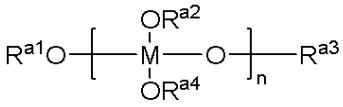
CLAIMS

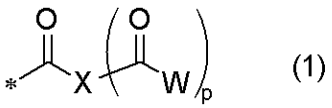
[Claim 1] A compound for forming a metal-containing film to be contained in a composition for forming a metal-containing film used in manufacturing a semiconductor, wherein

the compound is represented by the following general formula (A),



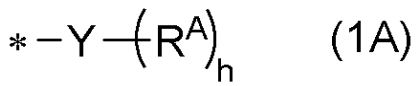
(A)

wherein M represents Ti, Zr, or Hf; R^{a1}, R^{a2}, R^{a3}, and R^{a4} each represent an organic group of the following general formula (1), a silicon-containing organic group of the following general formula (2), or an alkyl group having 1 to 10 carbon atoms, at least one of R^{a1}, R^{a2}, R^{a3}, and R^{a4} being an organic group of the following general formula (1) and at least one of R^{a1}, R^{a2}, R^{a3}, and R^{a4} being a silicon-containing organic group of the following general formula (2); and “n” represents 1 to 30,



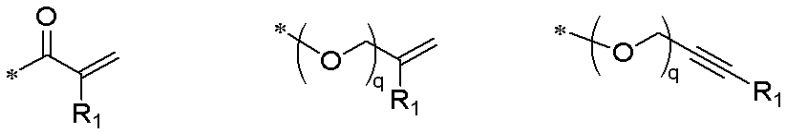
(1)

wherein “p” represents 0 or 1; “*” represents an attachment point to an oxygen atom; when “p” represents 1, W represents the following general formula (1A) and X represents a saturated divalent organic group having 1 to 20 carbon atoms or an unsaturated divalent organic group having 2 to 20 carbon atoms; and when “p” represents 0, X represents a monovalent organic group having 2 to 30 carbon atoms and containing a crosslinking group having a structure represented by one of the following general formulae (b-1) and (b-2),



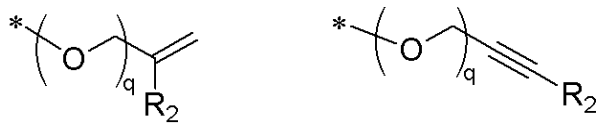
(1A)

wherein Y represents a saturated divalent organic group having 1 to 20 carbon atoms or an unsaturated divalent organic group having 2 to 20 carbon atoms; R^A represents a structure represented by one of the following general formulae (a-1) to (a-3); “h” represents 1 to 6; and “*” represents an attachment point to a carbon atom of a carbonyl group,



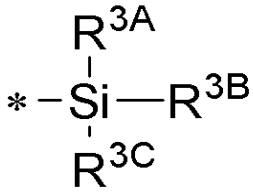
(a-1) (a-2) (a-3)

wherein each R_1 independently represents a hydrogen atom or a monovalent organic group having 1 to 10 carbon atoms; each “q” independently represents 0 or 1; and “*” represents an attachment point to Y,



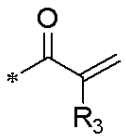
(b-1) (b-2)

wherein each R_2 independently represents a hydrogen atom or a monovalent organic group having 1 to 10 carbon atoms; each “q” independently represents 0 or 1; and “*” represents an attachment point,

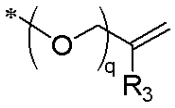


(2)

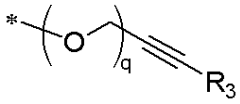
wherein R^{3A}, R^{3B}, and R^{3C} each represent an organic group selected from an organic group having 2 to 30 carbon atoms and containing a crosslinking group having a structure represented by one of the following general formulae (c-1) to (c-3), a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms, and an aryl group having 6 to 20 carbon atoms; and "*" represents an attachment point to an oxygen atom,



(c-1)



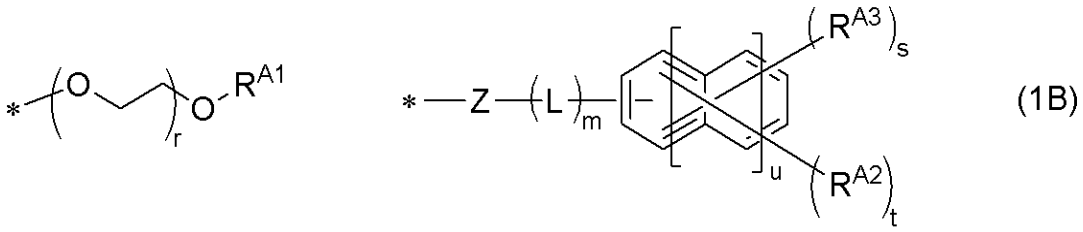
(c-2)



(c-3)

wherein each R_3 independently represents a hydrogen atom or a monovalent organic group having 1 to 10 carbon atoms; each "q" independently represents 0 or 1; and "*" represents an attachment point.

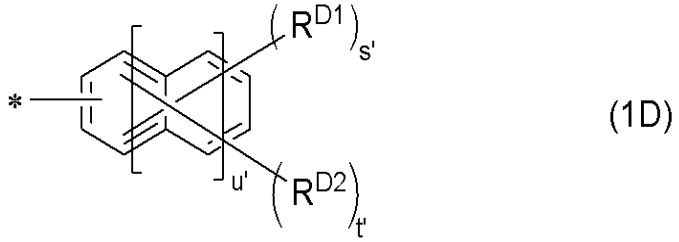
[Claim 2] The compound for forming a metal-containing film according to claim 1, wherein in the general formula (1), "p" represents 1, X represents a saturated divalent organic group having 1 to 20 carbon atoms or an unsaturated divalent organic group having 2 to 20 carbon atoms, and W represents either structure represented by the following general formulae (1B),



(1B)

wherein R^{A1} represents a structure represented by the general formula (a-1); each R^{A2} independently represents a structure represented by one of the general formulae (a-2) and (a-3); Z represents an oxygen atom or a secondary amine; L represents a divalent hydrocarbon group having 1 to 10 carbon atoms; each R^{A3} independently represents a saturated monovalent organic group having 1 to 20 carbon atoms or an unsaturated monovalent organic group having 2 to 20 carbon atoms; “t” represents 1 to 6 and “s” represents 0 to 5, provided that t+s is 1 or more and 6 or less; “r” represents 1 to 10; “u” represents 0 or 1; “m” represents 0 or 1; and “*” represents an attachment point to a carbon atom of a carbonyl group.

[Claim 3] The compound for forming a metal-containing film according to claim 1, wherein in the general formula (1), “p” represents 0 and X represents a structure represented by the following formula (1D),

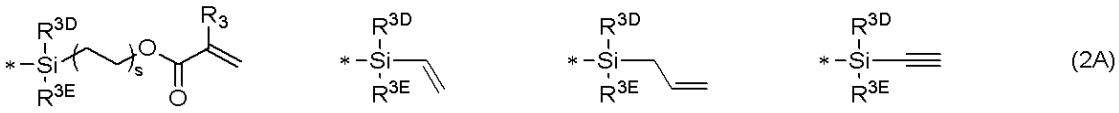


(1D)

wherein each R^{D2} independently represents a structure represented by one of the general formulae (b-1) and (b-2); each R^{D1} independently represents a saturated monovalent organic group having 1 to 20 carbon atoms or

an unsaturated monovalent organic group having 2 to 20 carbon atoms; “t’” represents 1 to 6 and “s’” represents 0 to 5, provided that t’+s’ is 1 or more and 6 or less; “u’” represents 0 or 1; and “*” represents an attachment point to a carbon atom of a carbonyl group.

[Claim 4] The compound for forming a metal-containing film according to any one of claims 1 to 3, wherein the silicon-containing organic group of the general formula (2) has any structure represented by the following formulae (2A),



(2A)

wherein R^{3D} and R^{3E} each independently represent an organic group selected from a substituted or unsubstituted alkyl group having 1 to 20 carbon atoms and an aryl group having 6 to 20 carbon atoms; R_3 is as defined above; “s” represents 1 to 10; and “*” represents an attachment point to an oxygen atom.

[Claim 5] A composition for forming a metal-containing film used in manufacturing a semiconductor, the composition comprising: (A) the compound for forming a metal-containing film according to any one of claims 1 to 4; and (B) an organic solvent.

[Claim 6] The composition for forming a metal-containing film according to claim 5, further comprising one or more of (C) a crosslinking agent and (E) a surfactant.

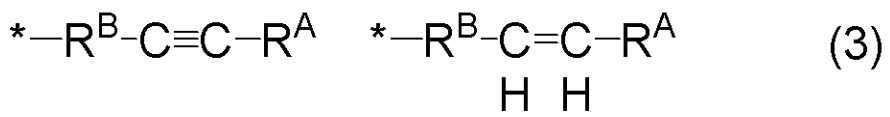
[Claim 7] The composition for forming a metal-containing

film according to claim 5 or 6, wherein the organic solvent (B) contains, as (B1) a high-boiling-point solvent, one or more kinds of organic solvent having a boiling point of 180°C or higher.

[Claim 8] The composition for forming a metal-containing film according to any one of claims 5 to 7, further comprising (F) metal oxide nanoparticles having an average primary particle size of 100 nm or less.

[Claim 9] The composition for forming a metal-containing film according to claim 8, wherein the metal oxide nanoparticles (F) are selected from the group consisting of zirconium oxide nanoparticles, hafnium oxide nanoparticles, titanium oxide nanoparticles, tin oxide nanoparticles, and tungsten oxide nanoparticles.

[Claim 10] The composition for forming a metal-containing film according to any one of claims 5 to 9, further comprising (BP) a flowability accelerator having any organic group represented by the following general formulae (3) and an aromatic ring,

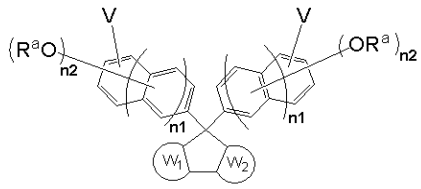


(3)

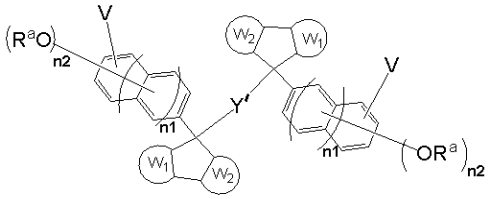
wherein "*" represents an attachment point to an oxygen atom; R^B represents a divalent organic group having 1 to 10 carbon atoms; and R^A represents a hydrogen atom or a monovalent organic group having 1 to 10 carbon atoms.

[Claim 11] The composition for forming a metal-containing film according to claim 10, wherein the flowability

accelerator (BP) has at least one constitutional unit represented by the following general formulae (BP-1), (BP-2), (BP-3), (BP-4), and (BP-5),

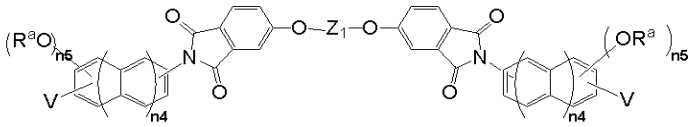


(BP-1)



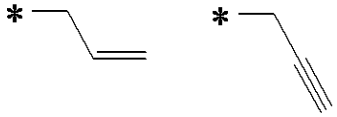
(BP-2)

wherein W_1 and W_2 each independently represent a benzene ring or a naphthalene ring, part of hydrogen atoms in the benzene ring and the naphthalene ring optionally being substituted with a hydrocarbon group having 1 to 6 carbon atoms; R^a represents either group represented by the following formulae (4); Y' represents any group represented by the following formulae (5); each "n_1" independently represents 0 or 1; each "n_2" independently represents 1 or 2; and each V independently represents a hydrogen atom or an attachment point,



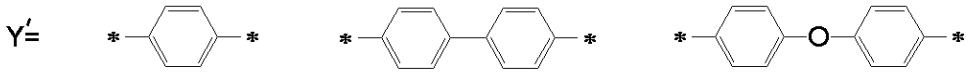
(BP-3)

wherein Z_1 represents any group represented by the following general formulae (6); each R^a independently represents either group represented by the following formulae (4); each "n_4" independently represents 0 or 1; each "n_5" independently represents 1 or 2; and each V independently represents a hydrogen atom or an attachment point,

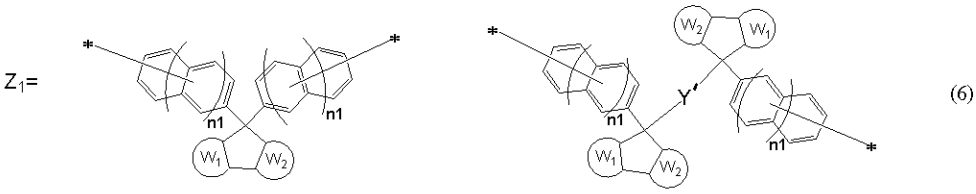


(4)

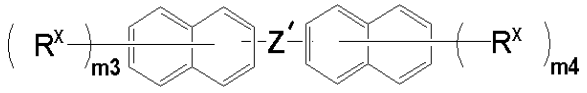
wherein "*" represents an attachment point to an oxygen atom,



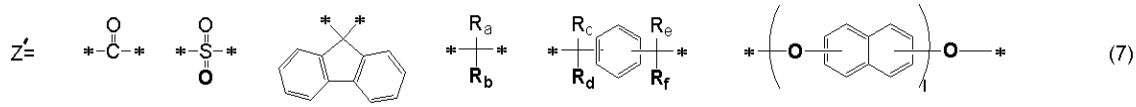
wherein "*" represents an attachment point,



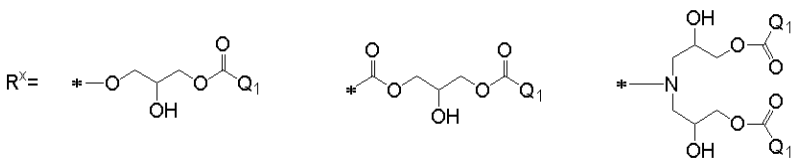
wherein W_1, W_2, Y', and "n_1" are as defined above; and "*" represents an attachment point,



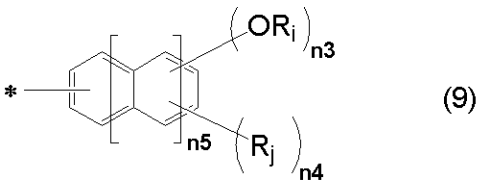
wherein "m_3" and "m_4" represent 1 or 2; Z' represents a single bond or any structure represented by the following general formulae (7); and R^x represents any structure represented by the following general formulae (8),



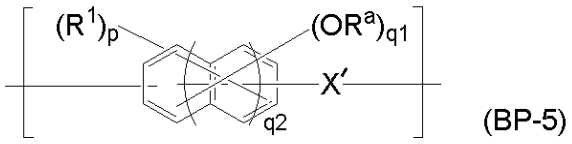
wherein "*" represents an attachment point; "l" represents an integer of 0 to 3; R_a to R_f each independently represent a hydrogen atom, an alkyl group having 1 to 10 carbon atoms and optionally having a substituent fluorine atom, a phenyl group, or a phenylethyl group, R_a and R_b optionally being bonded to each other to form a cyclic compound,



wherein "*" represents an attachment point to an aromatic ring; and each Q_1 independently represents a linear saturated hydrocarbon group having 1 to 30 carbon atoms or a structure represented by the following general formula (9),



wherein "*" represents an attachment point to a carbon atom of a carbonyl group; each R_i independently represents either group represented by the formulae (4); each R_j independently represents a linear or branched hydrocarbon group having 1 to 10 carbon atoms, a halogen atom, a nitro group, an amino group, a nitrile group, an alkoxycarbonyl group having 2 to 10 carbon atoms, or an alkanoyloxy group having 1 to 10 carbon atoms; "n_3" and "n_4" each represent a number of substituents on an aromatic ring, the number each representing an integer of 0 to 7, provided that n_3+n_4 is 0 or more and 7 or less; and "n_5" represents 0 to 2,



wherein each R^1 independently represents a saturated monovalent organic group having 1 to 30 carbon atoms or an unsaturated monovalent organic group having 2 to 30

carbon atoms; X’ represents a divalent organic group having 1 to 30 carbon atoms; each R^a independently represents either group represented by the formulae (4); “p” represents an integer of 0 to 5 and “q_1” represents an integer of 1 to 6, provided that $p+q_1$ is an integer of 1 or more and 6 or less; and “q_2” represents 0 or 1.

[Claim 12] A patterning process for forming a pattern in a substrate to be processed, comprising the steps of:

(I-1) applying the composition for forming a metal-containing film according to any one of claims 5 to 11 onto a substrate to be processed, followed by heating to form a metal-containing film;

(I-2) forming a resist upper layer film on the metal-containing film by using a photoresist material;

(I-3) subjecting the resist upper layer film to pattern exposure and then development with a developer to form a pattern in the resist upper layer film;

(I-4) transferring the pattern to the metal-containing film by dry etching while using the resist upper layer film having the formed pattern as a mask; and

(I-5) processing the substrate to be processed while using the metal-containing film having the formed pattern as a mask to form the pattern in the substrate to be processed.

[Claim 13] A patterning process for forming a pattern in a substrate to be processed, comprising the steps of:

(II-1) applying the composition for forming a metal-containing film according to any one of claims 5 to 11 onto a substrate to be processed, followed by heating to form a metal-containing film;

(II-2) forming a silicon-containing resist middle

layer film on the metal-containing film;

(II-3) forming a resist upper layer film on the silicon-containing resist middle layer film by using a photoresist material;

(II-4) subjecting the resist upper layer film to pattern exposure and then development with a developer to form a pattern in the resist upper layer film;

(II-5) transferring the pattern to the silicon-containing resist middle layer film by dry etching while using the resist upper layer film having the formed pattern as a mask;

(II-6) transferring the pattern to the metal-containing film by dry etching while using the silicon-containing resist middle layer film having the transferred pattern as a mask; and

(II-7) processing the substrate to be processed while using the metal-containing film having the formed pattern as a mask to form the pattern in the substrate to be processed.

[Claim 14] A patterning process for forming a pattern in a substrate to be processed, comprising the steps of:

(III-1) applying the composition for forming a metal-containing film according to any one of claims 5 to 11 onto a substrate to be processed, followed by heating to form a metal-containing film;

(III-2) forming an inorganic hard mask middle layer film selected from a silicon oxide film, a silicon nitride film, and a silicon oxynitride film on the metal-containing film;

(III-3) forming an organic thin film on the inorganic hard mask middle layer film;

(III-4) forming a resist upper layer film on the

organic thin film by using a photoresist material;

(III-5) subjecting the resist upper layer film to pattern exposure and then development with a developer to form a pattern in the resist upper layer film;

(III-6) transferring the pattern to the organic thin film and the inorganic hard mask middle layer film by dry etching while using the resist upper layer film having the formed pattern as a mask;

(III-7) transferring the pattern to the metal-containing film by dry etching while using the inorganic hard mask middle layer film having the transferred pattern as a mask; and

(III-8) processing the substrate to be processed while using the metal-containing film having the formed pattern as a mask to form the pattern in the substrate to be processed.

[Claim 15] The patterning process according to claim 14, wherein the inorganic hard mask middle layer film is formed by a CVD method or an ALD method.

[Claim 16] A patterning process for forming a pattern in a substrate to be processed, comprising the steps of:

(IV-1) applying the composition for forming a metal-containing film according to any one of claims 5 to 11 onto a substrate to be processed, followed by heating to form a metal-containing film;

(IV-2) forming a resist underlayer film on the metal-containing film;

(IV-3) forming a silicon-containing resist middle layer film or a combination of an inorganic hard mask middle layer film selected from a silicon oxide film, a silicon nitride film, and a silicon oxynitride film and

an organic thin film on the resist underlayer film;

(IV-4) forming a resist upper layer film on the silicon-containing resist middle layer film or the organic thin film by using a photoresist material;

(IV-5) subjecting the resist upper layer film to pattern exposure and then development with a developer to form a pattern in the resist upper layer film;

(IV-6) transferring the pattern to the silicon-containing resist middle layer film or the organic thin film and the inorganic hard mask middle layer film by dry etching while using the resist upper layer film having the formed pattern as a mask;

(IV-7) transferring the pattern to the resist underlayer film by dry etching while using the silicon-containing resist middle layer film or the inorganic hard mask middle layer film having the transferred pattern as a mask;

(IV-8) transferring the pattern to the metal-containing film by dry etching while using the resist underlayer film having the transferred pattern as a mask; and

(IV-9) processing the substrate to be processed while using the metal-containing film having the formed pattern as a mask to form the pattern in the substrate to be processed.

[Claim 17] A tone-reversal patterning process for forming a pattern in a substrate to be processed, comprising the steps of:

(V-1) forming a resist underlayer film on a substrate to be processed;

(V-2) forming a resist middle layer film or a combination of an inorganic hard mask middle layer film

selected from a silicon oxide film, a silicon nitride film, and a silicon oxynitride film and an organic thin film on the resist underlayer film;

(V-3) forming a resist upper layer film on the resist middle layer film or the combination of the inorganic hard mask middle layer film and the organic thin film by using a photoresist material;

(V-4) subjecting the resist upper layer film to pattern exposure and then development with a developer to form a pattern in the resist upper layer film;

(V-5) transferring the pattern to the resist middle layer film or the organic thin film and the inorganic hard mask middle layer film by dry etching while using the resist upper layer film having the formed pattern as a mask;

(V-6) transferring the pattern to the resist underlayer film by dry etching while using the resist middle layer film or the inorganic hard mask middle layer film having the transferred pattern as a mask;

(V-7) applying the composition for forming a metal-containing film according to any one of claims 5 to 11 onto the resist underlayer film having the formed pattern, followed by heating to cover the resist underlayer film with a metal-containing film, thereby filling a space between the resist underlayer film patterns with the metal-containing film;

(V-8) etching back the metal-containing film covering the resist underlayer film having the formed pattern by a chemical stripper or dry etching to expose an upper surface of the resist underlayer film having the formed pattern;

(V-9) removing the resist middle layer film or the inorganic hard mask middle layer film remaining on the

upper surface of the resist underlayer film by dry etching;

(V-10) removing the resist underlayer film having the formed pattern with its surface exposed by dry etching to form a reverse pattern of an original pattern on the metal-containing film; and

(V-11) processing the substrate to be processed while using the metal-containing film having the formed reverse pattern as a mask to form the reverse pattern in the substrate to be processed.