

a reflective multilayer film that reflects EUV light is formed on one main surface of a low thermal expansion substrate made of glass, and further an absorber film that absorbs EUV light is formed on the reflective multilayer film. The reflective mask blank has a basic structure including a reflective multilayer film and an absorber film.

5 As the reflective multilayer film, a Mo/Si reflective multilayer film in which molybdenum (Mo) layers and silicon (Si) layers are alternately laminated to ensure a reflectance for EUV light is commonly used. As the absorber film, a material containing tantalum (Ta), as a main component, which has a relatively large extinction coefficient with respect to EUV light, is used (Patent Document 1: JP-A 2002-246299). On the other
10 hand, a back-surface conductive film such as a metal film is formed on the other main surface of the substrate for electrostatic chucking in holding the reflective mask in an exposure apparatus. As the back-surface conductive film, a film containing mainly chromium (Cr) or tantalum (Ta) is used.

Further, a protection film for protecting the reflective multilayer film is commonly
15 formed between the reflective multilayer film and the absorber film. The protection film is formed to protect the reflective multilayer film when the reflective mask blank is exposed to etching gas during etching to form a mask pattern in the absorber film, or exposed to cleaning liquid during cleaning after forming the mask pattern. Further, the protection film is formed so that the reflective multilayer film is not be damaged in pattern
20 correction processing when a defect is detected after forming the mask pattern. As a material for the protection film, for example, ruthenium (Ru) is used (Patent Document 2: JP-A 2002-122981). When the protection film is required to have function of suppressing decrease in reflectance of the reflective multilayer film in EUV light exposure, use of a material including ruthenium (Ru) added with niobium (Nb), rhodium (Rh), zirconium (Zr),
25 or others has been proposed.

Citation List

Patent Document 1: JP-A 2002-246299

Patent Document 2: JP-A 2002-122981

30 SUMMARY

In manufacturing step of a reflective mask blank, after forming a reflective multilayer film, and then forming reference marks for defect coordinate position, ABI (Actinic Blank Inspection) using EUV light is performed to detect defects called phase

defect. When a reflective mask is processed, so-called mitigation (defect mitigation) is performed so as not to be caused defect transfer in pattern drawing process of the reflective mask based on information of the defect coordinate position in the ABI inspection, and finally, prescribed pattern is formed in an absorber film. From the viewpoints of preventing misalignment in the mitigation and change in shape of a substrate after patterning, film stress of the absorber film must be controlled as low as possible.

Since a part of the absorber film of the reflective mask blank is removed to form a pattern, if the film stress is large, an amount of warpage of the substrate changes due to pattern formation. Therefore, in order to maintain positional accuracy of the pattern, it is preferable that the film stress is small. However, in addition to film stress, the absorber film is required that: the absorber film must have a sufficiently low reflectance at a prescribed thickness; the absorber film has film qualities of microcrystalline structure and low surface roughness to control LER (Line Edge Roughness) of the pattern low; the absorber film has a high etching rate to ensure processability; and sheet resistance is suppressed to not more than $10^7 \text{ } \Omega/\text{square}$ so as not to cause charge of the substrate in EB (Electron Beam) drawing. The film stress of the absorber film can be adjusted to a certain extent by changing film forming conditions, however if the film forming conditions are changed, not only the film stress but also properties other than the film stress, such as film quality, change significantly. Particularly, it is difficult to reduce the film stress in the case of a film having a high degree of nitridation, since the film stress cannot be adjusted simply by changing the film forming conditions.

The present disclosure has been made to solve the above problems, and an object of the present disclosure is to provide a reflective mask blank that includes an absorber film having a low film stress, particularly, an absorber film having a low film stress with ensuring properties necessary for the absorber film.

The inventors have made earnestly studies to solve the above problems. As a result, the inventors found, in a protection film that is in contact with an absorber film and is formed of a material consists of ruthenium (Ru), niobium (Nb) and oxygen (O), the protection film having a composition containing ruthenium (Ru) and being free of oxygen (O), at the side close to a reflective multilayer film, and a composition consisting of ruthenium (Ru), niobium (Nb) and oxygen (O), or niobium (Nb) and oxygen (O), at the side in contact with the absorber film. Further, the inventors found that, by forming the

absorber film in contact with the protection film, it can be provided a reflective mask blank that includes an absorber film having a low film stress with ensuring properties necessary for the absorber film, particularly, an absorber film formed in contact with the protection film that have a film stress of not more than a film stress in the case of forming the
5 absorber film directly on the substrate.

In one aspect, the disclosure provides a reflective mask blank which is a material for a reflective mask used in EUV lithography in which EUV light is exposure light, including a substrate,

a reflective multilayer film that is formed on one main surface of the substrate, has
10 a periodically laminated structure in which layers having a comparatively low refractive index with respect to exposure light and layers having a comparatively high refractive index with respect to the exposure light are alternately laminated, and reflects the exposure light,

a protection film that is formed in contact with the reflective multilayer film, and
15 an absorber film that is formed in contact with the protection film, and absorbs the exposure light, wherein

the absorber film has a film stress of not more than a film stress in the case of forming the absorber film directly on the substrate.

Preferably, the protection film consists of ruthenium (Ru), niobium (Nb) and
20 oxygen (O), has a composition at the side close to the reflective multilayer film that includes ruthenium (Ru) and is free of oxygen (O), and has a composition at the side in contact with the absorber film that consists of ruthenium (Ru), niobium (Nb) and oxygen (O), or niobium (Nb) and oxygen (O).

Preferably, the protection film has a composition at the side close to the reflective
25 multilayer film that consists of ruthenium (Ru), or ruthenium (Ru) and niobium (Nb).

Preferably, in the protection film, the composition at the side close to the reflective multilayer film has a niobium (Nb) content of not more than 60 at%.

Preferably, the protection film has a niobium (Nb) content that stepwise and/or continuously increases along the thickness direction from the side close to the reflective
30 multilayer film to the side in contact with the absorber film.

Preferably, in the protection film, the composition at the side close to the absorber film has a total content of niobium (Nb) and oxygen (O) of not less than 60 at%.