by Using Atomic Layer Deposition. WO2015/047914 to Sanchez and Girard disclose Amine Substituted Trisilylamine and Tridisilylamine Compounds. US2014/0363985 to DNF Co., Ltd., discloses Amino-silyl Amine Compounds, Methods for Preparing the Same and Silicon-containing Thin-Film Using the Same. US5413813 to Cruse et al. disclose CVD of silicon-based ceramic materials on internal surfaces of a reactor using, among others, $R_3Si\text{-}N(X)\text{-}SiR_3$, wherein each R is H, $C_{1\text{-}20}$ alkyl, halogen (preferably Cl) or NR_2 and X is H, Li, or SiR_3. US2014/0158580A to Air Products and Chemicals, Inc., describes Alkoxysilylamine Compounds and Applications Thereof. US 7,122,222, also to Air Products and Chemicals, Inc., discloses Precursors for Depositing Silicon Containing Films and Processes Thereof. Silazane compounds $N\text{-}(SiR^1R^2R^3)_mR^4_{3\text{-}m}$ disclosed in WO2013/058061 are used as a coating gas. $(RR^1R^2M^a)_yA(R^3)_x$ disclosed in US 5,332,853 is used as a catalytic compound to produce a functionalized alkylalkali metal compound. Similar patents include US 5663398A, US 5332853A, US 5340507A, EP 525881 A1.

[0005] Industries using vapor-based deposition processes such as CVD or ALD (in all possible meanings, such as LPCVD, SACVD, PECVD, PEALD, *etc.*) are still looking for precursors that are ideal for their applications, *i.e.* having the highest possible deposition rates within the constraints of their processes, substrates and film targets.

Summary

[0005a] In one aspect, there is provided a Si-containing film forming composition comprising a mono-substituted TSA precursor having the formula: $(SiH_3)_2N\text{-}SiH_2\text{-}X$ wherein X is selected from an isocyanato group [–NCO]; an amino group [$–NR^1R^2$]; an N-containing C_4-C_{10} saturated or unsaturated heterocycle; or an alkoxy group [–O–R]; R^1, R^2 and R each is selected from H; a C_1-C_6 linear or branched, saturated or unsaturated hydrocarbyl group; or a silyl group [SiR'_3] with each R' being independently selected from H; a halogen atom selected from Cl, Br or I; a C_1-C_4 saturated or unsaturated hydrocarbyl group; a C_1-C_4 saturated or unsaturated alkoxy group; or an amino group [$–NR^3R^4$] with each R^3 and R^4 being selected from H or a C_1-C_6 linear or branched, saturated or unsaturated hydrocarbyl group; provided that if R^1 = H, then $R^2 \neq$ H or Me.

[0005b] In another aspect, there is provided a method for forming a Si-containing film, the method comprising the steps of: introducing into a reactor containing a substrate a vapor including the Si-containing film forming composition described herein; depositing at least part of the mono-substituted TSA precursor onto the substrate to form the silicon-containing film on the substrate using a vapor deposition process.

[0005c] In another aspect, there is provided a nitrogen-doped silicon oxide film, the film formed by the process of: introducing into a reactor containing a substrate a vapor including the Si-containing film forming composition described herein; reacting an oxidizing agent with the silicon-containing layer to form an oxidized silicon-containing layer by introducing the oxidizing agent into the reactor; reacting the mono-substituted TSA precursor with the oxidized silicon-containing layer to form a silicon-rich oxidized silicon-containing layer by introducing the mono-substituted TSA precursor into the reactor; reacting a nitrogen-containing reactant with the silicon-containing layer to form the nitrogen-doped silicon oxide film by introducing the nitrogen-containing reactant into the reactor.

[0006] Disclosed are Si-containing film forming compositions comprising a mono-substituted TSA precursor having the formula $(SiH_3)_2NSiH_2$-X, wherein X is a halogen atom selected from Cl, Br or I; an isocyanato group [–NCO]; an amino group [$–NR^1R^2$]; a N-containing C_4-C_{10} saturated or unsaturated heterocycle; or an alkoxy group [–O–R]; R^1, R^2 and R is independently selected from H; a silyl group [$-SiR'_3$]; or a C_1-C_6 linear or branched, saturated or unsaturated hydrocarbyl group; with each R' being independently selected from H; a halogen atom selected from Cl, Br, or I; a C_1-C_4 saturated or unsaturated hydrocarbyl group; a C_1-C_4 saturated or unsaturated alkoxy group; or an amino group [$–NR^3R^4$] with each R^3 and R^4 being independently selected from H and a C_1-C_6 linear or branched, saturated or unsaturated hydrocarbyl group, provided that if R^1 = H, then $R^2 \neq$ H, Me or Et. The disclosed Si-containing film forming compositions may include one or more of the following aspects:

What is claimed is:

1. A Si-containing film forming composition comprising a mono-substituted TSA precursor having the formula:

$$(SiH_3)_2N\text{-}SiH_2\text{-}X$$

wherein X is selected from an isocyanato group [–NCO]; an amino group [$–NR^1R^2$]; an N-containing C_4-C_{10} saturated or unsaturated heterocycle; or an alkoxy group [–O–R]; R^1, R^2 and R each is selected from H; a C_1-C_6 linear or branched, saturated or unsaturated hydrocarbyl group; or a silyl group [SiR'_3] with each R' being independently selected from H; a halogen atom selected from Cl, Br or I; a C_1-C_4 saturated or unsaturated hydrocarbyl group; a C_1-C_4 saturated or unsaturated alkoxy group; or an amino group [$–NR^3R^4$] with each R^3 and R^4 being selected from H or a C_1-C_6 linear or branched, saturated or unsaturated hydrocarbyl group; provided that if R^1 = H, then $R^2 \neq$ H or Me.

2. The Si-containing film forming composition of claim 1, wherein X= NR^1R^2 and R^1 and R^2 each is independently selected from H, Me, Et, or iPr.

3. The Si-containing film forming composition of claim 2, wherein the mono-substituted TSA precursor is $(SiH_3)_2N\text{-}SiH_2\text{-}NiPr_2$.

4. The Si-containing film forming composition of claim 2, wherein the mono-substituted TSA precursor is $(SiH_3)_2N\text{-}SiH_2\text{-}NEt_2$.

5. The Si-containing film forming composition of claim 2, wherein the mono-substituted TSA precursor is $(SiH_3)_2N\text{-}SiH_2\text{-}NHiPr$.

6. The Si-containing film forming composition of claim 1, wherein X = $–N(SiR_3)_2$, and each R is independently selected from a halogen, H, or a C_1-C_4 alkyl group.

7. The Si-containing film forming composition of claim 6, wherein the mono-substituted TSA precursor is $(SiH_3)_2N\text{-}SiH_2\text{-}N(SiH_3)_2$.

8. A method for forming a Si-containing film, the method comprising the steps of:

introducing into a reactor containing a substrate a vapor including the Si-containing film forming composition of any one of claims 1 to 7;

depositing at least part of the mono-substituted TSA precursor onto the substrate to form the silicon-containing film on the substrate using a vapor deposition process.

9. The method of claim 8, wherein the vapor deposition process is atomic layer deposition or chemical vapor deposition.

10. The method of claim 8, further comprising the step of delivering into the reactor a reactant and/or a second vapor including a second precursor.

11. The method of claim 8, wherein the substrate is selected from the group consisting of a silicon wafer, a glass substrate, and a plastic substrate.

12. The method of claim 11, wherein the substrate is coated with patterned or unpatterned organic or inorganic films.

13. The method of claim 10, further comprising the step of delivering into the reactor a second reactant, the second reactant being different than the reactant, the second reactant selected from the group consisting of O_2, O_3, H_2O, H_2O_2, NO, NO_2, N_2O, alcohols, diols, carboxylic acids, ketones, ethers, O atoms, O radicals, O ions, ammonia, N_2, N atoms, N radicals, N ions, saturated or unsaturated hydrazine, amines, diamines, ethanolamine, H_2, H atoms, H radicals, H ions, and combinations thereof.

14. A nitrogen-doped silicon oxide film, the film formed by the process of:

introducing into a reactor containing a substrate a vapor including the Si-containing film forming composition of any one of claims 1 to 7;

reacting an oxidizing agent with the silicon-containing layer to form an oxidized silicon-containing layer by introducing the oxidizing agent into the reactor;

reacting the mono-substituted TSA precursor with the oxidized silicon-containing layer to form a silicon-rich oxidized silicon-containing layer by introducing the mono-substituted TSA precursor into the reactor;

reacting a nitrogen-containing reactant with the silicon-containing layer to form the nitrogen-doped silicon oxide film by introducing the nitrogen-containing reactant into the reactor.

15. The nitrogen-doped silicon oxide film of claim 14, further comprising purging the reactor with an inert gas between each introduction step.