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### SEMICONDUCTOR PHOTORESIST COMPOSITIONS AND METHODS OF FORMING PATTERNS USING THE COMPOSITION

#### Abstract

A semiconductor photoresist composition and a method of forming patterns using the composition are disclosed. The semiconductor photoresist composition may include: a tin (Sn)-containing organometallic compound; a compound including at least two ketone groups; an aromatic ring compound substituted with at least one selected from among —OH, —SH, and —NR.sup.13R.sup.14, where R.sup.13 and R.sup.14 may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group; and a solvent.

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## Background/Summary

### CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to and the benefit of Korean Patent Application No. 10-2024-0022896, filed on Feb. 16, 2024, in the Korean Intellectual Property Office, the entire disclosure of which is incorporated herein by reference.

### BACKGROUND

#### 1. Field

[0002] One or more embodiments of the present disclosure relate to a semiconductor photoresist composition and a method of forming patterns using the semiconductor photoresist composition.

#### 2. Description of the Related Art

[0003] The extreme ultraviolet (EUV) lithography has drawn much attention as one essential technology for manufacturing a next generation semiconductor device. That is, for the production of next-generation semiconductor devices, EUV lithography has garnered significant attention as a crucial technology. The EUV lithography is a pattern-forming technology using an EUV ray that has a wavelength of 13.5 nm as an exposure light source. According to the EUV lithography, an extremely fine pattern (e.g., less than or equal to 20 nm) may be formed in an exposure process during a manufacture of a semiconductor device (e.g., a semiconductor chip).

[0004] The extreme ultraviolet (EUV) lithography is realized through development of compatible photoresists which may be performed at a spatial resolution of less than or equal to 16 nm. Efforts to satisfy insufficient specifications of chemically amplified (CA) photoresists, such as a resolution, a photospeed, and feature roughness (or also referred to as a line edge roughness or LER), for the next generation device have been or are being made.

[0005] An intrinsic image blurring due to an acid-catalyzed reaction in the polymer-type or kind photoresists limits a resolution in small feature sizes, which has existed in electron beam (e-beam) lithography. The chemically amplified (CA) photoresists are designed for high sensitivity. However, because their typical elemental makeups reduce light absorbance of the photoresists at a wavelength of 13.5 nm, it may decrease their sensitivity, and the chemically amplified (CA) photoresists may have more difficulties under an EUV exposure.

[0006] In addition, the CA photoresists may have difficulties in the small feature sizes due to roughness issues, and line edge roughness (LER) of the CA photoresists experimentally may be increased, as a photospeed may be decreased partially due to an essence of acid catalyst processes. Accordingly, a novel high-performance photoresist is desired or required in a semiconductor industry because of these defects and problems of the CA photoresists.

[0007] In order to overcome the aforementioned drawbacks of the chemically amplified (CA) organic photosensitive composition, an inorganic photosensitive composition has been researched. The inorganic photosensitive composition has been mainly or predominantly used for negative tone patterning which has resistance against removal by a developer composition due to chemical modification through non-chemical amplification mechanism. The inorganic composition includes an inorganic element that has a higher EUV absorption rate than hydrocarbon, and thus, it may secure sensitivity through the non-chemical amplification mechanism and may be less sensitive about a stochastic effect and thus may have low line edge roughness and small number of defects.

[0008] Inorganic photoresists based on peroxopolyacids of tungsten mixed with tungsten, niobium,

titanium, and/or tantalum have been reported as radiation sensitive materials for patterning.

[0009] These materials are effective for patterning large pitches for bilayer configuration as far ultraviolet (deep UV), X-ray, and electron beam sources. When cationic hafnium metal oxide sulfate (HfSO<sub>x</sub>) materials along with a peroxo complexing agent was used to image a 15 nm half-pitch (HP) through projection EUV exposure, improved performance was obtained. This system exhibits a high performance of a non-CA photoresist and has a practicable photospeed near to a requirement for an EUV photoresist. However, the hafnium metal oxide sulfate material including the peroxo complexing agent has some practical drawbacks. First, these materials are coated in a mixture of corrosive sulfuric acid/hydrogen peroxide and have insufficient shelf-life stability. Second, a structural change of the materials for performance improvement as a composite mixture is challenging. Third, development should be performed in a tetramethylammonium hydroxide (TMAH) solution at an extremely high concentration of 25 wt % and/or the like.

[0010] To address these issues, research has been focused on developing molecules that include tin (Sn), which have excellent or suitable absorption of extreme ultraviolet rays. As for an organotin polymer among the molecules containing tin, alkyl ligands are dissociated by light absorption or secondary electrons produced. The dissociated alkyl ligands are then crosslinked with adjacent chains through oxo bonds, and thus, enable the negative tone patterning which may not be removed by an organic developer. Although this organotin polymer exhibits greatly improved sensitivity and maintains a desired resolution and line edge roughness, the patterning characteristics need to be further improved for commercial availability.

## SUMMARY

[0011] One or more aspects of embodiments of the present disclosure are directed toward a semiconductor photoresist composition having reduced change in pattern line width and particle defects according to nitrogen oxide concentration and improved sensitivity.

[0012] One or more aspects of embodiments of the present disclosure are directed toward a method of forming patterns using the semiconductor photoresist composition.

[0013] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments of the disclosure.

[0014] A semiconductor photoresist composition according to one or more embodiments of the present disclosure may include a tin (Sn)-containing organometallic compound, a compound including at least two ketone groups, an aromatic ring compound substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup> (wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group), and a solvent.

[0015] The method of forming patterns according to one or more embodiments of the present disclosure may include forming an etching-objective layer on a substrate, coating the semiconductor photoresist composition on the etching-objective layer to form a photoresist layer, patterning the photoresist layer to form a photoresist pattern, and etching the etching-objective layer utilizing the photoresist pattern as an etching mask.

[0016] The semiconductor photoresist composition according to one or more embodiments of the present disclosure may enable the implementation of a clear pattern by reducing the change in pattern line width and particle defects depending on the nitrogen oxide concentration and improving sensitivity.

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## Description

### BRIEF DESCRIPTION OF THE DRAWING

[0017] FIGS. 1A-1E are cross-sectional views for illustrating a method of forming patterns using a

semiconductor photoresist composition according to one or more embodiments of the present disclosure.

## DETAILED DESCRIPTION

[0018] The present disclosure may be modified in one or more alternate forms, and thus specific embodiments will be exemplified in the drawing and described in more detail. It should be understood, however, that it is not intended to limit the present disclosure to the particular forms disclosed, but rather, is intended to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure.

[0019] Hereinafter, referring to the drawings, embodiments of the present disclosure are described in more detail. In the following description of the present disclosure, the well-suitable functions or constructions will not be described in order to clarify the present disclosure.

[0020] In order to clearly illustrate the present disclosure, the description and relationships may not be provided here, and throughout the disclosure, the same or similar configuration elements are designated by the same reference numerals. Also, because the size and thickness of each configuration shown in the drawing are arbitrarily shown for better understanding and ease of description, embodiments of the present disclosure are not necessarily limited thereto.

[0021] In the drawings, the thickness of layers, films, panels, regions, and/or the like, may be enlarged for clarity. In the drawings, the thickness of a part of layers or regions, and/or the like, may be exaggerated for clarity. It will be understood that if (e.g., when) an element, such as a layer, film, region, or substrate, is referred to as being “on” another element, it may be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being “directly on” another element, there are no intervening elements present.

[0022] As used herein, “substituted” refers to replacement of a hydrogen atom by deuterium, a halogen, a carboxyl group, a hydroxyl group, a thiol group, a cyano group, a nitro group, —NRR’ (wherein, R and R’ may each independently be hydrogen, a substituted or unsubstituted C1 to C30 saturated or unsaturated aliphatic hydrocarbon group, a substituted or unsubstituted C3 to C30 saturated or unsaturated alicyclic hydrocarbon group, or a substituted or unsubstituted C6 to C30 aromatic hydrocarbon group), —SiRR’R’’ (wherein, R, R’, and R’’ may each independently be hydrogen, a substituted or unsubstituted C1 to C30 saturated or unsaturated aliphatic hydrocarbon group, a substituted or unsubstituted C3 to C30 saturated or unsaturated alicyclic hydrocarbon group, or a substituted or unsubstituted C6 to C30 aromatic hydrocarbon group), a C1 to C30 alkyl group, a C1 to C10 haloalkyl group, a C1 to C10 alkylsilyl group, a C3 to C30 cycloalkyl group, a C6 to C30 aryl group, a C1 to C20 alkoxy group, a C1 to C20 sulfide group, or a (e.g., any suitable) combination thereof. “Unsubstituted” refers to non-replacement of a hydrogen atom by another substituent and remaining of the hydrogen atom.

[0023] As used herein, if (e.g., when) a definition is not otherwise provided, “alkyl group” refers to a linear or branched aliphatic hydrocarbon group. The alkyl group may be “saturated alkyl group” without any double bond or triple bond.

[0024] The alkyl group may be a C1 to C8 alkyl group. For example, the alkyl group may be a C1 to C7 alkyl group, a C1 to C6 alkyl group, or a C1 to C5 alkyl group. For example, the C1 to C5 alkyl group may be a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, or a 2,2-dimethylpropyl group.

[0025] As used herein, if (e.g., when) a definition is not otherwise provided, “cycloalkyl group” refers to a monovalent cyclic aliphatic hydrocarbon group.

[0026] The cycloalkyl group may be a C3 to C8 cycloalkyl group, for example, a C3 to C7 cycloalkyl group, a C3 to C6 cycloalkyl group, a C3 to C5 cycloalkyl group, or a C3 to C4 cycloalkyl group. For example, the cycloalkyl group may be a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, or a cyclohexyl group, but embodiments of the present disclosure are not limited thereto.

[0027] As used herein, “aliphatic unsaturated organic group” refers to a hydrocarbon group

including a bond in which the bond between the carbon and carbon atom in the molecule is a double bond, a triple bond, or a (e.g., any suitable) combination thereof.

[0028] The aliphatic unsaturated organic group may be a C2 to C8 aliphatic unsaturated organic group. For example, the aliphatic unsaturated organic group may be a C2 to C7 aliphatic unsaturated organic group, a C2 to C6 aliphatic unsaturated organic group, a C2 to C5 aliphatic unsaturated organic group, or a C2 to C4 aliphatic unsaturated organic group. For example, the C2 to C4 aliphatic unsaturated organic group may be a vinyl group, an ethynyl group, an allyl group, a 1-propenyl group, a 1-methyl-1-propenyl group, a 2-propenyl group, a 2-methyl-2-propenyl group, a 1-propynyl group, a 1-methyl-1-propynyl group, a 2-propynyl group, a 2-methyl-2-propynyl group, a 1-butenyl group, a 2-butenyl group, a 3-butenyl group, a 1-butynyl group, a 2-butynyl group, or a 3-butynyl group.

[0029] As used herein, “aryl group” refers to a substituent in which all atoms in the cyclic substituent have a p-orbital and these p-orbitals are conjugated and may include a monocyclic, polycyclic or fused ring (e.g., rings sharing adjacent pairs of carbon atoms) functional group.

[0030] As used herein, “heteroaryl group” may refer to an aryl group including at least one heteroatom selected from among nitrogen (N), oxygen (O), sulfur (S), phosphorus (P), and silicon (Si). Two or more heteroaryl groups are linked by a sigma bond directly, or if (e.g., when) the heteroaryl group includes two or more rings, the two or more rings may be fused. If (e.g., when) the heteroaryl group is a fused ring, each ring may include one to three heteroatoms.

[0031] As used herein, unless otherwise defined, “alkenyl group” refers to an aliphatic unsaturated alkenyl group including at least one double bond as a linear or branched aliphatic hydrocarbon group.

[0032] As used herein, unless otherwise defined, “alkynyl group” refers to an aliphatic unsaturated alkynyl group including at least one triple bond as a linear or branched aliphatic hydrocarbon group.

[0033] Hereinafter, a semiconductor photoresist composition according to one or more embodiments of the present disclosure is described.

[0034] The semiconductor photoresist composition according to one or more embodiments may include a tin (Sn)-containing organometallic compound; a compound including at least two ketone groups; an aromatic ring compound substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup> (wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group); and a solvent.

[0035] In the semiconductor photoresist composition, by including the compound including at least two ketone groups acting or serving as a scavenger, a line width change rate may be minimized or reduced, and [0036] in one or more embodiments, by including the aromatic ring compound substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup> (wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group), defects, sensitivity, and LER may be improved due to solvent stabilization, resulting in excellent or suitable resolution.

[0037] For example, the aromatic ring compound:the compound including at least two ketone groups may be in a weight ratio of about 1:1 to about 1:10.

[0038] For example, the aromatic ring compound:thecompound including at least two ketone groups may be in a weight ratio of about 1:1 to about 1:10, about 1:2 to about 1:10, or about 1:2 to about 1:9.

[0039] The compound including at least two ketone groups may be represented by Chemical Formula 1 or Chemical Formula 2.

##STR00001##

[0040] In Chemical Formula 1 and Chemical Formula 2, [0041] R<sup>sup.1</sup> to R<sup>sup.6</sup> may each

independently be hydrogen, a halogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof, [0042] L.sup.1 to L.sup.3 may each independently be a single bond, a carbonyl group, a substituted or unsubstituted C1 to C20 alkylene group, or a (e.g., any suitable) combination thereof, [0043] n1 and n2 may each independently be one of integers of 0 to 2, and [0044] n1+n2 may be greater than or equal to 1.

[0045] As an example, the aromatic ring compound may include a phenyl group substituted with at least one selected from among —OH, —SH, and —NR.sup.13R.sup.14; a naphthyl group substituted with at least one selected from among —OH, —SH, and —NR.sup.13R.sup.14; an anthracenyl group substituted with at least one selected from among —OH, —SH, and —NR.sup.13R.sup.14; a phenanthrene group substituted with at least one selected from among —OH, —SH, and —NR.sup.13R.sup.14; or a triphenylene group substituted with at least one selected from among —OH, —SH, and —NR.sup.13R.sup.14, and [0046] R.sup.13 and R.sup.14 may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group.

[0047] For example, the aromatic ring compound may be substituted with at least two selected from among —OH, —SH, and —NR.sup.13R.sup.14 (wherein R.sup.13 and R.sup.14 may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group).

[0048] In one or more embodiments, the aromatic ring compound may be substituted with at least two —OH.

[0049] In another example, the aromatic ring compound may be substituted with at least two —SH.

[0050] In one or more embodiments, the aromatic ring compound may be substituted with at least two NR.sup.13R.sup.14 (wherein R.sup.13 and R.sup.14 may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group).

[0051] For example, the compound including at least two ketone groups may be any one selected from among pentane-2,4-dione, 2,3-butanedione, 3-methyl-2,4-pentanedione, and 2,2,6,6-tetramethyl-3,5-heptanedione.

[0052] For example, the aromatic ring compound may be any one selected from among 1,4-hydroquinone, 1,2-benzenediol, 1,3-benzenediol, benzene-1,2-dithiol, 1,4-phenylenediamine, 4-amino benzene-1-thiol, 3-aminobenzene-1-thiol, and 2-aminobenzene-1-thiol.

[0053] The compound including at least two ketone groups and the aromatic ring compound may each be in an amount of about 0.001 wt % to about 10 wt % about based on 100 wt % of the semiconductor photoresist composition.

[0054] For example, the compound including at least two ketone groups and the aromatic ring compound may each be in an amount of about 0.005 wt % to about 10 wt %, about 0.01 wt % to about 10 wt %, or about 0.1 wt % to about 5 wt % based on 100 wt % of the semiconductor photoresist composition.

[0055] The Sn-containing organometallic compound may be in an amount of about 0.5 wt % to about 30 wt % based on 100 wt % of the semiconductor photoresist composition.

[0056] The semiconductor photoresist composition according to one or more embodiments of the present disclosure may include the Sn-containing organometallic compound, the compound including at least two ketone groups, and the aromatic ring compound within the above content (e.g., amount) range(s), thereby improving the sensitivity and solubility of the photoresist, and reducing a change rate in linewidth depending on an atmospheric environment.

[0057] In the semiconductor photoresist composition according to one or more embodiments, the Sn-containing organometallic compound:the compound including at least two ketone groups and the aromatic ring compound may be in a weight ratio of (e.g., the weight ratio of the Sn-containing

organometallic compound to the compound including the at least two ketone groups and the aromatic ring compound may be) about 90:10 to about 50:50. For example, the semiconductor photoresist composition may include the Sn-containing organometallic compound:the compound including the at least two ketone groups and the aromatic ring compound in the weight ratio of about 90:10 to about 60:40.

[0058] If (e.g., when) the weight ratio 1):2) of 1) the Sn-containing organometallic compound to 2) a) the compound including at least two ketone groups and 2) b) the aromatic ring compound satisfies the above range(s), a semiconductor photoresist composition that has excellent or suitable sensitivity may be provided.

[0059] The Sn-containing organometallic compound may include at least one of an organic oxy group and an organic carbonyloxy group.

[0060] The organometallic compound may be represented by Chemical Formula 3.

##STR00002##

[0061] In Chemical Formula 3, [0062] R.sup.7 may be selected from among a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, and a substituted or unsubstituted C7 to C30 arylalkyl group, [0063] R.sup.8 to R.sup.10 may each independently be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, a substituted or unsubstituted C7 to C30 arylalkyl group, an alkoxy or aryloxy group (—OR.sup.a, wherein R.sup.a may be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), a carboxyl group (—O(C=O)R.sup.b, wherein R.sup.b may be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an alkylamido or dialkylamido group (—NR.sup.cR.sup.d, wherein R.sup.c and R.sup.d may each independently be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an amidato group (—NR.sup.e(C=OR.sup.f), wherein R.sup.e and R.sup.f may each independently be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an amidinato group (—NR.sup.gC(NR.sup.h)R.sup.i, wherein R.sup.g, R.sup.h, and R.sup.i may each independently be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an alkylthio or arylthio group (—SR.sup.j, wherein R.sup.j may be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof) or a thiocarboxyl group (—S(C=O)R.sup.k, wherein R.sup.k may be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or

unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), and [0064] at least one of R.sup.8 to R.sup.10 may be selected from among an alkoxy or aryloxy group ( $\text{—OR.sup.a}$ , wherein R.sup.a may be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), a carboxyl group ( $\text{—O(C=O)R.sup.b}$ , wherein R.sup.b may be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an alkylamido or dialkylamido group ( $\text{—NR.sup.cR.sup.d}$ , wherein R.sup.c and R.sup.d may each independently be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an amidato group ( $\text{—NR.sup.e(C=OR.sup.f)}$ , wherein R.sup.e and R.sup.f may each independently be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an amidinato group ( $\text{—NR.sup.gC(NR.sup.h)R.sup.i}$ , wherein R.sup.g, R.sup.h, and R.sup.i may each independently be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), an alkylthio or arylthio group ( $\text{—SR.sup.j}$ , wherein R.sup.j may be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), or a thiocarboxyl group ( $\text{—S(C=O)R.sup.k}$ , R.sup.k may be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof).

[0065] At least one of (e.g., selected from among) R.sup.8 to R.sup.10 may be an alkoxy or aryloxy group ( $\text{—OR.sup.a}$ , wherein R.sup.a may be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof), or a carboxyl group ( $\text{—O(C=O)R.sup.b}$ , wherein R.sup.b may be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof).

[0066] In one or more embodiments, the compound represented by Chemical Formula 4 may include  $\text{—OR.sup.a}$  or  $\text{—OC(=O)R.sup.b}$  as a ligand, so that a pattern formed using a semiconductor photoresist composition including the compound may exhibit excellent or suitable limiting resolution.

[0067] In one or more embodiments, the  $\text{OR.sup.a}$  or  $\text{—OC(=O)R.sup.b}$  ligand may determine the solubility of the compound represented by Chemical Formula 4 in a solvent.

[0068] R.sup.7 may be a substituted or unsubstituted C1 to C8 alkyl group, a substituted or



unsubstituted C3 to C8 cycloalkyl group, a substituted or unsubstituted C2 to C8 aliphatic unsaturated organic group including one or more double bonds or triple bonds, a substituted or unsubstituted C6 to C20 aryl group, a substituted or unsubstituted C4 to C20 heteroaryl group, a carbonyl group, an ethoxy group, a propoxy group, or a (e.g., any suitable) combination thereof, [0069] R.sup.a may be a substituted or unsubstituted C1 to C8 alkyl group, a substituted or unsubstituted C3 to C8 cycloalkyl group, a substituted or unsubstituted C2 to C8 alkenyl group, a substituted or unsubstituted C2 to C8 alkynyl group, a substituted or unsubstituted C6 to C20 aryl group, or a (e.g., any suitable) combination thereof, and [0070] R.sup.b may be hydrogen, a substituted or unsubstituted C1 to C8 alkyl group, a substituted or unsubstituted C3 to C8 cycloalkyl group, a substituted or unsubstituted C2 to C8 alkenyl group, a substituted or unsubstituted C2 to C8 alkynyl group, a substituted or unsubstituted C6 to C20 aryl group, or a (e.g., any suitable) combination thereof.

[0071] R.sup.7 may be a methyl group, an ethyl group, a propyl group, a butyl group, an isopropyl group, a tert-butyl group, a 2,2-dimethylpropyl group, a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, an ethenyl group, a propenyl group, a butenyl group, an ethynyl group, a propynyl group, a butynyl group, a phenyl group, a tolyl group, a xylene group, a benzyl group, a formyl group, an acetyl group, a propanoyl group, a butanoyl group, a pentanoyl group, an ethoxy group, a propoxy group, or a (e.g., any suitable) combination thereof, [0072] R.sup.a may be an ethyl group, a propyl group, a butyl group, an isopropyl group, a tert-butyl group, a 2,2-dimethylpropyl group, a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, an ethenyl group, a propenyl group, a butenyl group, an ethynyl group, a propynyl group, a butynyl group, a phenyl group, a tolyl group, a xylene group, a benzyl group, or a (e.g., any suitable) combination thereof, and [0073] R.sup.b may be hydrogen, an ethyl group, a propyl group, a butyl group, an isopropyl group, a tert-butyl group, a 2,2-dimethylpropyl group, a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, an ethenyl group, a propenyl group, a butenyl group, an ethynyl group, a propynyl group, a butynyl group, a phenyl group, a tolyl group, a xylene group, a benzyl group, or a (e.g., any suitable) combination thereof. [0074] In one or more embodiments, the Sn-containing organometallic compound may be represented by Chemical Formula 4 or Chemical Formula 5.

R.sup.11.sub.zSnO.sub.(2-(z/2)-(x/2))(OH).sub.x      Chemical Formula 4

[0075] In Chemical Formula 4, [0076] R.sup.11 may be a C1 to C31 hydrocarbonyl group,  $0 < z \leq 2$ , and  $0 < (z+x) \leq 4$ ;

R.sup.12.sub.a1Sn.sub.b1X.sub.c1Y.sub.d1      Chemical Formula 5

[0077] In Chemical Formula 5, [0078] R.sup.12 may be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 aliphatic unsaturated organic group including one or more double bonds or triple bonds, a substituted or unsubstituted C6 to C30 aryl group, a substituted or unsubstituted C4 to C30 heteroaryl group, a carbonyl group, an ethylene oxide group, a propylene oxide group, or a (e.g., any suitable) combination thereof, [0079] X may be sulfur (S), selenium (Se), or tellurium (Te), [0080] Y may be —OR.sup.l or —OC(=O)R.sup.m, [0081] wherein R.sup.l may be a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof, [0082] R.sup.m may be hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a (e.g., any suitable) combination thereof, and [0083] a1, b1, c1, and d1 may each independently be an integer of 1 to

20.

[0084] The solvent of the semiconductor photoresist composition according to one or more embodiments may be an organic solvent, and may be, for example, one of more selected from aromatic compounds (e.g., xylene, toluene, and/or the like), alcohols (e.g., 4-methyl-2-pentanol, 4-methyl-2-propanol, 1-butanol, methanol, isopropyl alcohol, 1-propanol, and/or the like), ethers (e.g., anisole, tetrahydrofuran, and/or the like), esters (e.g., n-butyl acetate, propylene glycol monomethyl ether acetate, ethyl acetate, ethyl lactate, and/or the like), ketones (e.g., methyl ethyl ketone, 2-heptanone, and/or the like), and/or mixtures thereof, but embodiments of the present disclosure are not limited thereto.

[0085] The semiconductor photoresist composition according to one or more embodiments may further include a resin in addition to the aforementioned Sn-containing organometallic compound, compound including at least two ketone groups, aromatic ring compound substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup> (wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group), and solvent.

[0086] The resin may be a phenol-based resin including at least one aromatic moiety selected from moieties listed in Group 1.

##STR00003##

[0087] The resin may have a weight average molecular weight of about 500 g/mol to about 20,000 g/mol.

[0088] The resin may be in an amount of about 0.1 wt % to about 50 wt % based on a total amount of the semiconductor photoresist composition.

[0089] If (e.g., when) the resin is in the above content (e.g., amount) range, it may have excellent or suitable etch resistance and heat resistance.

[0090] In contrast, the semiconductor photoresist composition according to one or more embodiments may include (e.g., consist of) the aforementioned Sn-containing organometallic compound, a compound including at least two ketone groups, an aromatic ring compound substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup> (wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> may each independently be hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group), solvent, and resin.

[0091] However, the semiconductor photoresist composition according to the aforementioned embodiments may further include additives as needed or as desired. Examples of the additives may be a surfactant, a crosslinking agent, a leveling agent, an organic acid, a quencher, or a (e.g., any suitable) combination thereof.

[0092] The surfactant may include, for example, an alkyl benzene sulfonate salt, an alkyl pyridinium salt, polyethylene glycol, a quaternary ammonium salt, or a (e.g., any suitable) combination thereof, but embodiments of the present disclosure are not limited thereto.

[0093] The crosslinking agent may be, for example, a melamine-based crosslinking agent, a substituted urea-based crosslinking agent, an acryl-based crosslinking agent, an epoxy-based crosslinking agent, or a polymer-based crosslinking agent, but embodiments of the present disclosure are not limited thereto. It may be a crosslinking agent having at least two crosslinking forming substituents, for example, a compound, such as methoxymethylated glycoluril, butoxymethylated glycoluril, methoxymethylated melamine, butoxymethylated melamine, methoxymethylated benzoguanamine, butoxymethylated benzoguanamine, 4-hydroxybutyl acrylate, acrylic acid, urethane acrylate, acryl methacrylate, 1,4-butanediol diglycidyl ether, glycidol, diglycidyl 1,2-cyclohexane dicarboxylate, trimethylpropane triglycidyl ether, 1,3-bis(glycidoxypropyl)tetramethyldisiloxane, methoxymethylated urea, butoxymethylated urea, methoxymethylated thiourea, and/or the like.

[0094] The leveling agent may be used for improving coating flatness during printing and may be a

commercially available suitable leveling agent.

[0095] The organic acid may include p-toluenesulfonic acid, benzenesulfonic acid, p-dodecylbenzenesulfonic acid, 1,4-naphthalenedisulfonic acid, methanesulfonic acid, a fluorinated sulfonium salt, malonic acid, citric acid, propionic acid, methacrylic acid, oxalic acid, lactic acid, glycolic acid, succinic acid, or a (e.g., any suitable) combination thereof, but embodiments of the present disclosure are not limited thereto.

[0096] The quencher may be diphenyl (p-tolyl) amine, methyl diphenyl amine, triphenyl amine, phenylenediamine, naphthylamine, diaminonaphthalene, or a (e.g., any suitable) combination thereof.

[0097] A use amount of the additives may be controlled or selected depending on desired or suitable properties.

[0098] In one or more embodiments, the semiconductor photoresist composition may further include a silane coupling agent as an adherence enhancer in order to improve a close-contacting force with the substrate (e.g., in order to improve adherence of the semiconductor photoresist composition to the substrate). The silane coupling agent may be, for example, a silane compound including a carbon-carbon unsaturated bond, such as vinyltrimethoxysilane, vinyl triethoxysilane, vinyl trichlorosilane, vinyl tris( $\beta$ -methoxyethoxy)silane, or 3-methacryloxypropyltrimethoxysilane, 3-acryloxypropyltrimethoxysilane, p-styryl trimethoxysilane, 3-methacryloxypropylmethyldimethoxysilane, 3-methacryloxypropylmethyl diethoxysilane, trimethoxy[3-(phenylamino)propyl]silane, and/or the like, but embodiments of the present disclosure are not limited thereto.

[0099] The semiconductor photoresist composition may be formed into a pattern having a high aspect ratio without a collapse. In one or more embodiments, in order to form a fine pattern having a width (e.g., line width) of, for example, about 5 nm to about 100 nm, for example, about 5 nm to about 80 nm, for example, about 5 nm to about 70 nm, for example, about 5 nm to about 50 nm, for example, about 5 nm to about 40 nm, for example, about 5 nm to about 30 nm, or for example, about 5 nm to about 20 nm, the semiconductor photoresist composition may be used for a photoresist process using light in a wavelength in a range of about 5 nm to about 150 nm, for example, about 5 nm to about 100 nm, about 5 nm to about 80 nm, about 5 nm to about 50 nm, about 5 nm to about 30 nm, or about 5 nm to about 20 nm. In one or more embodiments, the semiconductor photoresist composition according to one or more embodiments may be used to realize extreme ultraviolet lithography using an EUV light source of a wavelength of about 13.5 nm.

[0100] According to one or more embodiments, a method of forming patterns using the aforementioned semiconductor photoresist composition is provided. For example, the manufactured pattern may be a photoresist pattern.

[0101] The method of forming patterns according to one or more embodiments may include forming an etching-objective layer (e.g., etching-target layer) on a substrate, coating the semiconductor photoresist composition on the etching-objective layer to form a photoresist layer, patterning the photoresist layer to form a photoresist pattern, and etching the etching-objective layer utilizing the photoresist pattern as an etching mask.

[0102] Hereinafter, a method of forming patterns using the semiconductor photoresist composition is described referring to FIGS. 1A-1E. FIGS. 1A-1E are cross-sectional views for illustrating a method of forming patterns using a semiconductor photoresist composition according to one or more embodiments.

[0103] Referring to FIG. 1A, an object for etching (e.g., etching-objective layer or etching-target layer) may be prepared. The object for etching may be a thin film **102** formed on a semiconductor substrate **100**. Hereinafter, the object for etching may be limited to the thin film **102**. A surface of the thin film **102** may be washed to remove impurities and/or the like remaining thereon. The thin film **102** may be, for example, a silicon nitride layer, a polysilicon layer, or a silicon oxide layer.

[0104] Subsequently, a resist underlayer composition for forming a resist underlayer **104** may be spin-coated on the surface of the washed thin film **102**. However, embodiments of the present disclosure are not limited thereto, and one or more suitable coating methods, for example, a spray coating, a dip coating, a knife edge coating, a printing method (for example, an inkjet printing and/or a screen printing), and/or the like may be used.

[0105] The coating process of the resist underlayer may not be provided, and hereinafter, a process including a coating of the resist underlayer is described.

[0106] Then, the coated composition may be dried and baked to form a resist underlayer **104** on the thin film **102**. The baking may be performed at about 100° C. to about 500° C., for example, about 100° C. to about 300° C.

[0107] The resist underlayer **104** may be formed between the substrate **100** and a photoresist layer **106** and thus may prevent or reduce non-uniformity and pattern formability of a photoresist line width if (e.g., when) a ray reflected from on the interface between the substrate **100** and the photoresist layer **106** or a hardmask between layers is scattered into an unintended photoresist region.

[0108] Referring to FIG. 1B, the photoresist layer **106** may be formed by coating the semiconductor photoresist composition on the resist underlayer **104**. The photoresist layer **106** may be obtained by coating the aforementioned semiconductor photoresist composition on the thin film **102** formed on the substrate **100** and then, curing it through a heat treatment.

[0109] For example, the formation of a pattern by using the semiconductor photoresist composition may include coating the semiconductor resist composition on the substrate **100** that has the thin film **102** through spin coating, slit coating, inkjet printing, and/or the like and then, drying it to form the photoresist layer **106**.

[0110] The semiconductor photoresist composition has already been illustrated in detail and will not be illustrated again.

[0111] Subsequently, a substrate **100** having the photoresist layer **106** may be subjected to a first baking (thermal treatment) process. The first baking process may be performed at about 80° C. to about 120° C.

[0112] Referring to FIG. 1C, the photoresist layer **106** may be selectively exposed using a patterned mask **110**.

[0113] For example, the exposure may use an activation radiation with light having a high energy wavelength, such as EUV (extreme ultraviolet; a wavelength of about 13.5 nm), an E-Beam (an electron beam), and/or the like, as well as light having a short wavelength, such as an i-line (a wavelength of about 365 nm), a KrF excimer laser (a wavelength of about 248 nm), an ArF excimer laser (a wavelength of about 193 nm), and/or the like.

[0114] For example, light or exposure beam for the exposure according to one or more embodiments may have a short wavelength in a range of about 5 nm to about 150 nm and/or a high energy wavelength, for example, may be an EUV (extreme ultraviolet; a wavelength of 13.5 nm), and/or may be an E-Beam (an electron beam), and/or the like.

[0115] The exposed region **106b** of the photoresist layer **106** may have a different solubility from the unexposed region **106a** of the photoresist layer **106** by forming a polymer by a crosslinking reaction, such as condensation between organometallic compounds.

[0116] Subsequently, the substrate **100** may be subjected to a second baking (thermal treatment) process. The second baking process may be performed at a temperature of about 90° C. to about 200° C. The exposed region **106b** of the photoresist layer **106** may become easily indissoluble regarding a developer due to the second baking process.

[0117] In FIG. 1D, the unexposed region **106a** of the photoresist layer may be dissolved and removed using the developer to form a photoresist pattern **108**. For example, the unexposed region **106a** of the photoresist layer may be dissolved and removed by using an organic solvent, such as 2-heptanone and/or the like, to complete the photoresist pattern **108** corresponding to a negative tone

image.

[0118] As described above, a developer used in the method of forming patterns according to one or more embodiments may be an organic solvent. The organic solvent used in the method of forming patterns according to one or more embodiments may be, for example, a ketone, such as methylethylketone, acetone, cyclohexanone, 2-heptanone, and/or the like, an alcohol, such as 4-methyl-2-propanol, 1-butanol, isopropanol, 1-propanol, methanol, and/or the like, an ester, such as propylene glycol monomethyl ether acetate, ethyl acetate, ethyl lactate, n-butyl acetate, butyrolactone, and/or the like, an aromatic compound, such as benzene, xylene, toluene, and/or the like, or a (e.g., any suitable) combination thereof.

[0119] However, the photoresist pattern according to one or more embodiments is not necessarily limited to the negative tone image but may be formed to have a positive tone image. In one or more embodiments, a developer used for forming the positive tone image may be a quaternary ammonium hydroxide composition, such as tetraethylammonium hydroxide, tetrapropylammonium hydroxide, tetrabutylammonium hydroxide, or a (e.g., any suitable) combination thereof.

[0120] In one or more embodiments, exposure to light having a high energy wavelength, such as EUV (extreme ultraviolet; a wavelength of 13.5 nm), to an E-Beam (an electron beam), and/or the like, and/or to light having a short wavelength, such as i-line (wavelength of about 365 nm), KrF excimer laser (wavelength of about 248 nm), ArF excimer laser (wavelength of about 193 nm), and/or the like, may provide a photoresist pattern **108** having a width of a thickness of about 5 nm to about 100 nm. For example, the photoresist pattern **108** may have a width of a thickness of about 5 nm to about 90 nm, about 5 nm to about 80 nm, about 5 nm to about 70 nm, about 5 nm to about 60 nm, about 5 nm to about 50 nm, about 5 nm to about 40 nm, about 5 nm to about 30 nm, or about 5 nm to about 20 nm.

[0121] In one of more embodiment, the photoresist pattern **108** may have a pitch having (with) a half-pitch of less than or equal to about 50 nm, for example, less than or equal to about 40 nm, for example, less than or equal to about 30 nm, for example, less than or equal to about 20 nm, or, for example, less than or equal to about 15 nm, and a line width roughness of less than or equal to about 10 nm, or less than or equal to about 5 nm, less than or equal to about 3 nm, or less than or equal to about 2 nm.

[0122] Subsequently, the photoresist pattern **108** may be used as an etching mask to etch the resist underlayer **104**. Through this etching process, an organic layer pattern **112** may be formed. The organic layer pattern **112** also may have a width corresponding to that of the photoresist pattern **108**.

[0123] Referring to FIG. 1E, the exposed thin film **102** may be etched by applying the photoresist pattern **108** as an etching mask. As a result, the thin film may be formed as a thin film pattern **114**.

[0124] The etching of the thin film **102** may be, for example, dry etching using an etching gas, and the etching gas may be, for example, CHF<sub>3</sub>, CF<sub>4</sub>, Cl<sub>2</sub>, BCl<sub>3</sub>, or a (e.g., any suitable) mixed gas thereof.

[0125] In the exposure process, the thin film pattern **114** formed by using the photoresist pattern **108** formed through the exposure process performed by using an EUV light source may have a width corresponding to that of the photoresist pattern **108**. For example, the thin film pattern **114** may have a width (e.g., line width) of about 5 nm to about 100 nm which may be equal to that of the photoresist pattern **108**. For example, the thin film pattern **114** formed by using the photoresist pattern **108** formed through the exposure process performed by using an EUV light source may have a width of about 5 nm to about 90 nm, about 5 nm to about 80 nm, about 5 nm to about 70 nm, about 5 nm to about 60 nm, about 5 nm to about 50 nm, about 5 nm to about 40 nm, about 5 nm to about 30 nm, or about 5 nm to about 20 nm, and, for example, a width (e.g., line width) of less than or equal to about 20 nm, like that of the photoresist pattern **108**.

[0126] Hereinafter, the present disclosure will be described in more detail through examples of the preparation of the aforementioned semiconductor photoresist composition. However, the present

disclosure are not technically restricted by the following examples.

## Synthesis of Organometallic Compound

### Synthesis Example 1

[0127] After adding 30 mL of anhydrous pentane to 10 g of t-AmylSnCl.sub.3 and maintaining their temperature at 0° C., 7.4 g of diethyl amine and 6.1 g of ethanol were added thereto and then, stirred at room temperature for 1 hour. When a reaction was completed, the resultant was filtered, concentrated, and vacuum-dried, obtaining a compound represented by Chemical Formula 6.

##STR00004##

### Synthesis Example 2

[0128] 40.7 g of t-butylSnPh.sub.3 and 300 g of propionic acid were added to a 250 mL 2-necked round-bottomed flask and then, refluxed by heating for 24 hours.

[0129] A compound represented by Chemical Formula 7 was obtained by removing the unreacted propionic acid under a reduced pressure therefrom.

##STR00005##

### Synthesis Example 3

[0130] 10 g of dibutyltin dichloride was dissolved 30 mL of ether, 70 mL of a 1 M sodium hydroxide (NaOH) aqueous solution was added thereto and then, stirred for 1 hour. After the stirring, a solid produced therein was filtered, washed with 25 mL of deionized water for three times, and dried at 100° C. under a reduced pressure to obtain an organometallic compound represented by Chemical Formula 8 and having a weight average molecular weight of 1,500 g/mol.

##STR00006##

## Preparation of Semiconductor Photoresist Composition

### Examples 1 to 10 and Comparative Examples 1 to 7

[0131] The organometallic compounds represented by Chemical Formulas 6 to 8 according to Synthesis Examples 1 to 3 and additives were respectively dissolved in propylene glycol methyl ether acetate (PGMEA) at a concentration of 3 wt % in a weight ratio shown in Table 1 and then, filtered with a 0.1 μm polytetrafluoroethylene (PTFE) syringe filter to prepare semiconductor photoresist compositions.

TABLE-US-00001 TABLE 1 Additive Organometallic (wt %) compound Aromatic ring Diketone (wt %) compound compound Example 1 Chemical Formula 6 A1 B1 (2.4) (0.13) (0.47) Example 2 Chemical Formula 6 A2 B1 (2.4) (0.13) (0.47) Example 3 Chemical Formula 6 A3 B1 (2.4) (0.13) (0.47) Example 4 Chemical Formula 6 A1 B2 (2.4) (0.13) (0.47) Example 5 Chemical Formula 6 A4 B1 (2.4) (0.13) (0.47) Example 6 Chemical Formula 6 A1 B1 (2.4) (0.06) (0.54) Example 7 Chemical Formula 6 A1 B1 (2.4) (0.18) (0.42) Example 8 Chemical Formula 7 A1 B1 (2.4) (0.13) (0.47) Example 9 Chemical Formula 8 A1 B1 (2.4) (0.13) (0.47) Example 10 Chemical Formula 6 A5 B1 (2.4) (0.13) (0.47) Comparative Chemical Formula 6 — — Example 1 (3.0) Comparative Chemical Formula 6 A1 — Example 2 (2.87) (0.13) Comparative Chemical Formula 6 — B1 Example 3 (2.53) (0.47) Comparative Chemical Formula 6 C1 B1 Example 4 2.4 (0.13) (0.47) Comparative Chemical Formula 6 A1 D1 Example 5 (2.4) (0.13) (0.47) Comparative Chemical Formula 6 A1 D2 Example 6 (2.4) (0.13) (0.47) Comparative Chemical Formula 6 A1 D3 Example 7 (2.4) (0.13) (0.47) A1: 1,4-Hydroquinone A2: 1,2-Benzenediol A3: 1,3-Benzenediol A4: Benzene-1,2-dithiol A5: 1,4-Phenylenediamine B1: Pentane-2,4-dione B2: 2,3-Butanedione C1: 1,4-Benzoquinone D1: Acetic Acid D2: 1-Butanol D3: 2-Methyl-2-butanol

### Evaluation 1: Evaluation of Sensitivity

[0132] Each of the photoresist compositions according to Examples and Comparative Examples was spin-coated at room temperature (23±2° C.) for 30 seconds at 1500 rpm, respectively, on a 200 mm circular silicon wafer whose surface was deposited with HMDS, and baked at 110° C. for 60 seconds (After application, it is baked (post-apply bake, PAB)).

[0133] Afterwards, EUV light was used to project onto the wafer coated with the photoresist composition. Herein, pad exposure time was adjusted to ensure that the EUV light in an increased

dose was applied to each pad.

[0134] Then, the resist and the substrate were baked at 170° C. for 60 seconds on a hot plate after the exposure. The baked film was developed with a developer including PGMEA solvent to form a negative tone image. Finally, the obtained film was baked again at 200° C. for 60 seconds on the hot plate, completing the process.

[0135] The residual resist thickness of the exposed pad was measured using an ellipsometer. The remaining thickness was measured for each exposure dose and graphed as a function of the exposure dose to measure sensitivity, and the results are shown in Table 2.

[0136] The measurement error is  $\pm 2$  mJ.

#### Evaluation 2: Evaluation of Resolution (CD)

[0137] After completing the process, a line/space CD pattern was formed on the patterned wafer, which was then transferred to CD-SEM measurement equipment (GC-9380, Hitachi) to measure the CD (Critical Dimension) size of the area where the half-pitch of the mask pattern is 14 nm, and the minimum value among space CDs, which is the distance between lines, are measured. The CD increase rate calculated according to Equation 1 is shown in Table 2. The measurement error is  $\pm 1.0$  nm.

[00001] Equation 1

CD:  $CD_{\text{when the } NO_x \text{ concentration in the air is high}} - CD_{\text{when the } NO_x \text{ concentration in the air is low}}$

[0138] Nitrogen oxide (NO<sub>x</sub>) concentration range: If the concentration of nitrogen oxides in the atmosphere is  $>0.015$  ppm, it is defined as high concentration. If the concentration of nitrogen oxides in the atmosphere is  $\leq 0.015$  ppm, it is defined as low concentration.

#### Evaluation 3: Evaluation of Particle Defects

[0139] Particle defects on patterned wafers for which the process was completed were analyzed using inspector equipment (AIT-FUSION, KLA). Contaminated particles and defects on the patterned wafer were observed, classified, and analyzed using a scanning electron microscope. Particle defect management is managed by the number of particles, and the N.D. (Non detectable) level refers to that there are no valid contaminant particles observed.

TABLE-US-00002

TABLE 2	Sensitivity	CD increase rate	Number of (mJ) (%)	particles	Example 1
52	<1.0	N.D.	Example 2	54	<1.0
N.D.	Example 3	52	<1.0	N.D.	Example 4
53	<1.0	N.D.	Example 5	51	<1.0
N.D.	Example 6	54	<1.0	N.D.	Example 7
51	<1.0	N.D.	Example 8	57	<1.0
N.D.	Example 9	56	<1.0	N.D.	Example 10
55	<1.0	N.D.	Comparative Example 1	52	42.2
>1000	Comparative Example 2	54	<1.0	>5000	Comparative Example 3
55	34.2	N.D.	Comparative Example 4	53	21.2
N.D.	Comparative Example 5	81	<1.0	500	Comparative Example 6
77	<1.0	780	Comparative Example 7	75	<1.0
900					

[0140] From the results in Table 2, the patterns formed using the semiconductor photoresist compositions according to Examples 1 to 10 each exhibited excellent or suitable sensitivity and LER, and excellent or suitable resolution characteristics with no increase in CD compared to Comparative Examples 1 to 7.

[0141] As utilized herein, the terms “and/or” and “or” may include any and all combinations of one or more of the associated listed items. Expressions such as “at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0142] It will be further understood that the terms “comprise”, “include,” or “have/has,” when utilized in the present disclosure, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The “/” utilized below may be interpreted as “and” or as “or” depending on the situation.

[0143] As utilized herein, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. Further, the utilization of “may” when describing embodiments of the present disclosure refers to “one or more embodiments of the present disclosure”.

[0144] In the context of the present disclosure and unless otherwise defined, the terms “use,” “using,” and “used” may be considered synonymous with the terms “utilize,” “utilizing,” and “utilized,” respectively.

[0145] As utilized herein, the term “about,” or similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art. “About” or “approximately,” as used herein, is also inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (e.g., the limitations of the measurement system). For example, “about” may mean within one or more standard deviations, or within  $\pm 30\%$ ,  $\pm 20\%$ ,  $\pm 10\%$ , or  $\pm 5\%$  of the stated value.

[0146] Any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of “1.0 to 10.0” is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

[0147] A person of ordinary skill in the art would appreciate, in view of the present disclosure in its entirety, that each suitable feature of the various embodiments of the present disclosure may be combined or combined with each other, partially or entirely, and may be technically interlocked and operated in various suitable ways, and each embodiment may be implemented independently of each other or in conjunction with each other in any suitable manner unless otherwise stated or implied.

[0148] A pattern forming device, a semiconductor forming device and/or any other relevant devices or components according to embodiments of the present invention described herein may be implemented utilizing any suitable hardware, firmware (e.g., an application-specific integrated circuit), software, or a combination of software, firmware, and hardware. For example, the one or more components of the device may be formed on one integrated circuit (IC) chip or on separate IC chips. Further, the one or more components of the device may be implemented on a flexible printed circuit film, a tape carrier package (TCP), a printed circuit board (PCB), or formed on one substrate. Further, the one or more components of the device may be a process or thread, running on one or more processors, in one or more computing devices, executing computer program instructions and interacting with other system components for performing the various functionalities described herein. The computer program instructions are stored in a memory which may be implemented in a computing device using a standard memory device, such as, for example, a random access memory (RAM). The computer program instructions may also be stored in other non-transitory computer readable media, such as, for example, a CD-ROM, flash drive, or the like. Also, a person of skill in the art should recognize that the functionality of various computing devices may be combined or integrated into a single computing device, or the functionality of a particular computing device may be distributed across one or more other computing devices without departing from the scope of the present disclosure.

[0149] Hereinbefore, the one or more embodiments of the present disclosure have been described and illustrated, however, it is apparent to a person with ordinary skill in the art that the present disclosure is not limited to one or more embodiments as described, and may be suitably modified and transformed without departing from the spirit and scope of the present disclosure. In one or



more embodiments, the modified or transformed embodiments as such may not be understood separately from the technical ideas and aspects of the present disclosure, and the modified embodiments are within the scope of the claims and equivalents thereof of the present disclosure.

## REFERENCE NUMERALS

TABLE-US-00003 100: substrate 102: thin film 104: resist underlayer 106: photoresist layer 106a: unexposed region 106b: exposed region 108: photoresist pattern 112: organic layer pattern 110: patterned mask 114: thin film pattern

## Claims

1. A semiconductor photoresist composition, comprising a tin (Sn)-containing organometallic compound; a compound comprising at least two ketone groups; an aromatic ring compound substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup>, wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> are each independently hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group; and a solvent.
2. The semiconductor photoresist composition as claimed in claim 1, wherein the aromatic ring compound; the compound comprising at least two ketone groups are in a weight ratio of about 1:1 to about 1:10.
3. The semiconductor photoresist composition as claimed in claim 1, wherein the compound comprising at least two ketone groups is represented by Chemical Formula 1 or Chemical Formula 2: ##STR00007## wherein, in Chemical Formula 1 and Chemical Formula 2, R<sup>sup.1</sup> to R<sup>sup.6</sup> are each independently hydrogen, a halogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof, L<sup>sup.1</sup> to L<sup>sup.3</sup> are each independently a single bond, a carbonyl group, a substituted or unsubstituted C1 to C20 alkylene group, or a combination thereof, n1 and n2 are each independently one of integers of 0 to 2, and n1+n2 is greater than or equal to 1.
4. The semiconductor photoresist composition as claimed in claim 1, wherein the aromatic ring compound comprises a phenyl group substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup>; a naphthyl group substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup>; an anthracenyl group substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup>; a phenanthrene group substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup>; or a triphenylene group substituted with at least one selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup>, and R<sup>sup.13</sup> and R<sup>sup.14</sup> are each independently hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group.
5. The semiconductor photoresist composition as claimed in claim 1, wherein the aromatic ring compound is substituted with at least two selected from among —OH, —SH, and —NR<sup>sup.13</sup>R<sup>sup.14</sup>, wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> are each independently hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group.
6. The semiconductor photoresist composition as claimed in claim 5, wherein the aromatic ring compound is substituted with at least two —OH.
7. The semiconductor photoresist composition as claimed in claim 5, wherein the aromatic ring compound is substituted with at least two —SH.
8. The semiconductor photoresist composition as claimed in claim 5, wherein the aromatic ring compound is substituted with at least two —NR<sup>sup.13</sup>R<sup>sup.14</sup>, wherein R<sup>sup.13</sup> and R<sup>sup.14</sup> are each independently hydrogen, a substituted or unsubstituted C1 to C10 alkyl group, or a substituted or unsubstituted C6 to C20 aryl group.
9. The semiconductor photoresist composition as claimed in claim 1, wherein the compound

comprising at least two ketone groups is any one selected from among pentane-2,4-dione, 2,3-butanedione, 3-methyl-2,4-pentanedione, and 2,2,6,6-tetramethyl-3,5-heptanedione.

**10.** The semiconductor photoresist composition as claimed in claim 1, wherein the aromatic ring compound is any one selected from among 1,4-hydroquinone, 1,2-benzenediol, 1,3-benzenediol, benzene-1,2-dithiol, 1,4-phenylenediamine, 4-amino benzene-1-thiol, 3-aminobenzene-1-thiol, and 2-aminobenzene-1-thiol.

**11.** The semiconductor photoresist composition as claimed in claim 1, wherein the compound comprising at least two ketone groups and the aromatic ring compound are each in an amount of about 0.001 wt % to about 10 wt % about based on 100 wt % of the semiconductor photoresist composition.

**12.** The semiconductor photoresist composition as claimed in claim 1, wherein the Sn-containing organometallic compound is in an amount of about 0.5 wt % to about 30 wt % based on 100 wt % of the semiconductor photoresist composition.

**13.** The semiconductor photoresist composition as claimed in claim 1, wherein the Sn-containing organometallic compound:the compound comprising at least two ketone groups and the aromatic ring compound are in a weight ratio of about 90:10 to about 50:50.

**14.** The semiconductor photoresist composition as claimed in claim 1, wherein the semiconductor photoresist composition further comprises an additive of a surfactant, a crosslinking agent, a leveling agent, an organic acid, a quencher, or a combination thereof.

**15.** The semiconductor photoresist composition as claimed in claim 1, wherein the Sn-containing organometallic compound comprises at least one of an organic oxy group and an organic carbonyloxy group.

**16.** The semiconductor photoresist composition as claimed in claim 1, wherein the Sn-containing organometallic compound is represented by Chemical Formula 3: ##STR00008## wherein, in Chemical Formula 3, R<sup>sup.7</sup> is selected from among a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, and a substituted or unsubstituted C7 to C30 arylalkyl group, R<sup>sup.8</sup> to R<sup>sup.10</sup> are each independently a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, a substituted or unsubstituted C7 to C30 arylalkyl group, an alkoxy or aryloxy group (—OR<sup>sup.a</sup>, wherein R<sup>sup.a</sup> is a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), a carboxyl group (—O(C=O)R<sup>sup.b</sup>, wherein R<sup>sup.b</sup> is hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an alkylamido or dialkylamido group (—NR<sup>sup.c</sup>R<sup>sup.d</sup>, wherein R<sup>sup.c</sup> and R<sup>sup.d</sup> are each independently hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an amidato group (—NR<sup>sup.e</sup>(C=OR<sup>sup.f</sup>), wherein R<sup>sup.e</sup> and R<sup>sup.f</sup> are each independently hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an amidinato group (—NR<sup>sup.g</sup>C(NR<sup>sup.h</sup>)R<sup>sup.i</sup>, wherein R<sup>sup.g</sup>, R<sup>sup.h</sup>, and R<sup>sup.i</sup> are each independently

hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an alkylthio or arylthio group ( $\text{—SR.sup.j}$ , wherein R.sup.j is a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), or a thiocarboxyl group ( $\text{—S(C=O)R.sup.k}$ , wherein R.sup.k is hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), and at least one of R.sup.8 to R.sup.10 is an alkoxy or aryloxy group ( $\text{—OR.sup.a}$ , wherein R.sup.a is a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), a carboxyl group ( $\text{—O(C=O)R.sup.b}$ , wherein R.sup.b is hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an alkylamido or dialkylamido group ( $\text{—NR.sup.cR.sup.d}$ , wherein R.sup.c and R.sup.d are each independently hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an amidato group ( $\text{—NR.sup.e(C=OR.sup.f)}$ , wherein R.sup.e and R.sup.f are each independently hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an amidinato group ( $\text{—NR.sup.gC(NR.sup.h)R.sup.i}$ , wherein R.sup.g, R.sup.h, and R.sup.i are each independently hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), an alkylthio or arylthio group ( $\text{—SR.sup.j}$ , wherein R.sup.j is a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof), or a thiocarboxyl group ( $\text{—S(C=O)R.sup.k}$ , wherein R.sup.k is hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof).

**17.** The semiconductor photoresist composition as claimed in claim 16, wherein at least one of R.sup.8 to R.sup.10 is an alkoxy or aryloxy group ( $\text{—OR.sup.a}$ , wherein R.sup.a is a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof) or a carboxyl group ( $\text{—O(C=O)R.sup.b}$ , wherein R.sup.b is hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof).

**18.** The semiconductor photoresist composition as claimed in claim 16, wherein R.sup.7 is a

substituted or unsubstituted C1 to C8 alkyl group, a substituted or unsubstituted C3 to C8 cycloalkyl group, a substituted or unsubstituted C2 to C8 aliphatic unsaturated organic group comprising one or more double bonds or triple bonds, a substituted or unsubstituted C6 to C20 aryl group, a substituted or unsubstituted C4 to C20 heteroaryl group, a carbonyl group, an ethoxy group, a propoxy group, or a combination thereof, R<sup>sup.a</sup> is a substituted or unsubstituted C1 to C8 alkyl group, a substituted or unsubstituted C3 to C8 cycloalkyl group, a substituted or unsubstituted C2 to C8 alkenyl group, a substituted or unsubstituted C2 to C8 alkynyl group, a substituted or unsubstituted C6 to C20 aryl group, or a combination thereof, and R<sup>sup.b</sup> is hydrogen, a substituted or unsubstituted C1 to C8 alkyl group, a substituted or unsubstituted C3 to C8 cycloalkyl group, a substituted or unsubstituted C2 to C8 alkenyl group, a substituted or unsubstituted C2 to C8 alkynyl group, a substituted or unsubstituted C6 to C20 aryl group, or a combination thereof.

**19.** The semiconductor photoresist composition as claimed in claim 1, wherein the Sn-containing organometallic compound is represented by Chemical Formula 4 or Chemical Formula 5:

R<sup>sup.11</sup>.sub.zSnO.sub.(2-(z/2)-(x/2))(OH).sub.x      Chemical Formula 4 wherein, in Chemical Formula 4, R<sup>sup.11</sup> is a C1 to C31 hydrocarbonyl group, 0<z≤2, 0<(z+x)≤4;

R<sup>sup.12</sup>.sub.a1Sn.sub.b1X.sub.c1Y.sub.d1      Chemical Formula 5 wherein, in Chemical Formula 5, R<sup>sup.12</sup> is a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 aliphatic unsaturated organic group comprising one or more double bonds or triple bonds, a substituted or unsubstituted C6 to C30 aryl group, a substituted or unsubstituted C4 to C30 heteroaryl group, a carbonyl group, an ethylene oxide group, a propylene oxide group, or a combination thereof, X is sulfur (S), selenium (Se), or tellurium (Te), Y is —OR<sup>sup.l</sup> or —OC(=O)R<sup>sup.m</sup>, wherein R<sup>sup.l</sup> is a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof, R<sup>sup.m</sup> is hydrogen, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C3 to C20 cycloalkyl group, a substituted or unsubstituted C2 to C20 alkenyl group, a substituted or unsubstituted C2 to C20 alkynyl group, a substituted or unsubstituted C6 to C30 aryl group, or a combination thereof, and a1, b1, c1, and d1 are each independently an integer of 1 to 20.

**20.** A method of forming patterns, comprising forming an etching-objective layer on a substrate; coating the semiconductor photoresist composition as claimed in claim 1 on the etching-objective layer to form a photoresist layer; patterning the photoresist layer to form a photoresist pattern; and etching the etching-objective layer utilizing the photoresist pattern as an etching mask.

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