CLAIMS

1. A resist underlayer film-forming composition for lithography having an aliphatic polycyclic structure, the composition comprising, as a silane, a hydrolysis-condensation product of a hydrolyzable silane in which the aliphatic polycyclic structure is

a structure which a hydrolyzable silane of Formula (1):

$$R^1{}_aR^2{}_bSi(R^3)_{4-(a+b)} \quad \text{Formula (1)}$$

where

R^1 is an organic group having an aliphatic polycyclic structure and bonded to a Si atom through a Si–C bond;

R^2 is an alkyl group, an aryl group, a halogenated alkyl group, a halogenated aryl group, an alkoxyaryl group, an alkenyl group, or an organic group having an epoxy group, an acryloyl group, a methacryloyl group, a mercapto group, an amino group, or a cyano group, and is bonded to a silicon atom through a Si–C bond;

R^3 is an ethoxy group; a is an integer of 1; b is an integer of 0 to 2; and

a + b is an integer of 1 to 3;

has, or

a structure included in a compound added as an aliphatic polycyclic compound, an aliphatic polycyclic dicarboxylic acid, or an aliphatic polycyclic dicarboxylic acid anhydride, each optionally having a double bond, a hydroxy group, or an epoxy group, wherein

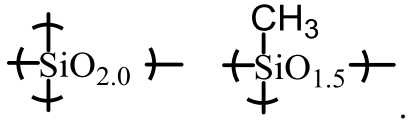
when the aliphatic polycyclic structure is a structure which is the hydrolyzable silane of Formula (1), the hydrolyzable silane contains a combination of

a first hydrolyzable silane (1-1) selected from the group consisting of tetraethoxysilane, tetramethoxysilane, methyltrialkoxysilane and phenyltrialkoxysilane, with

a second hydrolyzable silane (1-2) selected from the group consisting of norbornene,

norbornane, hetero atom-containing aliphatic polycyclic group, norbornene-containing aliphatic polycyclic group containing ester structure, norbornane-containing aliphatic polycyclic group containing ester structure, hetero atom-containing aliphatic polycyclic group containing ester structure, norbornene-containing aliphatic polycyclic group containing acid anhydride structure, norbornane-containing aliphatic polycyclic group containing acid anhydride structure, hetero atom-containing aliphatic polycyclic group containing acid anhydride structure, norbornene-containing aliphatic polycyclic group containing amide structure, norbornane-containing aliphatic polycyclic group containing amide structure, and hetero atom-containing aliphatic polycyclic group containing amide structure; and

the hydrolysis-condensation product contains the following two unit structures:



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2. The resist underlayer film-forming composition according to claim 1, wherein R^1 in Formula (1) is an optionally substituted norbornene, an optionally substituted norbornane, a cyclic aliphatic group containing a heteroatom, or an organic group comprising an optionally substituted norbornene, an optionally substituted norbornane, or a cyclic aliphatic group containing a heteroatom.

3. The resist underlayer film-forming composition according to claim 2, wherein a substituent of R^1 in Formula (1) is a carboxylic acid anhydride group, a carboxylic acid ester group, or an oxygen atom.

4. The resist underlayer film-forming composition according to claim 1, wherein the hydrolyzable silane is a combination of the hydrolyzable silane of Formula (1) and another hydrolyzable silane, the other hydrolyzable silane being at least one hydrolyzable silane selected from the group consisting of

a hydrolyzable silane of Formula (2):

$$R^4_cSi(R^5)_{4-c} \quad \text{Formula (2)}$$

where

R^4 is an alkyl group, an aryl group, a halogenated alkyl group, a halogenated aryl group, an alkoxyaryl group, an alkenyl group, or an organic group having an epoxy group, an acryloyl group, a methacryloyl group, a mercapto group, or a cyano group, and is bonded to a silicon atom through a Si–C bond;

R^5 is an alkoxy group, an acyloxy group, or a halogen group; and

c is an integer of 0 to 3; and

a hydrolyzable silane of Formula (3):

$$[R^6_dSi(R^7)_{3-d}]_2Y_e \quad \text{Formula (3)}$$

where

R^6 is an alkyl group and bonded to a silicon atom through a Si–C bond;

R^7 is an alkoxy group, an acyloxy group, or a halogen group;

Y is an alkylene group or an arylene group;

d is an integer of 0 or 1; and

e is an integer of 0 or 1.

5. The resist underlayer film-forming composition according to claim 1, further comprising an acid as a hydrolysis catalyst.

6. The resist underlayer film-forming composition according to claim 1, further comprising water.

7. The resist underlayer film-forming composition according to claim 1, further comprising the hydrolyzable silane and/or a hydrolysis product of the hydrolyzable silane.

8. A resist underlayer film-forming composition comprising, as a polymer, a hydrolysis-condensation product of a hydrolyzable silane formed of a combination of

a hydrolyzable silane of Formula (1):

$$R^1{}_aR^2{}_bSi(R^3)_{4-(a+b)} \quad \text{Formula (1)}$$

where

R^1 is an organic group having an aliphatic polycyclic structure and bonded to a Si atom through a Si–C bond;

R^2 is an alkyl group, an aryl group, a halogenated alkyl group, a halogenated aryl group, an alkoxyaryl group, an alkenyl group, or an organic group having an epoxy group, an acryloyl group, a methacryloyl group, a mercapto group, an amino group, or a cyano group, and is bonded to a silicon atom through a Si–C bond;

R^3 is an ethoxy group; a is an integer of 1;

b is an integer of 0 to 2; and

a + b is an integer of 1 to 3; wherein

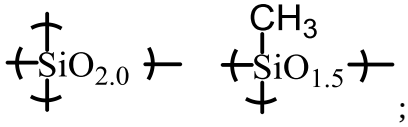
the hydrolyzable silane contains a combination of

a first hydrolyzable silane (1-1) selected from the group consisting of tetraethoxysilane, tetramethoxysilane, methyltrialkoxysilane and phenyltrialkoxysilane, with

a second hydrolyzable silane (1-2) selected from the group consisting of norbornene, norbornane, hetero atom-containing aliphatic polycyclic group, norbornene-containing

aliphatic polycyclic group containing ester structure, norbornane-containing aliphatic polycyclic group containing ester structure, hetero atom-containing aliphatic polycyclic group containing ester structure, norbornene-containing aliphatic polycyclic group containing acid anhydride structure, norbornane-containing aliphatic polycyclic group containing acid anhydride structure, hetero atom-containing aliphatic polycyclic group containing acid anhydride structure, norbornene-containing aliphatic polycyclic group containing amide structure, norbornane-containing aliphatic polycyclic group containing amide structure, and hetero atom-containing aliphatic polycyclic group containing amide structure; and

the hydrolysis-condensation product contains the following two unit structures:



;

and

a hydrolyzable silane of Formula (2):

$$R^4_cSi(R^5)_{4-c} \quad \text{Formula (2)}$$

where

R^4 is an alkyl group, an aryl group, a halogenated alkyl group, a halogenated aryl group, an alkoxyaryl group, an alkenyl group, or an organic group having an epoxy group, an acryloyl group, a methacryloyl group, a mercapto group, or a cyano group, and is bonded to a silicon atom through a Si–C bond;

R^5 is an alkoxy group, an acyloxy group, or a halogen group; and

c is an integer of 0 to 3.

9. A resist underlayer film obtained by applying the resist underlayer film-forming composition as claimed in claim 1 onto a semiconductor substrate and baking the applied resist underlayer film-forming composition.

10. A method for manufacturing a semiconductor device, the method comprising the steps of:

applying the resist underlayer film-forming composition as claimed in claim 1 onto a semiconductor substrate, and baking to form a resist underlayer film;

applying a resist composition onto the underlayer film to form a resist film;

exposing the resist film to light;

developing the resist film after the exposure to obtain a resist pattern;

etching the resist underlayer film using the resist pattern; and

processing the semiconductor substrate using the patterned resist and the patterned resist underlayer film.

11. A method for manufacturing a semiconductor device, the method comprising the steps of:

forming an organic underlayer film on a semiconductor substrate;

applying the resist underlayer film-forming composition as claimed in claim 1 onto the organic underlayer film, and baking the composition to form a resist underlayer film;

applying a resist composition onto the resist underlayer film to form a resist film;

exposing the resist film to light;

developing the resist film after the exposure to obtain a resist pattern; etching the resist underlayer film using the resist pattern;

etching the organic underlayer film using the patterned resist underlayer film; and

processing the semiconductor substrate using the patterned organic underlayer film.