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### AREA SELECTIVE DEPOSITION OF ALUMINUM BASED FILMS USING ALKYL ALUMINUM AMIDINATE PRECURSORS

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#### Abstract

Area selective deposition of aluminum-based films using alkyl aluminum amidinate precursors and methods thereof are provided. Area selective deposition comprises depositing an alkyl aluminum amidinate precursor on a substrate with a first surface portion comprising a metal and a second surface portion comprising a non-metal to form an aluminum-based film on the substrate. The aluminum-based film will be located on the second surface portion of the substrate and when the aluminum-based film is located on the first surface portion, a ratio of an average thickness of the film on the first surface portion to an average thickness of the film on the second surface portion is less than 1.

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application claims the benefit under 35 USC 119 of U.S. Provisional Patent Application Nos. 63/554,335, filed Feb. 16, 2024, and 63/706,386 filed on Oct. 11, 2024, the disclosure of each is hereby incorporated herein by reference in its entirety.

### FIELD

[0002] The present disclosure relates to aluminum-containing precursors and related compositions, methods, devices, and systems.

### BACKGROUND

[0003] Conventional methods for synthesizing aluminum-containing precursors can present risks because of the reagents being used and the reaction conditions being employed.

### SUMMARY

[0004] Some embodiments relate to a method for forming a vapor deposition precursor. In some embodiments, the method comprises contacting an aluminum halide compound, a Grignard reagent, and a carbodiimide compound to form the vapor deposition precursor. In some embodiments, the vapor deposition precursor comprises an aluminum amidinate.

[0005] Some embodiments relate to a composition. In some embodiments, the composition comprises a vapor deposition precursor comprising an aluminum amidinate. In some embodiments, the aluminum amidinate has the characteristics defined by the following process step contacting an aluminum halide compound, a Grignard reagent, and a carbodiimide compound to form the vapor deposition precursor.

[0006] Some embodiments relate to a method for forming a film. In some embodiments, the method comprises one or more of the following steps: obtaining at least a vapor deposition precursor comprising an aluminum amidinate; and exposing a substrate to at least the vapor deposition precursor, under vapor deposition conditions, to form a film on the substrate.

[0007] Some embodiments relate to an article. In some embodiments, the article comprises a substrate. In some embodiments, the substrate has a first surface portion comprising a metal and a second surface portion comprising a non-metal. In some embodiments, the article comprises a layer. In some embodiments, the layer comprises a reaction product of an aluminum amidinate. In some embodiments, the layer is located on the second surface portion.

[0008] Some embodiments relate to a method. In some embodiments, the method comprises obtaining a substrate. In some embodiments, the substrate has a first surface portion comprising a metal and a second surface portion comprising a non-metal. In some embodiments, the method comprises obtaining a vapor deposition precursor comprising an aluminum amidinate. In some embodiments, the method comprises vaporizing the vapor deposition precursor to obtain a precursor vapor. In some embodiments, the method comprises contacting the substrate with the precursor vapor to form a layer. In some embodiments, the layer is located on the second surface portion.

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## Description

### DRAWINGS

[0009] FIG. 1 is a flowchart of a method for synthesizing a precursor, according to some embodiments.

[0010] FIG. 2 is a flowchart of a method for making an aluminum-containing film, according to some embodiments.

[0011] FIG. 3 is a flowchart of a method for making an aluminum-containing layer on a substrate, according to some embodiments.

[0012] FIG. 4 is a graphical representation of the thickness of deposited aluminum-based films as a function of the number of ALD cycles for various substrates, according to Example 1.

[0013] FIG. 5 is a graphical representation of the thickness of deposited aluminum-based films as a function of the number of ALD cycles for various substrates, according to Example 2.

[0014] FIG. 6 is a graphical representation of the thickness of deposited aluminum-based films as a function of the number of ALD cycles for various substrates, according to Example 3.

#### DETAILED DESCRIPTION

[0015] 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.sub.n alkyl.” For example, a “C.sub.s 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.sub.1-C.sub.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.sub.1-C.sub.30 alkyl, C.sub.1-C.sub.29 alkyl, C.sub.1-C.sub.28 alkyl, C.sub.1-C.sub.27 alkyl, C.sub.1-C.sub.26 alkyl, C.sub.1-C.sub.25 alkyl, C.sub.1-C.sub.24 alkyl, C.sub.1-C.sub.23 alkyl, C.sub.1-C.sub.22 alkyl, C.sub.1-C.sub.21 alkyl, C.sub.1-C.sub.20 alkyl, C.sub.1-C.sub.19 alkyl, C.sub.1-C.sub.18 alkyl, C.sub.1-C.sub.17 alkyl, C.sub.1-C.sub.16 alkyl, C.sub.1-C.sub.15 alkyl, C.sub.1-C.sub.14 alkyl, C.sub.1-C.sub.13 alkyl, C.sub.1-C.sub.12 alkyl, C.sub.1-C.sub.11 alkyl, C.sub.1-C.sub.10 alkyl, a C.sub.1-C.sub.9 alkyl, a C.sub.1-C.sub.8 alkyl, a C.sub.1-C.sub.7 alkyl, a C.sub.1-C.sub.6 alkyl, a C.sub.1-C.sub.5 alkyl, a C.sub.1-C.sub.4 alkyl, a C.sub.1-C.sub.3 alkyl, a C.sub.1-C.sub.2 alkyl, a C.sub.2-C.sub.30 alkyl, a C.sub.3-C.sub.30 alkyl, a C.sub.4-C.sub.30 alkyl, a C.sub.5-C.sub.30 alkyl, a C.sub.6-C.sub.30 alkyl, a C.sub.7-C.sub.30 alkyl, a C.sub.8-C.sub.30 alkyl, a C.sub.9-C.sub.30 alkyl, a C.sub.10-C.sub.30 alkyl, a C.sub.11-C.sub.30 alkyl, a C.sub.12-C.sub.30 alkyl, a C.sub.13-C.sub.30 alkyl, a C.sub.14-C.sub.30 alkyl, a C.sub.15-C.sub.30 alkyl, a C.sub.16-C.sub.30 alkyl, a C.sub.17-C.sub.30 alkyl, a C.sub.18-C.sub.30 alkyl, a C.sub.19-C.sub.30 alkyl, a C.sub.20-C.sub.30 alkyl, a C.sub.21-C.sub.30 alkyl, a C.sub.22-C.sub.30 alkyl, a C.sub.23-C.sub.30 alkyl, a C.sub.24-C.sub.30 alkyl, a C.sub.25-C.sub.30 alkyl, a C.sub.26-C.sub.30 alkyl, a C.sub.27-C.sub.30 alkyl, a C.sub.28-C.sub.30 alkyl, a C.sub.29-C.sub.30 alkyl, a C.sub.2-C.sub.10 alkyl, a C.sub.3-C.sub.10 alkyl, a C.sub.4-C.sub.10 alkyl, a C.sub.5-C.sub.10 alkyl, a C.sub.6-C.sub.10 alkyl, a C.sub.7-C.sub.10 alkyl, a C.sub.8-C.sub.10 alkyl, a C.sub.2-C.sub.9 alkyl, a C.sub.2-C.sub.8 alkyl, a C.sub.2-C.sub.7 alkyl, a C.sub.2-C.sub.6 alkyl, a C.sub.2-C.sub.5 alkyl, a C.sub.3-C.sub.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.

[0016] 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.sub.1-C.sub.30 alkenyl, C.sub.1-C.sub.29 alkenyl, C.sub.1-C.sub.28 alkenyl, C.sub.1-C.sub.27 alkenyl, C.sub.1-C.sub.26 alkenyl, C.sub.1-C.sub.25 alkenyl, C.sub.1-C.sub.24 alkenyl, C.sub.1-C.sub.23 alkenyl, C.sub.1-C.sub.22 alkenyl, C.sub.1-C.sub.21 alkenyl, C.sub.1-C.sub.20 alkenyl, C.sub.1-C.sub.19 alkenyl, C.sub.1-C.sub.18 alkenyl, C.sub.1-C.sub.17 alkenyl, C.sub.1-C.sub.16 alkenyl, C.sub.1-

C.sub.15 alkenyl, C.sub.1-C.sub.14 alkenyl, C.sub.1-C.sub.13 alkenyl, C.sub.1-C.sub.12 alkenyl, C.sub.1-C.sub.11 alkenyl, C.sub.1-C.sub.10 alkenyl, a C.sub.1-C.sub.9 alkenyl, a C.sub.1-C.sub.8 alkenyl, a C.sub.1-C.sub.7 alkenyl, a C.sub.1-C.sub.6 alkenyl, a C.sub.1-C.sub.5 alkenyl, a C.sub.1-C.sub.4 alkenyl, a C.sub.1-C.sub.3 alkenyl, a C.sub.1-C.sub.2 alkenyl, a C.sub.2-C.sub.30 alkenyl, a C.sub.3-C.sub.30 alkenyl, a C.sub.4-C.sub.30 alkenyl, a C.sub.5-C.sub.30 alkenyl, a C.sub.6-C.sub.30 alkenyl, a C.sub.7-C.sub.30 alkenyl, a C.sub.8-C.sub.30 alkenyl, a C.sub.9-C.sub.30 alkenyl, a C.sub.10-C.sub.30 alkenyl, a C.sub.11-C.sub.30 alkenyl, a C.sub.12-C.sub.30 alkenyl, a C.sub.13-C.sub.30 alkenyl, a C.sub.14-C.sub.30 alkenyl, a C.sub.15-C.sub.30 alkenyl, a C.sub.16-C.sub.30 alkenyl, a C.sub.17-C.sub.30 alkenyl, a C.sub.18-C.sub.30 alkenyl, a C.sub.19-C.sub.30 alkenyl, a C.sub.20-C.sub.30 alkenyl, a C.sub.21-C.sub.30 alkenyl, a C.sub.22-C.sub.30 alkenyl, a C.sub.23-C.sub.30 alkenyl, a C.sub.24-C.sub.30 alkenyl, a C.sub.25-C.sub.30 alkenyl, a C.sub.26-C.sub.30 alkenyl, a C.sub.27-C.sub.30 alkenyl, a C.sub.28-C.sub.30 alkenyl, a C.sub.29-C.sub.30 alkenyl, a C.sub.2-C.sub.10 alkenyl, a C.sub.3-C.sub.10 alkenyl, a C.sub.4-C.sub.10 alkenyl, a C.sub.5-C.sub.10 alkenyl, a C.sub.6-C.sub.10 alkenyl, a C.sub.7-C.sub.10 alkenyl, a C.sub.8-C.sub.10 alkenyl, a C.sub.2-C.sub.9 alkenyl, a C.sub.2-C.sub.8 alkenyl, a C.sub.2-C.sub.7 alkenyl, a C.sub.2-C.sub.6 alkenyl, a C.sub.2-C.sub.5 alkenyl, a C.sub.3-C.sub.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.

[0017] 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.sub.1-C.sub.30 alkynyl, C.sub.1-C.sub.29 alkynyl, C.sub.1-C.sub.28 alkynyl, C.sub.1-C.sub.27 alkynyl, C.sub.1-C.sub.26 alkynyl, C.sub.1-C.sub.25 alkynyl, C.sub.1-C.sub.24 alkynyl, C.sub.1-C.sub.23 alkynyl, C.sub.1-C.sub.22 alkynyl, C.sub.1-C.sub.21 alkynyl, C.sub.1-C.sub.20 alkynyl, C.sub.1-C.sub.19 alkynyl, C.sub.1-C.sub.18 alkynyl, C.sub.1-C.sub.17 alkynyl, C.sub.1-C.sub.16 alkynyl, C.sub.1-C.sub.15 alkynyl, C.sub.1-C.sub.14 alkynyl, C.sub.1-C.sub.13 alkynyl, C.sub.1-C.sub.12 alkynyl, C.sub.1-C.sub.11 alkynyl, C.sub.1-C.sub.10 alkynyl, a C.sub.1-C.sub.9 alkynyl, a C.sub.1-C.sub.8 alkynyl, a C.sub.1-C.sub.7 alkynyl, a C.sub.1-C.sub.6 alkynyl, a C.sub.1-C.sub.5 alkynyl, a C.sub.1-C.sub.4 alkynyl, a C.sub.1-C.sub.3 alkynyl, a C.sub.1-C.sub.2 alkynyl, a C.sub.2-C.sub.30 alkynyl, a C.sub.3-C.sub.30 alkynyl, a C.sub.4-C.sub.30 alkynyl, a C.sub.5-C.sub.30 alkynyl, a C.sub.6-C.sub.30 alkynyl, a C.sub.7-C.sub.30 alkynyl, a C.sub.8-C.sub.30 alkynyl, a C.sub.9-C.sub.30 alkynyl, a C.sub.10-C.sub.30 alkynyl, a C.sub.11-C.sub.30 alkynyl, a C.sub.12-C.sub.30 alkynyl, a C.sub.13-C.sub.30 alkynyl, a C.sub.14-C.sub.30 alkynyl, a C.sub.15-C.sub.30 alkynyl, a C.sub.16-C.sub.30 alkynyl, a C.sub.17-C.sub.30 alkynyl, a C.sub.18-C.sub.30 alkynyl, a C.sub.19-C.sub.30 alkynyl, a C.sub.20-C.sub.30 alkynyl, a C.sub.21-C.sub.30 alkynyl, a C.sub.22-C.sub.30 alkynyl, a C.sub.23-C.sub.30 alkynyl, a C.sub.24-C.sub.30 alkynyl, a C.sub.25-C.sub.30 alkynyl, a C.sub.26-C.sub.30 alkynyl, a C.sub.27-C.sub.30 alkynyl, a C.sub.28-C.sub.30 alkynyl, a C.sub.29-C.sub.30 alkynyl, a C.sub.2-C.sub.10 alkynyl, a C.sub.3-C.sub.10 alkynyl, a C.sub.4-C.sub.10 alkynyl, a C.sub.5-C.sub.10 alkynyl, a C.sub.6-C.sub.10 alkynyl, a C.sub.7-C.sub.10 alkynyl, a C.sub.8-C.sub.10 alkynyl, a C.sub.2-C.sub.9 alkynyl, a C.sub.2-C.sub.8 alkynyl, a C.sub.2-C.sub.7 alkynyl, a C.sub.2-C.sub.6 alkynyl, a C.sub.2-C.sub.5 alkynyl, a C.sub.3-C.sub.5 alkynyl, or any combination thereof. Examples of alkynyl groups include, without limitation, at least one of ethynyl, propynyl, n-butylnyl, n-pentylnyl, 3-methyl-1-butylnyl, n-hexynyl, methyl-pentylnyl, or any combination thereof.

[0018] 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.

[0019] 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.sub.6H.sub.5.

[0020] Non-limiting examples of aryls include, without limitation, at least one of benzene, toluene, xylene (e.g., o-xylene, m-xylene, p-xylene), t-butyltoluene (e.g., o-t-butyltoluene, m-t-butyltoluene, p-t-butyltoluene), ethylmethylbenzene (e.g., 1-ethyl-4-methylbenzene, 1-ethyl-3-methylbenzene), 1-isopropyl-4-methylbenzene, 1-t-butyl-4-methylbenzene, mesitylene, pseudocumene, durene, methylbenzene, dimethylbenzene, trimethylbenzene, ethylbenzene, diethylbenzene (e.g., 1,4-diethylbenzene), triethylbenzene, propylbenzene, butylbenzene, iso-butylbenzene, sec-butylbenzene, t-butylbenzene, hexylbenzene, styrene, naphthalene, anthracene, phenanthrene, biphenyl, terphenyl, methylnaphthalene, biphenylene, dimethylnaphthalene, methylanthracene, 4,4'-dimethylbiphenyl, bibenzyl, diphenylmethane, any isomer thereof, or any combination thereof, and the like.

[0021] As used herein, the term “halide” refers to a —Cl, —Br, —I, or —F.

[0022] As used herein, the term “contacting” refers to bringing two or more components into immediate or close proximity, or into direct contact.

[0023] Some embodiments relate to precursors and related methods. At least some of these embodiments relate to precursors useful in the fabrication of microelectronic devices, including semiconductor devices, and the like. For example, the precursors can be used to form aluminum-containing films by one or more deposition processes. Examples of aluminum-containing films include, for example and without limitation, at least one of aluminum oxide (e.g., Al.sub.2O.sub.3), aluminum nitride (e.g., AlN), or any combination thereof, among others. 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. In some embodiments, the precursors disclosed herein are useful for area selective deposition.

[0024] FIG. 1 is a flowchart of a method for synthesizing a precursor, according to some embodiments. As shown in FIG. 1, the method comprises one or more of the following steps: obtaining **102** an aluminum halide compound; obtaining **104** a Grignard reagent; obtaining **106** a carbodiimide compound; and contacting **108** the aluminum halide compound, the Grignard reagent, and the carbodiimide compound to form a vapor deposition precursor. In some embodiments, the vapor deposition precursor comprises an aluminum amidinate. In some embodiments, the method is performed without use of a pyrophoric compound.

[0025] At step **102**, the method for synthesizing a precursor comprises obtaining an aluminum halide compound. In some embodiments, the aluminum halide compound comprises at least one of an aluminum bromide, an aluminum chloride, an aluminum fluoride, an aluminum iodide, or any combination thereof. In some embodiments, the aluminum halide compound comprises an aluminum trihalide. In some embodiments, the aluminum halide compound comprises a compound of the formula:  $\text{AlX}_{\text{sub.3}}$ , where X is independently a halide. In some embodiments, the aluminum halide compound comprises an aluminum tribromide ( $\text{AlBr}_{\text{sub.3}}$ ). In some embodiments, the aluminum halide compound comprises an aluminum trichloride ( $\text{AlCl}_{\text{sub.3}}$ ). In some embodiments, the aluminum halide compound comprises an aluminum trifluoride ( $\text{AlF}_{\text{sub.3}}$ ). In some embodiments, the aluminum halide compound comprises an aluminum triiodide ( $\text{AlI}_{\text{sub.3}}$ ). In some embodiments, at least two of the halides of the aluminum halide compound are different.

[0026] At step **104**, the method for synthesizing a precursor comprises obtaining a Grignard reagent. In some embodiments, the Grignard reagent comprises a compound of the formula:

$\text{R}_{\text{sup.1}}\text{MgX}$ , [0027] where: [0028]  $\text{R}_{\text{sup.1}}$  is at least one of an alkyl, an alkenyl, an alkyne, an aryl, a cycloalkyl, or any combination thereof; [0029] X is a halide.

[0030] In some embodiments,  $\text{R}_{\text{sup.1}}$  comprises an alkyl and X is Cl, Br, or I.

[0031] In some embodiments,  $\text{R}_{\text{sup.1}}$  comprises an alkenyl and X is Cl, Br, or I.

[0032] In some embodiments,  $\text{R}_{\text{sup.1}}$  comprises an alkyne and X is Cl, Br, or I.

[0033] In some embodiments,  $\text{R}_{\text{sup.1}}$  comprises an aryl and X is Cl, Br, or I.

[0034] In some embodiments,  $\text{R}_{\text{sup.1}}$  comprises a cycloalkyl and X is Cl, Br, or I.

[0035] At step **106**, the method for synthesizing a precursor comprises obtaining a carbodiimide compound. In some embodiments, the carbodiimide compound comprises a compound of the formula:

$\text{R}_{\text{sup.2}}\text{—N=C=N—R}_{\text{sup.2}}$ , [0036] where: [0037]  $\text{R}_{\text{sup.2}}$  is independently at least one of an alkyl, a cycloalkyl, or any combination thereof.

[0038] In some embodiments,  $\text{R}_{\text{sup.2}}$  comprises an alkyl.

[0039] In some embodiments,  $\text{R}_{\text{sup.2}}$  comprises a cycloalkyl.

[0040] At step **108**, the method for synthesizing a precursor comprises contacting the aluminum halide compound, the Grignard reagent, and the carbodiimide compound to form a vapor deposition precursor. In some embodiments, the contacting comprises bringing the aluminum halide compound, the Grignard reagent, and the carbodiimide compound into close or immediate proximity. In some embodiments, the contacting comprises bringing the aluminum halide compound, the Grignard reagent, and the carbodiimide compound into direct physical contact. In some embodiments, the contacting comprises stirring the aluminum halide compound, the Grignard reagent, and the carbodiimide compound. In some embodiments, the contacting comprises mixing the aluminum halide compound, the Grignard reagent, and the carbodiimide compound. In some embodiments, the contacting comprises agitating the aluminum halide compound, the Grignard reagent, and the carbodiimide compound. In some embodiments, the contacting comprises adding the aluminum halide compound, the Grignard reagent, and the carbodiimide compound to a reaction vessel (e.g., a flask, a vial, etc.). In some embodiments, the contacting comprises combining the aluminum halide compound, the Grignard reagent, and the carbodiimide compound in a reaction vessel. In some embodiments, the aluminum halide compound, the Grignard reagent, and the carbodiimide are contacted sequentially, in any order. In some embodiments, the aluminum halide compound, the Grignard reagent, and the carbodiimide compound are contacted substantially simultaneously or simultaneously.

[0041] In some embodiments, the Grignard reagent comprises a compound of the formula:

$\text{R}_{\text{sup.1}}\text{MgX}$ , [0042] where: [0043]  $\text{R}_{\text{sup.1}}$  is an alkyl; and [0044] X is Cl, Br, or I; and [0045] the

carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N=C=N-R_{sup.2}$ , [0046] where: [0047]  $R_{sup.2}$  is independently an alkyl.  
[0048] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0049] where: [0050]  $R_{sup.1}$  is an alkyl; and [0051] X is Cl, Br, or I; and [0052] the carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N-C=N-R_{sup.2}$ , [0053] where: [0054]  $R_{sup.2}$  is independently a cycloalkyl.  
[0055] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0056] where: [0057]  $R_{sup.1}$  is an alkenyl; and [0058] X is Cl, Br, or I; and [0059] the carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N=C=N-R_{sup.2}$ , [0060] where: [0061]  $R_{sup.2}$  is independently an alkyl.  
[0062] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0063] where: [0064]  $R_{sup.1}$  is an alkenyl; and [0065] X is Cl, Br, or I; and [0066] the carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N=C=N-R_{sup.2}$ , [0067] where: [0068]  $R_{sup.2}$  is independently a cycloalkyl.  
[0069] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0070] where: [0071]  $R_{sup.1}$  is an alkyne; and [0072] X is Cl, Br, or I; and [0073] the carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N=C=N-R_{sup.2}$ , [0074] where: [0075]  $R_{sup.2}$  is independently an alkyl.  
[0076] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0077] where: [0078]  $R_{sup.1}$  is an alkyne; and [0079] X is Cl, Br, or I; and [0080] the carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N=C=N-R_{sup.2}$ , [0081] where: [0082]  $R_{sup.2}$  is independently a cycloalkyl.  
[0083] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0084] where: [0085]  $R_{sup.1}$  is an aryl; and [0086] X is Cl, Br, or I; and [0087] the carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N=C=N-R_{sup.2}$ , [0088] where: [0089]  $R_{sup.2}$  is independently an alkyl.  
[0090] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0091] where: [0092]  $R_{sup.1}$  is an aryl; and [0093] X is Cl, Br, or I; and [0094] the carbodiimide compound comprises a compound of the formula:

$R_{sup.2}-N=C=N-R_{sup.2}$ , [0095] where: [0096]  $R_{sup.2}$  is independently a cycloalkyl.  
[0097] In some embodiments, the Grignard reagent comprises a compound of the formula:

$R_{sup.1}MgX$ , [0098] where: [0099]  $R_{sup.1}$  is a cycloalkyl; and [0100] X is Cl, Br, or I; and [0101] the carbodiimide compound comprises a compound of the formula:

R.sup.2—N=C=N—R.sup.2, [0102] where: [0103] R.sup.2 is independently an alkyl.  
[0104] In some embodiments, the Grignard reagent comprises a compound of the formula:

R.sup.1MgX, [0105] where: [0106] R.sup.1 is a cycloalkyl; and [0107] X is Cl, Br, or I; and [0108] the carbodiimide compound comprises a compound of the formula:

R.sup.2—N=C=N—R.sup.2, [0109] where: [0110] R.sup.2 is independently a cycloalkyl.  
[0111] In some embodiments, the vapor deposition precursor comprises an aluminum amidinate compound. In some embodiments, the vapor deposition precursor comprises an aluminum amidinate. In some embodiments, the vapor deposition precursor comprises a compound of the formula:

##STR00001##

##STR00002## [0112] where: [0113] R.sup.1 is independently at least one of an alkyl, an alkenyl, an alkyne, an aryl, or any combination thereof; and [0114] R.sup.2 is independently an alkyl.  
[0115] In some embodiments, the vapor deposition precursor comprises a compound of the formula:

##STR00003##

[0116] In some embodiments, the vapor deposition precursor is formed without use of a pyrophoric compound. In some embodiments, the vapor deposition precursor is formed without use of at least one of trimethyl aluminum, dimethyl aluminum chloride, methyl lithium, or any combination thereof. In some embodiments, the method does not comprise a step comprising a pyrophoric compound. For example, in some embodiments, the method does not comprise a step of contacting at least one of the aluminum halide compound, the Grignard reagent, the carbodiimide compound, or any combination thereof, with a pyrophoric compound.

[0117] Some embodiments relate to a composition. In some embodiments, the composition comprises a precursor. In some embodiments, the composition comprises a vapor deposition precursor. In some embodiments, the composition comprises a vapor deposition precursor formed according to the methods disclosed herein. In some embodiments, the vapor deposition precursor comprises an aluminum amidinate. In some embodiments, the aluminum amidinate is a reaction product of an aluminum halide compound, a Grignard reagent, and a carbodiimide compound. In some embodiments, the aluminum amidinate has the characteristics defined by the following process step(s): contacting an aluminum halide compound, a Grignard reagent, and a carbodiimide compound to form the vapor deposition precursor. It will be appreciated that the aluminum amidinate can have characteristics defined by any one or more of the methods disclosed herein; however, for simplicity, the methods disclosed herein are not repeated here.

[0118] In some embodiments, the vapor deposition precursor comprises a compound of the formula:

##STR00004##

##STR00005## [0119] where: [0120] R.sup.1 is independently at least one of an alkyl, an alkenyl, an alkyne, an aryl, a cycloalkyl, or any combination thereof; and [0121] R.sup.2 is independently at least one of an alkyl, a cycloalkyl, or any combination thereof.

[0122] In some embodiments, R.sup.1 is an alkyl and R.sup.2 is an alkyl.

[0123] In some embodiments, R.sup.1 is an alkyl and R.sup.2 is a cycloalkyl.

[0124] In some embodiments, R.sup.1 is an alkenyl and R.sup.2 is an alkyl.

[0125] In some embodiments, R.sup.1 is an alkenyl and R.sup.2 is a cycloalkyl.

[0126] In some embodiments, R.sup.1 is an alkyne and R.sup.2 is an alkyl.

[0127] In some embodiments, R.sup.1 is an alkyne and R.sup.2 is a cycloalkyl.

[0128] In some embodiments, R.sup.1 is an aryl and R.sup.2 is an alkyl.

[0129] In some embodiments, R.sup.1 is an aryl and R.sup.2 is a cycloalkyl.

[0130] In some embodiments, R.sup.1 is a cycloalkyl and R.sup.2 is an alkyl.



[0131] In some embodiments, R.sup.1 is a cycloalkyl and R.sup.2 is a cycloalkyl.

[0132] In some embodiments, the vapor deposition precursor comprises a compound of the formula:

##STR00006##

[0133] In some embodiments, the composition comprises less than 5% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 4% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 3% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 2% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 1% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 0.5% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 0.1% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 0.01% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition comprises less than 0.001% by weight of a pyrophoric compound based on a total weight of the composition. In some embodiments, the composition does not comprise a pyrophoric compound.

[0134] In some embodiments, the composition comprises 0.001% to 5% by weight of a pyrophoric compound based on a total weight of the composition, or any range or subrange between 0.001% and 5%. For example, in some embodiments, the composition comprises 0.001% to 4%, 0.001% to 3%, 0.001% to 2%, 0.001% to 1%, 0.001% to 0.1%, 0.001% to 0.01%, 0.01% to 5%, 0.1% to 5%, 1% to 5%, 2% to 5%, 3% to 5%, or 4% to 5% by weight of a pyrophoric compound based on a total weight of the composition. The pyrophoric compound may comprise any one or more of the pyrophoric compounds disclosed herein. Non-limiting examples of pyrophoric compounds include, for example and without limitation, at least one of trimethyl aluminum, dimethyl aluminum chloride, methyl lithium, or any combination thereof. It will be appreciated that the pyrophoric compound may include other types of pyrophoric compounds, without departing from the scope of this disclosure.

[0135] In some embodiments, the vapor deposition precursor has a purity of 95% to 99.9999%, or any range or subrange between 95% and 99.9999%. For example, in some embodiments, the vapor deposition precursor has 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%.

[0136] FIG. 2 is a flowchart of a method for making a film **200**, according to some embodiments. As shown in FIG. 2, the method for making a film **200** may comprise one or more of the following steps: obtaining **202** a precursor, obtaining **204** at least one co-reactant precursor, vaporizing **206** the precursor to obtain a vaporized precursor, vaporizing **208** the at least one co-reactant precursor to obtain at least one vaporized co-reactant precursor, exposing **210**, under vapor deposition conditions, a substrate to at least one of the vaporized precursor, the at least one vaporized co-reactant precursor, or any combination thereof, to form a film on the substrate.

[0137] At step **202**, in some embodiments, the method comprises obtaining a precursor. The precursor may comprise any one or more of the vapor deposition precursors disclosed herein. For example, in some embodiments, the precursor comprises an aluminum amidinate. In some embodiments, the obtaining comprises obtaining a vessel comprising the precursor. In some embodiments, the obtaining comprises obtaining a container comprising the precursor. In some embodiments, the precursor may be obtained in a container or other vessel in which the precursor is to be vaporized.

[0138] At step **204**, in some embodiments, the method comprises obtaining at least one co-reactant

precursor. In some embodiments, the at least one co-reactant precursor comprises at least one of an oxidizing gas, a reducing gas, a hydrocarbon, or any combination thereof. The at least one co-reactant precursor may be selected to obtain a desired film. In some embodiments, the at least one co-reactant precursor comprises at least one of N.sub.2, H.sub.2, NH.sub.3, N.sub.2H.sub.4, CH.sub.3HNNH.sub.2, CH.sub.3HNNHCH.sub.3, NCH.sub.3H.sub.2, NCH.sub.3CH.sub.2H.sub.2, N(CH.sub.3).sub.2H, N(CH.sub.3CH.sub.2).sub.2H, N(CH.sub.3).sub.3, N(CH.sub.3CH.sub.2).sub.3, Si(CH.sub.3).sub.2NH, pyrazoline, pyridine, ethylene diamine, a radical thereof, or any combination thereof. In some embodiments, the at least one co-reactant precursor comprises at least one of H.sub.2, O.sub.2, O.sub.3, H.sub.2O, H.sub.2O.sub.2, NO, N.sub.2O, NO.sub.2, CO, CO.sub.2, a carboxylic acid, an alcohol, a diol, a radical thereof, or any combination thereof. In some embodiments, the at least one co-reactant precursor comprises at least one of methane, ethane, ethylene, acetylene, or any combination thereof. The obtaining may comprise obtaining a container or other vessel comprising the at least one co-reactant precursor. In some embodiments, the at least one co-reactant precursor may be obtained in a container or other vessel in which the at least one co-reactant precursor is to be vaporized. In some embodiments, the method further comprises an inert gas, such as, for example, at least one of argon, helium, nitrogen, or any combination thereof.

[0139] At step **206**, in some embodiments, the method comprises vaporizing the precursor to obtain a vaporized precursor. The vaporizing may comprise heating the precursor sufficient to obtain the vaporized precursor. In some embodiments, the vaporizing comprises heating a container comprising the precursor. In some embodiments, the vaporizing comprises heating the precursor in a deposition chamber in which the vapor deposition process is performed. In some embodiments, the vaporizing comprises heating a conduit for delivering the precursor, the vaporized precursor, or any combination thereof to, for example, a deposition chamber. In some embodiments, the vaporizing comprises operating a vapor delivery system comprising the precursor. In some embodiments, the vaporizing comprises heating to a temperature sufficient to vaporize the precursor to obtain the vaporized precursor. In some embodiments, the vaporizing comprises heating to a temperature below a decomposition temperature of at least one of the precursor, the vaporized precursor, or any combination thereof. In some embodiments, the precursor may be present in a gas phase or other vaporizable phase, in which case the step **206** is optional and not required. For example, in some embodiments, the precursor comprises the vaporized precursor.

[0140] At step **208**, in some embodiments, the method comprises vaporizing the at least one co-reactant precursor to obtain the at least one vaporized co-reactant precursor. In some embodiments, the vaporizing comprises heating the at least one co-reactant precursor sufficient to obtain the at least one vaporized co-reactant precursor. In some embodiments, the vaporizing comprises heating a container comprising the at least one co-reactant precursor. In some embodiments, the vaporizing comprises heating the at least one co-reactant precursor in a deposition chamber in which the vapor deposition process is performed. In some embodiments, the vaporizing comprises heating a conduit for delivering the at least one co-reactant precursor, the at least one vaporized co-reactant precursor, or any combination thereof to, for example, a deposition chamber. In some embodiments, the vaporizing comprises operating a vapor delivery system comprising the at least one co-reactant precursor. In some embodiments, the vaporizing comprises heating to a temperature sufficient to vaporize the at least one co-reactant precursor to obtain the at least one vaporized co-reactant precursor. In some embodiments, the vaporizing comprises heating to a temperature below a decomposition temperature of at least one of the at least one co-reactant precursor, the at least one vaporized co-reactant precursor, or any combination thereof. In some embodiments, the at least one co-reactant precursor may be present in a gas phase or other vaporizable phase, in which case the step **208** is optional and not required. For example, in some embodiments, the at least one co-reactant precursor comprises the at least one vaporized co-reactant precursor.

[0141] At step **210**, in some embodiments, the method comprises exposing, under vapor deposition

conditions, a substrate to at least one of the vaporized precursor, the at least one vaporized co-reactant precursor, or any combination thereof, to form a film on the substrate. The exposing may be performed in any system, apparatus, device, assembly, chamber thereof, or component thereof suitable for vapor deposition processes, including, for example and without limitation, a deposition chamber, among others. In some embodiments, the exposing comprises contacting the substrate with at least one of the vaporized precursor, the at least one vaporized co-reactant precursor, or any combination thereof. The vaporized precursor and the at least one co-reactant precursor may be contacted with the substrate at the same time or at different times. For example, each of the vaporized precursor, the at least one vaporized co-reactant precursor, and the substrate may be present in the deposition chamber at the same time. That is, in some embodiments, the contacting may comprise contemporaneous contacting or simultaneous contacting of the vaporized precursor and the at least one vaporized co-reactant precursor with the substrate. Alternatively, each of the vaporized precursor and the at least one vaporized co-reactant precursor may be present in the deposition chamber at different times. That is, in some embodiments, the contacting may comprise alternate and/or sequential contacting, in one or more cycles, of the vaporized precursor with the substrate and subsequently contacting the at least one vaporized co-reactant precursor with the substrate.

[0142] The vapor deposition conditions may comprise conditions for vapor deposition processes. Examples of vapor deposition conditions include, without limitation, vapor deposition conditions for vapor deposition processes including 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.

[0143] The vapor deposition conditions may comprise a deposition temperature. The deposition temperature may be a temperature less than the thermal decomposition temperature of at least one of the vaporized precursor, the at least one vaporized co-reactant precursor, or any combination thereof. The deposition temperature may be sufficiently high to reduce or avoid condensation of at least one of the vaporized precursor, the at least one vaporized co-reactant precursor, or any combination thereof. In some embodiments, the substrate may be heated to the deposition temperature. In some embodiments, the chamber or other vessel in which the substrate is contacted with the vaporized precursor and the at least one vaporized co-reactant precursor is heated to the deposition temperature. In some embodiments, at least one of the vaporized precursor, the at least one vaporized co-reactant precursor, or any combination thereof may be heated to the deposition temperature.

[0144] The deposition temperature may be a temperature of 200° C. to 2500° C., or any range or subrange between 200° C. and 2500° C. In some embodiments, the deposition temperature may be a temperature of 500° C. to 700° C. For example, in some embodiments, the deposition temperature may be a temperature of 500° C. to 680° C., 500° C. to 660° C., 500° C. to 640° C., 500° C. to 620° C., 500° C. to 600° C., 500° C. to 580° C., 500° C. to 560° C., 500° C. to 540° C., 500° C. to 520° C., 520° C. to 700° C., 540° C. to 700° C., 560° C. to 700° C., 580° C. to 700° C., 600° C. to 700° C., 620° C. to 700° C., 640° C. to 700° C., 660° C. to 700° C., or 680° C. to 700° C. In other embodiments, the deposition temperature may be a temperature of greater than 200° C. to 2500° C., such as, for example and without limitation, a temperature of 400° C. to 2000, 500° C. to 2000° C., 550° C. to 2400° C., 600° C. to 2400° C., 625° C. to 2400° C., 650° C. to 2400° C., 675° C. to 2400° C., 700° C. to 2400° C., 725° C. to 2400° C., 750° C. to 2400° C., 775° C. to 2400° C., 800° C. to 2400° C., 825° C. to 2400° C., 850° C. to 2400° C., 875° C. to 2400° C., 900° C. to 2400° C., 925° C. to 2400° C., 950° C. to 2400° C., 975° C. to 2400° C., 1000° C. to 2400° C., 1025° C. to

2400° C., 1050° C. to 2400° C., 1075° C. to 2400° C., 1100° C. to 2400° C., 1200° C. to 2400° C., 1300° C. to 2400° C., 1400° C. to 2400° C., 1500° C. to 2400° C., 1600° C. to 2400° C., 1700° C. to 2400° C., 1800° C. to 2400° C., 1900° C. to 2400° C., 2000° C. to 2400° C., 2100° C. to 2400° C., 2200° C. to 2400° C., 2300° C. to 2400° C., 500° C. to 2000° C., 500° C. to 1900° C., 500° C. to 1800° C., 500° C. to 1700° C., 500° C. to 1600° C., 500° C. to 1500° C., 500° C. to 1400° C., 500° C. to 1300° C., 500° C. to 1200° C., 500° C. to 1100° C., 500° C. to 1000° C., 500° C. to 1000° C., 500° C. to 900° C., or 500° C. to 800° C.

[0145] The vapor deposition conditions may comprise a deposition pressure. In some embodiments, the deposition pressure may comprise a vapor pressure of at least one of the vaporized precursor, the at least one vaporized co-reactant precursor, or any combination thereof. In some embodiments, the deposition pressure may comprise a chamber pressure.

[0146] The deposition pressure may be a pressure of 0.001 Torr to 100 Torr, or any range or subrange between 0.001 Torr and 100 Torr. For example, in some embodiments, the deposition pressure may be a pressure of 1 Torr to 30 Torr, 1 Torr to 25 Torr, 1 Torr to 20 Torr, 1 Torr to 15 Torr, 1 Torr to 10 Torr, 5 Torr to 50 Torr, 5 Torr to 40 Torr, 5 Torr to 30 Torr, 5 Torr to 20 Torr, or 5 Torr to 15 Torr. In other embodiments, the deposition pressure may be a pressure of 1 Torr to 100 Torr, 5 Torr to 100 Torr, 10 Torr to 100 Torr, 15 Torr to 100 Torr, 20 Torr to 100 Torr, 25 Torr to 100 Torr, 30 Torr to 100 Torr, 35 Torr to 100 Torr, 40 Torr to 100 Torr, 45 Torr to 100 Torr, 50 Torr to 100 Torr, 55 Torr to 100 Torr, 60 Torr to 100 Torr, 65 Torr to 100 Torr, 70 Torr to 100 Torr, 75 Torr to 100 Torr, 80 Torr to 100 Torr, 85 Torr to 100 Torr, 90 Torr to 100 Torr, 95 Torr to 100 Torr, 1 Torr to 95 Torr, 1 Torr to 90 Torr, 1 Torr to 85 Torr, 1 Torr to 80 Torr, 1 Torr to 75 Torr, or 1 Torr to 70 Torr. In other further embodiments, the deposition pressure may be a pressure of 1 mTorr to 100 mTorr, 1 mTorr to 90 mTorr, 1 mTorr to 80 mTorr, 1 mTorr to 70 mTorr, 1 mTorr to 60 mTorr, 1 mTorr to 50 mTorr, 1 mTorr to 40 mTorr, 1 mTorr to 30 mTorr, 1 mTorr to 20 mTorr, 1 mTorr to 10 mTorr, 100 mTorr to 300 mTorr, 150 mTorr to 300 mTorr, 200 mTorr to 300 mTorr, or 150 mTorr to 250 mTorr, or 150 mTorr to 225 mTorr.

[0147] The substrate may comprise at least one of Si, Co, Cu, Al, W, WN, WC, TiN, Mo, MoC, SiO.sub.2, W, SiN, WCN, Al.sub.2O.sub.3, AlN, ZrO.sub.2, La.sub.2O.sub.3, TaN, RuO.sub.2, IrO.sub.2, Nb.sub.2O.sub.3, Y.sub.2O.sub.3, hafnium oxide, or any combination thereof.

[0148] In some embodiments, the film comprises an aluminum compound. For example, in some embodiments, the film comprises at least one of an aluminum, an aluminum oxide compound (e.g., Al.sub.2O.sub.3, etc.), an aluminum nitride compound, an aluminum oxynitride compound, an aluminum carbide compound, an aluminum carbonitride compound, or any combination thereof.

[0149] Some embodiments relate to an article. In some embodiments, the article comprises a substrate. In some embodiments, the substrate has a first surface portion and a second surface portion. In some embodiments, the first surface portion comprises a metal. In some embodiments, the metal comprises a ruthenium, a tungsten, a tantalum, a molybdenum, a titanium, a copper, a cobalt, or any combination thereof. In some embodiments, the metal comprises a tungsten, a tantalum nitride, a molybdenum, a titanium nitride, a copper, a cobalt, or any combination thereof. In some embodiments, the second surface portion comprises a non-metal. In some embodiments, the non-metal comprises a silicon dioxide.

[0150] In some embodiments, the article comprises a layer. In some embodiments, the layer comprises a reaction product of an aluminum amidinate. In some embodiments, the layer is located on the second surface portion of the substrate. In some embodiments, the aluminum amidinate has a selectivity for the non-metal versus the metal. In some embodiments, an inhibitor is not present. In some embodiments, an inhibitor is not used during the deposition of the aluminum amidinate. In some embodiments, the aluminum amidinate has a selectivity for the non-metal versus the metal without the use of an inhibitor.

[0151] In some embodiments, an average thickness of the layer on the second surface portion is at least 20 nm. In some embodiments, the average thickness of the layer on the second surface portion

is at least 30 nm, at least 40 nm, at least 50 nm, at least 60 nm, at least 70 nm, at least 80 nm, at least 90 nm, at least 100 nm, at least 200 nm, at least 300 nm, at least 400 nm, at least 500 nm, at least 600 nm, at least 700 nm, at least 800 nm, at least 900 nm, or at least 1000 nm. In some embodiments, the average thickness of the layer on the second surface portion is 20 nm to 1000 nm, or any range or subrange between 20 nm to 1000 nm. In some embodiments, the average thickness of the layer on the second surface portion is 20 nm to 900 nm, 20 nm to 800 nm, 20 nm to 700 nm, 20 nm to 600 nm, 20 nm to 500 nm, 20 nm to 400 nm, 20 nm to 300 nm, 20 nm to 200 nm, 20 nm to 100 nm, 20 nm to 90 nm, 20 nm to 80 nm, 20 nm to 70 nm, 20 nm to 60 nm, 20 nm to 50 nm, 20 nm to 40 nm, 20 nm to 30 nm, 30 nm to 1000 nm, 40 nm to 1000 nm, 50 nm to 1000 nm, 60 nm to 1000 nm, 70 nm to 1000 nm, 80 nm to 1000 nm, 90 nm to 1000 nm, 100 nm to 1000 nm, 200 nm to 1000 nm, 300 nm to 1000 nm, 400 nm to 1000 nm, 500 nm to 1000 nm, 600 nm to 1000 nm, 700 nm to 1000 nm, 800 nm to 1000 nm, or 900 nm to 1000 nm.

[0152] In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is less than 1. In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is 0 to less than 1, or any range or subrange between 0 to less than 1. In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is 0 to 0.95, 0 to 0.9, 0 to 0.85, 0 to 0.8, 0 to 0.75, 0 to 0.7, 0 to 0.65, 0 to 0.6, 0 to 0.55, 0 to 0.5, 0 to 0.45, 0 to 0.4, 0 to 0.35, 0 to 0.3, 0 to 0.25, 0 to 0.2, 0 to 0.15, 0 to 0.1, 0 to 0.09, 0 to 0.08, 0 to 0.07, 0 to 0.06, 0 to 0.05, 0 to 0.04, 0 to 0.03, 0 to 0.02, 0 to 0.01, 0.01 to less than 1, 0.02 to less than 1, 0.03 to less than 1, 0.04 to less than 1, 0.05 to less than 1, 0.06 to less than 1, 0.07 to less than 1, 0.08 to less than 1, 0.09 to less than 1, 0.1 to less than 1, 0.15 to less than 1, 0.2 to less than 1, 0.25 to less than 1, 0.3 to less than 1, 0.35 to less than 1, 0.4 to less than 1, 0.45 to less than 1, 0.5 to less than 1, 0.55 to less than 1, 0.6 to less than 1, 0.65 to less than 1, 0.7 to less than 1, 0.75 to less than 1, 0.8 to less than 1, 0.85 to less than 1, 0.9 to less than 1, or 0.95 to less than 1.

[0153] In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the second surface portion to an average thickness of the layer on the first surface portion is greater than 1. In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the second surface portion to an average thickness of the layer on the first surface portion is greater than 5, greater than 10, greater than 20, greater than 30, greater than 40, greater than 50, greater than 60, greater than 70, greater than 80, greater than 90, greater than 100, greater than 150, greater than 200, greater than 250, greater than 300, greater than 350, greater than 400, greater than 450, greater than 500, greater than 550, greater than 600, greater than 650, greater than 700, greater than 750, greater than 800, greater than 850, greater than 900, greater than 950, or greater than 1000.

[0154] In some embodiments, when the layer is located on the first surface portion, the average thickness of the layer on the first surface portion is 10 nm or less. In some embodiments, when the layer is located on the first surface portion, the average thickness of the layer on the first surface portion is 9 nm or less, 8 nm or less, 7 nm or less, 6 nm or less, 5 nm or less, 4 nm or less, 3 nm or less, 2 nm or less, 1 nm or less, 0.5 nm or less, or 0.1 nm or less. In some embodiments, when the layer is located on the first surface portion, the average thickness of the layer on the first surface portion is 0.1 nm to 10 nm, or any range or subrange between 0.1 nm to 10 nm. In some embodiments, when the layer is located on the first surface portion, the average thickness of the layer on the first surface portion is 0.1 nm to 9 nm, 0.1 nm to 8 nm, 0.1 nm to 7 nm, 0.1 nm to 6 nm, 0.1 nm to 5 nm, 0.1 nm to 4 nm, 0.1 nm to 3 nm, 0.1 nm to 2 nm, 0.1 nm to 1 nm, 0.1 nm to 0.5 nm, 0.5 nm to 10 nm, 1 nm to 10 nm, 2 nm to 10 nm, 3 nm to 10 nm, 4 nm to 10 nm, 5 nm to 10 nm, 6 nm to 10 nm, 7 nm to 10 nm, 8 nm to 10 nm, or 9 nm to 10 nm.

[0155] In some embodiments, the layer is not located on the first surface portion of the substrate. [0156] FIG. 3 is a flowchart of a method 300 for making a layer on a substrate, according to some embodiments. As shown in FIG. 3, the method 300 may comprise one or more of the following steps: obtaining a substrate having a first surface portion and a second surface portion 302, obtaining a vapor deposition precursor 304, vaporizing the vapor deposition precursor to obtain a precursor vapor 306, and contacting the substrate with the precursor vapor to form a layer 308.

[0157] At step 302, in some embodiments, the method comprises obtaining a substrate having a first surface portion and a second surface portion. In some embodiments, the first surface portion comprises a metal. In some embodiments, the metal comprises a ruthenium, a tungsten, a tantalum, a molybdenum, a titanium, a copper, a cobalt, or any combination thereof. In some embodiments, the metal comprises a tungsten, a tantalum nitride, a molybdenum, a titanium nitride, a copper, a cobalt, or any combination thereof. In some embodiments, the second surface portion comprises a non-metal. In some embodiments, the non-metal comprises a silicon dioxide.

[0158] At step 304, in some embodiments, the method comprises obtaining a vapor deposition precursor. The vapor deposition precursor may comprise any one or more of the vapor deposition precursors disclosed herein. For example, in some embodiments, the precursor comprises an aluminum amidinate. In some embodiments, the obtaining comprises obtaining a vessel comprising the vapor deposition precursor. In some embodiments, the obtaining comprises obtaining a container comprising the vapor deposition precursor. In some embodiments, the vapor deposition precursor may be obtained in a container or other vessel in which the vapor deposition precursor is to be vaporized.

[0159] At step 306, in some embodiments, the method comprises vaporizing the vapor deposition precursor to obtain a precursor vapor. The vaporizing may comprise heating the vapor deposition precursor sufficient to obtain the precursor vapor. In some embodiments, the vaporizing comprises heating a container comprising the vapor deposition precursor. In some embodiments, the vaporizing comprises heating the vapor deposition precursor in a deposition chamber in which the vapor deposition process is performed. In some embodiments, the vaporizing comprises heating a conduit for delivering the vapor deposition precursor, the precursor vapor, or any combination thereof to, for example, a deposition chamber. In some embodiments, the vaporizing comprises operating a vapor delivery system comprising the vapor deposition precursor. In some embodiments, the vaporizing comprises heating to a temperature sufficient to vaporize the vapor deposition precursor to obtain the precursor vapor. In some embodiments, the vaporizing comprises heating to a temperature below a decomposition temperature of at least one of the vapor deposition precursor, the precursor vapor, or any combination thereof. In some embodiments, the vapor deposition precursor may be present in a gas phase or other vaporizable phase, in which case the step 306 is optional and not required. For example, in some embodiments, the vapor deposition precursor comprises the precursor vapor.

[0160] At step 308, in some embodiments, the method comprises contacting the substrate with the precursor vapor to form a layer. In some embodiments, the layer is located on the second surface portion of the substrate. In some embodiments, contact may comprise contacting the substrate under vapor deposition conditions. The contacting may be performed in any system, apparatus, device, assembly, chamber thereof, or component thereof suitable for vapor deposition processes, including, for example and without limitation, a deposition chamber, among others.

[0161] The vapor deposition conditions may comprise conditions for vapor deposition processes. Examples of vapor deposition conditions include, without limitation, vapor deposition conditions for vapor deposition processes including 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.

[0162] The vapor deposition conditions may comprise a deposition temperature.

[0163] The deposition temperature may be a temperature less than the thermal decomposition temperature of precursor vapor. The deposition temperature may be sufficiently high to reduce or avoid condensation of precursor vapor. In some embodiments, the substrate may be heated to the deposition temperature. In some embodiments, the chamber or other vessel in which the substrate is contacted with precursor vapor is heated to the deposition temperature. In some embodiments, the precursor vapor may be heated to the deposition temperature.

[0164] The deposition temperature may be a temperature of 200° C. to 2500° C., or any range or subrange between 200° C. and 2500° C. In some embodiments, the deposition temperature may be a temperature of 500° C. to 700° C. For example, in some embodiments, the deposition temperature may be a temperature of 500° C. to 680° C., 500° C. to 660° C., 500° C. to 640° C., 500° C. to 620° C., 500° C. to 600° C., 500° C. to 580° C., 500° C. to 560° C., 500° C. to 540° C., 500° C. to 520° C., 520° C. to 700° C., 540° C. to 700° C., 560° C. to 700° C., 580° C. to 700° C., 600° C. to 700° C., 620° C. to 700° C., 640° C. to 700° C., 660° C. to 700° C., or 680° C. to 700° C. In other embodiments, the deposition temperature may be a temperature of greater than 200° C. to 2500° C., such as, for example and without limitation, a temperature of 400° C. to 2000, 500° C. to 2000° C., 550° C. to 2400° C., 600° C. to 2400° C., 625° C. to 2400° C., 650° C. to 2400° C., 675° C. to 2400° C., 700° C. to 2400° C., 725° C. to 2400° C., 750° C. to 2400° C., 775° C. to 2400° C., 800° C. to 2400° C., 825° C. to 2400° C., 850° C. to 2400° C., 875° C. to 2400° C., 900° C. to 2400° C., 925° C. to 2400° C., 950° C. to 2400° C., 975° C. to 2400° C., 1000° C. to 2400° C., 1025° C. to 2400° C., 1050° C. to 2400° C., 1075° C. to 2400° C., 1100° C. to 2400° C., 1200° C. to 2400° C., 1300° C. to 2400° C., 1400° C. to 2400° C., 1500° C. to 2400° C., 1600° C. to 2400° C., 1700° C. to 2400° C., 1800° C. to 2400° C., 1900° C. to 2400° C., 2000° C. to 2400° C., 2100° C. to 2400° C., 2200° C. to 2400° C., 2300° C. to 2400° C., 500° C. to 2000° C., 500° C. to 1900° C., 500° C. to 1800° C., 500° C. to 1700° C., 500° C. to 1600° C., 500° C. to 1500° C., 500° C. to 1400° C., 500° C. to 1300° C., 500° C. to 1200° C., 500° C. to 1100° C., 500° C. to 1000° C., 500° C. to 1000° C., 500° C. to 900° C., or 500° C. to 800° C.

[0165] The vapor deposition conditions may comprise a deposition pressure. In some embodiments, the deposition pressure may comprise a vapor pressure of precursor vapor. In some embodiments, the deposition pressure may comprise a chamber pressure.

[0166] The deposition pressure may be a pressure of 0.001 Torr to 100 Torr, or any range or subrange between 0.001 Torr and 100 Torr. For example, in some embodiments, the deposition pressure may be a pressure of 1 Torr to 30 Torr, 1 Torr to 25 Torr, 1 Torr to 20 Torr, 1 Torr to 15 Torr, 1 Torr to 10 Torr, 5 Torr to 50 Torr, 5 Torr to 40 Torr, 5 Torr to 30 Torr, 5 Torr to 20 Torr, or 5 Torr to 15 Torr. In other embodiments, the deposition pressure may be a pressure of 1 Torr to 100 Torr, 5 Torr to 100 Torr, 10 Torr to 100 Torr, 15 Torr to 100 Torr, 20 Torr to 100 Torr, 25 Torr to 100 Torr, 30 Torr to 100 Torr, 35 Torr to 100 Torr, 40 Torr to 100 Torr, 45 Torr to 100 Torr, 50 Torr to 100 Torr, 55 Torr to 100 Torr, 60 Torr to 100 Torr, 65 Torr to 100 Torr, 70 Torr to 100 Torr, 75 Torr to 100 Torr, 80 Torr to 100 Torr, 85 Torr to 100 Torr, 90 Torr to 100 Torr, 95 Torr to 100 Torr, 1 Torr to 95 Torr, 1 Torr to 90 Torr, 1 Torr to 85 Torr, 1 Torr to 80 Torr, 1 Torr to 75 Torr, or 1 Torr to 70 Torr. In other further embodiments, the deposition pressure may be a pressure of 1 mTorr to 100 mTorr, 1 mTorr to 90 mTorr, 1 mTorr to 80 mTorr, 1 mTorr to 70 mTorr, 1 mTorr to 60 mTorr, 1 mTorr to 50 mTorr, 1 mTorr to 40 mTorr, 1 mTorr to 30 mTorr, 1 mTorr to 20 mTorr, 1 mTorr to 10 mTorr, 100 mTorr to 300 mTorr, 150 mTorr to 300 mTorr, 200 mTorr to 300 mTorr, or 150 mTorr to 250 mTorr, or 150 mTorr to 225 m Torr.

[0167] In some embodiments, the layer is located on the second surface portion of the substrate. In some embodiments, the precursor vapor has a selectivity for the non-metal versus the metal. In some embodiments, an inhibitor is not present. In some embodiments, an inhibitor is not used

during the deposition of the precursor vapor. In some embodiments, the precursor vapor has a selectivity for the non-metal versus the metal without the use of an inhibitor.

[0168] In some embodiments, an average thickness of the layer on the second surface portion is at least 20 nm. In some embodiments, the average thickness of the layer on the second surface portion is at least 30 nm, at least 40 nm, at least 50 nm, at least 60 nm, at least 70 nm, at least 80 nm, at least 90 nm, at least 100 nm, at least 200 nm, at least 300 nm, at least 400 nm, at least 500 nm, at least 600 nm, at least 700 nm, at least 800 nm, at least 900 nm, or at least 1000 nm. In some embodiments, the average thickness of the layer on the second surface portion is 20 nm to 1000 nm, or any range or subrange between 20 nm to 1000 nm. In some embodiments, the average thickness of the layer on the second surface portion is 20 nm to 900 nm, 20 nm to 800 nm, 20 nm to 700 nm, 20 nm to 600 nm, 20 nm to 500 nm, 20 nm to 400 nm, 20 nm to 300 nm, 20 nm to 200 nm, 20 nm to 100 nm, 20 nm to 90 nm, 20 nm to 80 nm, 20 nm to 70 nm, 20 nm to 60 nm, 20 nm to 50 nm, 20 nm to 40 nm, 20 nm to 30 nm, 30 nm to 1000 nm, 40 nm to 1000 nm, 50 nm to 1000 nm, 60 nm to 1000 nm, 70 nm to 1000 nm, 80 nm to 1000 nm, 90 nm to 1000 nm, 100 nm to 1000 nm, 200 nm to 1000 nm, 300 nm to 1000 nm, 400 nm to 1000 nm, 500 nm to 1000 nm, 600 nm to 1000 nm, 700 nm to 1000 nm, 800 nm to 1000 nm, or 900 nm to 1000 nm.

[0169] In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is less than 1. In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is 0 to less than 1, or any range or subrange between 0 to less than 1. In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is 0 to 0.95, 0 to 0.9, 0 to 0.85, 0 to 0.8, 0 to 0.75, 0 to 0.7, 0 to 0.65, 0 to 0.6, 0 to 0.55, 0 to 0.5, 0 to 0.45, 0 to 0.4, 0 to 0.35, 0 to 0.3, 0 to 0.25, 0 to 0.2, 0 to 0.15, 0 to 0.1, 0 to 0.09, 0 to 0.08, 0 to 0.07, 0 to 0.06, 0 to 0.05, 0 to 0.04, 0 to 0.03, 0 to 0.02, 0 to 0.01, 0.01 to less than 1, 0.02 to less than 1, 0.03 to less than 1, 0.04 to less than 1, 0.05 to less than 1, 0.06 to less than 1, 0.07 to less than 1, 0.08 to less than 1, 0.09 to less than 1, 0.1 to less than 1, 0.15 to less than 1, 0.2 to less than 1, 0.25 to less than 1, 0.3 to less than 1, 0.35 to less than 1, 0.4 to less than 1, 0.45 to less than 1, 0.5 to less than 1, 0.55 to less than 1, 0.6 to less than 1, 0.65 to less than 1, 0.7 to less than 1, 0.75 to less than 1, 0.8 to less than 1, 0.85 to less than 1, 0.9 to less than 1, or 0.95 to less than 1.

[0170] In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the second surface portion to an average thickness of the layer on the first surface portion is greater than 1. In some embodiments, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the second surface portion to an average thickness of the layer on the first surface portion is greater than 5, greater than 10, greater than 20, greater than 30, greater than 40, greater than 50, greater than 60, greater than 70, greater than 80, greater than 90, greater than 100, greater than 150, greater than 200, greater than 250, greater than 300, greater than 350, greater than 400, greater than 450, greater than 500, greater than 550, greater than 600, greater than 650, greater than 700, greater than 750, greater than 800, greater than 850, greater than 900, greater than 950, or greater than 1000.

[0171] In some embodiments, when the layer is located on the first surface portion, the average thickness of the layer on the first surface portion is 10 nm or less. In some embodiments, when the layer is located on the first surface portion, the average thickness of the layer on the first surface portion is 9 nm or less, 8 nm or less, 7 nm or less, 6 nm or less, 5 nm or less, 4 nm or less, 3 nm or less, 2 nm or less, 1 nm or less, 0.5 nm or less, or 0.1 nm or less. In some embodiments, when the layer is located on the first surface portion, the average thickness of the layer on the first surface portion is 0.1 nm to 10 nm, or any range or subrange between 0.1 nm to 10 nm. In some embodiments, when the layer is located on the first surface portion, the average thickness of the



layer on the first surface portion is 0.1 nm to 9 nm, 0.1 nm to 8 nm, 0.1 nm to 7 nm, 0.1 nm to 6 nm, 0.1 nm to 5 nm, 0.1 nm to 4 nm, 0.1 nm to 3 nm, 0.1 nm to 2 nm, 0.1 nm to 1 nm, 0.1 nm to 0.5 nm, 0.5 nm to 10 nm, 1 nm to 10 nm, 2 nm to 10 nm, 3 nm to 10 nm, 4 nm to 10 nm, 5 nm to 10 nm, 6 nm to 10 nm, 7 nm to 10 nm, 8 nm to 10 nm, or 9 nm to 10 nm.

[0172] In some embodiments, the layer is not located on the first surface portion of the substrate.

[0173] Some embodiments relate to a film on a substrate. In some embodiments, the film comprises any film formed according to the methods disclosed herein. In some embodiments, the film comprises any film prepared from any one or more of the precursors disclosed herein.

[0174] Any one or more of the embodiments disclosed herein shall be understood to be combinable without departing from the scope or spirit of the disclosure.

#### Example 1

[0175] Trimethylaluminum (TMA) was used as a precursor to deposit an aluminum-based film on various substrates. The TMA was deposited using ALD. FIG. 4 is a graphical representation of the thickness of the deposited aluminum-based films as a function of the number of ALD cycles for the various substrates. The thickness of each deposited aluminum-based film was measured using X-ray fluorescence (XRF).

[0176] As shown in FIG. 4, TMA exhibits similar selectivity towards non-metal substrates (SiO.sub.2) as towards metal substrate.

#### Example 2

[0177] Dimethylaluminum isopropoxide (DMAI) was used as a precursor to deposit an aluminum-based film on various substrates. The DMAI was deposited using ALD. FIG. 5 is a graphical representation of the thickness of the deposited aluminum-based films as a function of the number of ALD cycles for the various substrates. The thickness of each deposited aluminum-based film was measured using X-ray fluorescence (XRF).

#### Example 3

[0178] An aluminum amidinate was used as a precursor to deposit an aluminum-based film on various substrates. The aluminum amidinate was deposited using ALD.

[0179] FIG. 6 is a graphical representation of the thickness of the deposited aluminum-based films as a function of the number of ALD cycles for the various substrates. The thickness of each deposited aluminum-based film was measured using X-ray fluorescence (XRF).

[0180] Comparing FIGS. 5 and 6, aluminum amidinate exhibits a greater selectivity towards non-metal substrates (SiO.sub.2) versus metal substrates than DMAI.

#### Example 4: Synthesis of [MeC(N.SUP.i.Pr).SUB.2.]AlMe.SUB.2

[0181] In a nitrogen filled glovebox, 40.0 grams of AlCl.sub.3 (300 mmol) was added to a 1 L single-neck round-bottom flask equipped with a stir bar and air-cooled condenser. 50 mL of pentane was added to the flask, forming a suspension to which 50 mL of THF was slowly added resulting in an exotherm that refluxed the pentane suspension. Note that the addition rate and pentane reflux were used to control the exotherm. This resulted in a yellow solution. Next, 37.86 grams of N,N'-Diisopropylcarbodiimide (DIC) (300 mmol, 1 eq) was added to a 100 mL round-bottom flask before being diluted with 50 mL of THF. Then 300 mL of MeMgBr (3.0M in diethyl ether, 900 mmol, 3 eq) was added to a 500 mL round-bottom flask along with a stir bar. The DIC solution was slowly added to the stirring MeMgBr solution which resulted in an exotherm that refluxed solvent. Once the addition was complete, the resulting solution was allowed to stir for 30 minutes before being slowly added to the stirring AlCl.sub.3 solution. Addition of the MeMgBr and DIC solution resulted in another exotherm that was controlled by the addition rate along with solvent refluxing facilitated by the air-cooled condenser. The resulting reaction mixture was allowed to stir overnight. Then 50 mL of pentane was added to further precipitate the magnesium salts before filtering through a disposable polypropylene filter into a 1 L Schlenk flask. The filter was washed with an additional 50 mL of pentane resulting in a pale-yellow filtrate. The solvent was then removed under vacuum resulting in a suspended white solid mixture. The product was then

extracted with 100 mL of pentane and filtered again before the solvent was removed under vacuum to yield 46.08 g of the crude product as a pale-yellow liquid. The crude material was then purified by vacuum distillation using a short path apparatus with a condenser cooled to  $-5^{\circ}\text{C}$ ., a pot temperature of  $45^{\circ}\text{C}$ ., a head temperature of  $28^{\circ}\text{C}$ ., and a pressure of 300 mTorr. The pure  $[\text{MeC}(\text{N}^{\text{sup.iPr}})_{\text{sub.2}}]\text{AlMe}_{\text{sub.2}}$  product was isolated as a clear colorless liquid, with a yield of 36.8 g (62%).

[0182]  $^1\text{H}$  NMR ( $\text{C}_{\text{sub.6D.sub.6}}$ ):  $\delta$  3.12 (sept, 2H,  $\text{CHCMe}_{\text{sub.2}}$ ), 1.27 (s, 3H, MeC), 0.95 (d, 12H,  $\text{CHCMe}_{\text{sub.2}}$ ),  $-0.27$  (s, 6H, AlMe)

## ASPECTS

[0183] 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).

[0184] Aspect 1. A method for forming a vapor deposition precursor, the method comprising: contacting an aluminum trichloride, a Grignard reagent, and a carbodiimide compound to form the vapor deposition precursor, [0185] wherein the vapor deposition precursor comprises an aluminum amidinate.

[0186] Aspect 2. The method according to Aspect 1, wherein the vapor deposition precursor is formed without use of a pyrophoric compound.

[0187] Aspect 3. The method according to any one of Aspects 1-2, wherein the vapor deposition precursor is formed without use of at least one of trimethyl aluminum, dimethyl aluminum chloride, methyl lithium, or any combination thereof.

[0188] Aspect 4. The method according to any one of Aspects 1-3, wherein the Grignard reagent comprises a compound of the formula:

$\text{R}^{\text{sup.1}}\text{MgX}$ , [0189] where: [0190]  $\text{R}^{\text{sup.1}}$  is at least one of an alkyl, an alkenyl, an alkyne, an aryl, a cycloalkyl, or any combination thereof; and [0191] X is Cl, Br, or I.

[0192] Aspect 5. The method according to any one of Aspects 1-4, wherein the carbodiimide compound comprises a compound of the formula:

$\text{R}^{\text{sup.2}}\text{—N=C=N—R}^{\text{sup.2}}$ , [0193] where: [0194]  $\text{R}^{\text{sup.2}}$  is independently at least one of an alkyl, a cycloalkyl, or any combination thereof.

[0195] The method according to any one of Aspects 1-5, Aspect 6, [0196] wherein the Grignard reagent comprises a compound of the formula:

$\text{R}^{\text{sup.1}}\text{MgX}$ , [0197] where: [0198]  $\text{R}^{\text{sup.1}}$  is an alkyl; and [0199] X is Cl, Br, or I, [0200] wherein the carbodiimide compound comprises a compound of the formula:

$\text{R}^{\text{sup.2}}\text{—N=C=N—R}^{\text{sup.2}}$ , [0201] where: [0202]  $\text{R}^{\text{sup.2}}$  is independently an alkyl.

[0203] Aspect 7. The method according to any one of Aspects 1-6, [0204] wherein the Grignard reagent comprises a compound of the formula:

$\text{R}^{\text{sup.1}}\text{MgX}$ , [0205] where: [0206]  $\text{R}^{\text{sup.1}}$  is an alkyl; and [0207] X is Cl, Br, or I, [0208] wherein the carbodiimide compound comprises a compound of the formula:

$\text{R}^{\text{sup.2}}\text{—N=C=N—R}^{\text{sup.2}}$ , [0209] where: [0210]  $\text{R}^{\text{sup.2}}$  is independently a cycloalkyl.

[0211] Aspect 8. The method according to any one of Aspects 1-7, [0212] wherein the Grignard reagent comprises a compound of the formula:

$\text{R}^{\text{sup.1}}\text{MgX}$ , [0213] where: [0214]  $\text{R}^{\text{sup.1}}$  is a  $\text{C}_{\text{sub.1-C.sub.10}}$  alkyl; and [0215] X is Cl, Br, or I, [0216] wherein the carbodiimide compound comprises a compound of the formula:

R.sup.2—N=C=N—R.sup.2, [0217] where: [0218] R.sup.2 is independently a C.sub.1-C.sub.10 alkyl.

[0219] Aspect 9. The method according to any one of Aspects 1-8, [0220] wherein the Grignard reagent comprises a compound of the formula:

R.sup.1MgX, [0221] where: [0222] R.sup.1 is a C.sub.1-C.sub.10 alkyl; and [0223] X is Cl, Br, or I, [0224] wherein the carbodiimide compound comprises a compound of the formula:

R.sup.2—N=C=N—R.sup.2, [0225] where: [0226] R.sup.2 is independently a C.sub.1-C.sub.10 cycloalkyl.

[0227] Aspect 10. The method according to any one of Aspects 1-9, wherein the vapor deposition precursor comprises a compound of the formula:

##STR00007## [0228] where: [0229] R.sup.1 is independently at least one of an alkyl, an alkenyl, an alkyne, a cycloalkyl, an aryl, a cycloalkyl, or any combination thereof; and [0230] R.sup.2 is independently an alkyl.

[0231] Aspect 11. The method according to any one of Aspects 1-10, the vapor deposition precursor comprises a compound of the formula:

##STR00008##

[0232] Aspect 12. A composition comprising: [0233] a vapor deposition precursor comprising an aluminum amidinate, wherein the aluminum amidinate having the characteristics defined by the following process step: [0234] contacting an aluminum chloride, a Grignard reagent, and a carbodiimide compound to form the vapor deposition precursor.

[0235] Aspect 13. The composition according to Aspect 12, wherein the composition comprises less than 0.5% by weight of a pyrophoric compound based on a total weight of the composition.

[0236] Aspect 14. The composition according to any one of Aspects 12-13, wherein the composition does not comprise a pyrophoric compound.

[0237] Aspect 15. The composition according to any one of Aspects 12-14, wherein the vapor deposition precursor comprises a compound of the formula:

##STR00009## [0238] where: [0239] R.sup.1 is independently at least one of an alkyl, an alkenyl, an alkyne, a cycloalkyl, an aryl, a cycloalkyl, or any combination thereof; and [0240] R.sup.2 is independently an alkyl.

[0241] Aspect 16. The composition according to Aspect 15, wherein R.sup.1 is an alkyl and wherein R.sup.2 is an alkyl.

[0242] Aspect 17. The composition according to Aspect 15, wherein R.sup.1 is an alkyl and wherein R.sup.2 is a cycloalkyl.

[0243] Aspect 18. The composition according to Aspect 15, wherein R.sup.1 is a C.sub.1-C.sub.10 alkyl and wherein R.sup.2 is C.sub.1-C.sub.10 alkyl.

[0244] Aspect 19. The composition according to Aspect 15, wherein R.sup.1 is a C.sub.1-C.sub.10 alkyl and wherein R.sup.2 is C.sub.1-C.sub.10 cycloalkyl.

[0245] Aspect 20. The composition according to any one of Aspects 12-19, the vapor deposition precursor comprises a compound of the formula:

##STR00010##

[0246] Aspect 21. An article comprising: [0247] a substrate, [0248] wherein the substrate has: [0249] a first surface portion comprising a metal; and [0250] a second surface portion comprising a non-metal; and a layer, [0251] wherein the layer comprises a reaction product of an aluminum amidinate; and [0252] wherein the layer is located on the second surface portion.

[0253] Aspect 22. The article according to Aspect 21, wherein, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is less than 1.

[0254] Aspect 23. The article according to any one of Aspects 21-22, wherein the layer on the

second surface portion has an average thickness of at least 20 nm.

[0255] Aspect 24. The article according to any one of Aspects 21-23, wherein the aluminum amidinate has a selectively for the non-metal versus the metal without the use of an inhibitor.

[0256] Aspect 25. The article according to any one of Aspects 21-24, wherein the non-metal comprises a silicon dioxide.

[0257] Aspect 26. The article according to any one of Aspects 21-25, wherein the metal comprises a tungsten, a tantalum, a molybdenum, a titanium, a copper, a cobalt, or any combination thereof.

[0258] Aspect 27. The article according to any one of Aspects 21-26, wherein the non-metal comprises a silicon dioxide; and wherein the metal comprises a tungsten, a tantalum, a molybdenum, a titanium, a copper, a cobalt, or any combination thereof.

[0259] Aspect 28. The article according to any one of Aspects 21-27, wherein the layer is not located on the first surface portion.

[0260] Aspect 29. The article according to any one of Aspects 21-28, wherein, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is less than 0.1.

[0261] Aspect 30. The article according to any one of Aspects 21-29, wherein the layer on the second surface portion has an average thickness of at least 20 nm.

[0262] Aspect 31. A method comprising: [0263] obtaining a substrate; [0264] wherein the substrate has: [0265] a first surface portion comprising a metal; and [0266] a second surface portion comprising a non-metal obtaining a vapor deposition precursor comprising an aluminum amidinate; [0267] vaporizing the vapor deposition precursor to obtain a precursor vapor; and [0268] contacting the substrate with the precursor vapor to form a layer, [0269] wherein the layer is located on the second surface portion.

[0270] Aspect 32. The method according to Aspect 31, wherein, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is less than 1.

[0271] Aspect 33. The method according to any one of Aspects 31-32, wherein the layer on the second surface portion has an average thickness of at least 20 nm.

[0272] Aspect 34. The method according to any one of Aspects 31-33, wherein the non-metal comprises a silicon dioxide.

[0273] Aspect 35. The method according to any one of Aspects 31-34, wherein the metal comprises a tungsten, a tantalum, a molybdenum, a titanium, a copper, a cobalt, or any combination thereof.

[0274] Aspect 36. The method according to any one of Aspects 31-35, wherein the layer is not located on the first surface portion.

[0275] Aspect 37. The method according to any one of Aspects 31-36, wherein, when the layer is located on the first surface portion, a ratio of an average thickness of the layer on the first surface portion to an average thickness of the layer on the second surface portion is less than 0.1.

[0276] Aspect 38. The method according to any one of Aspects 31-37, wherein the layer on the second surface portion has an average thickness of at least 20 nm.

[0277] Aspect 39. The method according to any one of Aspects 31-38, wherein the precursor vapor has a selectively for the non-metal versus the metal without the use of an inhibitor.

[0278] Aspect 40. The method according to any one of Aspects 31-39, wherein the non-metal comprises a silicon dioxide; and wherein the metal comprises a tungsten, a tantalum, a molybdenum, a titanium, a copper, a cobalt, or any combination thereof.

## Claims

**1.** A method for forming a vapor deposition precursor, the method comprising: contacting an aluminum trichloride, a Grignard reagent, and a carbodiimide compound to form the vapor deposition precursor, wherein the vapor deposition precursor comprises an aluminum amidinate.

2. The method of claim 1, wherein the vapor deposition precursor is formed without use of a pyrophoric compound.
3. The method of claim 1, wherein the vapor deposition precursor is formed without use of at least one of trimethyl aluminum, dimethyl aluminum chloride, methyl lithium, or any combination thereof.
4. The method of claim 1, wherein the Grignard reagent comprises a compound of the formula:  $R^{sup.1}MgX$ , where:  $R^{sup.1}$  is at least one of an alkyl, an alkenyl, an alkyne, an aryl, a cycloalkyl, or any combination thereof; and X is Cl, Br, or I.
5. The method of claim 1, wherein the carbodiimide compound comprises a compound of the formula:  
 $R^{sup.2}-N=C=N-R^{sup.2}$ , where:  $R^{sup.2}$  is independently at least one of an alkyl, a cycloalkyl, or any combination thereof.
6. The method of claim 1, wherein the Grignard reagent comprises a compound of the formula:  $R^{sup.1}MgX$ , where:  $R^{sup.1}$  is an alkyl; and X is Cl, Br, or I, wherein the carbodiimide compound comprises a compound of the formula:  
 $R^{sup.2}-N=C=N-R^{sup.2}$ , where:  $R^{sup.2}$  is independently an alkyl.
7. The method of claim 1, wherein the Grignard reagent comprises a compound of the formula:  $R^{sup.1}MgX$ , where:  $R^{sup.1}$  is an alkyl; and X is Cl, Br, or I, wherein the carbodiimide compound comprises a compound of the formula:  
 $R^{sup.2}-N=C=N-R^{sup.2}$ , where:  $R^{sup.2}$  is independently a cycloalkyl.
8. The method of claim 1, wherein the Grignard reagent comprises a compound of the formula:  $R^{sup.1}MgX$ , where:  $R^{sup.1}$  is a C.sub.1-C.sub.10 alkyl; and X is Cl, Br, or I, wherein the carbodiimide compound comprises a compound of the formula:  
 $R^{sup.2}-N=C=N-R^{sup.2}$ , where:  $R^{sup.2}$  is independently a C.sub.1-C.sub.10 alkyl.
9. The method of claim 1, wherein the Grignard reagent comprises a compound of the formula:  $R^{sup.1}MgX$ , where:  $R^{sup.1}$  is a C.sub.1-C.sub.10 alkyl; and X is Cl, Br, or I, wherein the carbodiimide compound comprises a compound of the formula:  
 $R^{sup.2}-N=C=N-R^{sup.2}$ , where:  $R^{sup.2}$  is independently a C.sub.1-C.sub.10 cycloalkyl.
10. The method of claim 1, wherein the vapor deposition precursor comprises a compound of the formula: ##STR00011## where:  $R^{sup.1}$  is independently at least one of an alkyl, an alkenyl, an alkyne, a cycloalkyl, an aryl, a cycloalkyl, or any combination thereof; and  $R^{sup.2}$  is independently an alkyl.
11. The method of claim 1, the vapor deposition precursor comprises a compound of the formula: ##STR00012##
12. A composition comprising: a vapor deposition precursor comprising an aluminum amidinate, wherein the aluminum amidinate having the characteristics defined by the following process step: contacting an aluminum chloride, a Grignard reagent, and a carbodiimide compound to form the vapor deposition precursor.
13. The composition of claim 12, wherein the composition comprises less than 0.5% by weight of a pyrophoric compound based on a total weight of the composition.
14. The composition of claim 12, wherein the composition does not comprise a pyrophoric compound.
15. The composition of claim 12, wherein the vapor deposition precursor comprises a compound of the formula: ##STR00013## where:  $R^{sup.1}$  is independently at least one of an alkyl, an alkenyl, an alkyne, a cycloalkyl, an aryl, a cycloalkyl, or any combination thereof; and  $R^{sup.2}$  is independently an alkyl.
16. The composition of claim 15, wherein  $R^{sup.1}$  is an alkyl and wherein  $R^{sup.2}$  is an alkyl.
17. The composition of claim 15, wherein  $R^{sup.1}$  is an alkyl and wherein  $R^{sup.2}$  is a cycloalkyl.
18. The composition of claim 15, wherein  $R^{sup.1}$  is a C.sub.1-C.sub.10 alkyl and wherein  $R^{sup.2}$  is C.sub.1-C.sub.10 alkyl.

**19.** The composition of claim 15, wherein R.sup.1 is a C.sub.1-C.sub.10 alkyl and wherein R.sup.2 is C.sub.1-C.sub.10 cycloalkyl.

**20.** The composition of claim 12, the vapor deposition precursor comprises a compound of the formula: ##STR00014##

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