

APPARATUS AND METHOD FOR COATING A SUBSTRATE

Cross Reference to Related Application(s)

- 5 The present disclosure claims the benefit of Singapore Patent Application No. 10202000657R filed on 23 January 2020, which is incorporated in its entirety by reference herein.

Technical Field

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The present disclosure generally relates to an apparatus and a method for coating a substrate. More particularly, the present disclosure describes various embodiments of an apparatus and a method for coating a substrate, such as a wafer, with a precursor material.

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Background

Many electronic devices are coated with thin films or layers during their manufacture for various purposes. For example, such thin films or layers are used to apply dopants, dielectric layers, and sealants in microelectronic parts. Thin films are layers of material deposited on a substrate in order to impart properties that cannot be easily attained (not attained at all) by the substrate material, as well as to modify surface interactions of the newly formed coating on the substrate.

25 Many semiconductor processes involve the coating of substrates in thin films or layers of materials in the fabrication of semiconductor devices. There are various known methods for coating the substrates, or more specifically for coating a surface of a substrate, such as a wafer. One example is by spray coating or air spraying which can be performed using a spray nozzle. The spray nozzle is a precision device that disperses a liquid into a spray towards the substrate surface. One example of the spray nozzle is an aspirator nozzle that can produce a fine spray of liquid based on the Venturi effect. However, because of the size of the spray nozzle, only a small area of the substrate surface can be coated in each spray. The spray nozzle must be moved

across the substrate surface in order for the whole substrate surface to be coated. There is less control of the coating thickness and uniformity due to movement of the spray nozzle and inconsistent sizes of droplets / particles, resulting in a non-uniformly coated substrate and consequently a defective semiconductor device. Air spraying
5 using the spray nozzle also tends to disperse too much the liquid, resulting in wastage of the liquid.

Another method for coating the substrate is by chemical vapour deposition (CVD). In CVD, the substrate is placed in a CVD chamber and exposed to one or more gaseous
10 materials that react and/or decompose on the substrate surface to produce the desired deposit. Although CVD allows for better control than spray coating and the coating is more uniform, it is a slow process because of the long duration times for the gaseous materials to settle on the substrate surface. There are also higher equipment and operation costs because CVD must be performed under vacuum conditions and the
15 CVD chamber must be designed with proper seals. The material costs are also higher because the coating material must be in gaseous form and there are difficulties in proper storage of such gaseous coating materials.

Therefore, in order to address or alleviate at least one of the aforementioned problems
20 and/or disadvantages, there is a need to provide an improved apparatus and method for coating a substrate.

Summary

25 According to a first aspect of the present disclosure, there is an apparatus for coating a substrate with a precursor material. The apparatus comprises:

- a support assembly for arranging the substrate such that a coating surface of the substrate faces substantially downwards;
- an inlet region for atomizing the precursor material in liquid form;
- 30 a chamber fluidically connected to the inlet region for receiving the atomized precursor material discharged from the inlet region, the chamber comprising a set of fluidic devices for breaking up the atomized precursor material; and

an outlet region fluidically connected to the chamber for receiving the atomized precursor material communicated from the chamber,

wherein the outlet region is configured for discharging the atomized precursor material substantially upwards to the substrate, thereby coating the substrate coating surface with the precursor material.

According to a second aspect of the present disclosure, there is a method for coating a substrate with a precursor material. The method comprises:

arranging the substrate on a support assembly such that a coating surface of the substrate faces substantially downwards to an outlet region;

atomizing the precursor material in liquid form at an inlet region;

discharging the atomized precursor material from the inlet region to a chamber;

breaking up the atomized precursor material in the chamber;

communicating the atomized precursor material from the chamber to the outlet region; and

discharging the atomized precursor material from the outlet region substantially upwards to the substrate, thereby coating the substrate coating surface with the precursor material.

An apparatus and a method for coating a substrate according to the present disclosure are thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figure 1A is an illustration of an apparatus for coating a substrate, in accordance with embodiments of the present disclosure.

Figure 1B is an illustration of the substrate.

Figure 2A and Figure 2B are illustrations of a support assembly of the apparatus.

Figure 3 is a block diagram illustration of coating the substrate using the apparatus.

5 Figure 4 is an illustration of a housing of the apparatus.

Figure 5 is another block diagram illustration of coating the substrate using the apparatus.

10 Figure 6 is a flowchart illustration of a method for coating a substrate, in accordance with embodiments of the present disclosure.

Figure 7A to Figure 7C are cross-sectional illustrations of an outlet region and a chamber of the apparatus.

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Figure 8A to Figure 8C are illustrations of a system comprising the apparatus for coating one or more substrates, in accordance with embodiments of the present disclosure.

20 **Detailed Description**

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to an apparatus and a method for coating a substrate, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognised by an individual having ordinary skill in the art, i.e. a skilled person, that the present disclosure may be practiced without specific details, and/or with multiple details arising

from combinations of aspects of particular embodiments. In a number of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

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In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith.

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References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

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The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment.

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As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise indicated. The term “set” is defined as a non-empty finite organisation of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an

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approximate numerical value or value range. The terms “first”, “second”, etc. are used merely as labels or identifiers and are not intended to impose numerical requirements on their associated terms.

5 In representative or exemplary embodiments of the present disclosure, with reference to Figure 1A, there is an apparatus 100 for coating a substrate with a precursor material. The substrate may refer to any structure having a coating surface to be coated with the precursor material. The precursor material can be defined as a compound or substance that participates in a chemical reaction and produces a
10 different compound or substance that is coated and becomes an intrinsic part of the substrate. Some non-limiting examples of the substrate material include silicon, ceramic, quartz, glass, silver, and gold. Some non-limiting examples of the precursor material, after being coated and cured on the substrate, include oxide or multi-oxide materials such as gallium (III) trioxide (Ga_2O_3), silicon dioxide (SiO_2), aluminium oxide
15 (Al_2O_3), and titanium dioxide (TiO_2).

In many embodiments as shown in Figure 1B, the substrate 102 is a silicon (or crystalline silicon) wafer that is used in semiconductor processes, such as for fabrication of semiconductor devices. For example, the wafer can be used for the
20 fabrication of the integrated circuits and in photovoltaics to manufacture solar cells. The wafer may have various diameters, such as ranging from 100 mm to 500 mm and may have a thickness of approximately 100 microns. The wafer is typically an ultra-flat disc that has been refined to a mirror-like surface or finish and has very subtle surface defects or irregularities. It will be appreciated that the substrate 102 can have
25 various shapes and sizes, such as a rectangular wafer.

As shown in Figure 1A, the apparatus 100 may include a frame or body 110 forming a housing 112 for housing various parts of the apparatus 100. The apparatus 100 includes a support assembly 120 for arranging the substrate 102. The apparatus 100
30 includes an outlet region 130 configured for discharging atomized precursor material substantially upwards to the substrate 102, thereby coating the substrate coating surface with the precursor material. Notably, the atomized precursor material is in the

form of fine particles or droplets that were produced from the precursor material in liquid form.

To enable the outlet region 130 to discharge the atomized precursor material substantially upwards to the substrate 102, the support assembly 120 is configured for arranging the substrate 102 such that the substrate coating surface faces substantially downwards. As shown in Figure 2A and Figure 2B, the support assembly 120 may include a flipper device 122 for flipping the substrate 102, i.e. rotate the substrate 102 by 180°, such that the substrate coating surface faces substantially downwards. The support assembly 120 may include a vacuum chuck 124 for holding the substrate 102, particularly when the substrate 102 is in an upside-down orientation. The vacuum chuck 124 may include an array of vacuum orifices for distributing the vacuum suction across the substrate, thereby enabling the vacuum chuck 124 to hold the substrate 102 more firmly.

With reference to Figure 3, the substrate 102 is first placed on the support assembly 120, wherein the substrate coating surface 104 faces substantially upwards. For example, robotic arms may be used to pick and place substrate 102 on the support assembly 120. The vacuum chuck 124 holds and secures the substrate 102 on the support assembly 120. The flipper device 122 then flips the substrate 102 such that the substrate coating surface 104 faces substantially downwards. In this orientation, the substrate coating surface 104 is in a wet environment as it is exposed to the outlet region 130 which discharges the atomized precursor material substantially upwards to the substrate 102. A coated layer 106 of precursor material is thus formed on the substrate coating surface 104. During coating by the outlet region 130, the vacuum chuck 124 maintains the substrate 102 in a substantially flat orientation, thereby mitigating risk of defects in the coated layer 106, such as uneven coating or presence of uncoated areas. The flipper device 122 then flips the substrate 102 back such that the substrate coating surface 104 and the coated layer 106 face substantially upwards. The substrate 102 is now in a dry environment and may be further processed. For example, the vacuum chuck 124 may release the substrate 102 and the substrate 102 may be removed from the apparatus 100 and transferred to another station for further processing. The flipper device 122 enables the substrate 102 to quickly and smoothly

change between the upwards and downwards orientations with minimal impact to the properties of the coated layer 106.

As shown in Figure 4, the apparatus 100 includes the outlet region 130 and further
5 includes an inlet region 140 and a chamber 150, wherein the chamber 150 is fluidically
connected to the inlet region 140 and outlet region 130. The inlet region 140 is
configured for atomizing the precursor material in liquid form. The chamber 150 is
configured for receiving the atomized precursor material discharged from the inlet
region 140 and for communicating the atomized precursor material to the outlet region
10 130.

The chamber 150 includes a set of fluidic devices for breaking up the atomized
precursor material. As the atomized precursor material entering the chamber 150 may
contain droplets of varying sizes, including large ones that are undesirable for coating
15 the substrate 102, the fluidic devices operate in the chamber 150 to break up and
reduce the droplets into smaller sizes. The atomized precursor material communicates
through the chamber 150 due to pressure differential between the inlet region 140
(higher pressure) and the outlet region 130 (lower pressure).

20 The outlet region 130 is configured for receiving the atomized precursor material
communicated from the chamber 150 and for discharging the atomized precursor
material to the substrate 102. More specifically, the atomized precursor material that
enter the outlet region 130 contains very fine droplets as they have been broken up
and reduced by the fluidic devices in the chamber 150. By discharging the atomized
25 precursor material with very fine droplets, a thinner and more uniform coated layer 106
can be formed on the substrate 102.

In some embodiments, the apparatus 100 includes an actuation mechanism 132 for
adjusting a vertical distance between the outlet region 130 and the support assembly
30 120. For example, adjusting the vertical distance can control the thickness and/or
uniformity of the coated layer 106. The actuation mechanism 132 may be configured
to move the outlet region 130 at variable speeds.

The inlet region 140 may include a spray nozzle or an atomizer nozzle for atomizing the liquid precursor material and to facilitate dispersion of the liquid precursor material into a spray. In many embodiments, the atomizer nozzle is a pneumatic nozzle which may be referred to as a twin-fluid nozzle. The pneumatic nozzle operates by mixing
5 two fluids together, usually a liquid and a gas, and atomizes the mixture into a mist form. In the apparatus 100, the pneumatic nozzle is configured to receive the liquid precursor material and a gas such as air. The pneumatic nozzle can be of the internal or external mixing type wherein the fluids are mixed either inside or outside, respectively, the nozzle. The pneumatic nozzle can atomize small quantities of liquid
10 to produce very fine droplets. The pneumatic nozzle can be operated with precise volume flow control and good atomization quality. These characteristics of the pneumatic nozzle make it suitable as the atomizer nozzle 130 to produce atomized precursor material for coating on the substrate 102.

15 It will be appreciated that other types of spray nozzle or atomizer nozzle may be used in the apparatus 100. For example, the atomizer nozzle may be a single-fluid nozzle, such as a plain-orifice nozzle or shaped-orifice nozzle. For example, the atomizer nozzle may be a rotary atomizer that uses a high-speed rotating element to discharge a liquid, wherein the rotational speed controls the drop size of the liquid. It will also be
20 appreciated that there may be other means of configuring the inlet region 140 to atomize the liquid precursor material, particularly into a spray form wherein the liquid precursor material is atomized into a collection of tiny droplets dispersed in a gas.

In many embodiments with reference to Figure 5, the inlet region 140 includes a
25 pneumatic nozzle configured to receive the liquid precursor material and a gas. The apparatus 100 includes a supply storage unit 160 for supplying the liquid precursor material to the inlet region 140. The apparatus 100 further includes a pneumatic compressor 162 fluidically connectable to the inlet region 140 and configured for supplying the gas to the inlet region 140. For example, the gas is air, and the
30 pneumatic compressor 162 is an air compressor. The pneumatic nozzle at the inlet region 140 mixes the liquid precursor material and air and atomizes the liquid precursor material.

The supply storage unit 160 may be connected to a precision spray controller configured control the amount of liquid precursor material communicated to the pneumatic nozzle. By controlling the amount of liquid precursor material, the thickness of the coated layer 106 can be more consistently and precisely controlled. The precision spray controller may further be configured to measure and monitor the amount of liquid precursor material communicated to the pneumatic nozzle and to thereby determine the amount of precursor material used for forming the coated layer 106.

In representative or exemplary embodiments of the present disclosure, with reference to Figure 6, there is a method 200 for coating the substrate 102 with the precursor material. The method 200 includes a step 202 of arranging the substrate 102 on the support assembly 120 such that the substrate coating surface 104 faces substantially downwards to the outlet region 130.

The method 200 includes a step 204 of atomizing the liquid precursor material at the inlet region 140. The method 200 includes a step 206 of discharging the atomized precursor material from the inlet region 140 to the chamber 150. In many embodiments, the inlet region 140 includes a pneumatic nozzle that mixes liquid precursor material and air together. This mixing causes atomization of the liquid precursor material which is then discharged into the chamber 150.

The method 200 includes a step 208 of breaking up the atomized precursor material in the chamber 150. The method 200 includes a step 210 of communicating the atomized precursor material from the chamber 150 to the outlet region 130. The method 200 includes a step 212 of discharging the atomized precursor material from the outlet region 130 substantially upwards to the substrate 102, thereby coating the substrate coating surface 104 with the precursor material and forming the coated layer 106.

Notably, the atomized precursor material that coats the substrate 102 and forms the coated layer 106 contains very fine droplets as they have been broken up in the chamber 150. The atomized precursor material is released in the form of a fine mist

or vapour that can distribute evenly across the substrate coating surface 104, thereby forming a thin and uniform coated layer 106.

5 The coated layer 106 may be measured after it has cured and hardened on the substrate 102. More specifically, the thickness of the coated layer 106 at various areas thereof are measured to evaluate the uniformity of the coated layer 106 and whether it is the same thickness throughout. The method 200 or coating process may be repeated if the coated layer 106 is not as uniform as desired and does not meet predefined specifications. One or more additional coating cycles can be performed to
10 improve the uniformity of the coated layer 106 and to achieve the same thickness throughout.

In some embodiments, the method 200 may be performed multiple times to coat the substrate 102 multiple times, in order to achieve a thicker coated layer 106 that is
15 formed by very fine particles of precursor material. For example, each cycle of the coating process may achieve a thickness of 100 nm. If an overall thickness of 1 micron for the coated layer 106 is desired, the coating process must be repeated 10 times. The apparatus 100 may include suitable measurement instruments for progressive measurements of the coated layer 106 while it is being grown by the method 200 in
20 several repetitive cycles.

In some embodiments as shown in Figure 7A, the apparatus 100 includes a fluidic channel 152 fluidically connected between the chamber 150 and the outlet region 130. The fluidic channel 152 is configured for facilitating communication of the atomized
25 precursor material from the chamber 150 to the outlet region 130, such as by converging said communication towards the outlet region 130. The fluidic channel 152 may be sized to allow only smaller droplets, such as those that have been broken up by the fluidic devices in the chamber 150, to communicate to the outlet region 130. In some other embodiments, the outlet region 130 is integrally formed with the chamber
30 150.

As shown in Figure 7B, the fluidic devices in the chamber 150 may include a set of fans 154 for breaking up the atomized precursor material. The fans 154 also facilitate

communication of the atomized precursor material through the chamber 150, and may function as a shield to prevent contaminants or unwanted materials from entering the outlet region 130. As the atomized precursor material entering the chamber 150 from the inlet region 140 may contain large droplets, the fans 154 operate to break them up into smaller sizes. The fans 154 may also assist in breaking up agglomerates in the atomized precursor material that may form when particles or droplets aggregate together as it communicates through the chamber 150. Alternatively or additionally, the fluidic devices may include a set of filters that prevent larger droplets from passing through, thereby allowing only smaller droplets to communicate to the outlet region 130. Notably, the size of the droplets that can pass through the filters is dependent on the pore size of the filters.

As shown in Figure 7C, the outlet region 130 may include an array of orifices 134 arranged such that the atomized precursor material can be discharged substantially upwards through the orifices 134. Additionally, the array of orifices 134 may be arranged according to the size of the support assembly 120 such that the whole substrate coating surface 104 is exposed to the orifices 134, enabling the orifices 134 to uniformly spray and distribute the discharged atomized precursor material across the whole substrate coating surface 104. The array of orifices 134 minimizes the spray pressure released from the outlet region 130, thereby reducing the impact of the discharged atomized precursor material on the substrate coating surface 104. This arrangement advantageously improves uniformity of the coated layer 106 and mitigates risk of defects in the coated layer 106, such as uneven coated areas or presence of uncoated areas. The array of orifices 134 may be adjustable or customizable according to the shape and size of the substrate 102. The multitude of orifices 134 allow the outlet region 130 to achieve a high deposition rate so that the substrate 102 can be more quickly coated. The deposition rate from each orifice 134 is consistent with the others so that the coated layer 106 is formed uniformly and the thickness of the coated layer 106 is consistent in every area and edge thereof.

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The outlet region 130 may include a cleaning mechanism configured for cleaning the outlet region 130, especially the orifices 134. For example, the cleaning mechanism may be configured to clean or purge the orifices 134 of any residual precursor material

and contaminants. The orifices 134 should be cleaned periodically as contaminants may be left behind in the orifices 134 after performing the method 200. Uncleaned orifices 134 could result in poor quality of coated layers 106 in the next batches of substrates 102. To clean the outlet region 130 and orifices 134, the supply storage unit 160 may be replaced with one containing a cleaning solution instead of the precursor material. A cleaning process is performed similar to the method 200 by communicating the cleaning solution from the supply storage unit 160 through the inlet region 140, chamber 150, and outlet region 130. The cleaning solution may circulate through the apparatus 100 for a predefined period, which may be based on a cleaning schedule, so that the various parts of the apparatus 100, especially the orifices 134, are properly cleaned. Periodically cleaning the apparatus 100 helps to maintain it and prolong its useable lifespan.

In some embodiments as shown in Figure 7C, the outlet region 130 is configured for collecting excess precursor material that has been discharged from the outlet region 130. For example, the outlet region 130 may include a collection portion 136 disposed around a periphery of the outlet region 130 and arranged to collect excess precursor material that fall downwards. More specifically, heavier / larger particles or droplets of precursor material are unlikely to reach the substrate coating surface 104 as they are moving against gravity. Instead, the heavier / larger droplets would fall downwards by gravity due to the downward-facing orientation of the substrate coating surface 104. The substrate 102 can thus be coated with consistently small-sized droplets, excluding the heavier / larger droplets, resulting in a more uniform coated layer 106. Additionally, the excess precursor material is collected by the outlet region 130 and may be recycled or reused, such as for coating the next substrate 102, thus minimizing wastage of precursor material.

Further as shown in Figure 7B, the chamber 150 may be configured for receiving the excess precursor material from the outlet region 130 and for releasing the excess precursor material to a collection storage unit 156. The excess precursor material is thus communicated from the outlet region 130 via the chamber 150 to the collection storage unit 156. The chamber 150 also releases excess precursor material that remained in the chamber 150 because they contain larger droplets and did not communicate to the outlet region 130. The chamber 150 may release the excess

precursor material through an opening 158 at the bottom of the chamber 150. The collection storage unit 156 may be the same as the supply storage unit or precursor solution container 160, such as shown in Figure 5, or they may be different storage units.

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In some embodiments, the apparatus 100 includes a set of heating elements for heating the substrate 102 during coating. The apparatus 100 may include a set of temperature sensors for monitoring temperature of the substrate 102, such as for controlling said heating. The heating elements may be disposed at the support
10 assembly 120 for heating the substrate 102 when the substrate 102 is being held by the support assembly 120. The heating elements generate heat at the non-coating surface of the substrate 102 and the heat is conducted to the substrate coating surface 104. Alternatively or additionally, the heating elements may be arranged in the housing 112 for creating a heated environment for the substrate 102. The heating elements
15 may be configured for multi-zone heating to heat various areas of the substrate 102 using respective heating elements at respective areas. Multi-zone heating can achieve more even heating across the substrate 102, thereby forming a better and more uniform coated layer 106 on the substrate 102. For example, the heating elements may cause the substrate 102 to be heated to a coating temperature between 380 °C
20 and 400 °C.

By heating the substrate 102 when it is being coated, spray pyrolysis occurs and enables formation of a thin coated layer or film 106 uniformly or homogeneously on the substrate coating surface 104. More specifically, the heating elements cause the
25 chemicals in the precursor material to thermally decompose to form the coated layer 106. As the atomized precursor material contains very fine droplets, the resultant coated layer 106 is thin and uniform. For example, the liquid precursor material stored in the supply storage unit 160 is titanium tetrachloride (TiCl_4) which is a colourless liquid. After the outlet region 130 or pneumatic nozzle sprays the atomized titanium
30 tetrachloride, the atomized titanium tetrachloride contacts the substrate coating surface 104 which is being heated. The heated titanium tetrachloride then undergoes a chemical reaction due to the heat and becomes titanium dioxide which forms the coated layer 106.

In some embodiments, the method 200 may include a step of curing the precursor material coated on the substrate 102 so that the coated layer 106 hardens and stabilizes on the substrate 102. The heating elements are configured to generate heat
5 for curing the coated layer 106. For example, the heating elements may cause the coated layer 106 to be heated to a curing temperature between 700 °C and 800 °C.

The heating elements may be controlled by pre-programmed temperature profiles. More specifically, the temperature profiles can establish suitable schedules and
10 coating and/or curing temperatures depending on the precursor material. For example, the temperature profile predefines a duration and temperature range to form the coated layer 106, after which the temperature profile begins the curing the coated layer 106 for a predefined duration and temperature range.

15 In some embodiments, the apparatus 100 includes a set of electromagnetic elements for emitting electromagnetic radiation, such as infrared and/or ultraviolet radiation, for curing the precursor material coated on the substrate 102 and thereby form and stabilize the coated layer 106. The electromagnetic elements are arranged such that the electromagnetic radiation is emitted towards the substrate coating surface 104.
20 The electromagnetic radiation reacts with the atomized precursor material sprayed towards the substrate coating surface 104 to cure the coated layer 106.

In many embodiments, the apparatus 100 may be integrated in a system 300 for coating one or more substrates 102 with the precursor material. The system 300
25 includes one or more apparatuses 100 for coating the one or more substrates 102. The system 300 further includes one or more loading ports 302 for loading the one or more substrates to be coated. The system 300 further includes one or more transfer mechanisms 304 for transferring the one or more substrates 102 from the one or more loading ports 302 to the one or more apparatuses 100.

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In one embodiment as shown in Figure 8A, the system 300 includes one apparatus 100 for coating one substrate 102 at any one time. The system 300 includes a loading port 302 for loading the substrate 102 and a transfer mechanism 304 for transferring

the substrate 102 from the loading port 302 to the apparatus 100. The system 300 has overall dimensions of approximately 1 m by 2 m by 2 m.

In another embodiment as shown in Figure 8B, the system 300 includes three apparatuses 100 for coating up to three substrates 102 at any one time. The system 300 includes two loading ports 302 for loading the substrates 102 and three transfer mechanisms 304 for transferring the substrates 102 from the loading ports 302 to the apparatuses 100. The system 300 has overall dimensions of approximately 3 m by 2 m by 2 m.

In another embodiment as shown in Figure 8C, the system 300 includes five apparatuses 100 for coating up to five substrates 102 at any one time. The system 300 includes two loading ports 302 for loading the substrates 102 and three transfer mechanisms 304 for transferring the substrates 102 from the loading ports 302 to the apparatuses 100. The system 300 has overall dimensions of approximately 5 m by 2 m by 2 m.

It will be appreciated that the system 300 may include any number of apparatuses 100. For example, the system 300 can be expanded with additional apparatuses 100 so that more substrates 102 can be coated simultaneously, thereby increasing productivity and output yield. It will also be appreciated that the system 300 can include any number of loading ports 302 and/or any number of transfer mechanisms 304 to facilitate transferring of the substrates 102 to the apparatuses 100.

Therefore, the apparatus 100 advantageously provides for improved coating of the substrate 102 with the precursor material. The inlet region 140 and chamber 150 cooperate to atomize the precursor material into very fine droplets. The outlet region 130 then sprays the atomized precursor material upwards to the substrate coating surface 104, distributing it evenly to form the coated layer 106. As the atomized precursor material has very fine droplets, the coated layer 106 can be very thin and uniform. The coated layer 106 may be referred to as a thin film having a thickness ranging, for example, from as thin as several nanometres or 100 nm to as thick as a few microns or even over 100 microns. The thinness of the coated layer 106 may allow

it to be substantially transparent, possibly improving the aesthetic appearance of the coated substrate 102. Nano or micro surface defects or irregularities that may be present on the substrate coating surface 104 can be filled and covered by the atomized precursor material, thereby forming a smooth exterior surface on the coated substrate 102.

Compared to conventional / manual spray coating, the apparatus 100 can achieve better control of the thickness and uniformity of the coated layer 106. Unlike CVD which must be performed under vacuum conditions, the apparatus 100 can be used and the method 200 can be performed under any environment conditions. For example, the method 200 may be performed under atmospheric conditions. The method 200 may be performed in the presence of a gaseous material, such as an inert gas. The operation and material costs of the apparatus 100 and precursor material are lower than that for CVD, as vacuum conditions are not necessary, and the precursor material can be in liquid form which is also easier to handle. Because the atomized precursor material deposited onto the substrate coating surface 104 is not in gaseous form, the coated layer 106 can be more quickly formed and cured as compared to CVD which requires the more expensive gaseous material to settle on the substrate surface.

The apparatus 100 is also less expensive than CVD equipment which includes costly parts like the vacuum chamber, vacuum tubes, and vacuum pump. The apparatus 100 is also more easily customized to technical requirements, such as depending on the shape and size of the substrate 102 as well as the material of the substrate 102 and precursor material. On the contrary, in CVD, it is difficult to customize the CVD equipment. For example, it is difficult to change the vacuum tubes where the chemical reactions take place.

The coated layer 106 or thin film on the substrate 102 can be used for various applications depending on the material and properties of the thin film. Some non-limiting examples are described as follows. The coated layer 106 can be an optical thin film that is reflective or anti-reflective. The substrate 102 coated with an optical thin film can be used in electronic devices such as solar cells, displays, waveguides, photodetector arrays, and memory discs. The coated layer 106 can be an electrical

thin film and the substrate 102 can be used for manufacturing electronic devices such as insulators, conductors, semiconductor devices, integrated circuits, solar cells, touch panels / screens, semiconductor photoresistors, photodetector arrays, and piezoelectric arrays. For example, the coated layer 106 is a transparent conductive film for touch panels / screens.

The coated layer 106 can be a magnetic thin film and the substrate 102 can be used for manufacturing memory discs. The coated layer 106 can be a chemical thin film for imparting to the substrate 102 resistance to alloying, oxidation, or corrosion. The substrate 102 can be used to manufacture sensors for fluids so the sensors are resistant to the fluids. The coated layer 106 can be a mechanical thin film which is a tribological coatings to protect the substrate 102 against wear, to impart hardness and micro-adhesion, and to take advantage of micromechanical properties. The coated layer 106 can be a thermal thin film and the substrate 102 can be used to manufacture barrier layers and heat sinks. The coated layer 106 can be applied for decorative purposes with optional functional properties.

The uniformity of the coated layer 106 is advantageous in meeting performance specifications of the various applications. A uniform coated layer 106 means that the coated layer 106 has the same thickness at every area thereof. The uniform thickness imparts material properties of the precursor material, such as chemical structure, dopant level, and resistivity, consistently across all areas of the coated layer 106. If the coated layer 106 does not meet the thickness requirement or is too thin / thick at some areas of the coated layer 106, then the subpar uniformity of the coated layer 106 may not meet the performance specifications or may even negatively affect the performance. For example, if the coated layer 106 is intended to impart a mirror finish to the substrate 102, subpar uniformity of the coated layer 106 can result in distortions in mirror images. In another example, a hip replacement part that is coated with the subpar coated layer 106 would not be properly reinforced against wear and degradation, potentially resulting in poorer quality of health for the patient wearing the hip replacement part.

In the foregoing detailed description, embodiments of the present disclosure in relation to an apparatus and a method for coating a substrate are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

Claims

1. An apparatus for coating a substrate with a precursor material, the apparatus comprising:
 - 5 a support assembly for arranging the substrate such that a coating surface of the substrate faces substantially downwards;
 - an inlet region for atomizing the precursor material in liquid form;
 - a chamber fluidically connected to the inlet region for receiving the atomized precursor material discharged from the inlet region, the chamber
 - 10 comprising a set of fluidic devices for breaking up the atomized precursor material; and
 - an outlet region fluidically connected to the chamber for receiving the atomized precursor material communicated from the chamber,
 - wherein the outlet region is configured for discharging the atomized
 - 15 precursor material substantially upwards to the substrate, thereby coating the substrate coating surface with the precursor material.
2. The apparatus according to claim 1, wherein the outlet region is configured for collecting excess precursor material that has been discharged from the outlet region.
- 20 3. The apparatus according to claim 2, wherein the chamber is configured for receiving the excess precursor material from the outlet region and for releasing the excess precursor material to a collection storage unit.
- 25 4. The apparatus according to any one of claims 1 to 3, further comprising an actuation mechanism for adjusting a vertical distance between the outlet region and the support assembly.
5. The apparatus according to any one of claims 1 to 4, further comprising a supply
- 30 storage unit for supplying the liquid precursor material to the inlet region.

6. The apparatus according to any one of claims 1 to 5, wherein the inlet region comprises a pneumatic nozzle configured to receive the liquid precursor material and a gas.
- 5 7. The apparatus according to claim 6, further comprising a pneumatic compressor for supplying the gas to the inlet region.
8. The apparatus according to any one of claims 1 to 7, wherein the support assembly comprises a vacuum chuck for holding the substrate.
- 10 9. The apparatus according to any one of claims 1 to 8, wherein the support assembly comprises a flipper device for flipping the substrate such that the substrate coating surface faces substantially downwards.
- 15 10. The apparatus according to any one of claims 1 to 9, wherein the fluidic devices are configured for facilitating communication of the atomized precursor material through the chamber.
- 20 11. The apparatus according to claim 10, wherein the fluidic devices comprise a set of fans.
12. The apparatus according to any one of claims 1 to 11, further comprising a set of heating elements for heating the substrate.
- 25 13. The apparatus according to claim 12, wherein the heating elements are disposed at the support assembly.
- 30 14. The apparatus according to any one of claims 1 to 13, further comprising a set of electromagnetic elements for emitting electromagnetic radiation for curing the precursor material coated on the substrate.
15. The apparatus according to claim 14, wherein the electromagnetic elements are configured for emitting infrared and/or ultraviolet radiation.

16. A method for coating a substrate with a precursor material, the method comprising:
- arranging the substrate on a support assembly such that a coating surface of the substrate faces substantially downwards to an outlet region;
 - atomizing the precursor material in liquid form at an inlet region;
 - discharging the atomized precursor material from the inlet region to a chamber;
 - breaking up the atomized precursor material in the chamber;
 - communicating the atomized precursor material from the chamber to the outlet region; and
 - discharging the atomized precursor material from the outlet region substantially upwards to the substrate, thereby coating the substrate coating surface with the precursor material.
17. The method according to claim 16, further comprising heating the substrate arranged on the support assembly.
18. The method according to claim 16 or 17, further comprising curing the precursor material coated on the substrate.
19. The method according to any one of claims 16 to 18, further comprising collecting, by the outlet region, excess precursor material that has been discharged from the outlet region.
20. The method according to claim 19, further comprising communicating the excess precursor material from the outlet region via the chamber to a collection storage unit.