SUMMARY OF INVENTION

With respect to the phase shift film, a thinner film may be advantageous for pattern formation and may be effective for reducing 3D effect. Thus a thinner film may be required in order for photolithography to form a finer size pattern.

As alluded to previously (Patent Document 1), a film containing molybdenum and silicon is mainly used as the phase shift film. Regrettably, the transition metal-containing film experiences a noticeable pattern size variation degradation by irradiation of ArF excimer laser light of wavelength 193 nm. Since cleaning is repeated during the mask manufacture process or mask use, the transition metal-containing film also undergoes noticeable changes of optical properties on every cleaning. These problems may be solved by forming the phase shift film from a transition metal-free silicon base material. Nevertheless, the phase shift film formed of a transition metal-free silicon base material, especially nitrogen-containing silicon base material contains a substantial stress therein. When a phase shift mask is manufactured from this phase shift mask blank by patterning the phase shift film, a flatness change occurs before and after the pattern formation of the phase shift film, resulting in misalignment of the pattern on the phase shift mask, that is, a low dimensional accuracy.

Embodiments of the invention seek to provide a phase shift mask blank having a phase shift film which is thin enough to be advantageous for pattern formation and 3D effect reduction while maintaining a necessary phase shift for the phase shift function to comply with pattern size miniaturization, and may be improved in quality and dimensional control so as to minimize pattern misalignment and dimensional accuracy lowering during the step of patterning the phase shift film to form a phase

shift mask. Embodiments of the invention provide a phase shift mask and a method for preparing the phase shift mask blank.

Aiming to develop a phase shift film which may have a reduced thickness and may be minimized in pattern misalignment and dimensional accuracy lowering during the step of patterning the phase shift film to form a phase shift mask while maintaining a necessary phase shift for the phase shift function, the inventors made a study on a transition metal-free phase shift film. It has been found that a desired phase shift film is formed on a transparent substrate by sputter depositing at least one layer of a silicon base material consisting of silicon, nitrogen and optionally oxygen and heat treating the film at 400°C or above for at least 5 minutes. Then the phase shift film has a thickness of up to 70 nm and a phase shift of 150 to 200° with respect to light of wavelength up to 200 nm light and provides a warpage change (ΔTIR) of up to 0.2 μm as absolute value in a central region of 142 mm squares on a surface of the substrate between before the deposition of the phase shift film on the substrate and the presence of the phase shift film on the substrate, or a warpage change (ΔTIR) of up to 0.2 μm as absolute value in a central region of 142 mm squares on a surface of the substrate between the presence of the phase shift film on the substrate and after complete removal of the phase shift film from the substrate by etching.

Once the phase shift film is constructed as above, there is obtained a phase shift mask blank which can be advantageously processed into a phase shift film pattern including a main photomask pattern with a width of about 100 to 200 nm, which is necessary in photolithography for forming a pattern with a half pitch of up to 50 nm on a processable substrate such as silicon wafer, using exposure light of

of the phase shift film and as an etch stopper during pattern formation of the third film, the third film is a light-shielding film or a combination of light-shielding film and antireflective film, and the fourth film is an auxiliary film which functions as a hard mask during pattern formation of the third film.

In any embodiments, the phase shift film has been sputter deposited and heat treated at 400°C or above for at least 5 minutes.

Also contemplated herein is a phase shift mask prepared from the phase shift mask blank defined above.

There is also disclosed a method for preparing a phase shift mask blank comprising the steps of sputter depositing a phase shift film on a transparent substrate, and heat treating the phase shift film on the substrate at 400°C or above for at least 5 minutes. The depositing step includes one or both of step (A) of depositing a layer composed of a silicon base material consisting of silicon and nitrogen on a transparent substrate by using a sputtering system with a chamber and at least one silicon target, and feeding argon gas and nitrogen gas into the chamber, and step (B) of depositing a layer composed of a silicon base material consisting of silicon, nitrogen and oxygen on a transparent substrate by using a sputtering system with a chamber and at least one silicon target, and feeding argon gas, and at least one gas selected from nitrogen gas, oxygen gas and nitrogen oxide gas into the chamber.

ADVANTAGEOUS EFFECTS OF INVENTION

The phase shift mask blank of the invention has a phase shift film which may be thin enough to be advantageous for photomask pattern formation, improved in quality and

Claims:

1. A phase shift mask blank comprising a transparent substrate of 152 mm squares and 6.35 mm thick and a phase shift film deposited on the substrate and having a phase shift of 150 to 200° with respect to light of wavelength up to 200 nm, wherein said phase shift film includes at least one layer composed of a silicon base material consisting of silicon and nitrogen or a silicon base material consisting of silicon, nitrogen and oxygen, wherein said phase shift mask blank is characterized in that the phase shift film has a thickness of up to 70 nm, and provides a warpage change (ΔTIR) of up to 0.2 μm as absolute value in a central region of 142 mm squares on a surface of the substrate between before the deposition of the phase shift film on the substrate and the presence of the phase shift film on the substrate.

2. A phase shift mask blank comprising a transparent substrate of 152 mm squares and 6.35 mm thick and a phase shift film deposited on the substrate and having a phase shift of 150 to 200° with respect to light of wavelength up to 200 nm, wherein said phase shift film includes at least one layer composed of a silicon base material consisting of silicon and nitrogen or a silicon base material consisting of silicon, nitrogen and oxygen, wherein said phase shift mask blank is characterized in that the phase shift film has a thickness of up to 70 nm, and provides a warpage change (ΔTIR) of up to 0.2 μm as absolute value in a central region of 142 mm squares on a surface of the substrate between the presence of the phase shift film on the substrate and after complete removal of the phase shift film from the substrate by etching.

3. The mask blank of claim 1 or 2 wherein said phase shift film is a halftone phase shift film composed of a silicon base material consisting of silicon and nitrogen and having a transmittance of 3% to less than 20% with respect to light of wavelength up to 200 nm.

4. The mask blank of claim 1 or 2 wherein said phase shift film is a halftone phase shift film composed of a silicon base material consisting of silicon, nitrogen and oxygen and having a transmittance of at least 20% with respect to light of wavelength up to 200 nm.

5. The mask blank of any one of claims 1 to 4, further comprising a second film on the phase shift film, the second film being a single layer or a multilayer film composed of a chromium-containing material.

6. The mask blank of claim 5 wherein the second film is a light-shielding film, a combination of light-shielding film and antireflective film, or an auxiliary film which functions as a hard mask during pattern formation of the phase shift film.

7. The mask blank of claim 5, further comprising a third film on the second film, the third film being a single layer or a multilayer film composed of a silicon-containing material.

8. The mask blank of claim 7 wherein the second film is a light-shielding film or a combination of light-shielding film and antireflective film, and the third film is an auxiliary film which functions as a hard mask during pattern formation of the second film.

9. The mask blank of claim 7 wherein the second film is an auxiliary film which functions as a hard mask during pattern formation of the phase shift film and as an etch stopper during pattern formation of the third film, and the third film is a light-shielding film or a combination of light-shielding film and antireflective film.

10. The mask blank of claim 7, further comprising a fourth film on the third film, the fourth film being a single layer or a multilayer film composed of a chromium-containing material.

11. The mask blank of claim 10 wherein the second film is an auxiliary film which functions as a hard mask during pattern formation of the phase shift film and as an etch stopper during pattern formation of the third film, the third film is a light-shielding film or a combination of light-shielding film and antireflective film, and the fourth film is an auxiliary film which functions as a hard mask during pattern formation of the third film.