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] ~~The~~Embodiments of the invention ~~has been~~ are made in view of such circumstances ~~and for achieving the following objects~~.

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

~~Another object~~ Embodiments of the invention ~~is 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.

~~Still another object~~ Embodiments of the invention ~~is to~~ provide a method of producing a semiconductor device using the pellicle membrane.

SOLUTION TO PROBLEM

[0009] Specific ~~means for achieving the above objects~~ embodiments are as follows.

~~<1> A~~ According to a first aspect, there is provided a pellicle membrane, comprising a film consisting of an organic material and an inorganic material, wherein a region containing an organic material and a region consisting of an inorganic 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 an inorganic material, and at least a peripheral edge portion of the film is a region containing an organic material.

~~<2> The pellicle membrane according to <1>, wherein~~ In an embodiment, the region containing the organic material is a region consisting of the organic material.

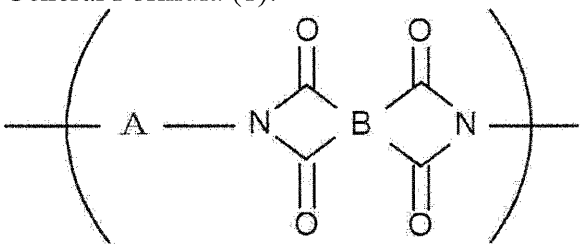
~~<3> The pellicle membrane according to <1> or <2>, wherein~~ In an embodiment, at least one of a glass transition temperature or a melting point of the organic material is 150°C or higher.

~~<4> The pellicle membrane according to any one of <1> to <3>, wherein~~ 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.

~~<5> The pellicle membrane according to any one of <1> to <4>, wherein~~ In an embodiment, 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 <1> to <5>, wherein~~ In an embodiment, the organic material is a polyimide compound.

~~<7> The pellicle membrane according to <6>, wherein~~ 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.

~~<8> The pellicle membrane according to any one of <1> to <7>, wherein~~ In an embodiment, the inorganic material is a carbon material.

~~<9> The pellicle membrane according to any one of <1> to <8>, further comprising~~ In an embodiment, the pellicle membrane further comprises a layer consisting of an inorganic material, on at least one side of the film.

~~[0010] <10> A~~ According to a second aspect, there is provided a pellicle, comprising:

the above pellicle membrane ~~according to any one of <1> to <9>~~; and

a support frame supporting the pellicle membrane.

~~<11> The pellicle according to <10>, wherein~~ In an embodiment, a portion of the pellicle membrane that is supported by the support frame is a region containing an organic material.

~~<12> A~~ According to a third 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.

~~[0011] <13> An~~ According to a fourth aspect, there is provided an original plate for exposure, comprising:

an original plate; and

the above pellicle ~~according to any one of <10> to <12>~~ mounted on the original plate.

~~[0012] <14> An~~ According to a fifth aspect, there is provided an exposure apparatus, comprising the above original plate for exposure ~~according to <13>~~.

~~<15> An~~ According to a sixth aspect, there is provided an exposure apparatus, comprising:

a light source that emits exposure light;

the above original plate for exposure ~~according to <13>~~; 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.

~~<16> The exposure apparatus according to <15>, wherein~~ In an embodiment, the exposure light is EUV light.

~~[0013] <17> A~~ According to a seventh 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 ~~according to <13>~~, 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.

~~<18> The method of producing a semiconductor device according to <17>, wherein~~ 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.