EUV light irradiation. As a pellicle membrane satisfying the requirements, a silicon crystal membrane such as a single-crystal silicon membrane (for example, see documents 1 and 2), an aluminum nitride membrane layered on a metal mesh (for example, see document 3), a graphene membrane (for example, see document 4), and the like have been proposed.

[0005] Document 1: Japanese Patent Application Laid-Open (JP-A) No. 2010-256434
Document 2: Japanese Patent Application Laid-Open (JP-A) No. 2009-116284
Document 3: Japanese Patent Application Laid-Open (JP-A) No. 2005-43895
Document 4: International Publication No. WO 2011/160861

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006] When a pellicle membrane is irradiated with exposure light such as EUV light, a part of the energy is absorbed by the pellicle membrane. The energy of EUV light absorbed by the pellicle membrane is converted to heat through various relaxation processes. Therefore during exposure, the temperature of a pellicle membrane increases. Therefore, a pellicle membrane is required to have a high heat dissipation performance and a high thermal resistance. Meanwhile, with respect to the single-crystal silicon membrane, the heat dissipation performance is low, and also the melting point is low. Therefore, there is a drawback that the membrane is apt to be damaged during EUV light irradiation. Further, there is another drawback that a single-crystal silicon membrane is expensive due to a complicated production process therefor.

[0007] With respect to an aluminum nitride membrane in document 3, since the EUV transmittance is low, there is a drawback that it is not suitable for use in lithography requiring a high EUV transmittance. With respect to a graphene membrane in document 4, since it is an aggregate of crystals with a small size (ordinarily approximately from 100 nm to 1,000 nm), there are drawbacks in that the membrane is brittle, the durability of the membrane is insufficient, and a self-supporting membrane is not obtainable. There is another drawback in that a sufficient strength can be hardly obtained, even when a large number of graphene membranes are layered one on another.

[0008] Embodiments of the invention are made in view of such circumstances.

Embodiments of the invention provide a pellicle membrane which is superior in EUV permeability and durability, and has a self-supporting property.

Embodiments of the invention provide a pellicle including the pelliclemembrane, an original plate for exposure including the pellicle, and an exposure apparatus including the original plate for exposure.

Embodiments of the invention provide a method of producing a semiconductor

device using the pellicle membrane.

SOLUTION TO PROBLEM

[0009] Specific embodiments are as follows.

According to a first aspect, there is provided a pellicle membrane, comprising a film consisting of an organic material and a carbon material, wherein a region containing an organic material and a region consisting of the carbon material are present in the same plane of the film, and wherein at least a central portion of the film is a region consisting of c the carbon material, and at least a peripheral edge portion of the film is a region containing the organic material.

In an embodiment, the region containing the organic material is a region consisting of the organic material.

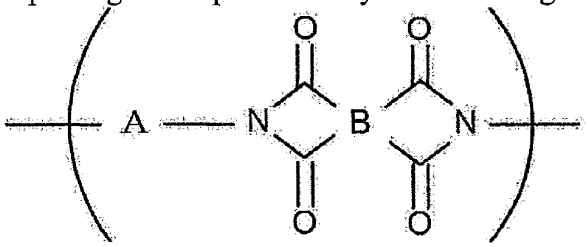
In an embodiment, at least one of a glass transition temperature or a melting point of the organic material is 150°C or higher.

In an embodiment, the organic material is at least one compound selected from the group consisting of a polyimide compound, a polyacrylonitrile compound, a polyisocyanate compound, a polyamide compound, a heteroaromatic ring compound, a polyphenylene resin, a polyether resin, a liquid crystal polymer resin, a poly(*para*-xylylene) resin, a phenol resin, an epoxy resin, and a furan resin.

In an embodiment, an aromatic ring equivalent of the organic material is from 3 mmol/g to 15 mmol/g.

In an embodiment, the organic material is a polyimide compound.

In an embodiment, the polyimide compound is an aromatic polyimide including a repeating unit represented by the following General Formula (1):



··· (1)

wherein, in General Formula (1), A is a divalent group derived from a diamine selected from the group consisting of *m*-phenylenediamine, *o*-phenylenediamine, *p*-phenylenediamine, 3,3'-diaminodiphenyl ether, 3,4'-diaminodiphenyl ether, 4,4'-diaminodiphenyl ether, 3,3'-diaminodiphenyl sulfone, 4,4'-diaminodiphenyl sulfone, 3,3'-diaminobenzophenone, 3,3'-diaminodiphenylmethane, 4,4'-diaminodiphenylmethane, 1,3-bis(3-aminophenoxy)benzene, 1,3-bis(4-aminophenoxy)benzene, and 4,4'-bis(3-aminophenoxy)biphenyl; and B is a tetravalent group derived from a

tetracarboxylic dianhydride selected from the group consisting of pyromellitic dianhydride, 3,3',4,4'-biphenyltetracarboxylic dianhydride, 2,3,3',4-biphenyltetracarboxylic dianhydride, 3,3',4,4'-benzophenone tetracarboxylic dianhydride, 4,4'-oxydiphthalic dianhydride, and 3,3',4,4'-diphenylsulfone tetracarboxylic dianhydride.

In an embodiment, the pellicle membrane further comprises a layer consisting of an inorganic material, on at least one side of the film.

Disclosed herein is a pellicle, comprising:

the above pellicle membrane; and

a support frame supporting the pellicle membrane.

In an embodiment, a portion of the pellicle membrane that is supported by the support frame is a region containing an organic material.

According to a second aspect, there is provided a pellicle, comprising:

a pellicle membrane comprising a film containing a polyimide compound; and

a support frame supporting the pellicle membrane.

According to a third aspect, there is provided an original plate for exposure, comprising:

an original plate; and

the above pellicle mounted on the original plate.

According to a fourth aspect, there is provided an exposure apparatus, comprising the above original plate for exposure.

According to a fifth aspect, there is provided an exposure apparatus, comprising:

a light source that emits exposure light;

the above original plate for exposure; and

an optical system that guides the exposure light emitted from the light source toward the original plate for exposure,

wherein the original plate for exposure is disposed such that the exposure light emitted from the light source passes through the pellicle membrane and irradiates the original plate.

In an embodiment, the exposure light is EUV light.

According to a sixth aspect, there is provided a method of producing a

semiconductor device, the method comprising:

a step of causing exposure light emitted from a light source to pass through the pellicle membrane of the above original plate for exposure, irradiate the original plate, and be reflected from the original plate; and

a step of causing the exposure light reflected from the original plate to pass through the pellicle membrane and irradiate a sensitive substrate, thereby patternwise exposing the sensitive substrate.

In an embodiment, the exposure light is EUV light.

ADVANTAGEOUS EFFECTS OF INVENTION

[0014] According to embodiments of the invention, it is possible to provide a pellicle membrane which is superior in EUV permeability and durability, and has a self-supporting property.

Further, according to embodiments of the invention, it is possible to provide a pellicle including the pellicle membrane, an original plate for exposure including the pellicle, and an exposure apparatus including the original plate for exposure.

Further, according to embodiments of the invention, it is possible to provide a method of producing a semiconductor device using the pellicle membrane.

BRIEF DESCRIPTION OF DRAWINGS

[0015] Fig. 1 is a schematic top view of a pellicle membrane according to the embodiment.

Fig. 2 is a graph showing the relationship between the temperature of a pellicle membrane and the elapsed time when the pellicle membrane is irradiated with EUV light.

Fig. 3 is an explanatory diagram showing the crystal structure of graphite.

Fig. 4 is a graph showing the relationship between the temperature T of a pellicle membrane and the emissivity ε of the pellicle membrane.

Fig. 5 is a graph showing the relationship between the temperature T of a pellicle membrane and the transmittance Tr of the pellicle membrane.

Fig. 6 is a schematic cross-sectional view of a pellicle according to the embodiment.

Fig. 7 is a schematic cross-sectional view of a variant of a pellicle according to the embodiment.

CLAIMS

1. A pellicle membrane, comprising a film consisting of an organic material and a carbon material, wherein a region containing the organic material and a region consisting of the carbon material are present in the same plane of the film, and wherein at least a central portion of the film is the region consisting of the carbon material, and at least a peripheral edge portion of the film is the region containing the organic material.

2. The pellicle membrane according to claim 1, wherein the region containing the organic material is a region consisting of the organic material.

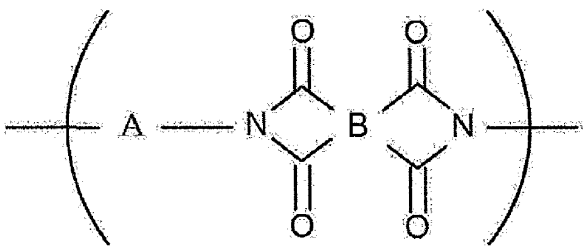
3. The pellicle membrane according to claim 1 or claim 2, wherein at least one of a glass transition temperature or a melting point of the organic material is 150°C or higher.

4. The pellicle membrane according to any one of claim 1 to claim 3, wherein the organic material is at least one compound selected from the group consisting of a polyimide compound, a polyacrylonitrile compound, a polyisocyanate compound, a polyamide compound, a heteroaromatic ring compound, a polyphenylene resin, a polyether resin, a liquid crystal polymer resin, a poly(*para*-xylylene) resin, a phenol resin, an epoxy resin, and a furan resin.

5. The pellicle membrane according to any one of claim 1 to claim 4, wherein an aromatic ring equivalent of the organic material is from 3 mmol/g to 15 mmol/g.

6. The pellicle membrane according to any one of claim 1 to claim 5, wherein the organic material is a polyimide compound.

7. The pellicle membrane according to claim 6, wherein the polyimide compound is an aromatic polyimide including a repeating unit represented by the following General Formula (1):



··· (1)

wherein, in General Formula (1), A is a divalent group derived from a diamine selected from the group consisting of *m*-phenylenediamine, *o*-phenylenediamine, *p*-phenylenediamine, 3,3'-diaminodiphenyl ether, 3,4'-diaminodiphenyl ether, 4,4'-diaminodiphenyl ether, 3,3'-diaminodiphenyl sulfone, 4,4'-diaminodiphenyl sulfone, 3,3'-diaminobenzophenone, 3,3'-diaminodiphenylmethane, 4,4'-diaminodiphenylmethane, 1,3-bis(3-aminophenoxy)benzene, 1,3-bis(4-aminophenoxy)benzene, and 4,4'-bis(3-aminophenoxy)biphenyl; and B is a tetravalent group derived from a tetracarboxylic dianhydride selected from the group consisting of pyromellitic dianhydride, 3,3',4,4'-biphenyltetracarboxylic dianhydride, 2,3,3',4-biphenyltetracarboxylic dianhydride, 3,3',4,4'-benzophenone tetracarboxylic dianhydride, 4,4'-oxydiphthalic dianhydride, and 3,3',4,4'-diphenylsulfone tetracarboxylic dianhydride.

8. The pellicle membrane according to any one of claim 1 to claim 7, further comprising a layer consisting of an inorganic material, on at least one side of the film.

9. A pellicle, comprising:
the pellicle membrane according to any one of claim 1 to claim 8; and
a support frame supporting the pellicle membrane.

10. The pellicle according to claim 9, wherein a portion of the pellicle membrane that is supported by the support frame is the region containing the organic material.

11. An original plate for exposure, comprising:
an original plate; and
the pellicle according to claim 9 or claim 10 mounted on the original plate.

12. An exposure apparatus, comprising the original plate for exposure according to claim 11.

13. An exposure apparatus, comprising:
a light source that emits exposure light;
the original plate for exposure according to claim 11; and
an optical system that guides the exposure light emitted from the light source toward the original plate for exposure,
wherein the original plate for exposure is disposed such that the exposure light

emitted from the light source passes through the pellicle membrane and irradiates the original plate.

14. The exposure apparatus according to claim 13, wherein the exposure light is EUV light.

15. A method of producing a semiconductor device, the method comprising:

a step of causing exposure light emitted from a light source to pass through the pellicle membrane of the original plate for exposure according to claim 11, irradiate the original plate, and be reflected from the original plate; and

a step of causing the exposure light reflected from the original plate to pass through the pellicle membrane and irradiate a sensitive substrate, thereby patternwise exposing the sensitive substrate.

16. The method of producing a semiconductor device according to claim 15, wherein the exposure light is EUV light.