US 20160289824A1

(19) United States
(12) Patent Application Publication
MATTZELA et al.
(10) Pub. No.: US 2016/0289824 A1
(43) Pub. Date: Oct. 6, 2016

(54) **ARTICLE INCLUDING A COATING AND PROCESS INCLUDING AN ARTICLE WITH A COATING**

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(21) Appl. No.: **14/675,795**

(22) Filed: **Apr. 1, 2015**

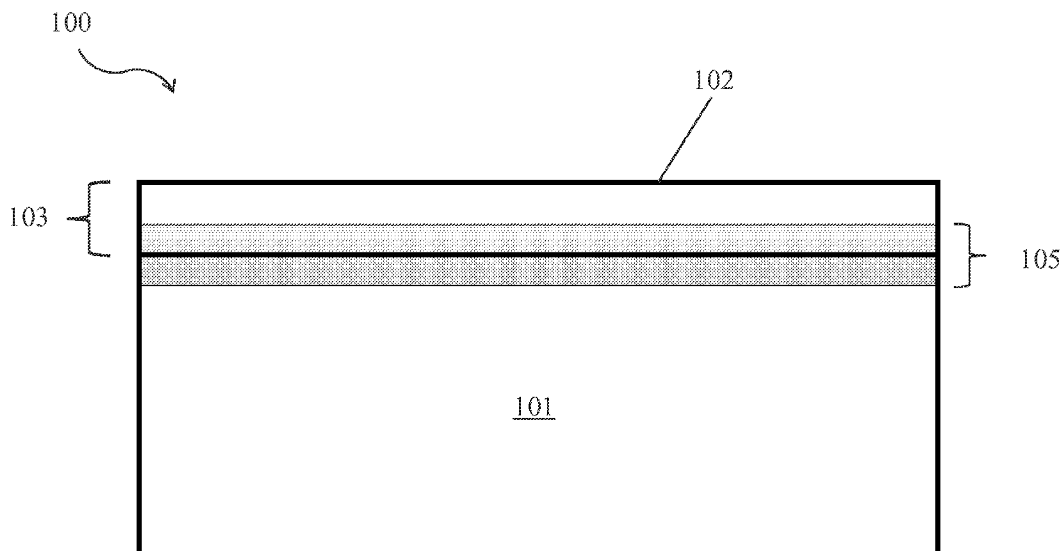
Publication Classification

(51) **Int. Cl.**
C23C 16/44 (2006.01)
C22C 21/08 (2006.01)
C23C 16/02 (2006.01)

(52) **U.S. Cl.**
CPC ***C23C 16/44*** (2013.01); ***C23C 16/0209*** (2013.01); ***C22C 21/08*** (2013.01)

(57) **ABSTRACT**

An article including a coating and a process including an article with a coating are disclosed. The article includes an aluminum-containing substrate including, by weight, at least 95% aluminum, and a coated and stabilized surface on the aluminum-containing substrate, the coated and stabilized surface being applied by thermal chemical vapor deposition at a temperature of less than 600° C. The process includes transporting fluid along a coated and stabilized surface positioned on an aluminum-containing substrate.



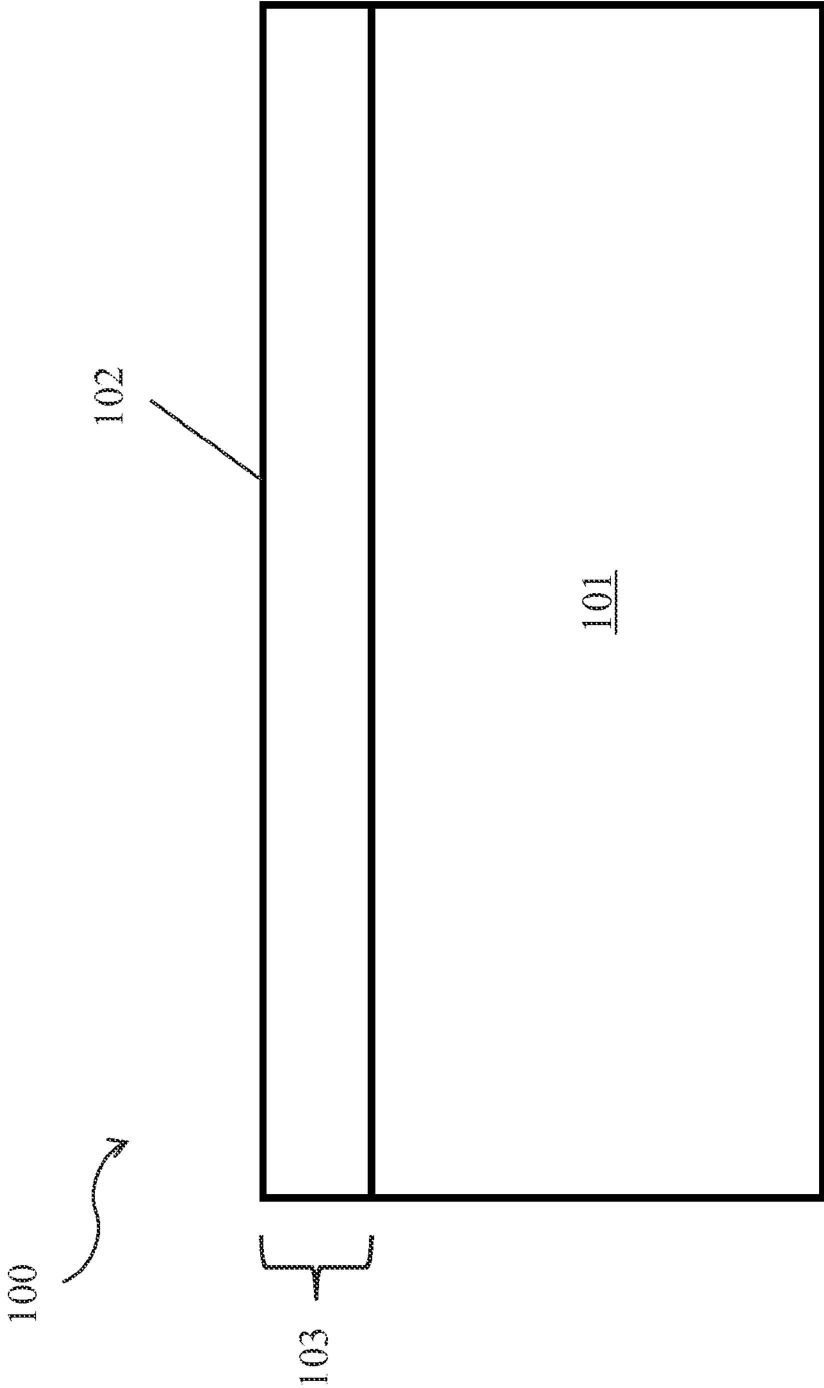


FIG. 1

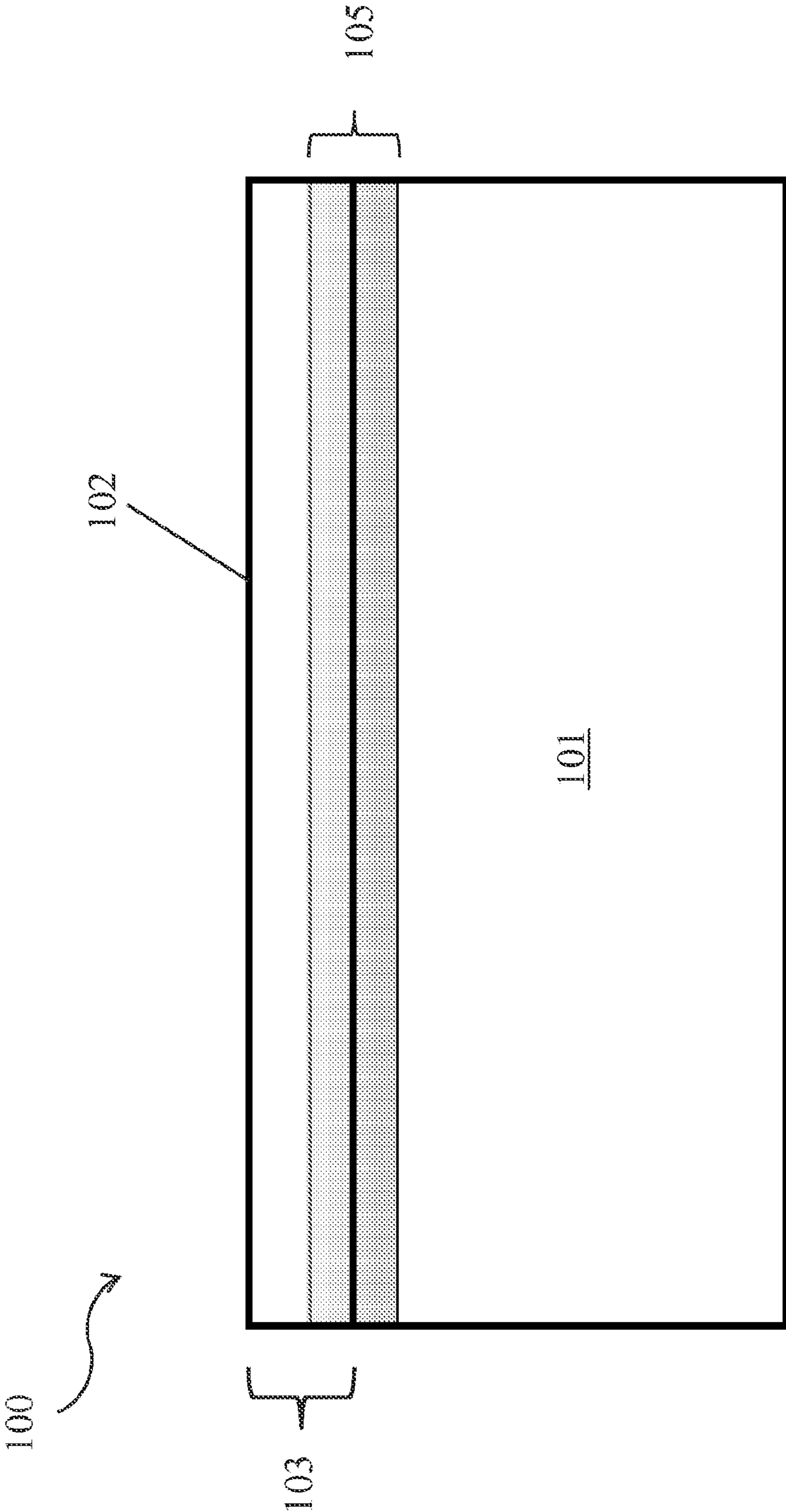


FIG. 2

ARTICLE INCLUDING A COATING AND PROCESS INCLUDING AN ARTICLE WITH A COATING

FIELD OF THE INVENTION

[0001] The present invention is directed to articles including a coating and a process including articles with a coating. More particularly, the present invention is directed to articles including a coating over an aluminum substrate, and a process of transporting fluid along the coating.

BACKGROUND OF THE INVENTION

[0002] Often, surfaces of substrates do not include desired performance characteristics. The failure to include specific desired performance characteristics can result in surface degradation in certain environments, an inability to meet certain performance requirements, or combinations thereof. For example, in certain environments, substrate surfaces can be subjected to wear and other undesirable surface activities such as chemical adsorption, catalytic activity, corrosive attack, oxidation, byproduct accumulation or stiction, and/or other undesirable surface activities.

[0003] Undesirable surface activities can cause chemisorption of other molecules, reversible and irreversible physisorption of other molecules, catalytic reactivity with other molecules, attack from foreign species, a molecular breakdown of the surface, physical loss of substrate, or combinations thereof. Specifically, aluminum substrates used within semiconductor manufacturing systems typically include porosity and chemical reactivity which can contribute to reagent retention, carryover, and contamination. Additionally, the surface of aluminum and aluminum alloy substrates is frequently non-uniform in structure and composition, which is undesirable.

[0004] To provide certain desired performance characteristics, the aluminum substrate may be coated, such as, by anodizing the substrate surface. However, anodizing aluminum suffers from the drawback that aluminum oxidizes unevenly. Due to the uneven oxidation, anodizing aluminum provides inconsistent results, which creates additional issues with components produced from the aluminum substrate. Furthermore, it is generally thought that aluminum and aluminum alloys are not suitable for chemical vapor deposition, as deposition temperatures are perceived to damage the aluminum substrate.

[0005] An article including a coating and a process including an article with a coating that show one or more improvements in comparison to the prior art would be desirable in the art.

BRIEF DESCRIPTION OF THE INVENTION

[0006] In an embodiment, an article includes an aluminum-containing substrate, and a coated and stabilized surface on the aluminum-containing substrate applied by thermal chemical vapor deposition at a temperature of less than 600° C. The aluminum-containing substrate includes, by weight, at least 95% aluminum.

[0007] In another embodiment, an article includes an aluminum-containing substrate, and a coated and stabilized surface on the aluminum-containing substrate. The aluminum-containing substrate includes, by weight, between 95.8% and 98.6% aluminum. The coated and stabilized surface is a thermal chemical vapor deposition coating, the thermal chemical vapor deposition coating including a carboxysilane.

[0008] In another embodiment, a process includes transporting fluid along a coated and stabilized surface, the coated and stabilized surface being positioned on an aluminum-containing substrate and being a thermal chemical vapor deposition coating.

[0009] Other features and advantages of the present invention will be apparent from the following more detailed description, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** shows a coating on a substrate, according to an embodiment of the disclosure.

[0011] FIG. **2** shows an article including a diffusion layer between a substrate and a coating, according to an embodiment of the disclosure.

[0012] Wherever possible, the same reference numbers will be used throughout the drawings to represent the same parts.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Provided are an article including a coating and a process including an article with a coating. Embodiments of the present disclosure, for example, in comparison to concepts failing to include one or more of the features disclosed herein, increase electrical conductivity, increase thermal conductivity, increase oxide thickness consistency of the barrier coating, increase grain size consistency of the barrier coating, increase phase consistency of the barrier coating, increase microstructure consistency of the barrier coating, permit use of aluminum in additional applications (for example, semiconductor process equipment, vacuum chambers), permit vapor deposition of coatings on aluminum, or permit a combination thereof.

[0014] Referring to FIGS. **1** and **2**, an article **100** includes an aluminum-containing substrate **101** and a coating **103** positioned over the substrate **101**. The coating **103** forms a coated and stabilized surface **102** on the aluminum-containing substrate **101**. The aluminum-containing substrate **101** includes pure or substantially pure aluminum, an aluminum alloy material, an impure metal with aluminum, and/or any aluminum-containing material used to form substrates in semiconductor manufacturing systems.

[0015] The aluminum-containing substrate **101** includes, by weight, at least 95% aluminum (Al), at least 95.8% Al, at least 98% Al, at least 99% Al, between 95.8% and 98.6% Al, between 95% and 99%, between 95% and 98%, between 98% and 99%, or any combination, sub-combination, range, or sub-range thereof. For example, in a further embodiment, the aluminum alloy material includes, by weight, at least 95% Al, between 0.2% and 3.0% magnesium (Mg), between 0.2% and 1.8% silicon (Si), and a balance incidental impurities.

[0016] One suitable aluminum alloy has a composition, by weight, of between 95.8% and 98.6% Al, between 0.8% and 1.2% Mg, between 0.4% and 0.8% Si, between 0.15% and 0.4% copper (Cu), between 0.04% and 0.35% chromium (Cr), up to 0.7% iron (Fe), up to 0.25% zinc (Zn), up to 0.15% titanium (Ti), up to 0.15% manganese (Mn), and a balance incidental impurities.

[0017] Another suitable aluminum alloy has a composition, by weight, of at least 95% Al, between 0.45% and 0.9% Mg,

between 0.2% and 0.6% Si, up to 0.35% Fe, up to 0.1% Cu, up to 0.1% Mn, up to 0.1% Cr, up to 0.1% Zn, up to 0.1% Ti, and a balance incidental impurities.

[0018] Other suitable constituents included in the aluminum alloy include, by weight, up to 1.5% bismuth (Bi), up to 0.06% boron (B), up to 2.0% lead (Pb), up to 0.2% nickel (Ni), up to 0.5% oxygen (O), up to 0.05% strontium (Sr), up to 2.0% tin (Sn), up to 0.3% vanadium (V), up to 0.2% zirconium (Zr), or a combination thereof.

[0019] The coating **103** is formed from decomposition of a silane material, such as, but not limited to, dimethylsilane, trimethylsilane, or a combination thereof. As disclosed in U.S. patent application Ser. No. 13/876,328, and U.S. patent application Ser. No. 13/504,533, both of which are incorporated herein by reference in their entirety, a process for forming the coating **103** includes chemical vapor deposition (CVD) of dimethylsilane. The chemical vapor deposition is by thermal application and not plasma-assisted methods.

[0020] In one embodiment, forming the coating **103** over the substrate **101** through CVD includes thermally decomposing dimethylsilane and/or any other suitable thermal decomposition gas and depositing amorphous carbosilane. In general, suitable species of the decomposition gas include, but are not limited to, an organosilane, dimethylsilane, any silane gas, or any other suitable chemical vapor decomposition gas. Other suitable materials for the introducing and/or subsequent treatment include, but are not limited to, trimethylsilane, dialkylsilyl dihydride, alkylsilyl trihydride, dialkylsilyl dihydride, alkylsilyl trihydride, organofluorotrialkoxysilanes, and/or organofluorosilylhydrides.

[0021] Any portion of the chemical vapor deposition process is capable of being preceded or followed by selectively applying a purge gas to the chemical vapor deposition chamber. The purge gas is nitrogen, helium, argon, or any other suitable inert gas. The purging is in one purge cycle, two purge cycles, three purge cycles, more than three purge cycles, or any suitable number of purge cycles that permits chemical vapor deposition chamber to be a chemically inert environment. The purging to provide a chemically inert environment is capable of eliminating or substantially eliminating exposure of the aluminum-containing substrate **101** to a corrosive environment, which facilitates the forming of the coating **103**.

[0022] In one embodiment, prior to forming the coating **103**, the aluminum-containing substrate **101** is modified to receive a CVD coating. Modifying the aluminum-containing substrate **101** includes any suitable treatment method. For example, modifying the aluminum-containing substrate **101** is capable of being achieved by isolating the aluminum-containing substrate **101** in a chemical vapor deposition chamber, preheating the aluminum-containing substrate **101**, flushing the chamber with an inert gas, and evacuating the chamber. The modifying of the aluminum-containing substrate **101** is capable of increasing adherence of the coating **103** to the aluminum-containing substrate **101**, which increases wear resistance of the article **100**. In addition, modifying the aluminum-containing substrate **101** through desorbing water is capable of reducing or eliminating corrosion of the article **100**.

[0023] In one embodiment, isolating of the aluminum-containing substrate **101** is performed in an inert atmosphere within the chamber. The flow of gas and/or maintenance of a vacuum in the chamber provides the controlled atmosphere. A heat source controls the temperature in the chamber to desorb water and remove remaining contaminants from the aluminum-containing substrate **101**. For example, in a further embodiment, the aluminum-containing substrate **101** to be treated is included within a chemical vapor deposition chamber with tubing connections to allow gas flow in and out of the chemical vapor deposition chamber. The chamber includes multiple controlled inlets and outlets configured for providing and removing multiple gas streams and/or a vacuum to one or more outlet tubes.

[0024] Depending upon the cleanliness of the aluminum-containing substrate **101**, in one embodiment, the aluminum-containing substrate **101** is prepared by heating at a temperature above 100° C. and a pressure of below 1 atmosphere for a period ranging from a few minutes to 15 hours. Generally, the temperature of the heating corresponds to the properties of the aluminum-containing substrate **101**. The period is from 0.5 to 15 hours and the heating, for example, is at about 450° C. for about 2 hours. After preparation under vacuum, in a further embodiment, the chamber is selectively flushed with an inert gas and evacuated.

[0025] The thermal decomposition of the decomposition gas includes introducing the decomposition gas into a reaction chamber at a pressure and temperature sufficient to decompose the decomposition gas, depositing constituents from the decomposition onto the aluminum-containing substrate **101**, coating the aluminum-containing substrate **101** for a period of time to achieve a thickness, and/or purging the chamber of decomposition gas. For example, in one embodiment, the dimethylsilane is introduced into the reaction chamber under reduced pressure or with an inert gas, such as nitrogen, helium, and/or argon, as a partial pressure dilutant. After introduction into the reaction chamber, the dimethylsilane is thermally dissociated into molecular fragments including H, C, Si, and combinations thereof. The thermally dissociated constituents are then deposited onto the aluminum-containing substrate **101**, thereby forming the coating **103** with a material including silicon, carbon, and hydrogen resulting from decomposition of dimethylsilane.

[0026] In one embodiment, at least during the introducing of the decomposition gas, the operating the chemical vapor deposition chamber is substantially devoid of catalyst (for example, being below a level that impacts the process) or devoid of catalyst (for example, being absent at detectable levels and/or being completely absent).

[0027] Although not intending to be bound by theory, it is believed that the dimethylsilane thermally decomposes to form carbosilyl fragments, which recombine and bind to the substrate **101**. It is believed that the resultant coating includes amorphous carbosilanes having carbon, silicon, and hydrogen on the substrate surface as well as on exposed surfaces of the chamber. The composition of the coating **103** includes a 1:0.95:0.12 ratio of C:Si:O (the small presence of oxygen from a depth of 5 nanometers to 120 nanometers is likely attributed to background noise and trace contamination). In contrast, the composition of dimethylsilane introduced into the chamber vapor deposition chamber has about a 2:1 ratio of C:Si. It is believed that CH_x (x=0–3) moieties are retained and Si—C bonds are broken thus indicating that the coating **103** includes an amorphous array of Si—C bonding and/or a polycrystalline microstructure. The amorphous array provides additional benefits such as decreased cracking or flaking (for example, upon tensile or compressive forces acting on the substrate **100**) and/or increased adhesion.

[0028] Depending upon the decomposition gas and other parameters, a suitable pressure for the decomposition is between 1.0 pound per square inch absolute (psia) and 250 psia, between 1.0 and 200 psia, between 1.0 psia and 150 psia, between 1.0 psia and 100 psia, between 1.0 psia and 75 psia, between 1.0 psia and 50 psia, between 1.0 psia and 40 psia, between 1.0 psia and 30 psia, between 1.0 psia and 20 psia, between 1.0 psia and 10 psia, between 1.0 psia and 5.0 psia, between 5 psia and 40 psia, 1.0 psia, 5 psia, 40 psia, 100 psia, 200 psia, or any suitable combination, sub-combination, range, or sub-range therein.

[0029] Depending upon the decomposition gas and other parameters, a suitable temperature for the decomposition is less than 30° C., less than 60° C., less than 100° C., less than 150° C., less than 200° C., less than 250° C., less than 300° C., less than 350° C., less than 400° C., less than 440° C., less than 450° C., less than 500° C., less than 600° C., between 100° C. and 300° C., between 125° C. and 275° C., between 200° C. and 300° C., between 230° C. and 270° C., between 300° C. and 600° C., between 400° C. and 500° C., or any suitable combination, sub-combination, range, or sub-range therein.

[0030] Depending upon the decomposition gas and other parameters, a suitable period of time for the decomposition are between 10 minutes and 24 hours, between 1 hours and 10 hours, between 2 hours and 10 hours, between 4 hours and 6 hours, between 4 hours and 8 hours, at least 10 minutes, at least 1 hours, at least 4 hours, at least 10 hours, less than 10 hours, less than 8 hours, less than 6 hours, less than 4 hours, or any suitable combination, sub-combination, range, or sub-range therein.

[0031] For example, in one embodiment, the dimethylsilane gas is introduced into the reaction chamber at a pressure of between 1.0 psia and 200 psia, and a temperature of between 300° C. and 600° C., and exposed to the aluminum-containing substrate **101** for 30 minutes to 24 hours. In another embodiment, the dimethylsilane gas is introduced into the reaction chamber at a pressure of between 5 psia and 40 psia, and a temperature between 400° C. and 500° C., and exposed to the aluminum-containing substrate **101** for 15 hours.

[0032] In one embodiment, the coated and stabilized surface **102** provided by the coating **103** is devoid or substantially devoid of surface activity, which decreases or eliminates reagent retention, carryover, contamination, and/or build-up on the coated and stabilized surface **102**, as compared to the aluminum-containing substrate **101** without the coating **103**. In addition to reagent reactivity, surface activity refers to, but is not limited to, discoloration of the coated and stabilized surface **102** and/or the substrate **101**, for example, to produce a blue or purple appearance. Furthermore, reducing or eliminating the surface activity of the article **100** increases the resistance of the article **100** to corrosion. In corrosive wear the surface reacts with the environment and reaction products are formed on the surface asperities. Attrition of the reaction products then occurs as a result of crack formation, and/or abrasion, in the contact interactions of the materials.

[0033] Additionally, in contrast to the belief that chemical vapor deposition is not suitable for aluminum-containing substrates due to damage of the substrate during coating, the CVD processes disclosed herein form the coated and stabilized surface **102** without damaging or without notable damage to the aluminum-containing substrate **101**. Doing so permits embodiments with the aluminum-containing substrates **101** being in applications, such as, but not limited to, semiconductor process equipment and/or vacuum chambers. Furthermore, such embodiments have less porosity, more uniform/homogenous in composition, and/or more uniform/homogenous structure (such as, for example, thickness, phase, and/or grain size) as compared to the aluminum-containing substrate **101** and/or oxide layers formed directly on the aluminum-containing substrate **101**. As compared to non-diffusion coatings, embodiments of the coated and stabilized surface **102** formed through CVD of the coating **103** also provide increased chemical resistance, increased inertness, and increased adhesion of the coating **103** to the aluminum-containing substrate **101**.

[0034] In another embodiment, a fluid is transported along the coated and stabilized surface **102** of the aluminum-containing substrate **101**. The coated and stabilized surface **102** decreases or eliminates reagent retention, reagent carryover, and or reagent contamination from the fluid, as compared to uncoated aluminum-containing substrates **101** and/or oxide layers formed directly on the aluminum-containing substrates **101**.

[0035] In one embodiment, the coating **103** is formed by cold fill deposition. Cold fill deposition includes positioning the aluminum-containing substrate **101** in a chemical vapor deposition chamber, then operating the chemical vapor deposition chamber. The operating of the chemical vapor deposition chamber includes purging the chemical vapor deposition chamber, introducing a decomposition gas to the chemical vapor deposition chamber, heating the chemical vapor deposition chamber, or a combination thereof. Throughout the operating of the chemical vapor deposition chamber, the pressure is adjusted or within a range, for example, of between 0.01 psia and 200 psia, between 1.0 psia and 100 psia, between 5 psia and 40 psia, about 1.0 psia, about 5 psia, about 40 psia, about 100 psia, about 200 psia, or any suitable combination, sub-combination, range, or sub-range therein.

[0036] The cold fill deposition includes introduction of the decomposition gas at a sub-decomposition temperature that is below the thermal decomposition temperature of the decomposition gas. As used herein, the phrase "sub-decomposition temperature" refers to conditions at which the decomposition gas will not detectably thermally decompose. Depending upon the species of the decomposition gas, suitable sub-decomposition temperatures include, but are not limited to, less than 30° C., less than 60° C., less than 100° C., less than 150° C., less than 200° C., less than 250° C., less than 300° C., less than 350° C., less than 400° C., less than 440° C., less than 450° C., between 100° C. and 300° C., between 125° C. and 275° C., between 200° C. and 300° C., between 230° C. and 270° C., or any suitable combination, sub-combination, range, or sub-range therein.

[0037] During and/or after the introducing of the decomposition gas, the operating of the chemical vapor deposition chamber includes heating the chemical vapor deposition chamber to a super-decomposition temperature that is equal to or above the thermal decomposition temperature of the decomposition gas. As used herein, the phrase "super-decomposition temperature" refers to conditions at which the decomposition gas will thermally decompose. Heating the chemical vapor deposition chamber to the super-decomposition temperature in the presence of the decomposition gas

forms the coating **103** on at least a surface of the aluminum-containing substrate **101**, which forms the coated and stabilized surface **102**.

[0038] The heating of the chemical vapor deposition chamber is at any suitable heating rate from the sub-decomposition temperature to the super-decomposition temperature. Depending upon the species of the decomposition gas, suitable super-decomposition temperatures include, but are not limited to, between 440° C. and 460° C., greater than 460° C., greater than 450° C., greater than 460° C., greater than 480° C., greater than 500° C., or any suitable combination, sub-combination, range, or sub-range therein. Suitable heating rates include, but are not limited to, between 6° C. per minute and 10° C. per minute, between 7° C. per minute and 9° C. per minute, greater than 6° C. per minute, greater than 7° C. per minute, less than 10° C. per minute, less than 9° C. per minute, at 8° C. per minute, or any suitable combination, sub-combination, range, or sub-range therein. At such rates, in one embodiment, the heating of the chemical vapor deposition chamber is for a period of between 3 minutes and 10 minutes, a period of between 5 minutes and 10 minutes, a period of between 7 minutes and 10 minutes, a period of between 3 minutes and 7 minutes, a period of between 3 minutes and 5 minutes, or any suitable combination, sub-combination, range, or sub-range therein.

[0039] The cold fill CVD process disclosed herein is capable of providing chemical vapor deposition of the decomposition gas to form the coating **103** without damaging the aluminum-containing substrate **101**. Furthermore, in addition to the advantages disclosed for the coating **103** formed through CVD, the coating **103** formed through cold fill deposition, as disclosed above, is capable of increasing cross-link density of the coating **103**.

[0040] In one embodiment, as illustrated in FIG. **2**, the deposited material diffuses into the aluminum-containing substrate **101**, forming a diffusion zone **105** extending between the aluminum-containing substrate **101** and the coating **103**. Subsequent to forming the coating **103**, the chamber is capable of being purged of dimethylsilane and volatile, non-deposited carbosilyl fragments. If a thicker deposition layer is desired, deposition conditions are changed. This is accomplished by changing temperature, pressure, time, or combinations thereof. Multiple layers are also capable of being applied by repeating the introduction and thermal decomposition of the dimethylsilane. Together, the one or more layers of the coating **103** form the coated and stabilized surface **102** on the aluminum-containing substrate **101**.

[0041] While a thickness of the coating **103** depends on the geometry of the substrate **101** to be coated and the type of finish required, in an embodiment made according to the methods disclosed herein, the coating **103** has a thickness of between 100 nm and 10,000 nm, between 100 nm and 5,000 nm, between 200 nm and 5,000 nm, between 100 nm and 3,000 nm, between 300 nm and 1,500 nm, or any combination, sub-combination, range, or sub-range thereof. In another embodiment, the diffusion zone **105** is between 5 nm and 500 nm. For example, in a further embodiment, the coating **103** extends to 130 nm and includes a portion of the diffusion zone **105**, which extends 20 nm, and is identifiable based upon an increased concentration of 0 and decreased in concentration of C and Si (for example, by at least a factor of four).

[0042] Any other suitable treating steps are performed on the coating **103** after the decomposition gas is introduced, to form the coated and stabilized surface **102**. The treating of the coating **103** includes, for example, heating and/or modifying the coating **103** applied over the substrate **101**. In one embodiment, the treating includes exposure of the substrate **101** and/or the coating **103** to a suitable organosilane reagent. One suitable organosilane reagent is a trifunctional organosilane that consists of the general formula RR'R"Si—H, where R,R', R" are organofunctional groups. Examples of the organofunctional groups are alkyl, aryl, halogenated alkyl and aryl, ketones, aldehydes, acyl, alcohol, epoxy, and nitro—organo groups, and organometallic functionalities. In one embodiment, the organosilane is trimethylsilane.

[0043] By modifying and varying the R' groups, or by using other molecules capable of hydroxyl reactivity, surface properties of the treated coated and stabilized surface **102** (for example, the air-oxidized carboxysilane layer) are adjusted. For example, in one embodiment, the adjustments increase or decrease hardness and wear resistance, inertness, stiction, coking, electrochemical impedance, contact angle, and combinations thereof. The adjustments provided through varying the R' groups provide physical performance characteristics expanding the applicability of aluminum-containing substrates **101** in the semiconductor industry. The R-groups are capable of being formed by hydrocarbons, substituted hydrocarbons, carbonyls, carboxyls, esters, ethers, amines, amides, sulfonic acids, organometallic complexes, and/or epoxides. Although not intending to be bound by theory, it is believed that the moieties of silicon hydride thermally react, via a hydrosilyation mechanism, with unsaturated hydrocarbon groups to covalently bond to the coated and stabilized surface **102** of the aluminum-containing substrate **101**. In one embodiment, the coated and stabilized surface **102** on all exposed surface within the reaction chamber includes covalently-bound R-groups which include the R-group and carbon, silicon, and hydrogen moieties.

[0044] In one embodiment, the CVD of the dimethylsilane is followed by oxidation to form a carboxysilane and/or functionalization to form a functionalized carboxysilane. Oxidation of the coating **103** includes exposure to any suitable chemical species capable of donating a reactive oxygen species into the coating **103** under predetermined oxidation conditions. In general, oxidation is a bulk reaction that affects the bulk of the coating **103**. The oxidation increases hardness and/or wear resistance of carbosilane and functionalized carbosilane-based chemical vapor deposition process materials of the coated and stabilized surface **102**. The oxidation is capable of being controlled by increasing or decreasing the temperature within the chamber, the exposure time within the chamber, the type and/or amount of diluent gases, pressure, and/or other suitable process conditions. Control of the oxidation is capable of increasing or decreasing the amount and/or depth of oxidation and, thus, the wear resistance and/or hardness of the coated and stabilized surface **102**. By increasing the wear resistance, the oxidation of the coated and stabilized surface **102** increases resistance of the article **100** to erosion (from both solid and liquid), which occurs when impinging particles or stream contact the surface of the article **100**.

[0045] The chemical species for the oxidation of the coating **103** are selected based upon the desired properties of the coated and stabilized surface **102**. Suitable chemical species for the oxidation of the coating **103** include, for example, water, oxygen, air, nitrous oxide, ozone, peroxide, and combinations thereof. In one embodiment, the coating **103** is oxidized with water as an oxidizing agent (for example,

within a temperature range of 100° C. to 600° C., a temperature range of 300° C. to 600° C., or at a temperature of 450° C.). In this embodiment, the oxidizing lowers friction of the coated and stabilized surface **102** (in comparison to using an oxidizing reagent of air and water), decreases wear resistance of the coated and stabilized surface **102** (for example, in comparison to using an oxidizing reagent of air and water), and forms Si—O—Si groups. The Si—O—Si groups formed in this embodiment are capable of further decreasing or eliminating surface activity of the coated and stabilized surface **102** as compared to an uncoated aluminum-containing substrate **101**.

[0046] In another embodiment, the coating **103** is oxidized with an oxidizing reagent including air and water (for example, within a temperature range of 100° C. to 600° C., a temperature range of 300° C. to 600° C., or at a temperature of 450° C.). In this embodiment, the oxidizing over-oxidizes and decreases an amount of C—H groups (for example, in comparison to using water alone as an oxidizing reagent), decreases an amount of Si—C groups (for example, in comparison to using water alone as an oxidizing reagent), and increases an amount of Si—OH/C—OH groups (for example, in comparison to using water alone as an oxidizing reagent). Depending on the reagents contacting the coated and stabilized surface **102**, the decreased amount of C—H and Si—C groups, and/or the increased an amount of Si—OH/C—OH groups are capable of further decreasing or eliminating surface activity of the coated and stabilized surface **102**.

[0047] In an alternate embodiment, the coating **103** is oxidized with air (only) (for example, within a temperature range of 100° C. to 600° C., a temperature range of 300° C. to 600° C., or at a temperature of 450° C.). In this embodiment, the oxidizing lowers friction of the coated and stabilized surface **102**, increases wear resistance of the coated and stabilized surface **102** (for example, in comparison to using an oxidizing reagent of water), and forms Si—O—Si and Si—OH groups. The Si—O—Si and Si—OH groups are capable of further decreasing or eliminating surface activity of the coated and stabilized surface **102**.

[0048] In one embodiment, the coating **103** is oxidized with nitrous oxide (N_2O). Specifically, N_2O is applied under heat (for example, about 450° C.) with a pressure of substantially pure N_2O in a vessel with carbosilane-coated samples. In this embodiment, the oxidizing over-oxidizes and the over-oxidizing increases an amount of N—H, Si—OH, and/or C—OH groups, and results in having relatively fragile scratch resistance. Alternatively, the oxidizing is performed with ozone. In this embodiment, the oxidizing is believed to decrease wear resistance, decrease chemical resistance, decrease scratch resistance, decrease hardness, and increase acid resistance/corrosion resistance of the coated and stabilized surface **102**.

[0049] In one embodiment, after forming the coating **103** on the aluminum-containing substrate **101**, the coating **103** is treated by trimethylsilane. In another embodiment, the coating **103** is oxidized to form the carboxysilane prior to treatment by trimethylsilane. In a further embodiment, after treating the carboxysilane with trimethylsilane, the coating **103** is functionalized. Treatment with the trimethylsilane is capable of providing increasing (over untreated oxidized and/or functionalized coatings) in inertness, corrosion resistance, hydrophobicity, pH resistance, wear resistance and hardness, and combinations thereof. For example, treating the coating **103** is capable of forming the coated and stabilized surface **102** having about a thirty-four-fold improvement in wear resistance over the untreated functionalized coating. Additionally or alternatively, the coating **103** is capable of being adjusted for anti-stiction and anti-coking properties, which reduces or eliminates byproduct accumulation and/or reagent adherence/retention on the coated and stabilized surface **102**, as compared to untreated coatings and/or substrates.

[0050] While the invention has been described with reference to one or more embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. In addition, all numerical values identified in the detailed description shall be interpreted as though the precise and approximate values are both expressly identified.

What is claimed is:

1. An article, comprising:

an aluminum-containing substrate; and

a coated and stabilized surface on the aluminum-containing substrate, the coated and stabilized surface being applied by thermal chemical vapor deposition at a temperature of less than 600° C.;

wherein the aluminum-containing substrate includes, by weight, at least 95% aluminum.

2. The article of claim **1**, wherein the coated and stabilized surface is formed from the thermal chemical vapor deposition of dimethylsilane.

3. The article of claim **2**, wherein the coated and stabilized surface is oxidized.

4. The article of claim **3**, wherein the coated and stabilized surface is functionalized.

5. The article of claim **2**, wherein the coated and stabilized surface is treated with trimethylsilane.

6. The article of claim **5**, wherein the trimethylsilane is functionalized.

7. The article of claim **1**, wherein the aluminum-containing substrate comprises pure aluminum.

8. The article of claim **1**, wherein the aluminum-containing substrate includes, by weight, between 95.8% and 98.6% aluminum.

9. The article of claim **1**, wherein the aluminum-containing substrate includes, by weight, between 0.2% and 3.0% magnesium, and between 0.2% and 1.8% silicon.

10. The article of claim **9**, wherein the aluminum-containing substrate includes at least one element selected from the group consisting of, by weight, between 0.01% and 0.25% titanium, between 0.02% and 1.4% manganese, between 0.03% and 0.4% chromium, between 0.01% and 1.2% copper, between 0.04% and 1.0% iron, between 0.05% and 0.5% oxygen, and combinations thereof.

11. The article of claim **9**, wherein the aluminum-containing material includes a composition, by weight, of between 95.8% and 98.6% aluminum, between 0.8% and 1.2% magnesium, between 0.4% and 0.8% silicon, between 0.15% and 0.4% copper, between 0.04% and 0.35% chromium, up to 0.7% iron, up to 0.25% zinc, up to 0.15% titanium, up to 0.15% manganese, and a balance incidental impurities.

12. The article of claim **1**, wherein the coated and stabilized surface is deposited at a super-decomposition temperature of dimethylsilane.

13. The article of claim **1**, wherein the coated and stabilized surface is substantially devoid of surface activity.

14. The article of claim **1**, wherein the coated and stabilized surface is substantially devoid of discoloration.

15. The article of claim **1**, wherein the coated and stabilized surface has less porosity than the aluminum substrate.

16. The article of claim **1**, wherein the coated and stabilized surface includes increased thickness surface homogeneity as compared to the aluminum-containing substrate.

17. The article of claim **1**, wherein the coated and stabilized surface is more uniform in composition than the aluminum-containing substrate.

18. The article of claim **1**, wherein the coated and stabilized surface is more uniform in grain size than the aluminum-containing substrate.

19. An article, comprising:

an aluminum-containing substrate; and

a coated and stabilized surface on the aluminum-containing substrate;

wherein the aluminum-containing substrate includes, by weight, between 95.8% and 98.6% aluminum; and

wherein the coated and stabilized surface is a thermal chemical vapor deposition coating, the thermal chemical vapor deposition coating including a carboxysilane.

20. A process comprising transporting fluid along a coated and stabilized surface, the coated and stabilized surface being positioned on an aluminum-containing substrate and being a thermal chemical vapor deposition coating.

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