a minimized possibility of defect generation. A silicon-containing film is left on a chromium-containing film (formed for providing a high degree of light shielding) via a simple pattern forming step, at the outer periphery of the photomask. In the photomask, the surface of the chromium-

CLAIMS:

1. A halftone phase shift photomask blank comprising a transparent substrate, a first film serving as a halftone phase shift film on the substrate, a second film serving as a light shielding film formed contiguous to the first film, a third film serving as a hard mask film formed contiguous to the second film, and a fourth film formed contiguous to the third film, wherein

the first and third films are formed of silicon containing materials which are resistant to chlorine base dry etching and removable by fluorine base dry etching,

the second and fourth films are formed of silicon-free, chromium-containing materials which are resistant to fluorine base dry etching and removable by chlorine base dry etching,

the fourth film has a thickness of 30 to 120 nm, and

the second and fourth films are constructed such that an etching clear time of the fourth film on chlorine base dry etching under one set of conditions is longer than an etching clear time of the second film on chlorine base dry etching under said one set of conditions.

2. The photomask blank of claim 1 wherein the second film has a sheet resistance of up to 10,000 □/□.

3. The photomask blank of claim 1 or 2 wherein the third film has a thickness of 1 to 20 nm.

4. The photomask blank of any one of claims 1 to 3 wherein the third film is thinner than the second film.

5. The photomask blank of any one of claims 1 to 4 wherein the fourth film has a thickness of more than 30 nm to 120 nm.

6. The photomask blank of any one of claims 1 to 4 wherein the fourth film has a thickness of 40 to 120 nm.

7. The photomask blank of any one of claims 1 to 6 wherein the first, second and third films have a total optical density of at least 2 relative to exposure light.