(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 May 2025 (30.05.2025)

WIPO | PCT

(10) International Publication Number
WO 2025/111187 A1

(51) International Patent Classification:
C23C 16/455 (2006.01) *C23C 16/52* (2006.01)
C23C 16/34 (2006.01)

(21) International Application Number:
PCT/US2024/055898

(22) International Filing Date:
14 November 2024 (14.11.2024)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/601,524 21 November 2023 (21.11.2023) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *with international search report (Art. 21(3))*

(54) **Title:** TIN PRECURSOR COMPOUNDS AND RELATED COMPOSITIONS AND METHODS

$[(R^1)N{=}C(R^2){-}E]_a\,Sn(Q)_b$,

(57) **Abstract:** Tin precursor compounds and related compositions and methods are provided. A composition comprises a compound of the formula: where: $a+b=2$ or 4; R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, or any combination thereof; E independently comprises $N(R^3)$, O, or S, where: R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; and Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof. Other precursor compounds, compositions, and methods are provided.

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TIN PRECURSOR COMPOUNDS AND RELATED COMPOSITIONS AND METHODS

FIELD

[001] The present disclosure relates to tin precursor compounds and related compositions and methods.

CROSS-REFERENCE TO RELATED APPLICATIONS

[002] This application claims the benefit under 35 USC 119 of U.S. Provisional Patent Application No. 63/601,524, filed Nov. 21, 2023, the disclosure of which is hereby incorporated herein by reference in its entirety.

BACKGROUND

[003] Some precursors are useful in the manufacture of microelectronic devices. The manufacture of such devices can involve use of deposition processes to form thin films, as well as extreme ultraviolet (EUV) lithography to form thin films.

SUMMARY

[004] Some embodiments relate to a composition. In some embodiments, the composition comprises a compound of the formula:

$$[(R^1)N{---}C(R^2){---}E]_a\,Sn(Q)_b\,,$$

[005] where:

[006] $a + b = 2$ or 4;

[007] R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

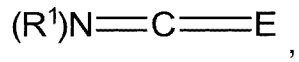
[008] R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, or any combination thereof;

[009] E independently comprises $N(R^3)$, O, or S, where:

[0010] R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; and

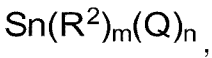
[0011] Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

[0012] Some embodiments relate to a method. In some embodiments, the method comprises contacting a compound of the formula:



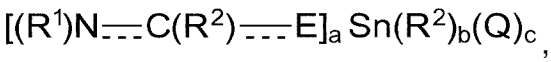
,

[0013] with a compound of the formula:



,

[0014] to form a compound of the formula:



,

[0015] where:

[0016] m + n = 2 or 4;

[0017] a + b + c = 2 or 4;

[0018] R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

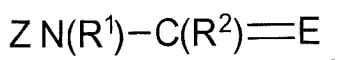
[0019] R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an amide, an alkoxide, or any combination thereof;

[0020] E independently comprises $N(R^3)$, O, or S, where:

[0021] R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; and

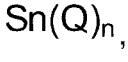
[0022] Q independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

[0023] Some embodiments relate to a method. In some embodiments, the method comprises contacting a compound of the formula:



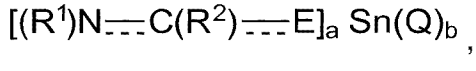
,

[0024] with a compound of the formula:



,

[0025] to form a compound of the formula:



,

[0026] where:

[0027] n is 2 or 4;

[0028] a + b = 2 or 4;

[0029] Z is a hydrogen (H) or a metal (M);

[0030] R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

[0031] R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, or any combination thereof;

[0032] E independently comprises N(R^3), O, or S, where:

[0033] R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; and

[0034] Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

DETAILED DESCRIPTION

[0035] Among those benefits and improvements that have been disclosed, other objects and advantages of this disclosure will become apparent from the following description taken in conjunction with the accompanying figures. Detailed embodiments of the present disclosure are disclosed herein; however, it is to be understood that the disclosed embodiments are merely illustrative of the disclosure that may be embodied in various forms. In addition, each of the examples given regarding the various embodiments of the disclosure which are intended to be illustrative, and not restrictive.

[0036] Any prior patents and publications referenced herein are incorporated by reference in their entireties.

[0037] Throughout the specification and claims, the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise. The phrases "in one embodiment," “in an embodiment,” and "in some embodiments" as used herein do not necessarily refer to the same embodiment(s), though it may. Furthermore, the phrases "in another embodiment" and "in some other embodiments" as used herein do not necessarily refer to a different embodiment,

although it may. All embodiments of the disclosure are intended to be combinable without departing from the scope or spirit of the disclosure.

[0038] As used herein, the term "based on" is not exclusive and allows for being based on additional factors not described, unless the context clearly dictates otherwise. In addition, throughout the specification, the meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[0039] As used herein, the term “contacting” refers to bringing two or more components into immediate or close proximity, or into direct contact.

[0040] As used herein, the term “alkyl” refers to a hydrocarbyl having from 1 to 30 carbon atoms. The alkyl may be attached via a single bond. An alkyl having *n* carbon atoms may be designated as a “C_n alkyl.” For example, a “C_3 alkyl” may include *n*-propyl and isopropyl. An alkyl having a range of carbon atoms, such as 1 to 30 carbon atoms, may be designated as a C_1-C_{30} alkyl. In some embodiments, the alkyl is linear. In some embodiments, the alkyl is branched. In some embodiments, the alkyl is substituted. In some embodiments, the alkyl is unsubstituted. In some embodiments, the alkyl comprises or is selected from the group consisting of at least one of a C_1-C_{30} alkyl, C_1-C_{29} alkyl, C_1-C_{28} alkyl, C_1-C_{27} alkyl, C_1-C_{27} alkyl, C_1-C_{26} alkyl, C_1-C_{25} alkyl, C_1-C_{24} alkyl, C_1-C_{23} alkyl, C_1-C_{22} alkyl, C_1-C_{21} alkyl, C_1-C_{20} alkyl, C_1-C_{19} alkyl, C_1-C_{18} alkyl, C_1-C_{17} alkyl, C_1-C_{16} alkyl, C_1-C_{15} alkyl, C_1-C_{14} alkyl, C_1-C_{13} alkyl, C_1-C_{12} alkyl, C_1-C_{11} alkyl, C_1-C_{10} alkyl, a C_1-C_9 alkyl, a C_1-C_8 alkyl, a C_1-C_7 alkyl, a C_1-C_6 alkyl, a C_1-C_5 alkyl, a C_1-C_4 alkyl, a C_1-C_3 alkyl, a C_1-C_2 alkyl, a C_2-C_{30} alkyl, a C_3-C_{30} alkyl, a C_4-C_{30} alkyl, a C_5-C_{30} alkyl, a C_6-C_{30} alkyl, a C_7-C_{30} alkyl, a C_8-C_{30} alkyl, a C_9-C_{30} alkyl, a C_{10}-C_{30} alkyl, a C_{11}-C_{30} alkyl, a C_{12}-C_{30} alkyl, a C_{13}-C_{30} alkyl, a C_{14}-C_{30} alkyl, a C_{15}-C_{30} alkyl, a C_{16}-C_{30} alkyl, a C_{17}-C_{30} alkyl, a C_{18}-C_{30} alkyl, a C_{19}-C_{30} alkyl, a C_{20}-C_{30} alkyl, a C_{21}-C_{30} alkyl, a C_{22}-C_{30} alkyl, a C_{23}-C_{30} alkyl, a C_{24}-C_{30} alkyl, a C_{25}-C_{30} alkyl, a C_{26}-C_{30} alkyl, a C_{27}-C_{30} alkyl, a C_{28}-C_{30} alkyl, a C_{29}-C_{30} alkyl, a C_2-C_{10} alkyl, a C_3-C_{10} alkyl, a C_4-C_{10} alkyl, a C_5-C_{10} alkyl, a C_6-C_{10} alkyl, a C_7-C_{10} alkyl, a C_8-C_{10} alkyl, a C_2-C_9 alkyl, a C_2-C_8 alkyl, a C_2-C_7 alkyl, a C_2-C_6 alkyl, a C_2-C_5 alkyl, a C_3-C_5 alkyl, or any combination thereof. In some embodiments, the alkyl comprises or is selected from the group consisting of at least one of methyl, ethyl, n-propyl, 1-methylethyl (iso-propyl), n-

butyl, iso-butyl, sec-butyl, n-pentyl, 1,1-dimethylethyl (t-butyl), n-pentyl, iso-pentyl, n-hexyl, isohexyl, 3-methylhexyl, 2-methylhexyl, heptyl, octyl, nonyl, decyl, dodecyl, octadecyl, or any combination thereof. In some embodiments, the term "alkyl" refers generally to alkyls, alkenyls, alkynyls, and/or cycloalkyls.

[0041] As used herein, the term "alkenyl" refers to a hydrocarbyl having from 1 to 30 carbon atoms and at least one carbon-carbon double bond. In some embodiments, the alkenyl comprises or is selected from the group consisting of at least one of a C_1-C_{30} alkenyl, C_1-C_{29} alkenyl, C_1-C_{28} alkenyl, C_1-C_{27} alkenyl, C_1-C_{27} alkenyl, C_1-C_{26} alkenyl, C_1-C_{25} alkenyl, C_1-C_{24} alkenyl, C_1-C_{23} alkenyl, C_1-C_{22} alkenyl, C_1-C_{21} alkenyl, C_1-C_{20} alkenyl, C_1-C_{19} alkenyl, C_1-C_{18} alkenyl, C_1-C_{17} alkenyl, C_1-C_{16} alkenyl, C_1-C_{15} alkenyl, C_1-C_{14} alkenyl, C_1-C_{13} alkenyl, C_1-C_{12} alkenyl, C_1-C_{11} alkenyl, C_1-C_{10} alkenyl, a C_1-C_9 alkenyl, a C_1-C_8 alkenyl, a C_1-C_7 alkenyl, a C_1-C_6 alkenyl, a C_1-C_5 alkenyl, a C_1-C_4 alkenyl, a C_1-C_3 alkenyl, a C_1-C_2 alkenyl, a C_2-C_{30} alkenyl, a C_3-C_{30} alkenyl, a C_4-C_{30} alkenyl, a C_5-C_{30} alkenyl, a C_6-C_{30} alkenyl, a C_7-C_{30} alkenyl, a C_8-C_{30} alkenyl, a C_9-C_{30} alkenyl, a C_{10}-C_{30} alkenyl, a C_{11}-C_{30} alkenyl, a C_{12}-C_{30} alkenyl, a C_{13}-C_{30} alkenyl, a C_{14}-C_{30} alkenyl, a C_{15}-C_{30} alkenyl, a C_{16}-C_{30} alkenyl, a C_{17}-C_{30} alkenyl, a C_{18}-C_{30} alkenyl, a C_{19}-C_{30} alkenyl, a C_{20}-C_{30} alkenyl, a C_{21}-C_{30} alkenyl, a C_{22}-C_{30} alkenyl, a C_{23}-C_{30} alkenyl, a C_{24}-C_{30} alkenyl, a C_{25}-C_{30} alkenyl, a C_{26}-C_{30} alkenyl, a C_{27}-C_{30} alkenyl, a C_{28}-C_{30} alkenyl, a C_{29}-C_{30} alkenyl, a C_2-C_{10} alkenyl, a C_3-C_{10} alkenyl, a C_4-C_{10} alkenyl, a C_5-C_{10} alkenyl, a C_6-C_{10} alkenyl, a C_7-C_{10} alkenyl, a C_8-C_{10} alkenyl, a C_2-C_9 alkenyl, a C_2-C_8 alkenyl, a C_2-C_7 alkenyl, a C_2-C_6 alkenyl, a C_2-C_5 alkenyl, a C_3-C_5 alkenyl, or any combination thereof. Examples of alkenyl groups include, without limitation, at least one of vinyl, allyl, 1-methylvinyl, 1-propenyl, 1-butenyl, 2-butenyl, 3-butenyl, 1,3-butadienyl, 2-methyl-1-propenyl, 2-methyl-2-propenyl, 1-pentenyl, 2-pentenyl, 3-pentenyl, 4-pentenyl, 1,3-pentadienyl, 2,4-pentadienyl, 1,4-pentadienyl, 3-methyl-2-butenyl, 1-hexenyl, 2-hexenyl, 3-hexenyl, 1,3-hexadienyl, 1,4-hexadienyl, 2-methylpentenyl, 1-heptenyl, 3-heptenyl, 1-octenyl, 1,3-octadienyl, 1-nonenyl, 2-nonenyl, 3-nonenyl, 1-decenyl, 3-decenyl, 1-undecenyl, oleyl, linoleyl, linolenyl, or any combination thereof.

[0042] As used herein, the term “alkynyl” refers to a hydrocarbyl having from 1 to 30 carbon atoms and at least one carbon-carbon triple bond. In some embodiments, the alkynyl comprises or is selected from the group consisting of at least one of a C_1-C_{30} alkynyl, C_1-C_{29} alkynyl, C_1-C_{28} alkynyl, C_1-C_{27} alkynyl, C_1-C_{27} alkynyl, C_1-C_{26} alkynyl, C_1-C_{25} alkynyl, C_1-C_{24} alkynyl, C_1-C_{23} alkynyl, C_1-C_{22} alkynyl, C_1-C_{21} alkynyl, C_1-C_{20} alkynyl, C_1-C_{19} alkynyl, C_1-C_{18} alkynyl, C_1-C_{17} alkynyl, C_1-C_{16} alkynyl, C_1-C_{15} alkynyl, C_1-C_{14} alkynyl, C_1-C_{13} alkynyl, C_1-C_{12} alkynyl, C_1-C_{11} alkynyl, C_1-C_{10} alkynyl, a C_1-C_9 alkynyl, a C_1-C_8 alkynyl, a C_1-C_7 alkynyl, a C_1-C_6 alkynyl, a C_1-C_5 alkynyl, a C_1-C_4 alkynyl, a C_1-C_3 alkynyl, a C_1-C_2 alkynyl, a C_2-C_{30} alkynyl, a C_3-C_{30} alkynyl, a C_4-C_{30} alkynyl, a C_5-C_{30} alkynyl, a C_6-C_{30} alkynyl, a C_7-C_{30} alkynyl, a C_8-C_{30} alkynyl, a C_9-C_{30} alkynyl, a C_{10}-C_{30} alkynyl, a C_{11}-C_{30} alkynyl, a C_{12}-C_{30} alkynyl, a C_{13}-C_{30} alkynyl, a C_{14}-C_{30} alkynyl, a C_{15}-C_{30} alkynyl, a C_{16}-C_{30} alkynyl, a C_{17}-C_{30} alkynyl, a C_{18}-C_{30} alkynyl, a C_{19}-C_{30} alkynyl, a C_{20}-C_{30} alkynyl, a C_{21}-C_{30} alkynyl, a C_{22}-C_{30} alkynyl, a C_{23}-C_{30} alkynyl, a C_{24}-C_{30} alkynyl, a C_{25}-C_{30} alkynyl, a C_{26}-C_{30} alkynyl, a C_{27}-C_{30} alkynyl, a C_{28}-C_{30} alkynyl, a C_{29}-C_{30} alkynyl, a C_2-C_{10} alkynyl, a C_3-C_{10} alkynyl, a C_4-C_{10} alkynyl, a C_5-C_{10} alkynyl, a C_6-C_{10} alkynyl, a C_7-C_{10} alkynyl, a C_8-C_{10} alkynyl, a C_2-C_9 alkynyl, a C_2-C_8 alkynyl, a C_2-C_7 alkynyl, a C_2-C_6 alkynyl, a C_2-C_5 alkynyl, a C_3-C_5 alkynyl, or any combination thereof. Examples of alkynyl groups include, without limitation, at least one of ethynyl, propynyl, n-butynyl, n-pentynyl, 3-methyl-1-butynyl, n-hexynyl, methyl-pentynyl, or any combination thereof.

[0043] As used herein, the term “cycloalkyl” refers to a non-aromatic carbocyclic ring having from 3 to 8 carbon atoms in the ring. The term includes a monocyclic non-aromatic carbocyclic ring and a polycyclic non-aromatic carbocyclic ring. The term "monocyclic," when used as a modifier, refers to a cycloalkyl having a single cyclic ring structure. The term "polycyclic," when used as a modifier, refers to a cycloalkyl having more than one cyclic ring structure, which may be fused, bridged, spiro, or otherwise bonded ring structures. For example, two or more cycloalkyls may be fused, bridged, or fused and bridged to obtain the polycyclic non-aromatic carbocyclic ring. In some embodiments, the cycloalkyl may comprise, consist of, or consist essentially of, or may be selected from the group consisting of, at least

one of cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl, or any combination thereof.

[0044] As used herein, the term "aryl" refers to a monocyclic or polycyclic aromatic hydrocarbon. The number of carbon atoms of the aryl may be in a range of 5 carbon atoms to 100 carbon atoms. In some embodiments, the aryl has 5 to 20 carbon atoms. For example, in some embodiments, the aryl has 6 to 8 carbon atoms, 6 to 10 carbon atoms, 6 to 12 carbon atoms, 6 to 15 carbon atoms, or 6 to 20 carbon atoms. The term "monocyclic," when used as a modifier, refers to an aryl having a single aromatic ring structure. The term "polycyclic," when used as a modifier, refers to an aryl having more than one aromatic ring structure, which may be fused, bridged, spiro, or otherwise bonded ring structures. In some embodiments, the aryl is —C_6H_5.

[0045] As used herein, the term “amino” and/or “amine” refers to a functional group of formula —$N(R^aR^b)$, wherein R^a and R^b are independently a hydrogen, an alkyl (as defined herein), an aminoalkyl (as defined herein), or a silyl (as defined herein), or R^a and R^b are bonded to each other to form a C_3-C_{20} N-heterocycle. In some embodiments, the amino may comprise an alkylamino or a dialkylamino. In some embodiments, the amino may comprise at least one of methylamino, dimethylamino, ethylamino, diethylamino, isopropylamino, di-isopropylamino, butylamino, sec-butylamino, tert-butylamino, di-sec-butylamino, isobutylamino, di-isobutylamino, di-tert-pentylamino, ethylmethylamino, isopropyl-n-propylamino, or any combination thereof. Examples of the alkylaminos may include, without limitation, one or more of the following: primary alkylaminos, such as, for example and without limitation, methylamino, ethylamino, n-propylamino, isopropylamino, n-butylamino, sec-butylamino, isobutylamino, t-butylamino, pentylamino, 2-aminopentane, 3-aminopentane, 1-amino-2-methylbutane, 2-amino-2-methylbutane, 3-amino-2-methylbutane, 4-amino-2-methylbutane, hexylamino, 5-amino-2-methylpentane, heptylamino, octylamino, nonylamino, decylamino, undecylamino, dodecylamino, tridecylamino, tetradecylamino, pentadecylamino, hexadecylamino, heptadecylamino, and octadecylamino; and secondary alkylaminos, such as, for example and without limitation, dimethylamino,

diethylamino, dipropylamino, diisopropylamino, dibutylamino, diisobutylamino, di-sec-butylamino, di-t-butylamino, dipentylamino, dihexylamino, diheptylamino, dioctylamino, dinonylamino, didecylamino, methylethylamino, methylpropylamino, methylisopropylamino, methylbutylamino, methylisobutylamino, methyl-sec-butylamino, methyl-t-butylamino, methylamylamino, methylisoamylamino, ethylpropylamino, ethylisopropylamino, ethylbutylamino, ethylisobutylamino, ethyl-sec-butylamino, ethylamino, ethylisoamylamino, propylbutylamino, and propylisobutylamino. Unless otherwise provided herein, the terms "amine" and "amino" may be used interchangeably throughout this disclosure.

[0046] As used herein, the term "alkoxy" or "alkoxide" refers to a functional group of formula —OR^c, wherein R^c is an alkyl (as defined herein), a silylalkyl, a cycloalkyl, or an aryl. In some embodiments, the alkoxy may comprise, consist of, or consist essentially of, or may selected from the group consisting of, at least one of methoxy, ethoxy, methoxy, ethoxy, n-propoxy, 1-methylethoxy (isopropoxy), n-butoxy, iso-butoxy, sec-butoxy, tert-butoxy, or any combination thereof.

[0047] As used herein, the term "silyl" refers to a functional group of formula —$Si(R^eR^fR^g)$, where each of R^e, R^f, and R^g is independently a hydrogen or an alkyl, as defined herein. In some embodiments, the silyl is a functional group of formula —SiH_3. In some embodiments, the silyl is a functional group of formula —SiR^eH_2, where R^e is not hydrogen. In some embodiments, the silyl is a functional group of formula —SiR^eR^fH, where R^e and R^f are not hydrogen. In some embodiments, the silyl is a functional group of the formula —$Si(R^eR^fR^g)$, where R^e, R^f, and R^g are not hydrogen. In some embodiments, the silyl is a functional group of formula —$Si(CH_3)_3$.

[0048] As used herein, the term "alkoxyalkyl" refers to an alkyl as defined herein, wherein at least one of the hydrogen atoms of the alkyl is replaced with an alkoxy as defined herein. In some embodiments, the term "alkoxyalkyl" refers to a functional group of formula —(alkyl)OR^a, wherein the alkyl is defined above and wherein the R^a is defined above. In some embodiments, the alkoxyalkyl is a functional group of formula —$(CH_2)_nOR^a$, where n is 1 to 10 and R^a is defined above. In some embodiments, the alkoxyalkyl is a functional group of the formula —$CH_2CH_2OCH_3$.

[0049] As used herein, the term "aralkyl" refers to an alkyl as defined herein, wherein at least one of the hydrogen atoms of the alkyl is replaced with an aryl as defined herein. In some embodiments, the term "aralkyl" refers to a functional group of formula —(alkyl)(aryl), wherein the alkyl is defined herein and the aryl is defined herein. In some embodiments, the aralkyl is —$CH_2(C_6H_5)$.

[0050] As used herein, the term "aminoalkyl" refers to an alkyl as defined herein, wherein at least one of the hydrogen atoms of the alkyl is replaced with an amino as defined herein. In some embodiments, the term "aminoalkyl" refers to a functional group of formula —(alkyl)$N(R^bR^cR^d)$, wherein the alkyl is defined above and wherein R^b, R^c, and R^d are defined above. In some embodiments, the aminoalkyl is —$CH_2N(CH_3)_2$. In some embodiments, the aminoalkyl is —$(CH_2)_3N(CH_3)_2$. In some embodiments, the aminoalkyl is aminomethyl (—CH_2NH_2). In some embodiments, the aminoalkyl is N,N-dimethylaminoethyl (—$CH_2CH_2N(CH_3)_2$). In some embodiments, the aminoalkyl is 3-(N-cyclopropylamino)propyl (—$CH_2CH_2CH_2NH$—Pr).

[0051] As used herein, the term "silylalkyl" refers to an alkyl as defined herein, wherein at least one of the hydrogen atoms of the alkyl is replaced with a silyl as defined herein. In some embodiments, the term "silylalkyl" refers to a functional group of formula —(alkyl)$Si(R^eR^fR^g)$, wherein the alkyl is defined above and wherein R^e, R^f, and R^g are defined above. In some embodiments, the silylalky is a functional group of formula —$(CH_2)_mSi(R^eR^fR^g)$, where m is 1 to 10 and where R^e, R^f, and R^g are defined above. In some embodiments, the silylalkyl is a functional group of formula —$CH_2Si(CH_3)_3$.

[0052] As used herein, the term "haloalkyl" refers to an alkyl as defined here, wherein at least one of the hydrogen atoms of the alkyl is replaced with a halide as defined herein. In some embodiments, the haloalkyl comprises a fluoroalkyl. In some embodiments, the fluoroalkyl comprises at least one of —CH_2CF_3, —$CH(CF_3)_2$, —CH_2F, —CH_2CH_2F, —CF_3, —CF_2CF_3, or any combination thereof.

[0053] As used herein, the term "halogen" refers to a —Cl, —Br, —I, or —F.

[0054] As used herein, the term "metal" refers to at least one of an alkali metal, an alkaline earth metal, a transition metal, a post-transition metal, or any combination thereof. In some embodiments, the metal comprises a metal cation. In some embodiments,

the metal cation comprises at least one of a lithium cation, a sodium cation, a potassium cation, a rubidium cation, a cesium cation, a francium cation, a beryllium cation, a magnesium cation, a calcium cation, a strontium cation, a barium cation, a radium cation, a scandium cation, a titanium cation, a vanadium cation, a chromium cation, a manganese cation, an iron cation, a cobalt cation, a nickel cation, a copper cation, a zinc cation, a yttrium cation, a zirconium cation, a niobium cation, a molybdenum cation, a technetium cation, a ruthenium cation, a rhodium cation, a palladium cation, a silver cation, a cadmium cation, a hafnium cation, a tantalum cation, a tungsten cation, a rhenium cation, an osmium cation, an iridium cation, a platinum cation, a gold cation, a mercury cation, an aluminum cation, a gallium cation, an indium cation, tin cation, a thallum cation, a lead cation, a bismuth cation, a polonium cation, or any combination thereof. The charge(s) of the metal cations are known and, for simplicity, thus are not repeated here; however, it will be appreciated that the metal cations can have any known charge.

[0055] Some embodiments relate to compositions useful in extreme-ultraviolet (EUV) lithography, among other applications, and related methods. The compositions disclosed herein comprise tin precursor compounds. The tin precursor compounds may be used to form tin-containing films useful in the fabrication of microelectronic devices, including semiconductor devices. In some embodiments, for example, the tin precursor compounds comprise tin (IV) monoalkyl species with at least one mono-ionic bidentate ligand. The precursor compositions may be used as deposition precursors for generating tin-containing films. The tin-containing films may be used in dry resist applications or as reflective coatings for extreme-ultraviolet (EUV) lithography, among others. The precursor compositions may be formed according to the methods disclosed herein in high yield and high purity, while also minimizing the number of steps required to produce the precursor compositions.

[0056] The tin-containing films may also be formed according to the methods disclosed herein. That is, the tin-containing films disclosed herein may be formed by one or more deposition processes that utilize the precursor compositions. Examples of deposition processes include, without limitation, at least one of a chemical vapor

deposition (CVD) process, a digital or pulsed chemical vapor deposition process, a plasma-enhanced cyclical chemical vapor deposition process (PECCVD), a flowable chemical vapor deposition process (FCVD), an atomic layer deposition (ALD) process, a thermal atomic layer deposition, a plasma-enhanced atomic layer deposition (PEALD) process, a metal organic chemical vapor deposition (MOCVD) process, a plasma-enhanced chemical vapor deposition (PECVD) process, or any combination thereof.

[0057] Some embodiments relate to a composition. In some embodiments, the composition comprises a precursor compound. For example, in some embodiments, the composition comprises a compound of the formula:

$$[(R^1)N\text{---}C(R^2)\text{---}E]_a Sn(Q)_b ,$$

[0058] where:

[0059] $a + b = 2$ or 4;

[0060] R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

[0061] R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, or any combination thereof;

[0062] E independently comprises $N(R^3)$, O, or S, where:

[0063] R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

[0064] Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

[0065] In some embodiments, E is $N(R^3)$; Q is independently a halogen; a is 1; and b is 3.

[0066] In some embodiments, E is $N(R^3)$; Q independently comprises at least one of a halogen, an amine, or any combination thereof; a is 2; and b is 2.

[0067] In some embodiments, E is O or S; Q is independently a halogen; a is 1; and b is 3.

[0068] In some embodiments, E is O or S; Q independently comprises at least one of a halogen, an amine, or any combination thereof; a is 2; and b is 2.

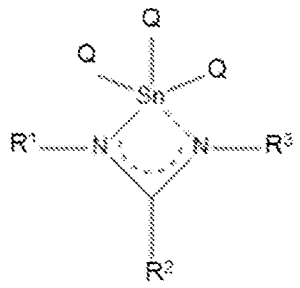
[0069] In some embodiments, E is $N(R^3)$; Q is a halogen; a is 1; and b is 1.

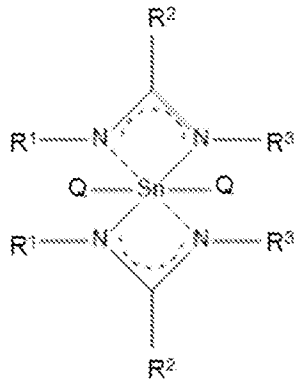
[0070] In some embodiments, E is N(R^3); a is 2; and b is 0.

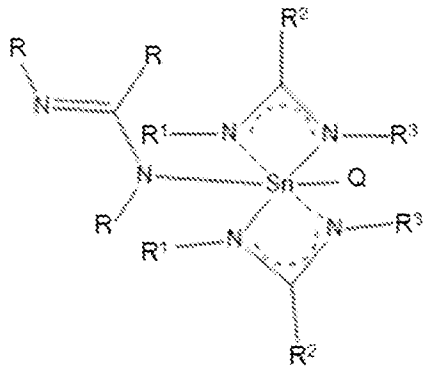
[0071] In some embodiments, E is O or S; Q is a halogen; a is 1; and b is 1.

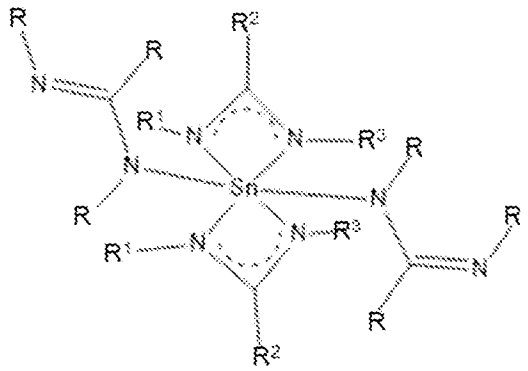
[0072] In some embodiments, E is O or S; a is 2; and b is 0.

[0073] In some embodiments, the compound comprises at least one of the following:

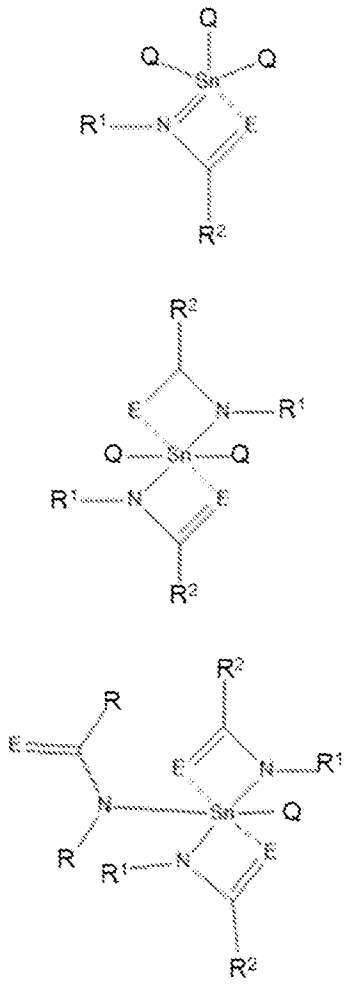


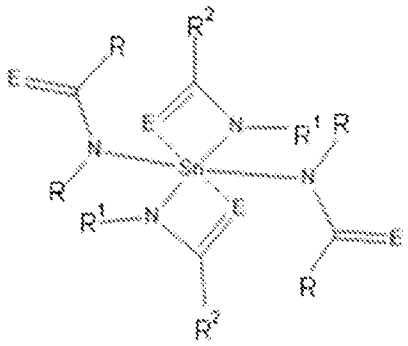




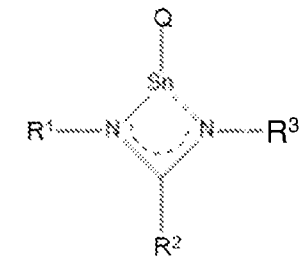


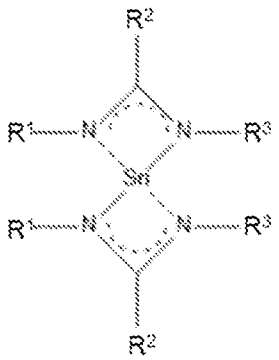
[0074] In some embodiments, the compound comprises at least one of the following:



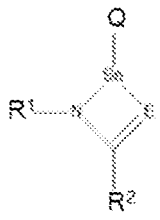


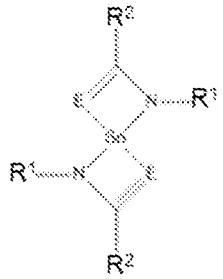
[0075] In some embodiments, the compound comprises at least one of the following:





[0076] In some embodiments, the compound comprises at least one of the following:





[0077] In some embodiments, the compound is present in the composition at a purity of 95% to 99.9999%, or any range or subrange between 95% and 99.9999%. In some embodiments, the compound is present in the composition at a purity of 96% to 99.9999%, 97% to 99.9999%, 98% to 99.9999%, 99% to 99.9999%, 99.9% to 99.9999%, 99.99% to 99.9999%, 99.999% to 99.9999%, 95% to 99.999%, 95% to 99.99%, 95% to 99.9%, 95% to 99%, 95% to 98%, 95% to 97%, or 95% to 96%.

[0078] Some embodiments relate to a method of forming a precursor compound. In some embodiments, the method of forming a precursor compound comprises contacting a compound of the formula:

$$(R^1)N{=}C{=}E,$$

[0079] with a compound of the formula:

$$Sn(R^2)_m(Q)_n,$$

[0080] to form a compound of the formula:

$$[(R^1)N{=}C(R^2){=}E]_a\,Sn(R^2)_b(Q)_c,$$

[0081] where:

[0082] $m + n = 2$ or 4;

[0083] $a + b + c = 2$ or 4;

[0084] R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

[0085] R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an amide, an alkoxide, or any combination thereof;

[0086] E independently comprises $N(R^3)$, O, or S, where:

[0087] R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

[0088] Q independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

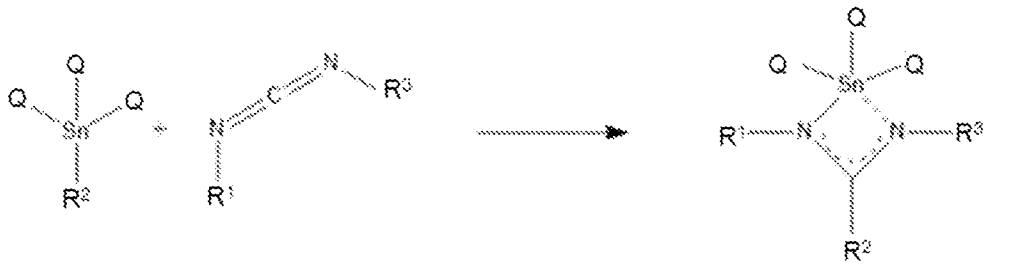
[0089] In some embodiments, E is N(R^3); Q is independently a halogen; m is 1; n is 3; a is 1; b is 1; and c is 3.

[0090] In some embodiments, E is O or S; Q is independently a halogen; m is 1; n is 3; a is 1; b is 1; and c is 3.

[0091] In some embodiments, E is N(R^3); Q is a halogen; m is 1; n is 1; a is 1; b is 1; and c is 1.

[0092] In some embodiments, E is O or S; Q is a halogen; m is 1; n is 1; a is 1; b is 1; and c is 1.

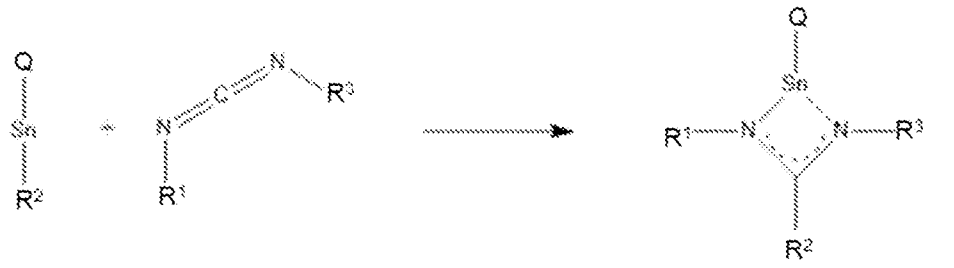
[0093] In some embodiments, the method comprises:



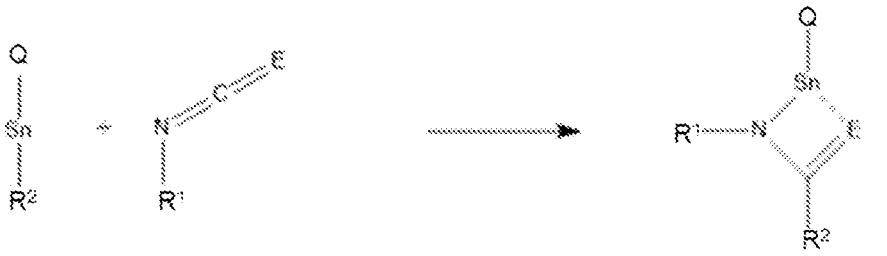
[0094] In some embodiments, the method comprises:



[0095] In some embodiments, the method comprises:



[0096] In some embodiments, the method comprises:



[0097] In some embodiments, the compound is produced at a purity of 95% to 99.9999%, or any range or subrange between 95% and 99.9999%. In some embodiments, the compound is present in the composition at a purity of 96% to 99.9999%, 97% to 99.9999%, 98% to 99.9999%, 99% to 99.9999%, 99.9% to 99.9999%, 99.99% to 99.9999%, 99.999% to 99.9999%, 95% to 99.999%, 95% to 99.99%, 95% to 99.9%, 95% to 99%, 95% to 98%, 95% to 97%, or 95% to 96%.

[0098] Some embodiments relate to a method of forming a precursor compound. In some embodiments, the method of forming a precursor compound comprises contacting a compound of the formula:

$$Z\,N(R^1)-C(R^2)=\!=E,$$

[0099] with a compound of the formula:

$$Sn(Q)_n,$$

[00100] to form a compound of the formula:

$$[(R^1)N=\!=C(R^2)=\!=E]_a\,Sn(Q)_b,$$

[00101] where:

[00102] n is 2 or 4;

[00103] a + b = 2 or 4;

[00104] Z is a hydrogen (H) or a metal (M);

[00105] R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

[00106] R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, or any combination thereof;

[00107] E independently comprises $N(R^3)$, O, or S, where:

[00108] R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

[00109] Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

[00110] In some embodiments, the contacting further forms a compound of the formula MQ.

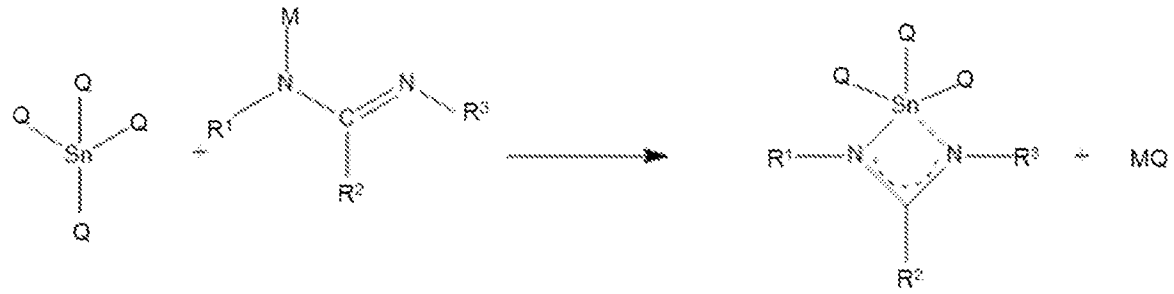
[00111] In some embodiments, Z is a metal; E is $N(R^3)$; n is 4; a is 1; and b is 3.

[00112] In some embodiments, Z is a metal; E is O or S; n is 4; a is 1; and b is 3.

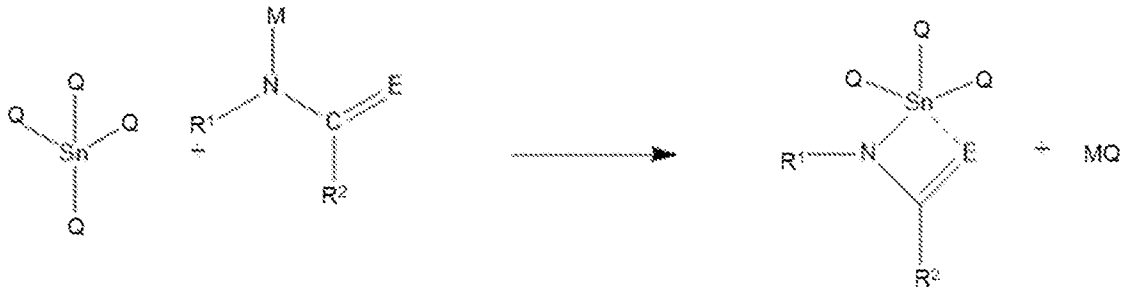
[00113] In some embodiments, Z is a metal; E is $N(R^3)$; n is 2; a is 1; and b is 1.

[00114] In some embodiments, Z is a metal; E is O or S; n is 2; a is 1; and b is 1.

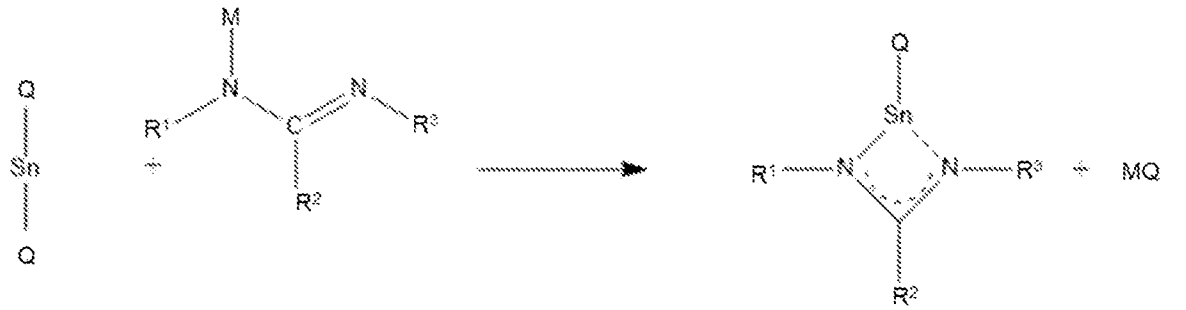
[00115] In some embodiments, the method comprises:



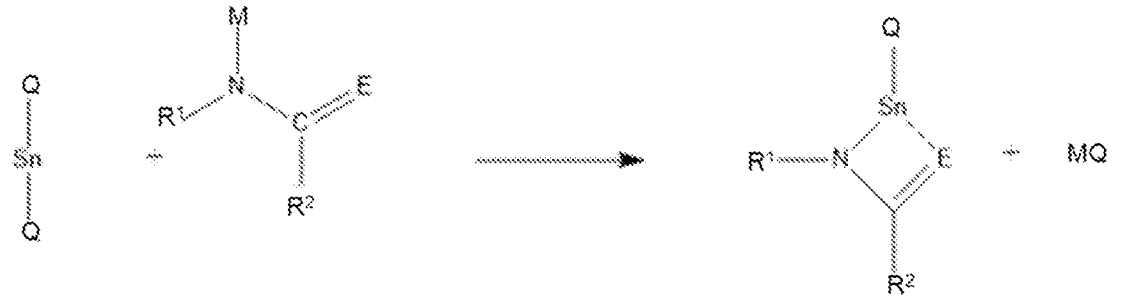
[00116] In some embodiments, the method comprises:



[00117] In some embodiments, the method comprises:



[00118] In some embodiments, the method comprises:



[00119] In some embodiments, the method comprises: the contacting further forms a compound of the formula HZ.

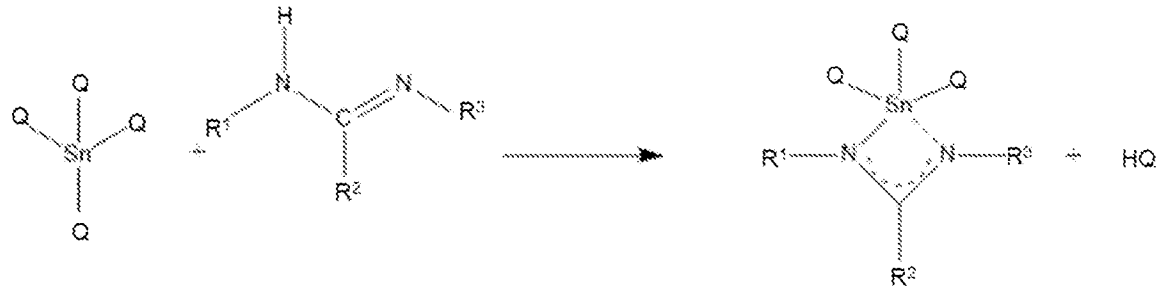
[00120] In some embodiments, Z is a metal; E is $N(R^3)$; n is 4; a is 1; and b is 3.

[00121] In some embodiments, Z is a metal; E is O or S; n is 4; a is 1; and b is 3.

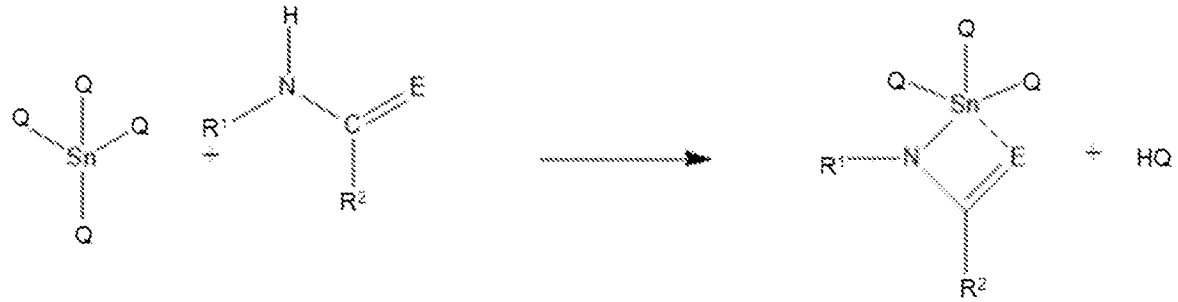
[00122] In some embodiments, Z is a metal; E is $N(R^3)$; n is 2; a is 1; and b is 1.

[00123] In some embodiments, Z is a metal; E is O or S; n is 2; a is 1; and b is 1.

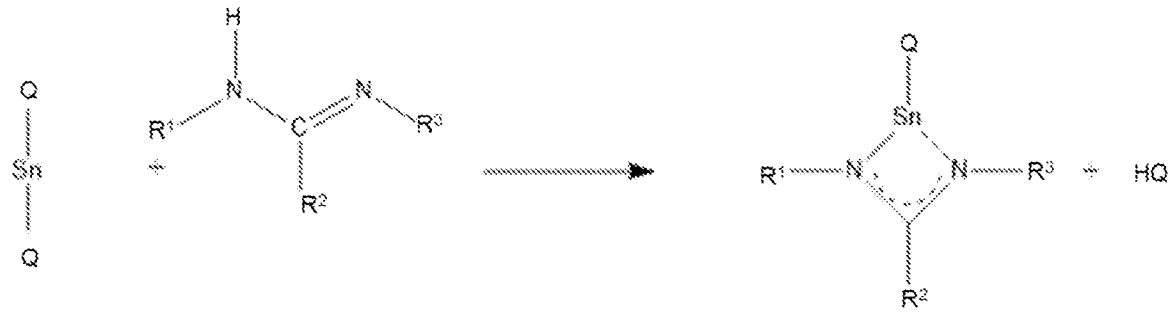
[00124] In some embodiments, the method comprises:



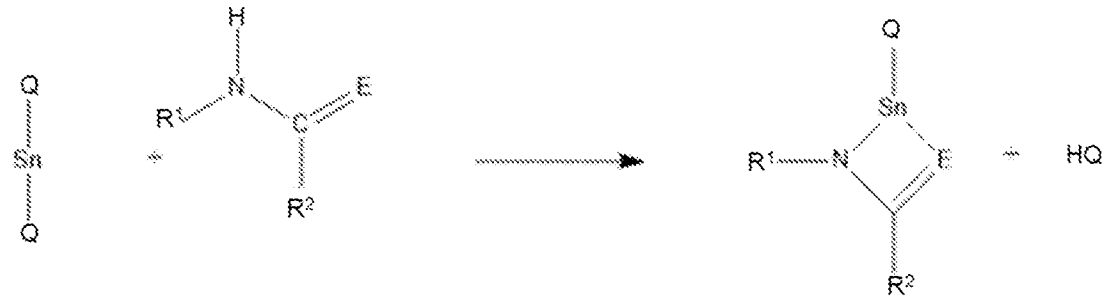
[00125] In some embodiments, the method comprises:



[00126] In some embodiments, the method comprises:



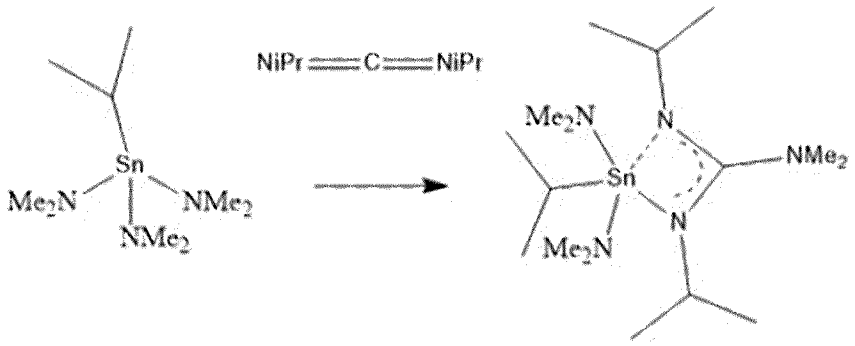
[00127] In some embodiments, the method comprises:



[00128] In some embodiments, the compound is present in the composition at a purity of 95% to 99.9999%, or any range or subrange between 95% and 99.9999%. In some embodiments, the compound is present in the composition at a purity of 96% to 99.9999%, 97% to 99.9999%, 98% to 99.9999%, 99% to 99.9999%, 99.9% to 99.9999%, 99.99% to 99.9999%, 99.999% to 99.9999%, 95% to 99.999%, 95% to 99.99%, 95% to 99.9%, 95% to 99%, 95% to 98%, 95% to 97%, or 95% to 96%.

EXAMPLE 1

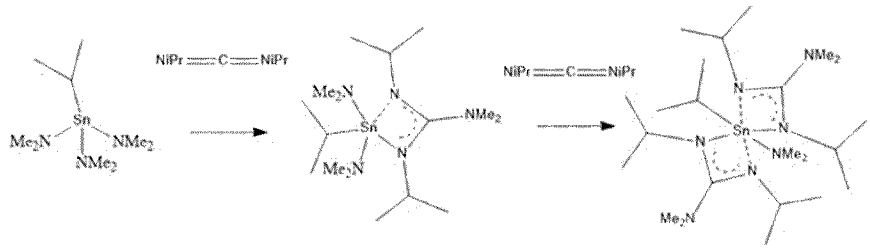
Synthesis of $iPrSn(NMe_2)_2[(iPr)N{=}C(NMe_2){=}N(iPr)]$



[00129] A tin (IV) compound of the formula $Sn(N(CH_3)_2)_3(iPr)$ (5g, 17.0 mmol) was diluted in 10 mL of anhydrous hexanes and cooled to –10C. To this solution a carbodiimide of the formula N(iPr)=C=N(iPr) (2.14g, 17.0 mmol) was added slowly dropwise. The solvent then was removed under vacuum and yielded a clear viscous liquid: mass 7.3g, yield:100%. Purity: 97.1% by ^{119}Sn-NMR. $^{119}Sn\{^1H\}$-NMR (149 MHz, C_6D_6, 298K): -199.9 ppm; $^1H\{^{13}C\}$-NMR (400 MHz, C_6D_6, 298K): 1.06 (12H), 1.41 (6H), 1.75 (1H), 2.52 (6H), 2.75 (12 H), 3.46 (2H); $^{13}C\{^1H\}$-NMR (100 MHz, C_6D_6, 298K) : 21.04, 24.58, 26.45, 40.36, 43.81, 46.62, 164.79.

EXAMPLE 2

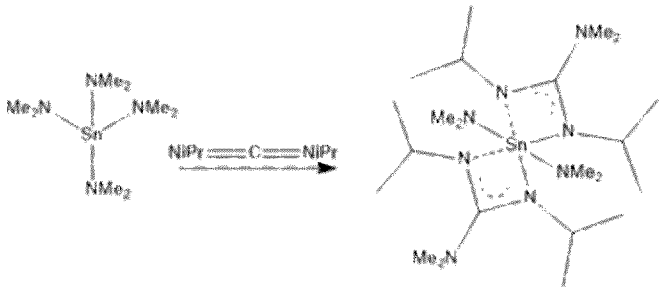
Synthesis of $iPrSn(NMe_2)[(iPr)N{=}C(NMe_2){=}N(iPr)]_2$



[00130] A tin (IV) compound of the formula $Sn(N(CH_3)_2)_3(iPr)$ (1g, 3.40 mmol) was diluted in 1 mL of anhydrous C_6D_6. To this solution a carbodiimide of the formula N(iPr)=C=N(iPr) (1.28g, 10.2 mmol) was added slowly dropwise. $^{119}Sn\{^1H\}$-NMR (149 MHz, C_6D_6, 298K): -406.2 ppm.

EXAMPLE 3

Synthesis of $Sn(NMe_2)_2[(iPr)N{=}C(NMe_2){=}N(iPr)]_2$



[00131] A tin (IV) compound of the formula $Sn(N(CH_3)_2)_4$ (5g, 16.9 mmol) was diluted in 50 mL of anhydrous hexanes. To this solution a carbodiimide of the formula N(iPr)=C=N(iPr) (2.14g, 17.0 mmol) was added slowly dropwise; an exotherm was observed. The rate of addition was such to maintain a solution temperature below 30C. The reaction solution was stirred overnight and the following day the solvent was removed under vacuum. A sticky solid was obtained. The material was dissolved in ~ 7 mL of hexanes and cooled to –35C. A crystalline white solid was collected: mass 7.7g, yield:83%. Melting Point: 61.1 °C (by DSC) Purity: 100% by ^{119}Sn-NMR. $^{119}Sn\{^1H\}$-NMR (149 MHz, NEAT, 298K): -478.4 ppm; $^1H\{^{13}C\}$-NMR (400 MHz, C_6D_6, 298K): 1.18-1.38 (multiple d, 24H), 2.52 (s, 12H),

2.99 (s, 12H), 3.55-3.72 (m, 4H); $^{13}C\{^{1}H\}$-NMR (100 MHz, C_6D_6, 298K) : 23.20, 24.28, 24.54, 25.51, 40.34, 44.29, 46.85, 165.74.

[00132] ASPECTS

[00133] Various Aspects are described below. It is to be understood that any one or more of the features recited in the following Aspect(s) can be combined with any one or more other Aspect(s).

Aspect 1. A composition comprising:

a compound of the formula:

$$[(R^1)N{=}C(R^2){-}E]_a\,Sn(Q)_b,$$

where:

$a + b = 2$ or 4;

R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, or any combination thereof;

E independently comprises $N(R^3)$, O, or S, where:

R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

Aspect 2. The composition according to Aspect 1,

wherein:

E is $N(R^3)$;

Q is independently a halogen;

a is 1;

b is 3.

Aspect 3. The composition according to Aspect 1,

wherein:

E is $N(R^3)$;

Q independently comprises at least one of a halogen, an amine, or any combination thereof;

a is 2; and

b is 2.

Aspect 4. The composition according to Aspect 1,

wherein:

E is O or S;

Q is independently a halogen;

a is 1; and

b is 3.

Aspect 5. The composition according to Aspect 1,

wherein:

E is O or S;

Q independently comprises at least one of a halogen, an amine, or any combination thereof;

a is 2; and

b is 2.

Aspect 6. The composition according to Aspect 1,

wherein:

E is $N(R^3)$;

Q is a halogen;

a is 1; and

b is 1.

Aspect 7. The composition according to Aspect 1,

wherein:

E is $N(R^3)$;

a is 2; and

b is 0.

Aspect 8. The composition according to Aspect 1,

wherein:

E is O or S;

Q is a halogen;

a is 1; and

b is 1.

Aspect 9. The composition according to Aspect 1,

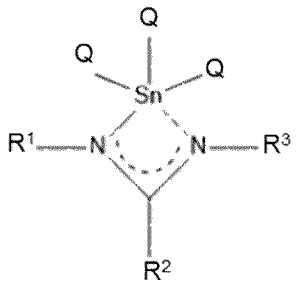
wherein:

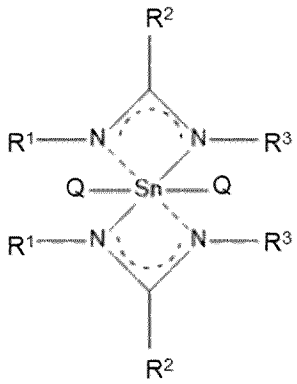
E is O or S;

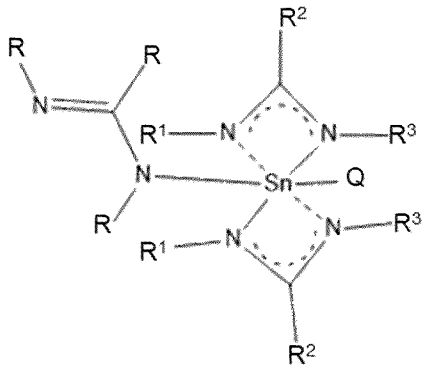
a is 2; and

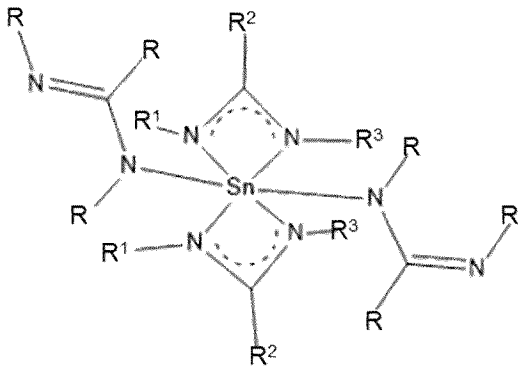
b is 0.

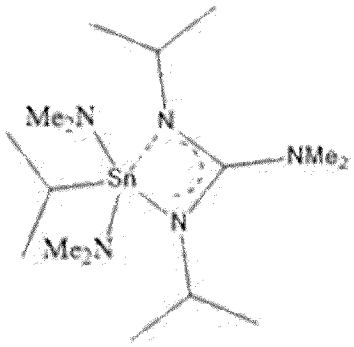
Aspect 10. The composition according to Aspect 1, wherein the compound comprises at least one of the following:

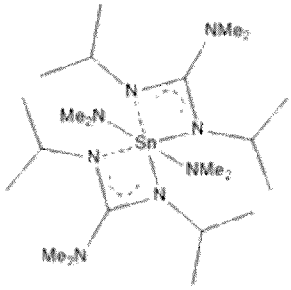

Q
Q
Q
Sn
R1
N
N
R3
R2

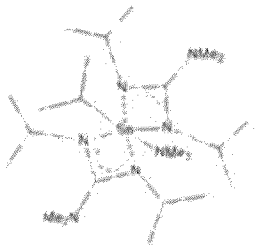

R2
R1
N
N
R3
Q
Sn
Q
R1
N
N
R3
R2


R2
R
R
N
R1
N
N
R3
N
Sn
Q
R
R1
N
N
R3
R2

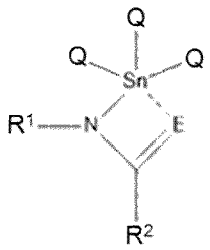

R
R2
N
R
R1
N
N
R3
N
R
Sn
N
R
R1
N
N
R3
R
N
R
R2

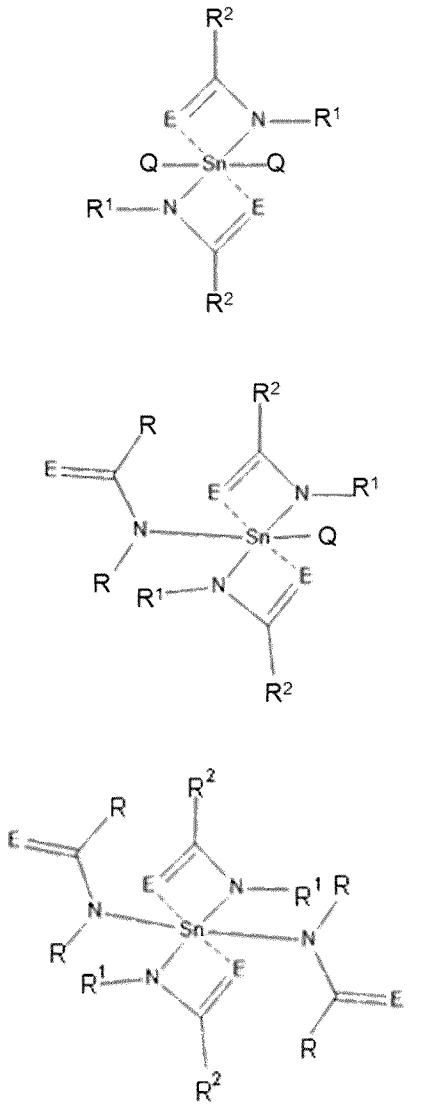




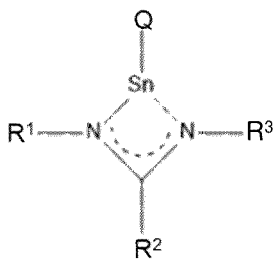


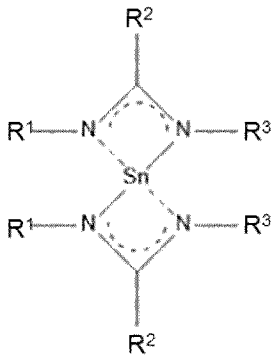
Aspect 11. The composition according to Aspect 1, wherein the compound comprises at least one of the following:





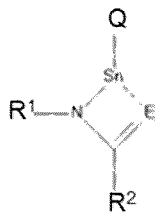
Aspect 12. The composition according to Aspect 1, wherein the compound comprises at least one of the following:

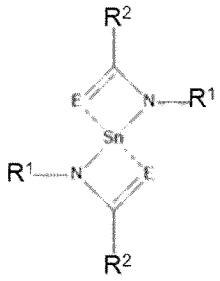




.

Aspect 13. The composition according to Aspect 1, wherein the compound comprises at least one of the following:





.

Aspect 14. A method comprising:

contacting a compound of the formula:

$$(R^1)N{=}C{=}E,$$

with a compound of the formula:

$$Sn(R^2)_m(Q)_n,$$

to form a compound of the formula:

$$[(R^1)N{-}C(R^2){-}E]_a\,Sn(R^2)_b(Q)_c,$$

where:

$m + n = 2$ or 4;

$a + b + c = 2$ or 4;

R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an amide, an alkoxide, or any combination thereof;

E independently comprises $N(R^3)$, O, or S, where:

R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

Q independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

Aspect 15. The method according to Aspect 14,

wherein:

E is $N(R^3)$;

Q is independently a halogen;

m is 1;

n is 3;

a is 1;

b is 1; and

c is 3.

Aspect 16. The method according to Aspect 14,

wherein:

E is O or S;

Q is independently a halogen;

m is 1;

n is 3;

a is 1;

b is 1; and

c is 3.

Aspect 17. The method according to Aspect 14,

wherein:

E is $N(R^3)$;

Q is a halogen;

m is 1;

n is 1;

a is 1;

b is 1; and

c is 1.

Aspect 18. The method according to Aspect 14,

wherein:

E is O or S;

Q is a halogen;

m is 1;

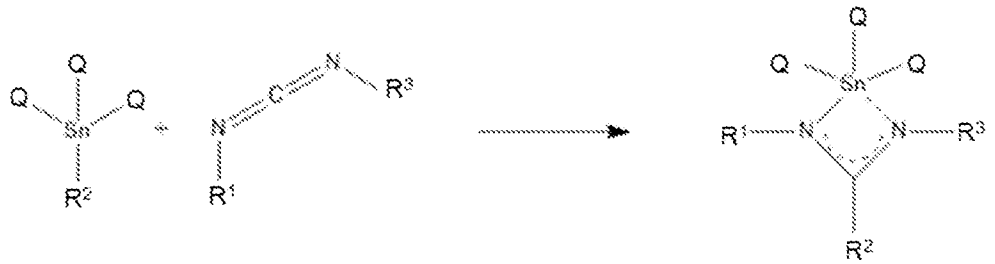
n is 1;

a is 1;

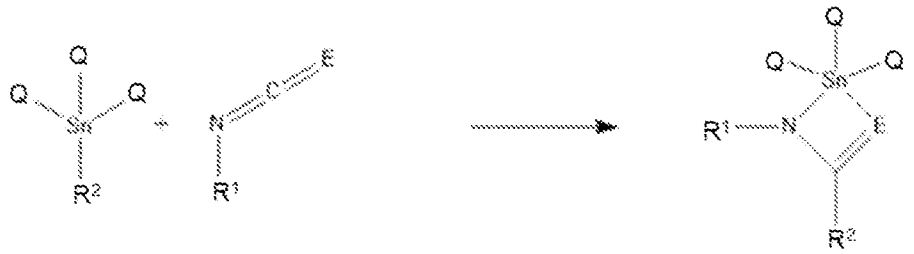
b is 1; and

c is 1.

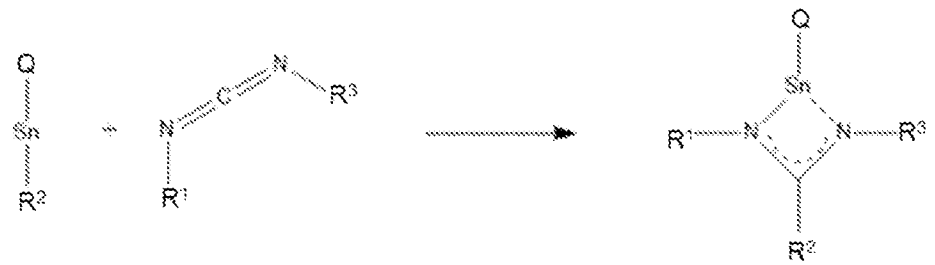
Aspect 19. The method according to Aspect 14, wherein the method comprises:



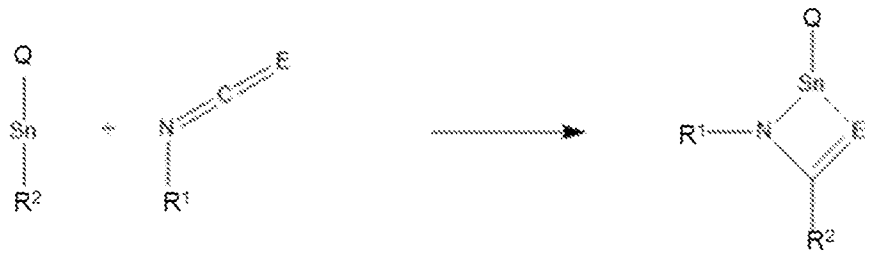
Aspect 20. The method according to Aspect 14, wherein the method comprises:



Aspect 21. The method according to Aspect 14, wherein the method comprises:

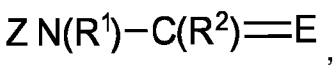


Aspect 22. The method according to Aspect 14, wherein the method comprises:

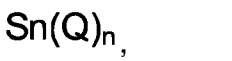


Aspect 23. A method comprising:

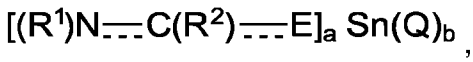
contacting a compound of the formula:



with a compound of the formula:



to form a compound of the formula:



where:

n is 2 or 4;

a + b = 2 or 4;

Z is a hydrogen (H) or a metal (M);

R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, or any combination thereof;

E independently comprises $N(R^3)$, O, or S, where:

R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

Aspect 24. The method according to Aspect 23, wherein the contacting further forms a compound of the formula MQ.

Aspect 25. The method according to Aspect 24, wherein:

Z is a metal;

E is $N(R^3)$;

n is 4;

a is 1; and

b is 3.

Aspect 26. The method according to Aspect 24, wherein:

Z is a metal;

E is O or S;

n is 4;

a is 1; and

b is 3.

Aspect 27. The method according to Aspect 24, wherein:

Z is a metal;

E is $N(R^3)$;

n is 2;

a is 1; and

b is 1.

Aspect 28. The method according to Aspect 24, wherein:

Z is a metal;

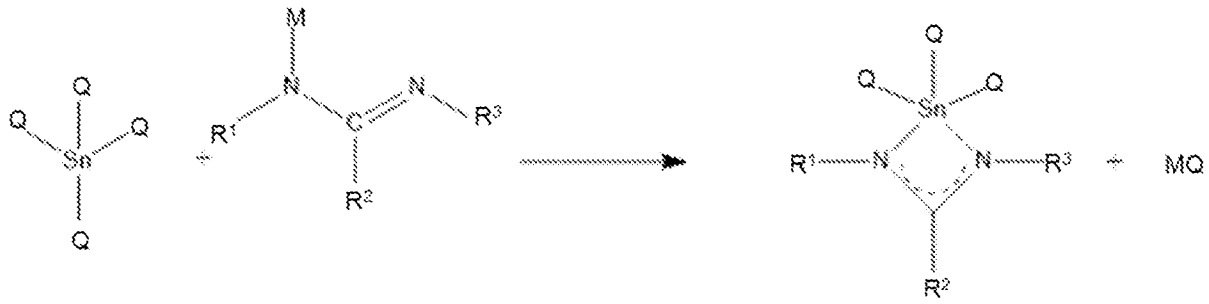
E is O or S;

n is 2;

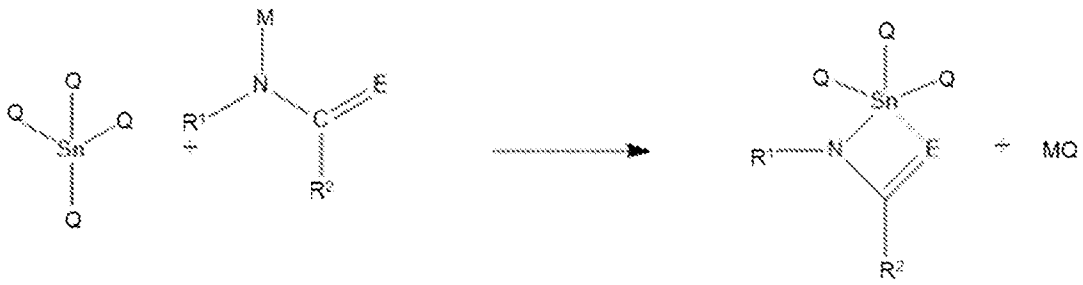
a is 1; and

b is 1.

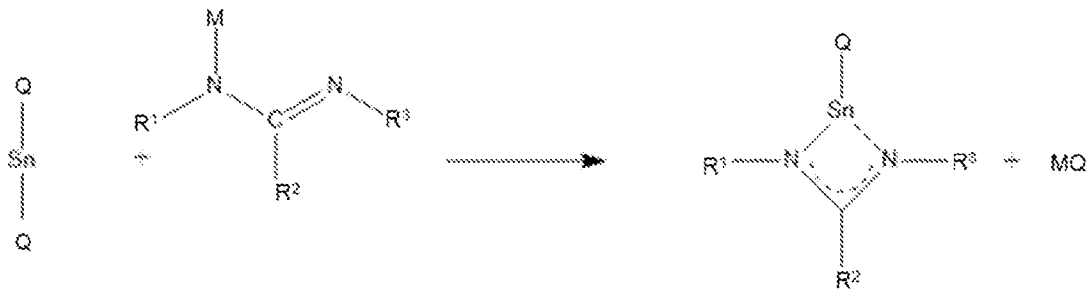
Aspect 29. The method according to Aspect 24, wherein the method comprises:



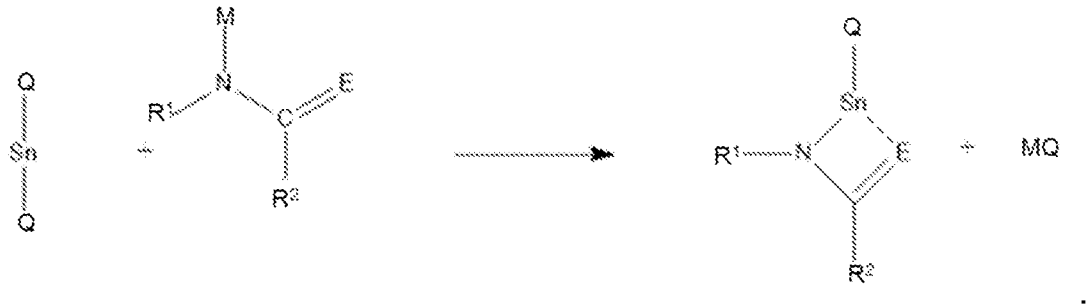
Aspect 30. The method according to Aspect 24, wherein the method comprises:



Aspect 31. The method according to Aspect 24, wherein the method comprises:



Aspect 32. The method according to Aspect 24, wherein the method comprises:



Aspect 33. The method according to Aspect 23, wherein the contacting further forms a compound of the formula HZ.

Aspect 34. The method according to Aspect 33,

wherein:

Z is a metal;

E is $N(R^3)$;

n is 4;

a is 1; and

b is 3.

Aspect 35. The method according to Aspect 33,

wherein:

Z is a metal;

E is O or S;

n is 4;

a is 1; and

b is 3.

Aspect 36. The method according to Aspect 33,

wherein:

Z is a metal;

E is $N(R^3)$;

n is 2;

a is 1; and

b is 1.

Aspect 37. The method according to Aspect 33,

wherein:

Z is a metal;

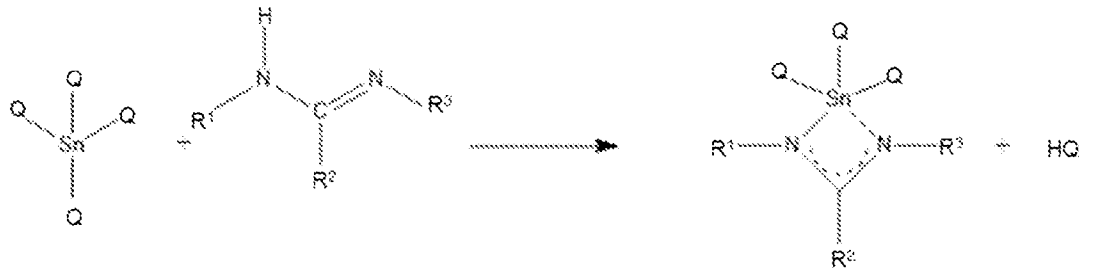
E is O or S;

n is 2;

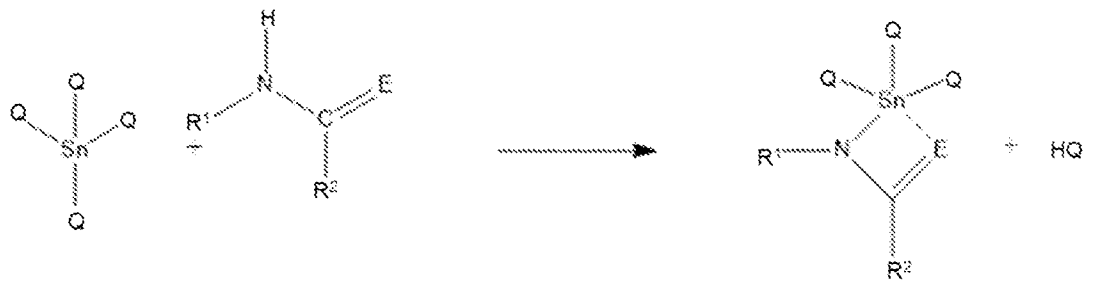
a is 1; and

b is 1.

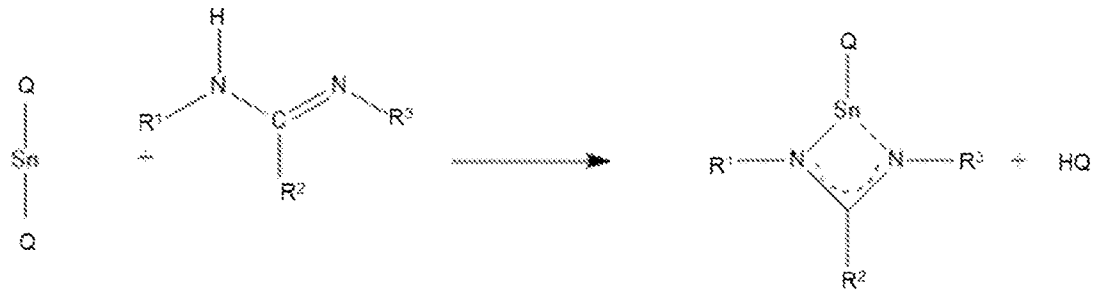
Aspect 34. The method according to Aspect 33, wherein the method comprises:



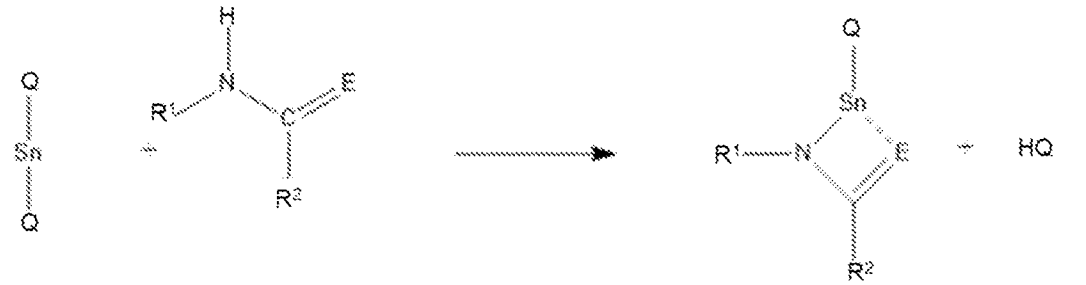
Aspect 35. The method according to Aspect 33, wherein the method comprises:



Aspect 36. The method according to Aspect 33, wherein the method comprises:



Aspect 37. The method according to Aspect 33, wherein the method comprises:



It is to be understood that changes may be made in detail, especially in matters of the construction materials employed and the shape, size, and arrangement of parts without departing from the scope of the present disclosure. This Specification and the embodiments described are examples, with the true scope and spirit of the disclosure being indicated by the claims that follow.

CLAIMS

What is claimed is:

1. A composition comprising:

a compound of the formula:

$$[(R^1)N{=}C(R^2){-}E]_a\,Sn(Q)_b\,,$$

where:

$a + b = 2$ or 4;

R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, or any combination thereof;

E independently comprises $N(R^3)$, O, or S, where:

R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; and

Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

2. The composition of claim 1,

wherein:

E is $N(R^3)$;

Q is independently a halogen;

a is 1; and

b is 3.

3. The composition of claim 1,

wherein:

E is $N(R^3)$;

Q independently comprises at least one of a halogen, an amine, or any combination thereof;

a is 2; and

b is 2.

4. The composition of claim 1,

wherein:

E is O or S;

Q is independently a halogen;

a is 1; and

b is 3.

5. The composition of claim 1,

wherein:

E is O or S;

Q independently comprises at least one of a halogen, an amine, or any combination thereof;

a is 2; and

b is 2.

6. The composition of claim 1,

wherein:

E is $N(R^3)$;

Q is a halogen;

a is 1; and

b is 1.

7. The composition of claim 1,

wherein:

E is N(R^3);

a is 2; and

b is 0.

8. The composition of claim 1,

wherein:

E is O or S;

Q is a halogen;

a is 1; and

b is 1.

9. The composition of claim 1,

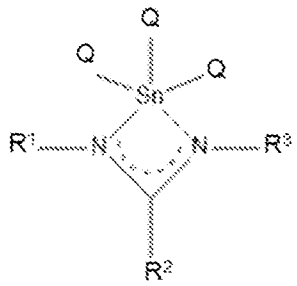
wherein:

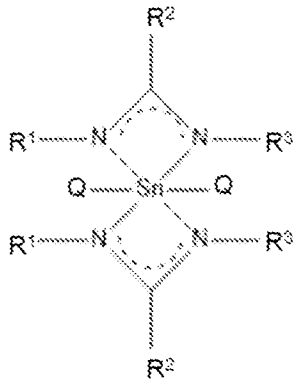
E is O or S;

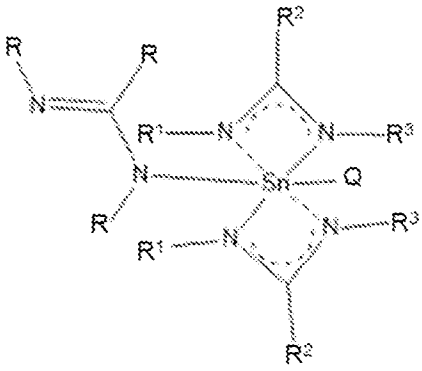
a is 2; and

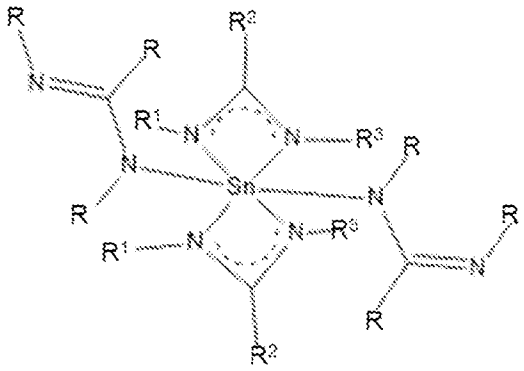
b is 0.

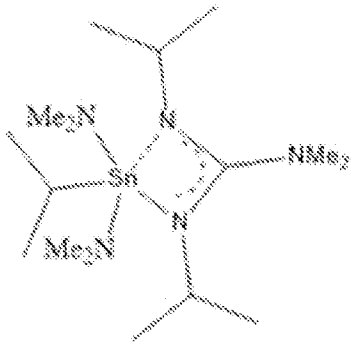
10. The composition of claim 1, wherein the compound comprises at least one of the following:

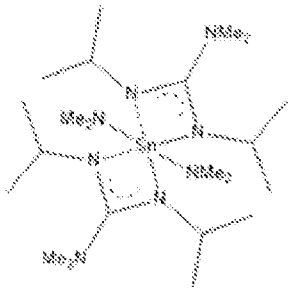


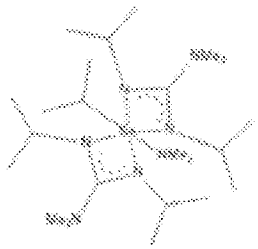




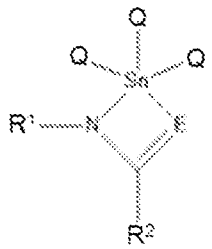


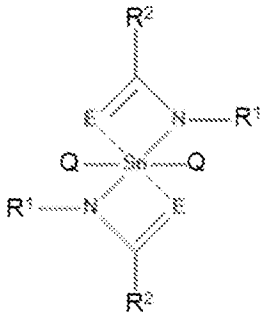


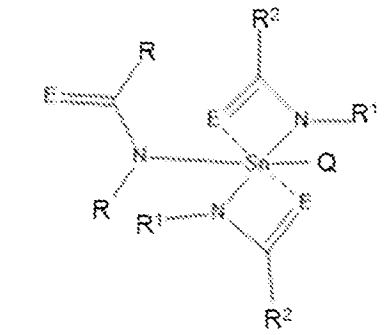


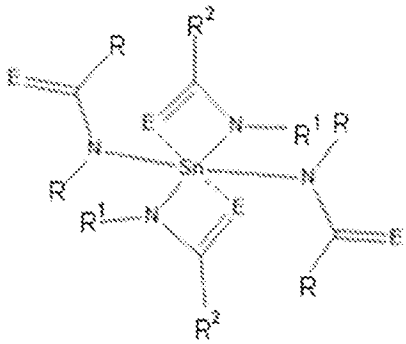


11. The composition of claim 1, wherein the compound comprises at least one of the following:

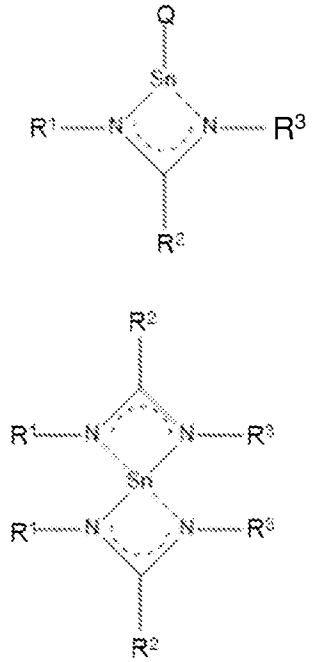




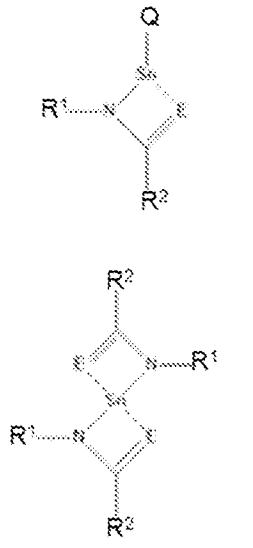




12. The composition of claim 1, wherein the compound comprises at least one of the following:



13. The composition of claim 1, wherein the compound comprises at least one of the following:



14. A method comprising:

contacting a compound of the formula:

$$(R^1)N{=}C{=}E,$$

with a compound of the formula:

$$Sn(R^2)_m(Q)_n,$$

to form a compound of the formula:

$$[(R^1)N{=}C(R^2){-}E]_a\,Sn(R^2)_b(Q)_c,$$

where:

$m + n = 2$ or 4;

$a + b + c = 2$ or 4;

R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an amide, an alkoxide, or any combination thereof;

E independently comprises $N(R^3)$, O, or S, where:

R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; and

Q independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

15. The method of claim 14,

wherein:

E is $N(R^3)$;

Q is independently a halogen;

m is 1;

n is 3;

a is 1;

b is 1; and

c is 3.

16. The method of claim 14,

wherein:

E is O or S;

Q is independently a halogen;

m is 1;

n is 3;

a is 1;

b is 1; and

c is 3.

17. The method of claim 14,

wherein:

E is $N(R^3)$;

Q is a halogen;

m is 1;

n is 1;

a is 1;

b is 1; and

c is 1.

18. The method of claim 14,

wherein:

E is O or S;

Q is a halogen;

m is 1;

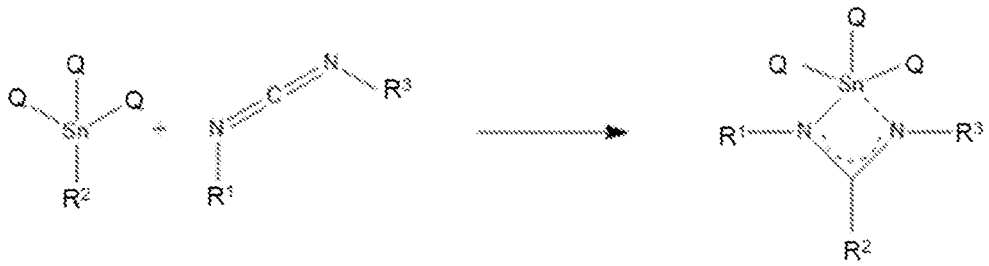
n is 1;

a is 1;

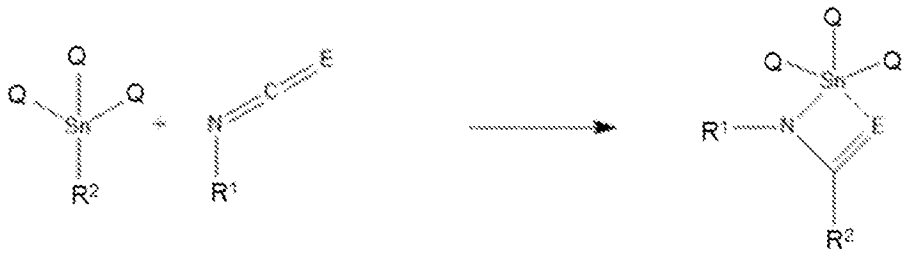
b is 1; and

c is 1.

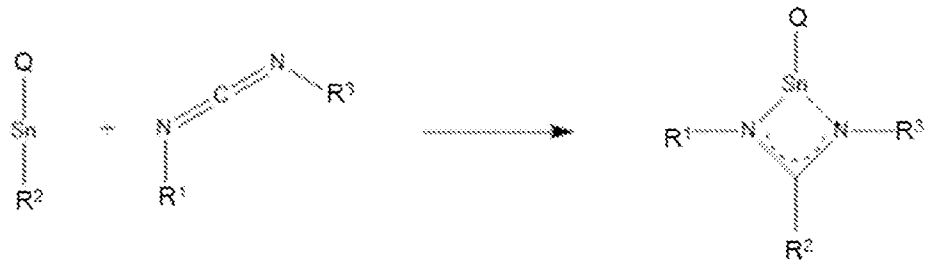
19. The method of claim 14, wherein the method comprises:



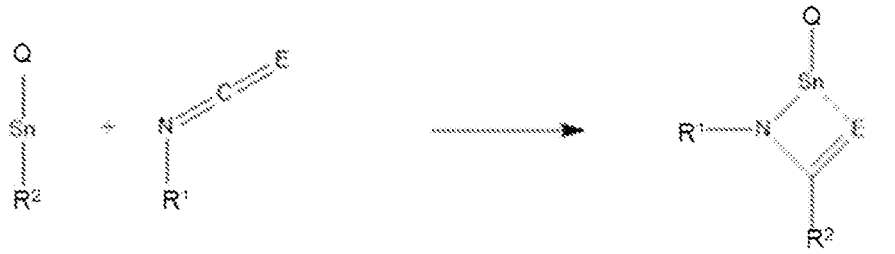
20. The method of claim 14, wherein the method comprises:



21. The method of claim 14, wherein the method comprises:



22. The method of claim 14, wherein the method comprises:



23. A method comprising:

contacting a compound of the formula:

$$Z\,N(R^1)-C(R^2)=\!=E,$$

with a compound of the formula:

$$Sn(Q)_n,$$

to form a compound of the formula:

$$[(R^1)N\!=\!=\!=C(R^2)\!=\!=\!=E]_a\,Sn(Q)_b,$$

where:

n is 2 or 4;

a + b = 2 or 4;

Z is a hydrogen (H) or a metal (M);

R^1 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof;

R^2 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, or any combination thereof;

E independently comprises $N(R^3)$, O, or S, where:

R^3 independently comprises at least one of a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, or any combination thereof; and

Q independently comprises a hydrogen, an alkyl, an alkenyl, an aryl, a silyl, an amine, an alkoxide, a halogen, or any combination thereof.

24. The method of claim 23, wherein the contacting further forms a compound of the formula MQ.

25. The method of claim 24,

wherein:

Z is a metal;

E is $N(R^3)$;

n is 4;

a is 1; and

b is 3.

26. The method of claim 24,

wherein:

Z is a metal;

E is O or S;

n is 4;

a is 1; and

b is 3.

27. The method of claim 24,

wherein:

Z is a metal;

E is $N(R^3)$;

n is 2;

a is 1; and

b is 1.

28. The method of claim 24, wherein:

Z is a metal;

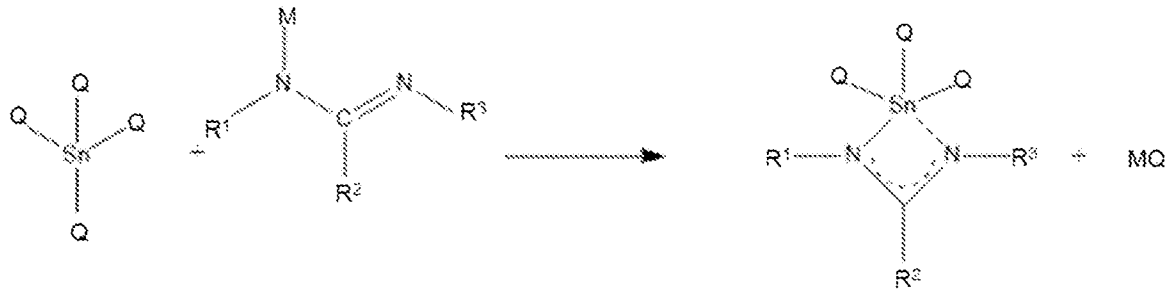
E is O or S;

n is 2;

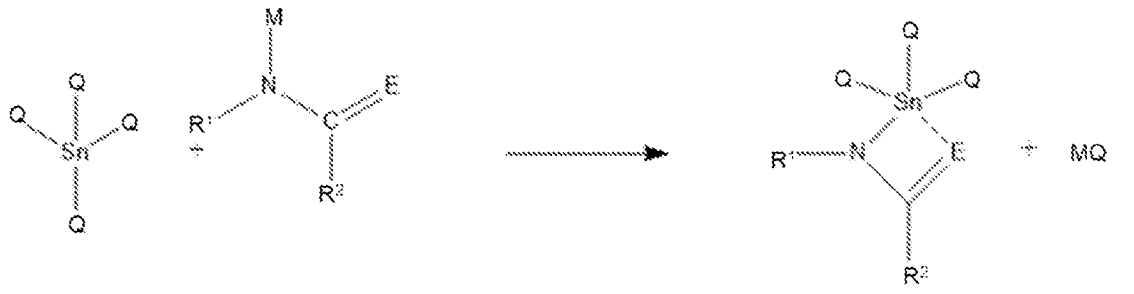
a is 1; and

b is 1.

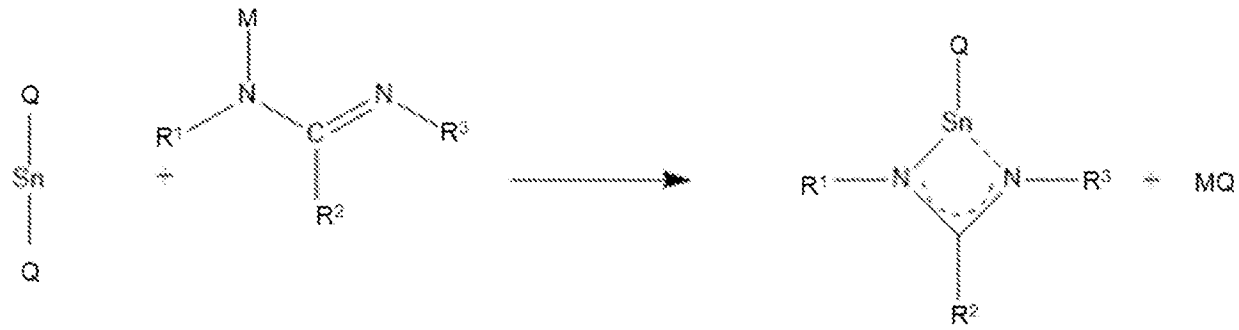
29. The method of claim 24, wherein the method comprises:



30. The method of claim 24, wherein the method comprises:

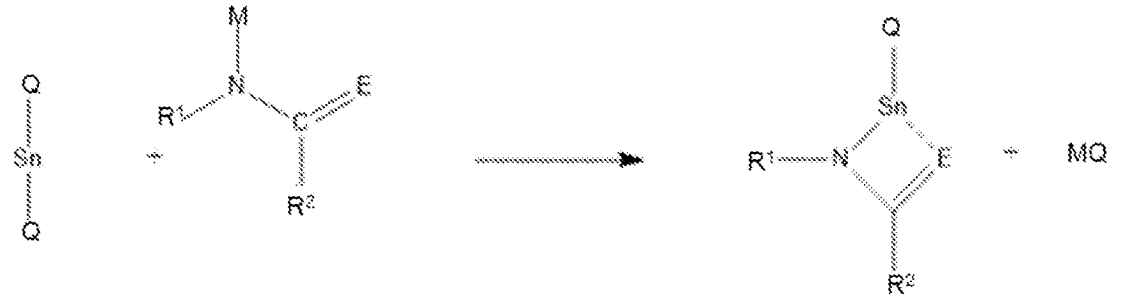


31. The method of claim 24, wherein the method comprises:



.

32. The method of claim 24, wherein the method comprises:



.

33. The method of claim 23, wherein the contacting further forms a compound of the formula HZ.

34. The method of claim 33,
wherein:

Z is a metal;

E is N(R^3);

n is 4;

a is 1; and

b is 3.

35. The method of claim 33,
wherein:

Z is a metal;

E is O or S;

n is 4;

a is 1; and

b is 3.

36. The method of claim 33, wherein:

Z is a metal;

E is N(R^3);

n is 2;

a is 1; and

b is 1.

37. The method of claim 33, wherein:

Z is a metal;

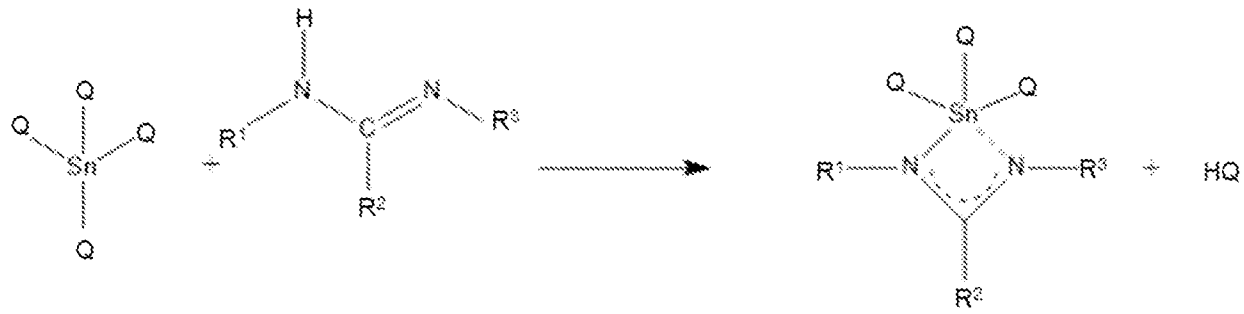
E is O or S;

n is 2;

a is 1; and

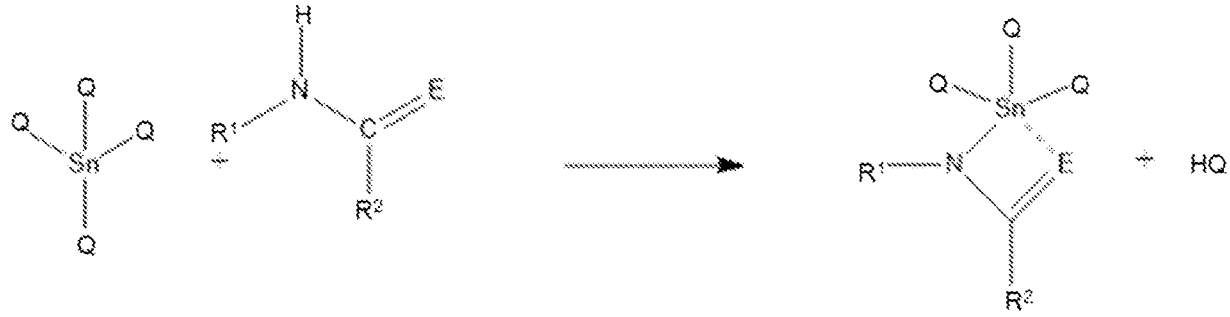
b is 1.

38. The method of claim 33, wherein the method comprises:



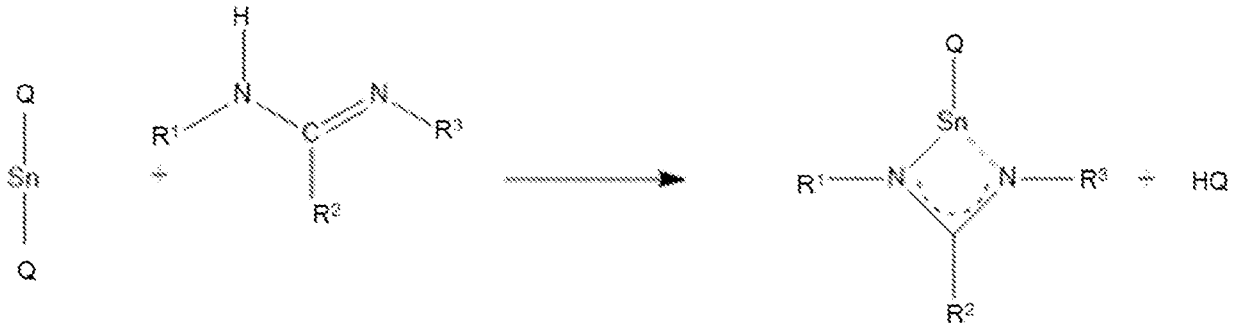
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39. The method of claim 33, wherein the method comprises:



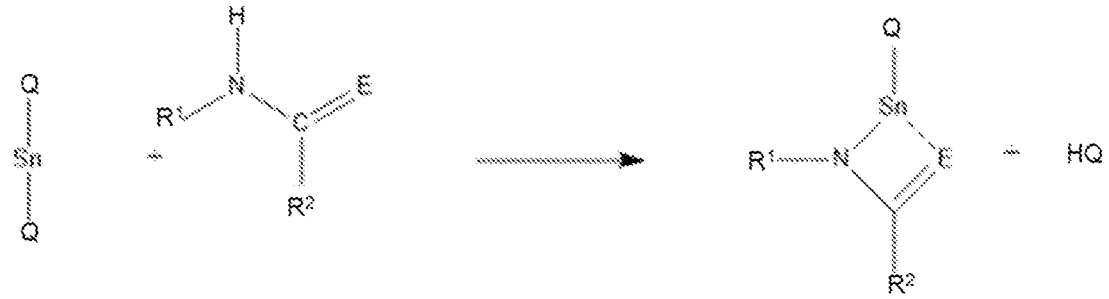
.

40. The method of claim 33, wherein the method comprises:



.

41. The method of claim 33, wherein the method comprises:



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/055898

A. CLASSIFICATION OF SUBJECT MATTER

C23C 16/455(2006.01)i; **C23C 16/34**(2006.01)i; **C23C 16/52**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C23C 16/455(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal), STN(Registry, Caplus) & Keywords: tin complex, amidine, amidate, thioamidate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	FOLEY, S. R. et al., "Synthesis of MII[N(SiMe3)2][Me3SiNC(tBu)NSiMe3] (M = Sn, Ge) from amidinate precursors: active catalysts for phenyl isocyanate cyclization", Inorganic Chemistry, 2000, Vol. 39, No. 5, pp. 924-929	
X	pages 925, 926; schemes 1, 3	1-3,6,7,10-13,23-25,27,29-31,34,36
Y		4,5,15,17,19,20,26,35,38-41
A		8,9,14,16,18,21,22,28,32,33,37
	AHMET, I. Y. et al., "Tin guanidinato complexes: oxidative control of Sn, SnS, SnSe and SnTe thin film deposition", Dalton Transactions, 2018, Vol. 47, pp. 5031-5048	
X	abstract; schemes 2, 3	1,7,12-14,21,22
Y		15-20
	DEHNICKE, K. et al., "N,N,N`-Tris(trimethylsilyl)organoamidine as reagents in complex chemistry", Journal of Organometallic Chemistry, 1988, Vol. 352, pp. C1-C4	
X	page C2; scheme 1; table 1	1,2,6,10-13

☑ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 February 2025	**28 February 2025**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**LEE, Eon Su**
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	ÁLVAREZ-RODRÍGUEZ, L. et al., "Organic amides as suitable precursors to stabilize stannylenes", Organometallics, 2013, Vol. 32, No. 12, pp. 3557-3561	
X	page 3558; scheme 1	1,8,9,13,23, 24,28,32,33,37
Y		4,5,16,18,26,35,38-41
	CATHERALL, A. L. et al., "Deposition of SnS thin films from Sn(II) thioamidate precursors", Crystal Growth and Design, 2017, Vol. 17, pp. 5544-5551	
X	schemes 2, 3	1,9,13,23
Y		38-41