[0010] In manufacturing a semiconductor device, a pattern is formed on a substrate such as a semiconductor wafer by a lithography process. In the lithography process, a photoresist film is formed on a surface of the substrate. Further, in the lithography process, a pattern having a predetermined shape is formed on the photoresist film by subjecting the formed photoresist film to selective exposure via a mask having a predetermined pattern and a development process. In the related art, a carbon-based photoresist has been used for the photoresist film. For example, in the related art, a chemically amplified resist has been used for the photoresist film.

[0011] In recent years, with miniaturization of semiconductor devices, miniaturization has also progressed using lithography technology. As a miniaturization technique, shortening a wavelength of an exposure light source may be used. Recently, extreme ultraviolet (EUV) exposure using EUV light has been performed.

[0012] However, since a carbon-based photoresist film in the related art has poor absorption of EUV, a reaction takes a long time. Therefore, in the EUV exposure, a photoresist film containing a metal oxide is used. For example, in the EUV exposure, a metal oxide resist (MOR) such as a tin oxide is used for the photoresist film.

[0013] Here, Non-Patent Document 1 discloses an atomic absorption cross section of EUV light. FIG. 1 is a diagram illustrating an atomic absorption cross section of EUV light. A horizontal axis of FIG. 1 represents an atomic number of each atom. A vertical axis of FIG. 1 represents an atomic absorption cross section. The absorption cross section indicates a ratio at which EUV light is absorbed upon passing through an atom. In FIG. 1, the atomic absorption cross sections for respective atomic numbers are shown with respect to each atomic number. For example, the absorption cross section for atomic number 6 is the absorption cross section of carbon. The absorption cross section for atomic number 50 is the absorption cross section of tin. Tin has a larger absorption cross section of EUV light than carbon. That is, tin has a higher EUV absorption rate than carbon.

[0014] In EUV exposure, a substrate on which a photoresist film has been formed is transferred to an EUV exposure apparatus, and the photoresist film is irradiated with EUV light in the EUV

the second underlayer film 13, and the organic film 14 are etched by using the pattern of the metal oxide resist film 20.

[0052] In the above embodiment, the case in which the metal oxide resist film 20 is a tin oxide film has mainly been described as an example. However, the technology of the present disclosure is not limited thereto. The metal oxide resist film 20 may be an oxide of any one of Sn, W, Te, Sb, In, Zn, Zr, In, and Hf. In this case, a metal oxide contained in the organic film 14 may be any metal oxide which has metal-oxygen binding energy lower than that of a metal oxide of the metal oxide resist film 20, and from which oxygen is dissociated by EUV light.

[0053] In addition, in the above embodiment, the case in which a photoresist film is the metal oxide resist film 20 has mainly been described as an example. However, the technology of the present disclosure is not limited thereto. The photoresist film may be any film that contains a metal oxide and reacts with EUV light. For example, the photoresist film may be a chemically amplified resist containing a metal oxide. The metal oxide contained in the photoresist film may be a metal oxide having a high absorption rate for EUV and may be, for example, an oxide of any one of Sn, W, Te, Sb, In, Zn, Zr, In, and Hf.

[0054] Hereinabove, the embodiments have been described. As described above, the substrate 10 according to the embodiment includes a photoresist film and the organic film 14. The photoresist film includes a first metal oxide and reacts with EUV light. The organic film 14 is formed under the photoresist film and includes a second metal oxide which has metal-oxygen binding energy lower than that of the first metal oxide constituting the photoresist film, and from which oxygen is dissociated by EUV light. Therefore, in the substrate 10 according to the embodiment, it is possible to oxidize the photoresist film during the exposure.

[0055] In addition, the photoresist film is the metal oxide resist film 20. Therefore, in the substrate 10 according to the embodiment, it is possible to oxidize the metal oxide resist film 20 during the exposure.

[0067] The substrate of Supplementary note 4 or 5, wherein a concentration of the second metal oxide of the organic film increases toward an interface between the organic film and the metal oxide resist film.

(Supplementary note 7)

[0068] The substrate of any one of Supplementary notes 1 to 6, wherein the first metal oxide is an oxide of Sn.

(Supplementary note 8)

[0069] The substrate of Supplementary note 7, wherein the second metal oxide is any one of an oxide of Cs having a valence of 2 or more, an oxide of Te, and an oxide of Se.

(Supplementary note 9)

[0070] The substrate of Supplementary note 8, wherein the oxide of Cs having the valence of 2 or more is any one of Cs_2O_2, Cs_2O_3, and CsO_2.

(Supplementary note 10)

[0071] A substrate processing method of forming a pattern in a photoresist film that includes a first metal oxide and reacts with extreme ultraviolet (EUV) light, the method including:

a) forming, on a substrate, an organic film including a second metal oxide which has metal-oxygen binding energy lower than metal-oxygen binding energy of the first metal oxide, and from which oxygen is dissociated by EUV light;

b) forming the photoresist film on the organic film of the substrate;

c) irradiating the photoresist film with the EUV light via a mask having a predetermined pattern;

d) heating the photoresist film irradiated with the EUV light; and

e) developing the heated photoresist film to form the pattern on the photoresist film.

WHAT IS CLAIMED IS:

1. A substrate comprising:

a photoresist film including a first metal oxide and reacting with extreme ultraviolet (EUV) light; and

an organic film provided under the photoresist film, and including a second metal oxide which has metal-oxygen binding energy lower than metal-oxygen binding energy of the first metal oxide constituting the photoresist film, and from which oxygen is dissociated by the EUV light.

2. The substrate of Claim 1, wherein the photoresist film is a metal oxide resist film.

3. The substrate of Claim 2, wherein the organic film constitutes an underlying layer of the metal oxide resist film.

4. The substrate of Claim 3, wherein the second metal oxide of the organic film is unevenly distributed on a side of the metal oxide resist film.

5. The substrate of Claim 4, wherein the second metal oxide of the organic film is unevenly distributed within a range of 5 nm from an interface between the organic film and the metal oxide resist film.

6. The substrate of Claim 4, wherein a concentration of the second metal oxide of the organic film increases toward an interface between the organic film and the metal oxide resist film.

7. The substrate of Claim 1, wherein the first metal oxide is an oxide of Sn.

8. The substrate of Claim 7, wherein the second metal oxide is any one of an oxide of Cs having a valence of 2 or more, an oxide of Te, and an oxide of Se.

9. The substrate of Claim 8, wherein the oxide of Cs having the valence of 2 or more is any one of Cs_2O_2, Cs_2O_3, and CsO_2.

10. A substrate processing method of forming a pattern in a photoresist film that includes a first metal oxide and reacts with extreme ultraviolet (EUV) light, the method comprising:

a) forming, on a substrate, an organic film including a second metal oxide which has metal-oxygen binding energy lower than metal-oxygen binding energy of the first metal oxide constituting the photoresist film, and from which oxygen is dissociated by EUV light;

b) forming the photoresist film on the organic film of the substrate;

c) irradiating the photoresist film with the EUV light via a mask having a predetermined pattern;

d) heating the photoresist film irradiated with the EUV light; and

e) developing the heated photoresist film to form the pattern on the photoresist film.