DISCLOSURE OF INVENTION

All the inspection systems described in Patent Documents 1 to 4 adopt optical defect detection, enabling broad range defect inspection in a relatively short time and identification of defects of bump/pit shape. With respect to the EUV mask blank, Patent Document 5 describes the method for identifying whether phase defects are of bump or pit shape.

As long as the inventors studied by an inspection experiment using an atomic force microscope and an electron microscope in combination, the prior art method of examining the arrangement of bright and dark parts in inspection signals from a photomask blank sometimes fails in identification of bump/pit shape. That is, in some inspection signals of pinhole defects, the positional arrangement relationship of bright and dark parts necessary for bump/pit shape discrimination is vague. Particularly in the defect inspection of a processing aid film which is formed for processing of advanced masks, that is, a hard mask film of up to 10 nm thick, the problem of difficult bump/pit shape identification is likely to occur.

Under the circumstances, practical inspection experiments using the inspection systems described in Patent Documents 1 to 4 do not always succeed in identifying the bump/pit shape of a defect at a high accuracy. The method of Patent Document 5 is applicable to phase defects inherent to EUV mask blanks, but with difficulty, to the photomask blanks used in the current mainstream ArF lithography. It is thus desired to establish the method for identifying the bump/pit shape of a defect in a hard mask thin film at a high accuracy, which is difficult with the prior art methods.

Embodiments of the invention seek to provide a method for optically inspecting a defect on a photomask blank for identifying whether the surface shape of the defect is bump or pit at a highly reliable manner, especially identifying whether the shape of a defect in a hard mask thin film (used as a processing aid film in mask pattern processing) is bump or pit, as well as methods for sorting and manufacturing photomask blanks by utilizing the method for identifying the bump/pit shape of a defect on a photomask blank and excluding pinhole defect-bearing substrates.

Making a study on the light intensity distribution of inspection signals from defects in various optical films from both the aspects of an inspection experiment and simulation, the inventors have found that a bright/dark change and a positional arrangement

relationship of bright/dark parts in a defect observation image are different, depending on the values of complex refractive index with respect to inspection light of an optical film and an underlying optical film. The invention is predicated on this and further findings.

In one aspect, the invention provides a method for inspecting a defect on a photomask blank, comprising the steps of:

(A1) preparing a photomask blank having at least one thin film on an optically transparent substrate, the photomask blank bearing a defect on its surface,

(A2) moving the photomask blank to move the defect on the photomask blank surface to a position observable by an inspection optical system, irradiating inspection light to a defect-bearing surface region, and collecting the reflected light from the irradiated region as a magnified image of the region via the inspection optical system,

(A3) extracting a feature parameter from the magnified image, and

(A4) identifying the shape of the defect on the basis of the feature parameter combined with the structure of the photomask blank thin film, wherein the magnified image in step (A2) is created by diffraction components of the reflected light that are transmitted through the inspection optical system, and higher-order diffraction components as said diffraction components are asymmetric between positive and negative sides with respect to the zeroth-order diffraction component (specular component) of the reflected light.

In a preferred embodiment, the magnified image in step (A2) is created by diffraction components of the reflected light that are transmitted through the inspection optical system, and higher-order diffraction components as said diffraction components are asymmetric between positive and negative sides with respect to the zeroth-order diffraction component (specular component) of the reflected light.

In a preferred embodiment, step (A3) includes a processing step of comparing a variation of the light intensity level of a defect area in the magnified image with the light intensity level of a defect-surrounding area, for thereby extracting the feature parameter from the defect inspection image which contains the intensity difference between a bright part with a high light intensity and a dark part with a low light intensity and the positional arrangement relationship between the bright part and the dark part.

Further preferably, in step (A4), the shape of the defect is identified on the basis of data including the feature parameter of the magnified image and the structure of the

photomask blank thin film, and with reference to a table which is previously formed based on optical simulation or empirical data for enabling a choice between pinhole defect and bump defect.

In a preferred embodiment, provided that the outermost surface of the photomask blank under inspection is a thin film which is transparent to the inspection light, when a

feature parameter indicating that the magnified image of the defect is a bright part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect.

In another preferred embodiment, provided that the photomask blank under inspection has a film structure that a thin film at the outermost surface has a higher reflectivity of inspection light than an underlying layer, when a feature parameter indicating that the magnified image of the defect is a dark part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect.

In a preferred embodiment, the thin film has a thickness of up to 10 nm; and the inspection light is light having a wavelength of 210 to 550 nm.

In another aspect, the invention provides a system for inspecting a defect on a photomask blank having at least one thin film on an optically transparent substrate, comprising

an inspection system adapted to irradiate inspection light to a surface region of the thin film and to capture the reflected light from the irradiated region, for thereby inspecting any defects on the surface of the photomask blank, and

a computer having installed therein a program for executing the steps in the photomask blank defect inspection method as disclosed.

In a further aspect, the invention provides a method for inspecting a defect on a photomask blank, comprising the steps of: (A1) preparing a photomask blank having at least one thin film on an optically transparent substrate, the photomask blank bearing a defect on its surface, (A2) moving the photomask blank to move the defect on the photomask blank surface to a position observable by an inspection optical system, irradiating inspection light to a defect-bearing surface region, and collecting the reflected light from the irradiated region as a magnified image of the region via the inspection optical system, (A3) extracting a feature parameter from the magnified image, and (A4) identifying the shape of the defect on the basis of the feature parameter combined with the structure of the photomask blank thin film, wherein in step (A4), the shape of the defect is identified on the basis of data including the feature parameter of the magnified image and the structure of the photomask blank thin film, and with reference to a table which is previously formed based on optical simulation or empirical data for enabling a choice between pinhole defect and bump defect, and wherein i) provided that the outermost

surface of the photomask blank under inspection is a thin film which is transparent to the inspection light, when a feature parameter indicating that the magnified image of the defect is a bright part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect, or ii) provided that the photomask blank under inspection has a film structure that a thin film at the outermost surface has a higher reflectivity of inspection light than an underlying layer, when a feature parameter indicating that the magnified image of the defect is a dark part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect.

In a further aspect, the invention provides a method of sorting photomask blanks, comprising sorting photomask blanks having no pinhole defects, based on the identification whether defects are of bump or pit shape by the inspection method as disclosed.

In a still further aspect, the invention provides a method for manufacturing a photomask blank, comprising the steps of forming at least one thin film on an optically transparent substrate to construct a photomask blank, and sorting a photomask blank having no pinhole defects by the sorting method as disclosed.

ADVANTAGEOUS EFFECTS OF INVENTION

The optical defect inspection method of the invention may be effective for discriminating defects of bump or pit shape on a photomask blank in a highly reliable manner, for thereby identifying pit defect and pinhole defect which are fatal defects. The application of the defect inspection method may ensure that photomask blanks having pit defects which are fatal

CLAIMS:

1. A method for inspecting a defect on a photomask blank, comprising the steps of:

(A1) preparing a photomask blank having at least one thin film on an optically transparent substrate, the photomask blank bearing a defect on its surface,

(A2) moving the photomask blank to move the defect on the photomask blank surface to a position observable by an inspection optical system, irradiating inspection light to a defect-bearing surface region, and collecting the reflected light from the irradiated region as a magnified image of the region via the inspection optical system,

(A3) extracting a feature parameter from the magnified image, and

(A4) identifying the shape of the defect on the basis of the feature parameter combined with the structure of the photomask blank thin film, wherein

the magnified image in step (A2) is created by diffraction components of the reflected light that are transmitted through the inspection optical system, and higher-order diffraction components as said diffraction components are asymmetric between positive and negative sides with respect to the zeroth-order diffraction component (specular component) of the reflected light.

2. The method of claim 1 wherein step (A3) includes a processing step of comparing a variation of the light intensity level of a defect area in the magnified image with the light intensity level of a defect-surrounding area, for thereby extracting the feature parameter from the defect inspection image which contains the intensity difference between a bright part with a high light intensity and a dark part with a low light intensity and the positional arrangement relationship between the bright part and the dark part.

3. The method of claim 1 wherein in step (A4), the shape of the defect is identified on the basis of data including the feature parameter of the magnified image and the structure of the photomask blank thin film, and with reference to a table which is previously formed based on optical simulation or empirical data for enabling a choice between pinhole defect and bump defect.

4. The method of claim 3 wherein provided that the outermost surface of the photomask blank under inspection is a thin film which is transparent to the inspection light, when a feature parameter indicating that the magnified image of the defect is a bright part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect.

5. The method of claim 3 wherein provided that the photomask blank under inspection has a film structure that a thin film at the outermost surface has a higher reflectivity of inspection light than an underlying layer, when a feature parameter indicating that the magnified image of the defect is a dark part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect.

6. The method of claim 1 wherein the thin film has a thickness of up to 10 nm.

7. The method of claim 1 wherein the inspection light is light having a wavelength of 210 to 550 nm.

8. A system for inspecting a defect on a photomask blank having at least one thin film on an optically transparent substrate, comprising

an inspection system adapted to irradiate inspection light to a surface region of the thin film and to capture the reflected light from the irradiated region, for thereby inspecting any defects on the surface of the photomask blank, and

a computer having installed therein a program for executing the steps in the photomask blank defect inspection method of claim 1.

9. A method of sorting photomask blanks, comprising sorting photomask blanks having no pinhole defects, based on the identification whether defects are of bump or pit shape by the inspection method of claim 1.

10. A method for manufacturing a photomask blank, comprising the steps of:

forming at least one thin film on an optically transparent substrate to construct a photomask blank, and

sorting a photomask blank having no pinhole defects by the sorting method of claim 9.

11. A method for inspecting a defect on a photomask blank, comprising the steps of:

(A1) preparing a photomask blank having at least one thin film on an optically transparent substrate, the photomask blank bearing a defect on its surface,

(A2) moving the photomask blank to move the defect on the photomask blank surface to a position observable by an inspection optical system, irradiating inspection light to a

defect-bearing surface region, and collecting the reflected light from the irradiated region as a magnified image of the region via the inspection optical system,

(A3) extracting a feature parameter from the magnified image, and

(A4) identifying the shape of the defect on the basis of the feature parameter combined with the structure of the photomask blank thin film, wherein in step (A4), the shape of the defect is identified on the basis of data including the feature parameter of the magnified image and the structure of the photomask blank thin film, and with reference to a table which is previously formed based on optical simulation or empirical data for enabling a choice between pinhole defect and bump defect, and wherein

i) provided that the outermost surface of the photomask blank under inspection is a thin film which is transparent to the inspection light, when a feature parameter indicating that the magnified image of the defect is a bright part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect, or

ii) provided that the photomask blank under inspection has a film structure that a thin film at the outermost surface has a higher reflectivity of inspection light than an underlying layer, when a feature parameter indicating that the magnified image of the defect is a dark part-predominant image is extracted in step (A3), the defect detected is identified to be a pinhole defect.

12. The method of claim 11 wherein the magnified image in step (A2) is created by diffraction components of the reflected light that are transmitted through the inspection optical system, and higher-order diffraction components as said diffraction components are asymmetric between positive and negative sides with respect to the zeroth-order diffraction component (specular component) of the reflected light.

13. The method of claim 11 wherein step (A3) includes a processing step of comparing a variation of the light intensity level of a defect area in the magnified image with the light intensity level of a defect-surrounding area, for thereby extracting the feature parameter from the defect inspection image which contains the intensity difference between a bright part with a high light intensity and a dark part with a low light intensity and the positional arrangement relationship between the bright part and the dark part.

14. The method of claim 11 wherein the thin film has a thickness of up to 10 nm.

15. The method of claim 11 wherein the inspection light is light having a wavelength of 210 to 550 nm.

16. A system for inspecting a defect on a photomask blank having at least one thin film on an optically transparent substrate, comprising

an inspection system adapted to irradiate inspection light to a surface region of the thin film and to capture the reflected light from the irradiated region, for thereby inspecting any defects on the surface of the photomask blank, and

a computer having installed therein a program for executing the steps in the photomask blank detect inspection method of claim 11.

17. A method of sorting photomask blanks, comprising sorting photomask blanks having no pinhole defects, based on the identification whether defects are of bump or pit shape by the inspection method of claim 11.

18. A method for manufacturing a photomask blank, comprising the steps of:

forming at least one thin film on an optically transparent substrate to construct a photomask blank, and

sorting a photomask blank having no pinhole defects by the sorting method of claim 17.