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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 February 2016 (04.02.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/018747 A1

(51) International Patent Classification:
H01L 21/31 (2006.01) *H01L 21/205* (2006.01)

(21) International Application Number:
PCT/US2015/041977

(22) International Filing Date:
24 July 2015 (24.07.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/029,479 26 July 2014 (26.07.2014) US
14/801,215 16 July 2015 (16.07.2015) US

(71) Applicant: **APPLIED MATERIALS, INC.** [US/US]; 3050 Bowers Avenue, Santa Clara, California 95054 (US).

(72) Inventors: **SALY, Mark**; 111 Saratoga Avenue, Apt. 2314, Santa Clara, California 95051 (US). **THOMPSON, David**; 2193 Bentley Ridge Drive, San Jose, California 95138 (US). **KALUTARAGE, Lakmal**; 1588 Ambergrove Dr., San Jose, California 95131 (US).

(74) Agent: **BLANKMAN, Jeffrey I.**; Servilla Whitney LLC, 33 Wood Avenue South, Suite 830, Iselin, New Jersey 08830 (US).

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

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

Published:

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

(54) Title: LOW TEMPERATURE MOLECULAR LAYER DEPOSITION OF SiCON

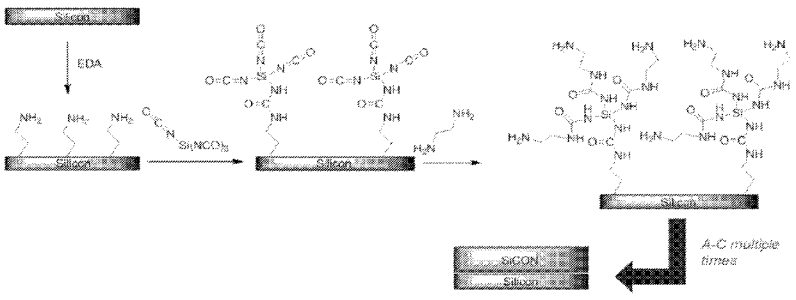


FIG. 1

(57) Abstract: Methods for the deposition of a SiCON film by molecular layer deposition using a multi-functional amine and a silicon containing precursor having a reactive moiety.

WO 2016/018747 A1

LOW TEMPERATURE MOLECULAR LAYER DEPOSITION OF SiCON

TECHNICAL FIELD

[0001] Embodiments of the disclosure generally relate to methods for molecular layer deposition. More specifically, embodiments of the disclosure are directed to methods for the molecular layer deposition of silicon carbon oxynitride (SiCON) films.

BACKGROUND

[0002] Deposition of thin films on a substrate surface is an important process in a variety of industries including semiconductor processing, diffusion barrier coatings and dielectrics for magnetic read/write heads. In the semiconductor industry, in particular, miniaturization requires atomic level control of thin film deposition to produce conformal coatings on high aspect ratio structures.

[0003] Silicon carbon oxynitride (SiCON) is being considered for spacer and etch-stop layer applications due to a low dielectric constant (k). Excellent conformality coverage of dielectric films on high aspect ratio structures is needed as device nodes shrink down below 45 nm. Silicon carbide (oxy)nitride (SiCON/SiCN) films can exhibit some of these favorable qualities, but deposition of SiCON/SiCN films from furnace processes has several drawbacks. For example, these drawbacks include a high temperature requirement ($\geq$ 550 °C), few capabilities to engineer film compositions and bonding structures. These properties impact wet etch resistance and electrical stability during thermal cycling for front-end of line (FEOL) applications. Films deposited via plasma enhanced chemical vapor deposition (PE-CVD) at lower temperature have poor step coverage due to directionality of the radicals' fluxes.

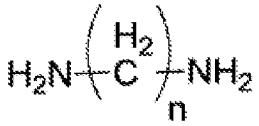
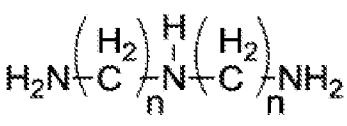
[0004] Accordingly, there is a need for improved methods for depositing various silicon containing films such as SiCN.

SUMMARY

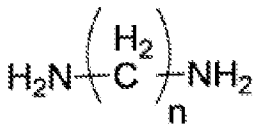
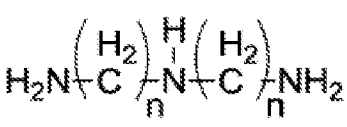
[0005] One or more embodiments of the disclosure are directed to methods of depositing a film. At least a portion of a substrate surface is exposed to a first precursor comprising a multi-functional amine to form an amine-containing film on the substrate surface. The amine-

containing film is exposed to a second precursor comprising at least one silicon atom and at least one reactive moiety to form an SiCON film on at least a portion of the substrate surface.

[0006] Additional embodiments of the disclosure are directed to methods of depositing a film. At least a portion of a substrate surface is exposed to a first precursor comprising a multi-functional amine to form an amine-containing film on the substrate surface. The first precursor comprises a compound having the formula selected from the group consisting of


, 
, and combinations thereof, where n is in the range of about 1 and about 6. Unreacted first precursor is removed from the substrate surface. The amine-containing film is exposed to a second precursor comprising at least one silicon atom and at least one reactive moiety to form an SiCON film on at least a portion of the substrate surface. The reactive moiety is selected from the group consisting of isocyanato, aldehyde, ketone, acyl chloride, anhydrides and combinations thereof. Unreacted second precursor is removed from the substrate surface.

[0007] Further embodiments of the disclosure are directed to methods of depositing a film. At least a portion of a substrate surface is exposed to a first precursor comprising a multi-functional amine to form an amine-containing film on the substrate surface at a temperature in the range of about 50 °C to about 200 °C. The first precursor comprises a compound having the formula selected from the group consisting of


, 
, and combinations thereof, where n is in the range of about 1 and about 6. Unreacted first precursor is removed from the substrate surface. The amine-containing film is exposed to a second precursor comprising at least one silicon atom and at least one reactive moiety to form an SiCON film on at least a portion of the substrate surface at a temperature in the range of about 50 °C to about 200 °C. The reactive moiety is selected from the group consisting of isocyanato, aldehyde, ketone, acyl chloride, anhydrides and combinations thereof. Unreacted second precursor is removed from the substrate surface. The exposure of at least a portion of the substrate surface to the first

precursor, removing reacted first precursor, exposure to the second precursor and removing unreacted second precursor is sequentially repeated to form an SiCON film of a chosen thickness. The SiCON film is annealed in a gas selected from the group consisting of silane, dichlorosilane, trichlorosilane, ammonia, oxygen and combinations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Further features of embodiment of the present disclosure, their nature and various advantages will become more apparent upon consideration of the following detailed description, taken in conjunction with the accompanying drawings, which are also illustrative of the best mode contemplated by the applicants, and in which like reference characters refer to like parts throughout, where:

[0009] FIG. 1 illustrates an exemplary MLD process in accordance with one or more embodiment of the disclosure as described in the Example; and

[0010] FIG. 2 shows an FTIR spectrum of the film deposited using the process of the Example as exemplified in FIG. 1.

DETAILED DESCRIPTION

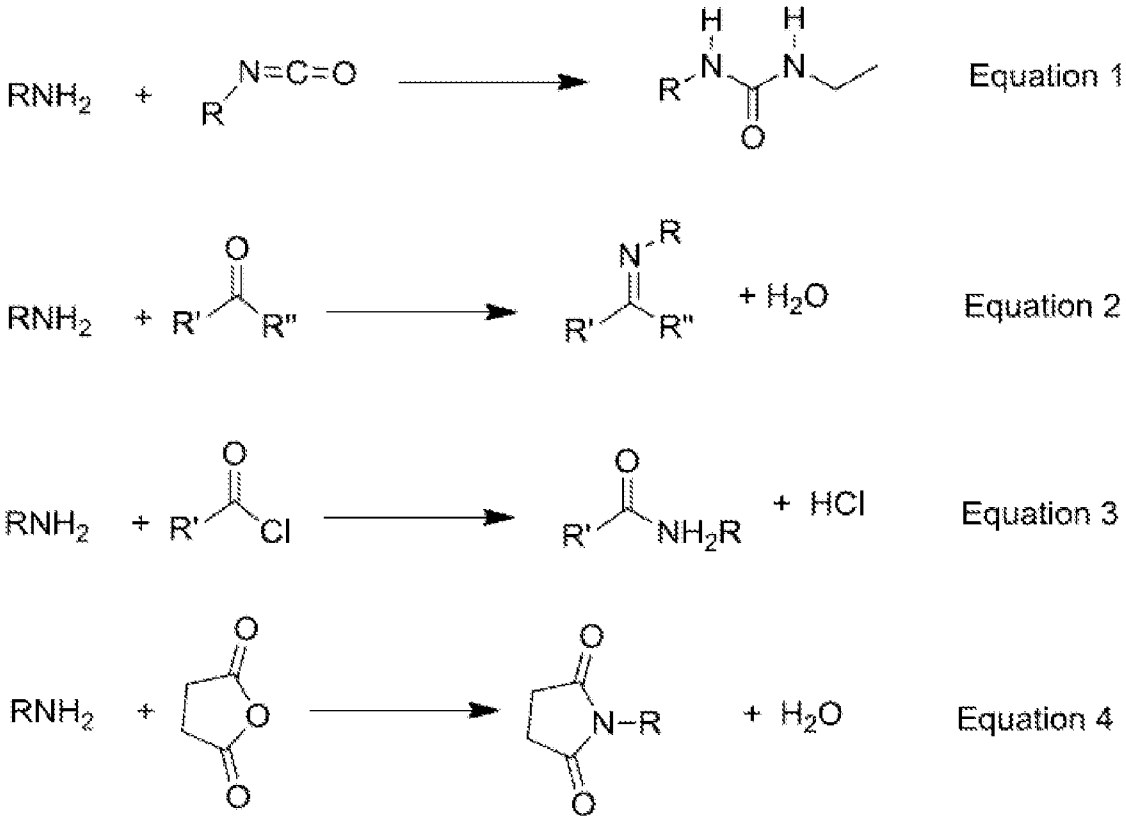
[0011] Before describing several exemplary embodiments of the disclosure, it is to be understood that the disclosure is not limited to the details of construction or process steps set forth in the following description. The disclosure is capable of other embodiments and of being practiced or being carried out in various ways.

[0012] A "substrate surface" as used herein, refers to any substrate or material surface formed on a substrate upon which film processing is performed during a fabrication process. For example, a substrate surface on which processing can be performed include materials such as silicon, silicon oxide, strained silicon, silicon on insulator (SOI), carbon doped silicon oxides, silicon nitride, doped silicon, germanium, gallium arsenide, glass, sapphire, and any other materials such as metals, metal nitrides, metal alloys, and other conductive materials, depending on the application. Substrates include, without limitation, semiconductor wafers. Substrates may be exposed to a pretreatment process to polish, etch, reduce, oxidize, hydroxylate, anneal and/or bake the substrate surface. In addition to film processing directly on the surface of the substrate itself, in the embodiments of the present disclosure any of the

film processing steps disclosed may also be performed on an underlayer formed on the substrate as disclosed in more detail below, and the term "substrate surface" is intended to include such underlayer as the context indicates.

[0013] One or more embodiments of the disclosure use a variant of atomic layer deposition (ALD) called molecular layer deposition (MLD). MLD processes can be used to deposit polymers such as polyimide, polyamide, or polyurea. For example, MLD of polyurea may be performed by alternating exposures of 1,4-diisocyanatobutane with various amines, such as ethylenediamine or tris(2-aminoethyl)amine. The inventors have surprisingly found that silicon precursors comprising reactive moieties can also be deposited by MLD. Reactive moieties such as isocyanato groups (see equation 1), aldehydes or ketones (see equation 2), acyl chlorides (see equation 3) and anhydrides (see equation 4) can participate in MLD reactions with various amines such as ethylenediamine.

[0014] Equations 1-4 show common organic reactions that occur between amines and aldehydes, ketones, acyl chlorides and anhydrides.



[0015] In some embodiments, the amine is at least bifunctional so that one amine can react with the substrate surface while the other amine may remain unreacted to participate in a subsequent ALD half-reaction.

[0016] The inventors have found that a network of silicon, carbon, oxygen and nitrogen can be deposited using two precursors. While the term SiCON is used to describe a film having silicon, carbon, oxygen and nitrogen, it will be understood by those skilled in the art that no stoichiometry is intended by such formula. For example, an SiCON film is not limited to films with equal numbers of silicon, carbon, oxygen and nitrogen atoms, the term SiCON is merely representative of the majority makeup of the film. Additionally, it will be understood that an SiCON film may also contain some other impurities or trace elements. For example, an SiCON film may contain up to about 5% on an atomic basis of other elements, or up to about 4%, or up to about 3%, or up to about 2%, or up to about 1%, or up to about 0.5%, or up to about 0.2%.

[0017] In some embodiments, the amine is modified to contain more than two NH_2 groups. Without being bound by any particular theory of operation, it is believed that the amines can cross link the film and increase the mechanical strength.

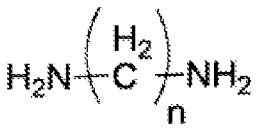
[0018] One or more embodiments of the disclosure involve the low temperature MLD of SiCON by the following method: First, a multifunctional amine is transported to a reaction chamber which will react with a substrate to form a layer of NH_2 groups on the surface. Next a purge is performed to get rid of any unreacted amine. Next a Si precursor is transported to the reactor chamber so that the precursor reacts with the NH_2 groups on the surface to form new carbon to nitrogen bonds. The chamber is purged to get rid of any unreacted Si precursor. Multiple cycles of this process should result in the low temperature deposition of SiCON. The deposition temperature can be 50 °C – 200 °C, and the pressures would be 0 – 300 Torr.

[0019] The quality of the film can vary depending on a number of factors. The film formed might be of poor quality because of the low temperature and the relatively low density of the deposited film. In some embodiments, annealing under gases such as (H_2SiCl_2, $SiCl_3$, silane, NH_3, O_2, etc.) may help densify the film and also tune the film's properties.

[0020] Accordingly, one or more embodiment of the disclosure is directed to methods of depositing a film. At least a portion of a substrate surface is exposed to a first precursor comprising a multi-functional amine to form an amine-containing film on the substrate surface.

In some embodiments, the multi-functional amine comprises two amine groups, three amine groups, four amine groups, five amine groups or more.

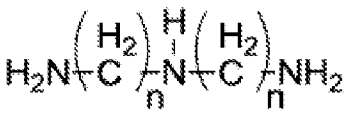
[0021] In some embodiments, the first precursor comprises a compound having the formula



,

where n is up to about 16, or up to about 15, or up to about 14, or up to about 13, or up to about 12, or up to about 11, or up to about 10, or up to about 9, or up to about 8, or up to about 7, or up to about 6 or in the range of about 1 to about 8, or in the range of about 1 to about 6.

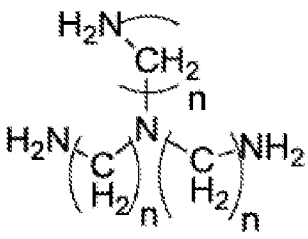
[0022] In some embodiments, the first precursor comprises a compound having the formula



,

where n is up to about 16, or up to about 15, or up to about 14, or up to about 13, or up to about 12, or up to about 11, or up to about 10, or up to about 9, or up to about 8, or up to about 7, or up to about 6 or in the range of about 1 to about 8, or in the range of about 1 to about 6.

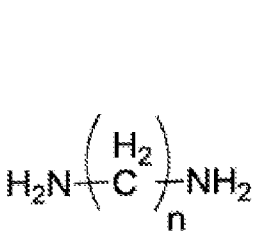
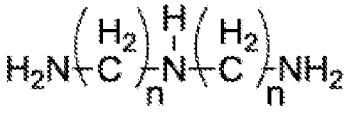
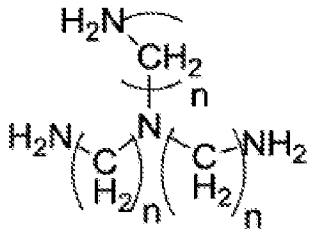
[0023] In some embodiments, the first precursor comprises a compound having the formula



,

where n is up to about 16, or up to about 15, or up to about 14, or up to about 13, or up to about 12, or up to about 11, or up to about 10, or up to about 9, or up to about 8, or up to about 7, or up to about 6 or in the range of about 1 to about 8, or in the range of about 1 to about 6.

[0024] In some embodiments, the first precursor comprises a compound having the formula selected from the group consisting of

or combinations thereof, where n is up to about 16, or up to about 15, or up to about 14, or up to about 13, or up to about 12, or up to about 11, or up to about 10, or up to about 9, or up to about 8, or up to about 7, or up to about 6 or in the range of about 1 to about 8, or in the range of about 1 to about 6.

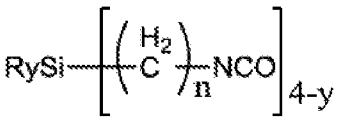
[0025] In some embodiments, after exposure to the first precursor, the processing chamber, or substrate surface may be purged of excess or unreacted first precursor. This prevents any gas phase reactions between the first precursor and a subsequent second precursor. When a chemical vapor deposition (CVD) reaction is intended, there is no need to purge between the exposure to the first and second precursor. For a CVD reaction, the first and second precursors may be exposed simultaneously.

[0026] In a traditional time-domain ALD process, the entire processing chamber might be purged of the first precursor before exposure to the second precursor. In a spatial ALD process, the first precursor and the second precursor are flowed into separate portions of the processing chamber and are separated by a gas curtain to prevent gas phase reactions. In the spatial process, the substrate is moved between the different regions of the processing chamber through the gas curtain so that different portions of the substrate are exposed to the first and second precursors at the same time.

[0027] In the ALD type process, after formation of the amine-containing film, the amine-containing film can be exposed to a second precursor. The second precursor comprises a silicon atom and at least one reactive moiety to form an SiCON film on at least a portion of the substrate surface. In some embodiments, the reactive moiety of the second precursor comprises an isocyanato group. In some embodiments, the reactive moiety of the second precursor comprises an aldehyde. In some embodiments, the reactive moiety of the second precursor comprises a ketone. In some embodiments, the reactive moiety of the second precursor comprises an acyl chloride. In some embodiments, the reactive moiety of the second precursor comprises an anhydride. In some embodiments, the reactive moiety of the second

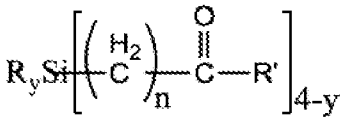
precursor is selected from the group consisting of isocyanato, aldehyde, ketone, acyl chloride, anhydride and combinations thereof.

[0028] In one or more embodiments, the second precursor comprises a compound having the formula



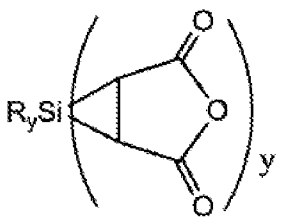
where n is up to about 16, or up to about 15, or up to about 14, or up to about 13, or up to about 12, or up to about 11, or up to about 10, or up to about 9, or up to about 8, or up to about 7, or up to about 6 or in the range of about 1 to about 8, or in the range of about 1 to about 6, y is in the range of about 1 to about 3 and R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof.

[0029] In some embodiments, the second precursor comprises a compound having the formula



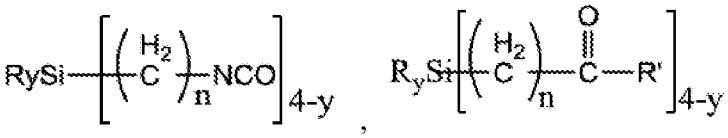
where n is up to about 16, or up to about 15, or up to about 14, or up to about 13, or up to about 12, or up to about 11, or up to about 10, or up to about 9, or up to about 8, or up to about 7, or up to about 6 or in the range of about 1 to about 8, or in the range of about 1 to about 6, y is in the range of about 1 to about 3, R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof and R' is selected from the group consisting of hydrogen, alkyl groups or halides.

[0030] In some embodiments, the second precursor comprises a compound having the formula

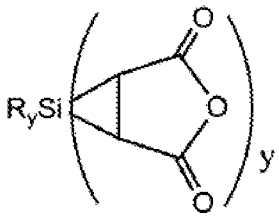


where each y is independently in the range of about 1 to about 2 and R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof.

[0031] In one or more embodiments, the second precursor comprises a compound having the formula selected from one or more of



where n is up to about 16, or up to about 15, or up to about 14, or up to about 13, or up to about 12, or up to about 11, or up to about 10, or up to about 9, or up to about 8, or up to about 7, or up to about 6 or in the range of about 1 to about 8, or in the range of about 1 to about 6, y is in the range of about 1 to about 3 and R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof,



where each y is independently in the range of about 1 to about 2 and R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof.

[0032] In some embodiments, after exposure to the second precursor, the processing chamber, or substrate surface may be purged of excess or unreacted second precursor. This prevents any gas phase reactions between the second precursor and a subsequent first precursor.

[0033] Some embodiments of the method further comprise annealing the SiCON film. The film can be annealed under an inert atmosphere or a reactive atmosphere. Without being bound by any particular theory of operation, it is believed that annealing the film can result in densification and strengthening of the film. In one or more embodiments, the film is annealed in an environment comprising a silicon-containing gas. In one or more embodiments, the film is annealed under a gas selected from the group consisting of silane, dichlorosilane, trichlorosilane, ammonia, oxygen and combinations thereof.

[0034] The temperature of the deposition process can be less than about 400 °C, 350 °C, 300 °C, 250 °C or 200 °C. In some embodiments, the deposition temperature of the substrate surface during either the first precursor exposure, the second precursor exposure or both the first and second precursor exposures can be less than about 400 °C, 350 °C, 300 °C, 250 °C or 200 °C. In one or more embodiments, the substrate surface is maintained at a temperature in the range of about 25°C to about 400 °C, or in the range of about 50 °C to about 300 °C or in the range of about 50 °C to about 200 °C during exposure to the first precursor and the second precursor.

[0035] Example

[0036] A SiCON film was deposited by an MLD process by sequential exposure to tetraisocyanato silicon ($Si(NCO)_4$); TICS) and ethylenediamine (EDA). FIG. 1 shows an illustration of the MLD of SiCON involving TICS and ethylenediamine. A silicon substrate with a native oxide was exposed to 20 seconds of ammonia plasma treatment (100W at 0.78 Torr). The substrate temperature was maintained at 125 °C throughout deposition. The TICS bubbler was maintained at a temperature of about 70 °C and the EDA bubbler was maintained at a temperature of about 23 °C. Nitrogen gas was flowed through the TICS bubbler at about 250 sccms and through the EDA bubbler at about 250 sccms. The chamber pressure was maintained at about 30-35 Torr during deposition with about 35 seconds of purge between precursors (5 seconds purge and 30 seconds pump). Two hundred cycles of first and second precursor with intervening purges was performed. A film of about 99Å (measured by ellipsometry) of SiCON was deposited with a growth rate of about 0.5Å/cycle.

[0037] FIG. 2 shows the FTIR spectrum of the deposited film. The FTIR spectrum is labelled with resonances believed to belong to NH, CH_2, C=), H-NCO, and Si-O or Si-N bonding.

[0038] X-ray photoelectron spectroscopy (XPS) results of the deposited film are shown in Table 1.

Table 1. XPS Results of the Film Deposited

	C1s	N1s	O1s	Si2p
Time (s)	Atomic %	Atomic %	Atomic %	Atomic %

0.0	28.9	21.7	33.2	16.2
15.0	11.8	12.6	42.1	33.5
30.0	5.9	8.4	42.6	43.2
45.0	3.0	5.4	39.4	52.2

[0039] Reference throughout this specification to “one embodiment,” “certain embodiments,” “various embodiments,” “one or more embodiments,” "in some embodiments," or "an embodiment" means that a particular feature, structure, material, or characteristic described in connection with the embodiment may be included in at least one embodiment of the disclosure. Furthermore, the appearances of the phrases such as “in one or more embodiments,” “in certain embodiments,” "in some embodiments," “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily referring to the same embodiment of the disclosure. In addition, the particular features, structures, materials, or characteristics described may be combined in any suitable manner in one or more embodiments.

[0040] Although the disclosure herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present disclosure. It will be apparent to those skilled in the art that various modifications and variations can be made to the material, method, and apparatus of the present disclosure without departing from the spirit and scope of the disclosure. Thus, it is intended that the present disclosure include modifications and variations that are within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method of depositing a film, the method comprising:

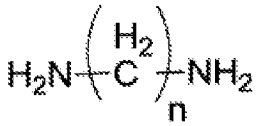
exposing at least a portion of a substrate surface to a first precursor comprising a multi-functional amine to form an amine-containing film on the substrate surface; and

exposing the amine-containing film to a second precursor comprising at least one silicon atom and at least one reactive moiety to form an SiCON film on at least a portion of the substrate surface.

2. The method of claim 1, wherein the multi-functional amine comprises two amine groups.

3. The method of claim 1, wherein the multi-functional amine comprises three amine groups.

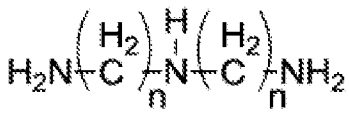
4. The method of claim 1, wherein the first precursor comprises a compound having the formula



,

where n is in the range of about 1 and about 6.

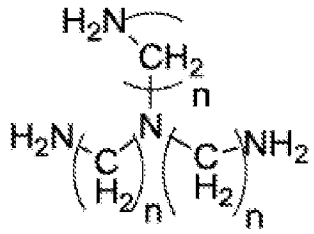
5. The method of claim 1, wherein the first precursor comprises a compound having the formula



,

where n is in the range of about 1 and about 6.

6. The method of claim 1, wherein the first precursor comprises a compound having the formula



,

where n is in the range of about 1 to about 6.

7. The method of claim 1, wherein the reactive moiety of the second precursor comprises an isocyanato group.

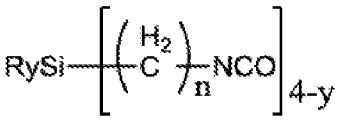
8. The method of claim 1, wherein the reactive moiety of the second precursor comprises an aldehyde.

9. The method of claim 1, wherein the reactive moiety of the second precursor comprises a ketone.

10. The method of claim 1, wherein the reactive moiety of the second precursor comprises an acyl chloride.

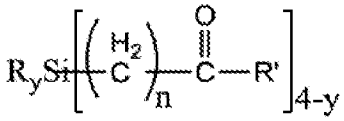
11. The method of claim 1, wherein the reactive moiety of the second precursor comprises an anhydride.

12. The method of claim 1, wherein the second precursor comprises a compound having the formula



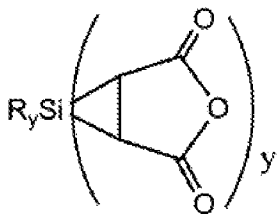
where n is in the range of about 0 to about 6, y is in the range of about 1 to about 3 and R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof.

13. The method of claim 1, wherein the second precursor comprises a compound having the formula



where n is in the range of about 0 to about 6, y is in the range of about 1 to about 3, R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof and R' is selected from the group consisting of hydrogen, alkyl groups or halides.

14. The method of claim 1, wherein the second precursor comprises a compound having the formula



where each y is independently in the range of about 1 to about 2 and R is selected from the group consisting of hydrogen, alkyl groups, amino groups and combinations thereof.

15. The method of claim 1, further comprising annealing the SiCON film under a gas selected from the group consisting of silane, dichlorosilane, trichlorosilane, ammonia, oxygen and combinations thereof.

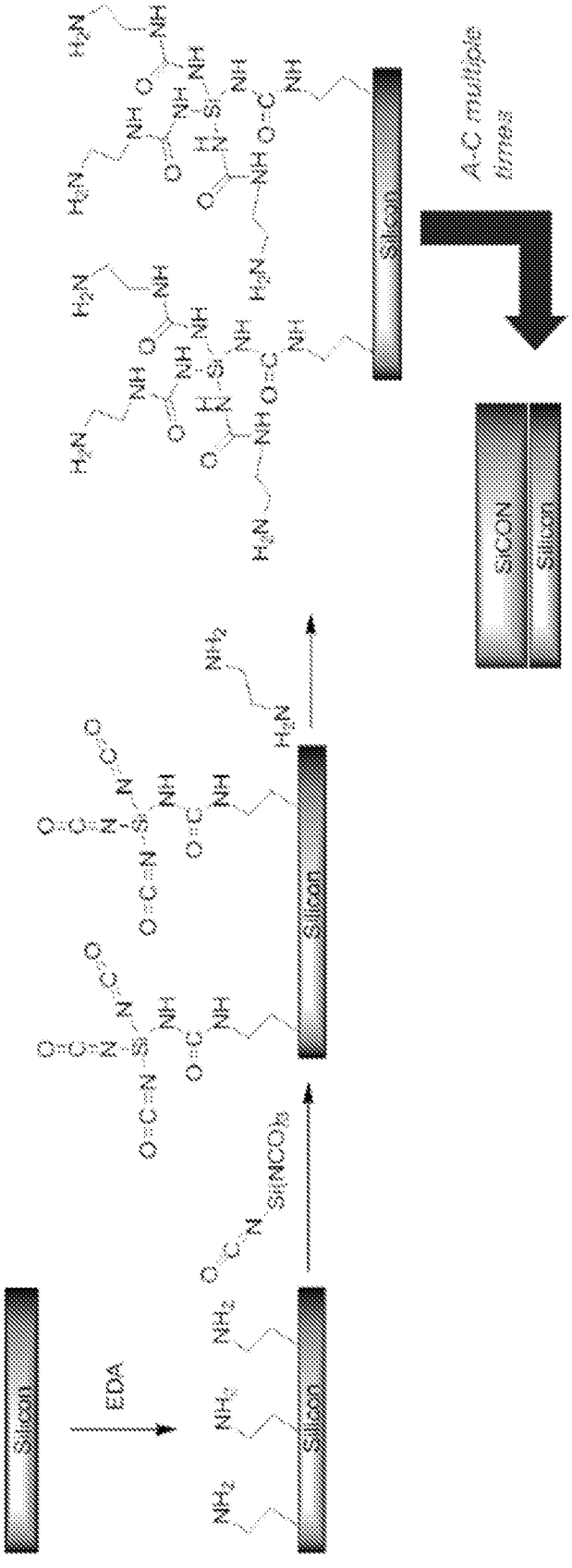

Silicon
EDA
Silicon
Silicon
Silicon
A-C multiple times
SiCON
Silicon

FIG. 1

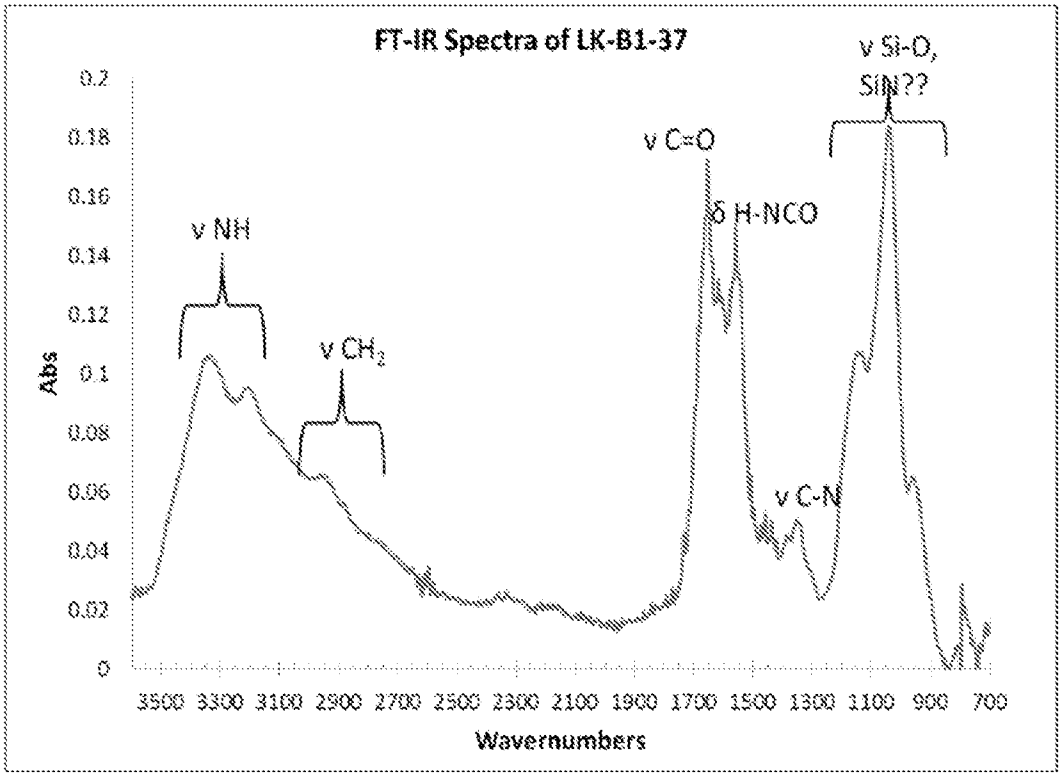

FT-IR Spectra of LK-B1-37
ν Si-O, SiN??
ν C=O
δ H-NCO
ν NH
ν CH2
ν C-N
Abs
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
3500 3300 3100 2900 2700 2500 2300 2100 1900 1700 1500 1300 1100 900 700
Wavenumbers

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/041977

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/31(2006.01)i, H01L 21/205(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L 21/31; H01L 21/469; H05H 1/24; C23C 16/00; H01L 21/205

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: silicon carbon oxynitride, SiCON, amine, multifunctional, expose, method, depositing film, silicon atom, precursor, isocyanato, aldehyde, ketone

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0164946 A1 (TOKYO ELECTRON LIMITED) 27 June 2013 See abstract, claims 1-10 and figures 1-12C.	1-15
A	US 2006-0228903 A1 (MICHAEL L. MCSWINEY et al.) 12 October 2006 See abstract, paragraphs [0014]-[0024], claims 1-7 and figures 1-7.	1-15
A	US 2010-0081293 A1 (ABHIJIT BASU MALLICK et al.) 01 April 2010 See abstract, paragraphs [0006]-[0010], claims 1-16.	1-15
A	US 2006-0014399 A1 (RAYMOND JOE) 19 January 2006 See abstract, claims 1-22 and figures 1-3.	1-15
A	US 8080282 B2 (ATSUKI FUKAZAWA et al.) 20 December 2011 See abstract, claims 1-9 and figures 1 and 2.	1-15

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2015 (29.10.2015)	**29 October 2015 (29.10.2015)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 35208, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
CHOI, Sang Won
Telephone No. +82-42-481-8291

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/041977

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0164946 A1	27/06/2013	CN 103187268 A	03/07/2013
		JP 2013-135176 A	08/07/2013
		KR 10-2013-0075698 A	05/07/2013
		TW 201341568 A	16/10/2013
		US 8871655 B2	28/10/2014
US 2006-0228903 A1	12/10/2006	None	
US 2010-0081293 A1	01/04/2010	CN 102171796 A	31/08/2011
		JP 2012-504867 A	23/02/2012
		KR 10-2011-0082025 A	15/07/2011
		TW 201026879 A	16/07/2010
		WO 2010-039363 A2	08/04/2010
		WO 2010-039363 A3	03/06/2010
US 2006-0014399 A1	19/01/2006	JP 2008-507130 A	06/03/2008
		TW I271803 B	21/01/2007
		US 7129187 B2	31/10/2006
		WO 2006-019438 A2	23/02/2006
		WO 2006-019438 A3	13/07/2006
US 8080282 B2	20/12/2011	JP 2008-042208 A	21/02/2008
		JP 5268130 B2	21/08/2013
		US 2008-0038485 A1	14/02/2008