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(54) **METHODS FOR CONTROLLING FORMATION OF DEPOSITS IN A DEPOSITION SYSTEM AND DEPOSITION METHODS INCLUDING THE SAME**

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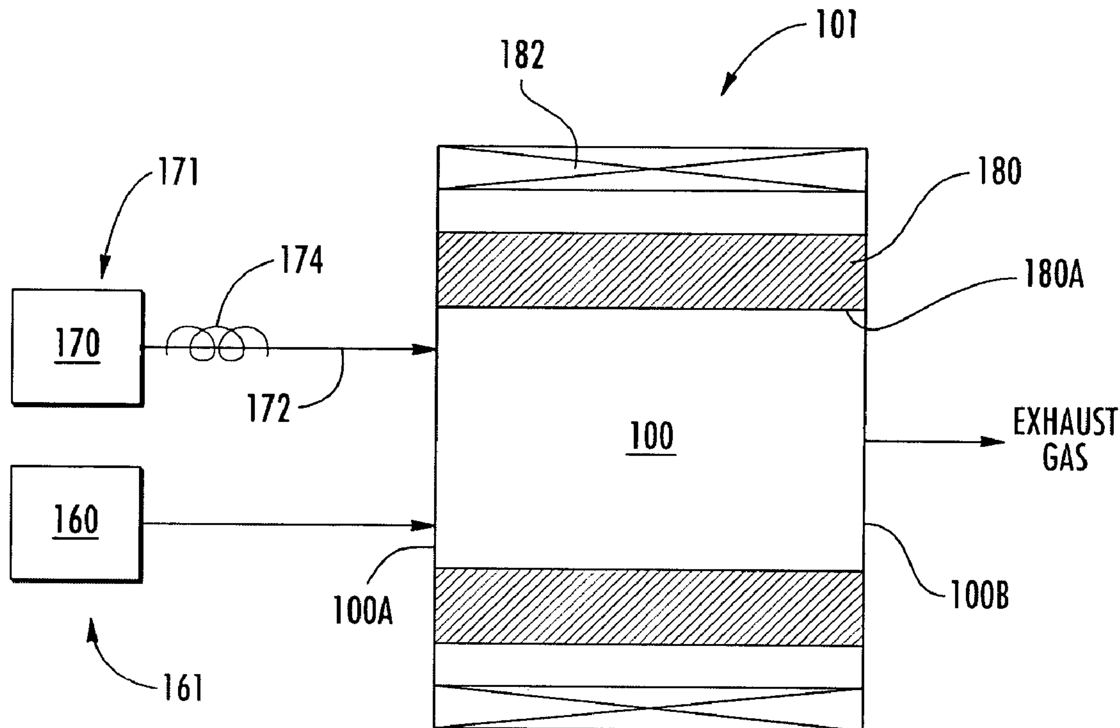
(57) **ABSTRACT**

A method for controlling parasitic deposits in a deposition system for depositing a film on a substrate, the deposition system defining a reaction chamber for receiving the substrate and including a process gas in the reaction chamber and an interior surface contiguous with the reaction chamber, includes flowing a buffer gas between the interior surface and at least a portion of the process gas to form a gas barrier layer such that the gas barrier layer inhibits contact between the interior surface and components of the process gas.



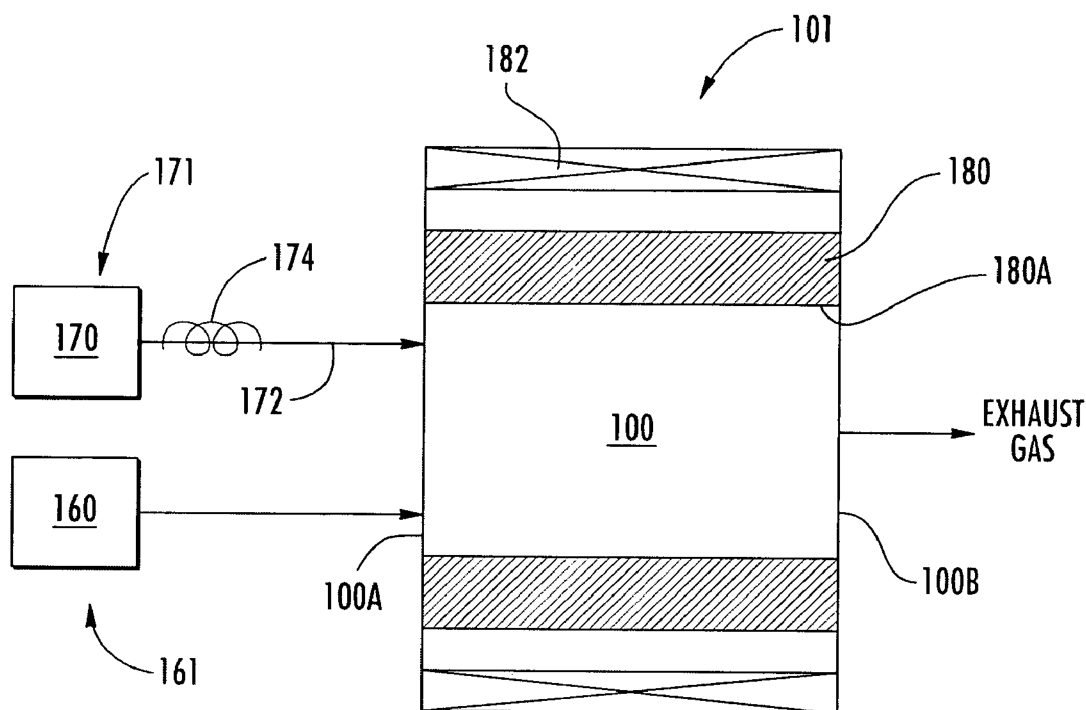



FIG. 1

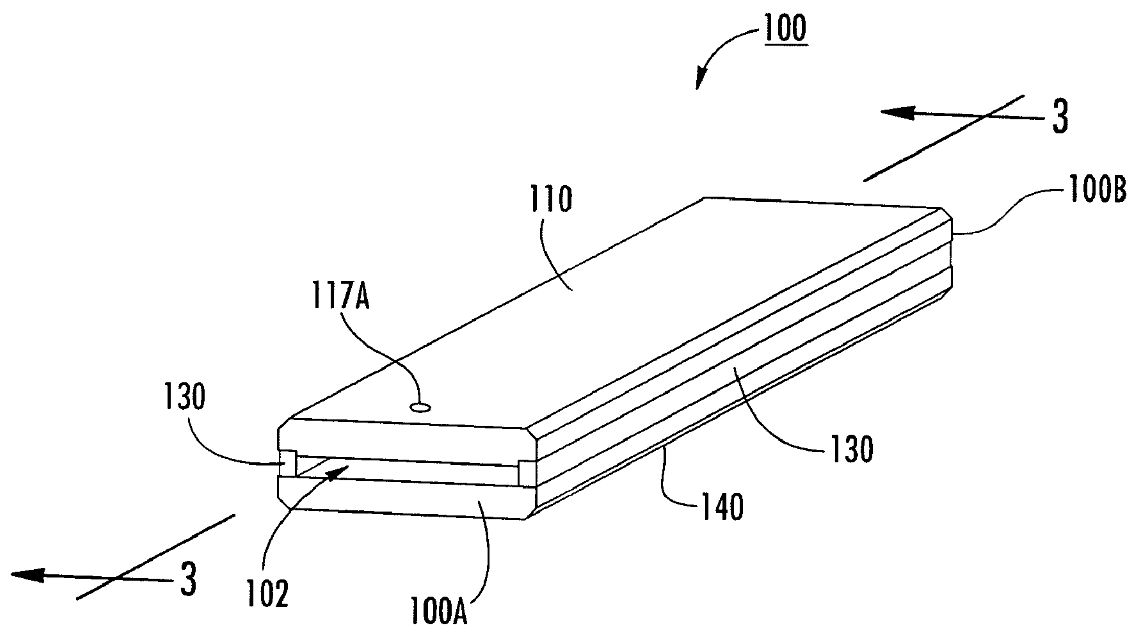



FIG. 2

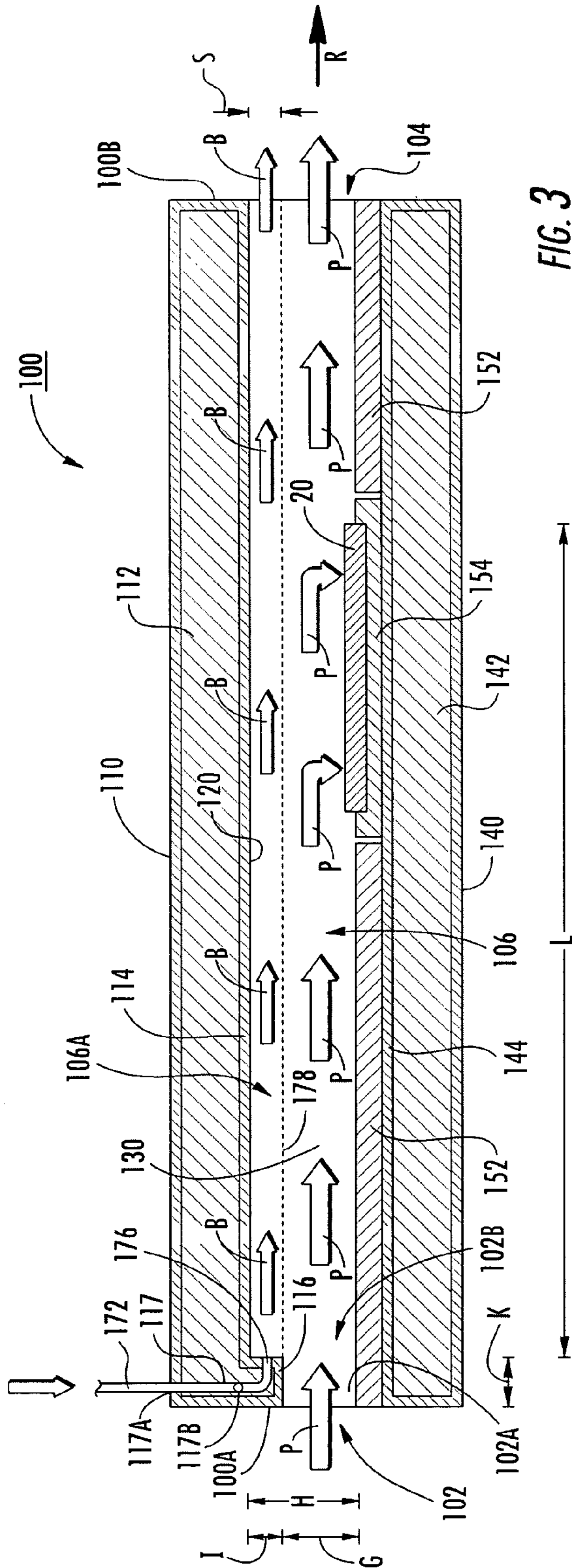



FIG. 3

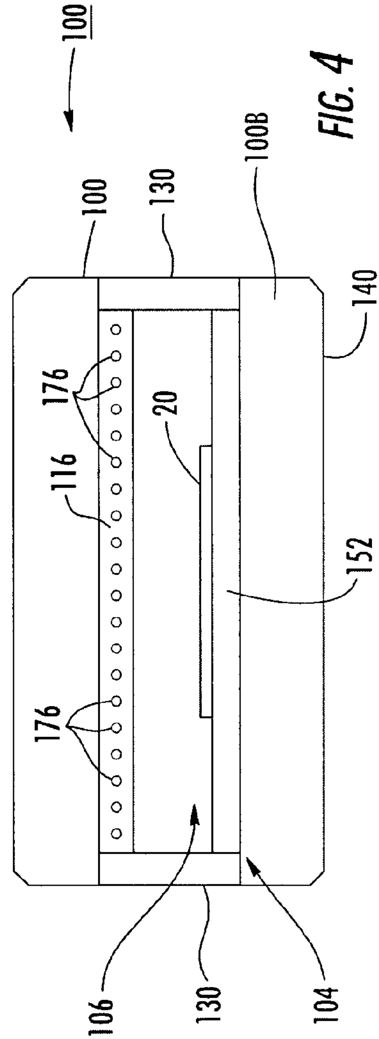



FIG. 4

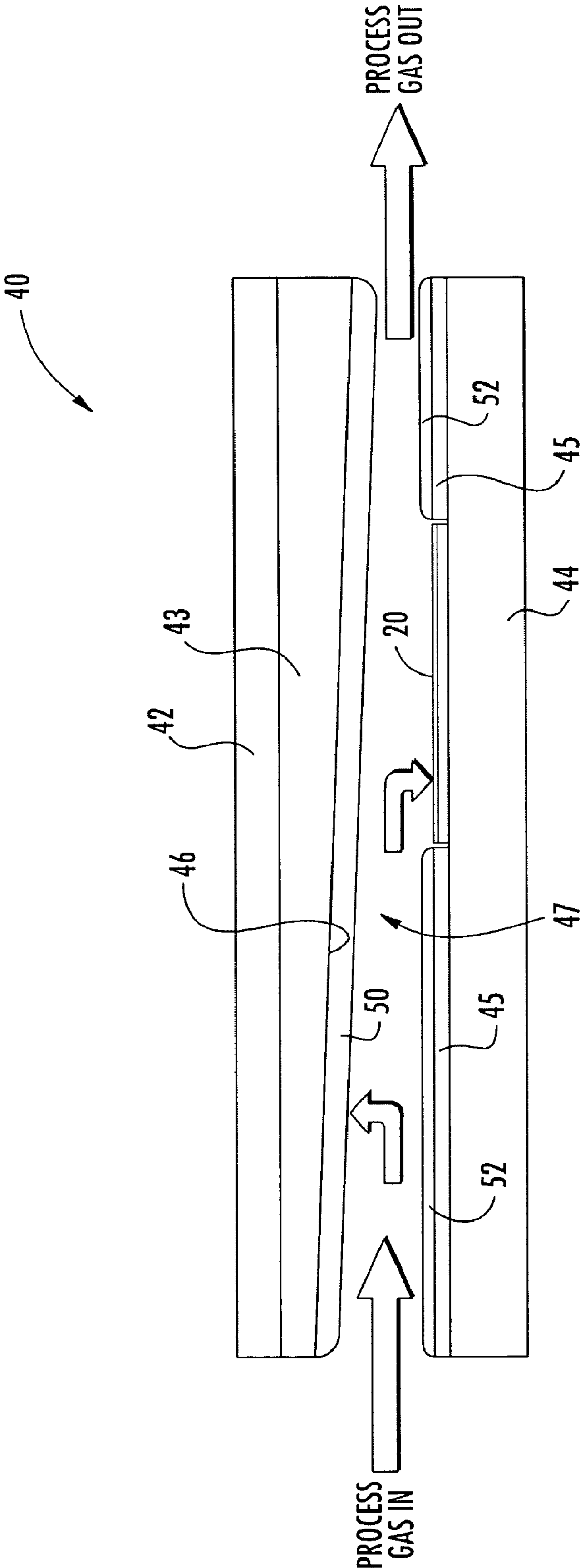



FIG. 5
(PRIOR ART)

# METHODS FOR CONTROLLING FORMATION OF DEPOSITS IN A DEPOSITION SYSTEM AND DEPOSITION METHODS INCLUDING THE SAME

## STATEMENT OF GOVERNMENT SUPPORT

[0001] The present invention was made, at least in part, with government support under Office of Naval Research Contract No. N00014-02-C-0302. The United States government may have certain rights to this invention.

## FIELD OF THE INVENTION

[0002] The present invention relates to deposition processes and apparatus and, more particularly, to methods and apparatus for depositing a film on a substrate.

## BACKGROUND OF THE INVENTION

[0003] Deposition systems and methods are commonly used to form layers such as relatively thin films on substrates. For example, a chemical vapor deposition (CVD) reactor system and process may be used to form a layer of semiconductor material such as silicon carbide (SiC) on a substrate. CVD processes may be particularly effective for forming layers with controlled properties, thicknesses, and/or arrangements such as epitaxial layers. Typically, in a deposition system, such as a CVD system, the substrate is placed in a chamber and a process gas including reagents or reactants to be deposited on the substrate is introduced into the chamber adjacent the substrate. The process gas may be flowed through the reaction chamber in order to provide a uniform or controlled concentration of the reagents or reactants to the substrate. Undesirably, the reagents or reactants may tend to deposit on interior surfaces of the reaction chamber as well. Such deposits may be referred to as "parasitic" deposits because they remove reagents or reactants from the process.

[0004] With reference to **FIG. 5**, an exemplary conventional deposition system **40** is shown therein and illustrates the process by which deposits may be formed on unintended surfaces of a reaction chamber. The system **40** is, for example, a flow through, hot wall, CVD reactor. The system **40** has a top susceptor member **42** and a bottom susceptor member **44**. The system **40** also has a top liner **43** and a bottom liner **45** defining a reaction chamber **47** therebetween. A substrate **20**, such as a wafer, is positioned in the reaction chamber **47** and may be situated on an interior surface of a platter (which may rotate), for example. A process gas is introduced to the reaction chamber **47** at one end, flowed through the reaction chamber **47** past the substrate **20**, and finally exhausted from the reaction chamber **47** at the opposite end. As indicated by the arrows in the reaction chamber **47** as shown in **FIG. 5**, as the process gas flows through the reaction chamber **47** a portion of the process gas may contact the substrate **20** as intended and thereby deposit the reagents or reactants on the substrate **20** to form a layer thereon. However, as indicated by the arrows, a portion of the process gas also contacts an interior surface or ceiling **46** of the top liner **43** as well as interior surfaces of the bottom liner **45** and side walls. As a result, parasitic deposits **50** and **52** of the reagents or reactants from the process gas tend to form on the ceiling **46** and the bottom liner **45**, respectively, as well as on the sidewalls. The parasitic deposits on the ceiling **46** may be particularly harmful because they may dislodge and fall onto the substrate **20** during processing, reducing the quality of the formed layer. Moreover, the changing amount of the parasitic deposits may introduce undesirable variations in temperature and gas flow dynamics, thereby influencing the growth of the layer on the substrate **20**. Depletion of the process gas because of the formation of the parasitic deposits may tend to waste reactants, thereby reducing efficiency and growth rate.

[0005] Typically, the deposition process is managed to accommodate the formation of parasitic deposits. The cumulative growth time may be limited to reduce the impact of parasitic deposits on product material. After a set time, the susceptor may be cleaned and reconditioned before more production growth runs are attempted. This procedure may limit both the possible length of any single growth run and the number of runs of shorter duration between cleaning cycles. Despite such efforts, parasitic deposits may nonetheless negatively impact product material due to particle formation, process variability and reduced reactant utilization efficiency.

## SUMMARY OF THE INVENTION

[0006] According to embodiments of the present invention, parasitic deposits are controlled in a deposition system for depositing a film on a substrate, the deposition system of the type defining a reaction chamber for receiving the substrate and including a process gas in the reaction chamber and an interior surface contiguous with the reaction chamber. Such control is provided by flowing a buffer gas to form a gas barrier layer between the interior surface and at least a portion of the process gas such that the gas barrier layer inhibits contact between the interior surface and components of the process gas.

[0007] According to further embodiments of the present invention, a deposition system for depositing a film on a substrate using a process gas includes a reaction chamber adapted to receive the substrate and the process gas. The system further includes an interior surface contiguous with the reaction chamber. A buffer gas supply system is adapted to supply a flow of a buffer gas between the interior surface and at least a portion of the process gas such that the flow of the buffer gas forms a gas barrier layer to inhibit contact between the interior surface and components of the process gas when the process gas is disposed in the reaction chamber.

[0008] According to yet further embodiments of the present invention, a deposition control system is provided for controlling parasitic deposits in a deposition system for depositing a film on a substrate, the deposition system of the type defining a reaction chamber for holding the substrate and including a process gas in the reaction chamber and an interior surface contiguous with the reaction chamber. The deposition control system includes a buffer gas supply system adapted to provide a flow of a buffer gas between the interior surface and at least a portion of the process gas such that the flow of the buffer gas forms a gas barrier layer to inhibit contact between the interior surface and components of the process gas.

[0009] According to further embodiments of the present invention, a deposition system for depositing a film on a substrate includes a reaction chamber adapted to receive the

substrate and an interior surface contiguous with the reaction chamber. A process gas is disposed within the reaction chamber. A flow of a buffer gas is disposed between the interior surface and at least a portion of the process gas. The flow of the buffer gas forms a gas barrier layer to inhibit contact between the interior surface and components of the process gas.

[**0010**] According to further embodiments of the present invention, a susceptor assembly for depositing a film on a substrate using a process gas and a buffer gas each flowed in a flow direction includes at least one susceptor member. The at least one susceptor member defines a reaction chamber, a process gas inlet and a buffer gas inlet. The reaction chamber is adapted to receive the substrate and has a buffer gas region to receive the buffer gas. The reaction chamber has a first cross-sectional area perpendicular to the flow direction. The process gas inlet has a second cross-sectional area perpendicular to the flow direction. The second cross-sectional area is less than the first cross-sectional area. The buffer gas inlet is adjacent the process gas inlet and is adapted to direct the buffer gas into the buffer gas region of the reaction chamber.

## BRIEF DESCRIPTION OF THE DRAWINGS

[**0011**] **FIG. 1** is a schematic view of a deposition system according to embodiments of the present invention;

[**0012**] **FIG. 2** is a perspective view of a susceptor assembly forming a part of the deposition system of **FIG. 1**;

[**0013**] **FIG. 3** is a cross-sectional view of the susceptor assembly of **FIG. 2** taken along the line **3-3** of **FIG. 2**, wherein a buffer gas supply line, a substrate, a flow of buffer gas and a flow of process gas are also shown;

[**0014**] **FIG. 4** is a rear end elevational view of the susceptor assembly of **FIG. 2** and the substrate; and

[**0015**] **FIG. 5** is a schematic view of a conventional deposition system.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[**0016**] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the relative sizes of regions or layers may be exaggerated for clarity. It will be understood that when an element such as a layer, region or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present.

[**0017**] With reference to **FIG. 1**, a deposition system **101** according to embodiments of the present invention is schematically shown therein. The deposition system **101** may be a horizontal, hot wall, flow through, CVD system as shown including a susceptor assembly **100**, a quartz tube **180** defining a through passage **180**A, an electromagnetic frequency (EMF) generator **182** (for example, including a power supply and an RF coil surrounding the tube **180**) and a process gas supply system **161**. An insulative cover may be provided about the susceptor assembly **100** in addition to or in place of the quartz tube **180**. The deposition system **101** further includes a buffer gas supply system **171** in accordance with the present invention. The deposition system **101** may be used to form a layer or film on a substrate **20** (**FIG. 3**). While only a single substrate **20** is illustrated in **FIGS. 3 and 4**, the system **101** may be adapted to form films concurrently on multiple substrates **20**.

[**0018**] The substrate **20** may be a wafer or other structure formed of the same or a different material than that of the layer to be deposited. The substrate **20** may be formed of, for example, SiC, sapphire, a Group III nitride, silicon, germanium, and/or a III-V or II-VI compound or interalloy, or the like. The substrate surface upon which the film is deposited may be a base substrate or a first or subsequent layer superimposed on a base substrate. For example, the surface of the substrate **20** for receiving the deposited film may be a layer previously deposited using the deposition system **101** or an alternative apparatus. As will be appreciated by those of skill in the art in light of the present disclosure, embodiments of the present invention may be advantageously utilized with semiconductor materials other than those specifically mentioned herein. As used herein, the term "Group III nitride" refers to those semiconducting compounds formed between nitrogen and the elements in Group IIIA of the periodic table, usually aluminum (Al), gallium (Ga), and/or indium (In). The term also refers to ternary and quaternary compounds such as AlGaN and AlInGaN. As is well understood by those in this art, the Group III elements can combine with nitrogen to form binary (e.g., GaN), ternary (e.g., AlGaN, AlInN), and quaternary (e.g., AlInGaN) compounds. These compounds all have empirical formulas in which one mole of nitrogen is combined with a total of one mole of the Group III elements. Accordingly, formulas such as $Al_xGa_{1-x}N$ where $0 \leqq x \leqq 1$ are often used to describe them.

[**0019**] Generally, the process gas supply system **161** supplies a process gas into and through the susceptor assembly **100** as discussed below. The EMF generator **182** inductively heats the susceptor assembly **100** to provide a hot zone in the susceptor assembly **100** where deposition reactions take place. The process gas continues through and out of the susceptor assembly **100** as an exhaust gas which may include remaining components of the process gas as well as reaction by-products, for example. Embodiments of the present invention may be used in types of deposition systems other than hot wall CVD systems. Other modifications to the systems and methods of the present invention will be apparent to those of ordinary skill in the art upon reading the description herein.

[**0020**] The process gas supply system **161** includes a supply **160** of the process gas. The process gas includes one or more components such as reagents, reactants, species, carriers and the like. One or more of these components may be capable, alone or in combination with one or more other components (which may also be present in the process gas), of forming deposits on a surface such as the ceiling or interior surface **120** (**FIG. 3**). Exemplary components that may form or assist in forming deposits upon contacting the ceiling surface **120** include $SiH_4$, $C_3H_8$, $C_2H_4$, $Si_2H_6$, $SiCl_4$,

$SiH_2Cl_2$, $SiCl_3(CH_3)$, $NH_3$, trimethyl gallium, and trimethyl aluminum. Where it is desired to form a SiC layer on a substrate, the process gas may include precursor gases such as silane ($SiH_4$) and propane ($C_3H_8$) along with a carrier gas such as purified hydrogen gas ($H_2$). The process gas supply **160** may be provided from one or more pressurized containers of the gases with flow control and/or metering devices as needed. The process gas may be adapted to deposit a layer of SiC, a Group III nitride, silicon, germanium, and/or a III-V and/or II-VI compound or interalloy on the substrate **20**.

[**0021**] The buffer gas supply system **171** includes a supply **170** of a buffer gas fluidly connected to the susceptor assembly **100** by a line **172**. The buffer gas supply **170** may be provided from one or more pressurized canisters of the gas or gases with flow control and/or metering devices as needed. A heater **174** may be provided along the line **172**, in or at the susceptor assembly **100**, or at the buffer gas supply **160** for preheating the buffer gas.

[**0022**] The buffer gas may be any suitable gas. According to some embodiments, the buffer gas is a gas having relatively low diffusion rates for many or selected ones of the species or components present in the process gas. According to some embodiments, the buffer gas is a noble gas. The noble gas may include argon, helium, neon, krypton, radon, or xenon. Other suitable gases include $H_2$, $N_2$, $NH_3$ or air. The buffer gas may include or be substantially composed of a species capable of chemically assisting in removing or inhibiting deposits of reactants from the process gas. For example, in accordance with some embodiments and particularly in the case of a process for growing a layer of SiC on a substrate, the buffer gas includes an etchant such as HCl, $Cl_2$ and/or a carbon-containing gas such as propane.

[**0023**] Turning to the susceptor assembly **100** in greater detail and with reference to FIGS. **2** to **4** the susceptor assembly **100** includes a top member **110**, a pair of side members **130**, and a bottom member **140**. The susceptor assembly **100** extends from an entrance end **100**A to an exit end **100**B. The members **110**, **130**, **140** define an entrance opening **102** (at the end **100**A) and an exit opening **104** (at the end **100**B). The members **110**, **130**, **140** also define a reaction chamber **106** extending from a process gas inlet **102**B to the opening **104**. According to some embodiments, the reaction chamber **106** has a length of between about 0.1 and 1 meter, a width of between about 0.05 and 0.5 meter, and a height of between about 1 and 10 cm.

[**0024**] The top member **110** includes a core or susceptor body **112** covered (and preferably substantially fully surrounded) by a layer **114**. The layer **114** includes the ceiling or interior surface **120** facing and contiguous with the reaction chamber **106**.

[**0025**] The core **112** is preferably formed of a susceptor material suitable to generate heat responsive to eddy currents generated therein by the EMF generator **182**, such materials and inductive heating arrangements being well known to those of skill in the art. The core **112** may be formed of graphite, and more preferably of high purity graphite.

[**0026**] The layer **114** may be formed of a material having high purity and which is able to withstand the process temperatures (typically in the range of 1500 to 1800° C. for SiC deposition). The layer **114** may be formed of, for example, SiC or a refractory metal carbide such as TaC, NbC and/or TiC. The layer **114** may be applied to the core **112** by any suitable method. Preferably, the layer **114** is a dense, impervious coating and has a thickness of at least about 10 μm, and more preferably, between about 20 μm and 100 μm.

[**0027**] The top member **110** further includes a downwardly stepped portion **116** adjacent the opening **102**. The stepped portion **116** and the underlying portion of the liner **152** define the process gas inlet **102**B and a process gas inlet passage **102**A extending from the opening **102** to the process gas inlet **102**B. The step portion **116** also defines a buffer gas region **106**A (**FIG. 3**) in the upper portion of the reaction chamber **106**.

[**0028**] A plurality of passages **117** (one shown in **FIG. 3**) extend through the top member **110** and terminate at a respective port **176** (see **FIGS. 3 and 4**). A common feed inlet **117**A (**FIGS. 2 and 3**) is provided for connecting the buffer gas line **172** to the passages **117** which may be interconnected in a manifold arrangement by a lateral passage **117**B (**FIG. 3**). Alternatively, separate lines and/or inlets may be provided for some or each of the ports **176**. The passages **117**, the inlet **117**A and the ports **176** may be formed in the top member **110** by any suitable method such as drilling or molding.

[**0029**] The bottom member **140** includes a core **142** covered by a coating or layer **144**. Suitable materials and methods for forming the core **142** and the layer **144** are as described above for the core **112** and the layer **114**. The side members **130** similarly include respective cores (not shown) and covering layers which may be formed of the same materials and using the same methods as described above for the core **112** and the layer **114**.

[**0030**] A liner or liners **152** may overlie the bottom member **140** as shown in **FIGS. 3 and 4**. The liner **152** may be formed of SiC or SiC coated graphite, for example, as disclosed in U.S. patent application Ser. No. 10/017,492, filed Oct. 20, 2001, the disclosure of which is incorporated herein by reference.

[**0031**] A platter **154** or the like may be situated between the bottom member **140** and the substrate **20** to support the substrate **20**. According to some embodiments, the platter **154** may be rotatively driven by a suitable mechanism (not shown). For example, the system may include a gas-driven rotation system as described in Applicant's U.S. application Ser. No. 09/756,548, titled Gas Driven Rotation Apparatus and Method for Forming Silicon Carbide Layers, filed Jan. 8, 2001, and/or as described in Applicant's U.S. application Ser. No. 10/117,858, titled Gas Driven Planetary Rotation Apparatus and Methods for Forming Silicon Carbide Layers, filed Apr. 8, 2002, the disclosures of which are hereby incorporated herein by reference in their entireties. Alternatively, the platter **154** may be stationary. The platter **154** may be adapted to hold one or multiple substrates **20**. The platter **154** may be formed of any suitable material such as SiC coated graphite, solid SiC or solid SiC alloy. The platter **154** may be omitted such that the substrate rests on the bottom member **140**, the liner **152**, or other suitable support.

[**0032**] In use, the process gas supply system **161** supplies a flow of the process gas to the reaction chamber **106** through the inlet opening **102**. The process gas P flows

generally in a flow direction R (**FIG. 3**). The arrows labeled P in **FIG. 3** indicate the general flow path of the process gas and the reagents therein. As shown, the process gas and the reagents therein contact the substrate **20** to form the desired layer (e.g., an epilayer) on the exposed surface of the substrate **20**.

[**0033**] Concurrently, the buffer gas supply system **171** supplies or inserts a flow of the buffer gas into the buffer gas region **106**A of the reaction chamber **106** through the ports **176** such that the buffer gas B flows through the reaction chamber **106** generally in the flow direction R. The arrows labeled B in **FIG. 3** indicate the general flow path of the flow of buffer gas. The buffer gas B flows in the buffer gas region **106**A along the ceiling or interior surface **120** so as to form a barrier layer **178** of flowing buffer gas extending upwardly from the dashed line of **FIG. 3** to the ceiling surface **120**.

[**0034**] The barrier layer **178** serves to inhibit or impede the movement of the process gas P and components thereof from moving into contact with the ceiling surface **120** where reagents or reactants of the process gas P might otherwise form deposits. Below the barrier layer **178**, the process gas P is permitted to flow in the normal manner to, over and beyond the substrate **20**. In this manner, the process gas P and the deposition system **101** form the desired layer(s) on the exposed surface(s) of the substrate **20**. The flow of buffer gas B may also serve to push the reactant stream of the process gas P toward the substrate **20**, thereby accelerating the growth rate.

[**0035**] As discussed in more detail below, according to some embodiments, the buffer gas B flow is maintained as a substantially laminar flow. As long as the flow of the buffer gas B is laminar, the only way reagents or other components from the process gas P can reach the ceiling surface is by diffusing from the process gas P flow and through the barrier gas B flow. In general, the distance S a diffusing species will traverse during time span of t follows the relationship $S \approx \sqrt{Dt}$, where D is the diffusion rate. In the present case, t is the transit time of species through the reaction chamber **106**. The transit distance of concern will depend on to what lengthwise extent the operator or designer desires to inhibit deposits downstream of the process gas inlet **102**B. In most cases, it will be deemed sufficient to inhibit or prevent the formation of deposits on the ceiling surface **120** up to the downstream edge of the substrate **20**. In the susceptor assembly **100** illustrated in **FIG. 3**, this transit distance is indicated by the distance L. The transit time can generally be determined as follows:

$$t \approx \frac{L}{\left(\frac{M}{\rho A}\right)}$$

Where:

L=Length of susceptor

M=Mass flow rate

ρ=Average density of gas within susceptor, determined by pressure, temperature and gas composition.

A=Cross sectional area of susceptor opening.

In order for the barrier layer **178** to prevent all diffusion of the components of the process gas P, the thickness S of the barrier layer **178** (which may correspond generally to the height I of the step portion **116**) should satisfy:

$$S \geq \sqrt{Dt} = \sqrt{\frac{DL}{\left(\frac{M}{\rho A}\right)}}$$

[**0036**] It will be appreciated by those of ordinary skill in the art upon reading the description herein that, in accordance with the present invention, it is not necessary to completely prevent all components of the process gas P from contacting the ceiling surface **120** as may be accomplished by providing fully laminar flow of the buffer gas B and a barrier layer **178** having a thickness S satisfying the foregoing criteria. Rather, the system **101** may be designed to allow some turbulence and/or have a barrier layer thickness S less than that necessary to preclude all deposits. In this manner, for example, the system **101** may provide a significant reduction in parasitic deposits while allowing some deposits to occur. According to some embodiments, the rate of formation of parasitic deposits on the ceiling surface **120** is preferably no more than one half the growth rate on the substrate **20** and more preferably no more than one quarter the growth rate on the substrate **20**.

[**0037**] The barrier layer thickness S may be increased to provide an additional margin of protection for the ceiling surface **120** or to compensate for turbulence in the buffer gas flow B. The height of the buffer gas region **106**A may be greater than, less than, or the same as the optimal thickness S of the barrier layer **178**.

[**0038**] Further, various process parameters may be considered in determining the degree of laminarity of the buffer gas B flow and the distance S needed to obtain the desired reduction or prevention of deposits on the ceiling surface **120**. For example, at typical SiC epilayer growth temperatures (i.e., in the range of about 1500 to 1800° C.), simultaneous etch and deposition processes may take place. Therefore, for a given growth condition, there may exist a critical minimum reagent supply rate necessary to stabilize the surface (in this case, the ceiling surface **120**). A reagent supply rate above critical will result in growth of parasitic deposits on the ceiling surface **120** while a supply rate below critical will result in etching of parasitic deposits from the ceiling surface **120**. Accordingly, even if the reagent flux to the ceiling were only reduced to the critical supply rate, then essentially no net deposition would occur on the ceiling.

[**0039**] Preferably, the deposition system **101** is adapted to maintain the flow of the buffer gas B and the flow of the process gas P as a laminar flow to at least a location downstream of the substrate **20**, and more preferably, throughout the reaction chamber **106**, to reduce or prevent mixing or turbulence between the flows that may promote transport of the process gas P through the barrier layer **178**.

[**0040**] The relative dimensions and configurations of the reaction chamber **106**, the process gas inlet **102**B, and the buffer gas ports **176** may be selected to promote laminar

flow. According to some embodiments and as illustrated (see **FIGS. 3 and 4**), the process gas inlet **102**B is smaller in cross-section (i.e., generally perpendicular to the flow direction R of the gases, and as shown in **FIG. 4**) than the reaction chamber **106** so that a remaining space (i.e., the buffer gas region **106**A) is available in the reaction chamber **106** for insertion of the buffer gas B into the reaction chamber **106** without inserting the buffer gas B into the process gas or into the unmodified flow path of the process gas P.

[**0041**] In the illustrated embodiment, the provision of the stepped portion **116** may facilitate laminar flow. According to some embodiments of the present invention, the sum of the height G of the opening **102** and the height I of the step portion **116** is substantially the same as the full height H of the reaction chamber **106** (see **FIG. 3**). Preferably, the widths of the process gas inlet **102**B, the step portion **116**, and the reaction chamber **106** are substantially the same so that the cross-sectional area (i.e., generally perpendicular to the flow direction R of the gases, and as shown in **FIG. 4**) of the reaction chamber **106** is substantially the same as the combined cross-sectional area of the process gas inlet **102**B and the step portion **116**. In this manner, the flow of the process gas P and the flow of the buffer gas B enter the reaction chamber **106**, in parallel, at substantially the same axial location in the reaction chamber **106** along the direction of flow R of the gases P, B. Because the buffer gas region **106**A is provided above the natural flow path of the process gas P, the buffer gas B can be inserted into the reaction chamber **106** without substantially displacing the process gas P. As a result, turbulence and mixing of the gas flows that might otherwise be created by initially introducing the buffer gas B into the path of the process gas P may be avoided. The height I of the step portion **116** is preferably between about 5 and 25% of the height H of the reaction chamber **106**.

[**0042**] According to some embodiments and as illustrated, the reaction chamber **106** has a substantially uniform height H along substantially its full length. In this case, the reaction chamber **106** may have a substantially uniform cross-sectional area along its full length. This configuration may serve to promote the integrity of the boundary layer between the flow of the process gas P and the flow of the buffer gas B. The height H of the reaction chamber **106** is preferably between about 0.5 and 5 cm. According to further embodiments, the height H is not uniform, but rather the ceiling is tilted or curved in either direction to improve uniformity or efficiency of the process. In this case, the cross-sectional area of the reaction chamber **106** may vary, uniformly or non-uniformly.

[**0043**] While a step portion **116** and ports **176** are shown and described, other features and geometries may be used to control the flow of the buffer gas B so as to control turbulence in the flow of the buffer gas B. The configurations of the process gas inlet passage **102**A, the process gas inlet **102**B, the inlet opening **102**, the buffer gas passages **117**, and/or the buffer gas inlets **176** may be adapted to promote laminar flow of and between the process gas P and the buffer gas B. The axial length K (**FIG. 3**) of the process gas inlet passage **102**A may be extended to reduce turbulence in the process gas P entering through the inlet **102** before the process gas P enters the reaction chamber **106** through the process gas inlet **102**B. However, because the passage **102**A is within the susceptor assembly **100** and is thus heated, reactions may occur which tend to form deposits or the ceiling surface of the passage **102**A. For this reason, it may be desirable to minimize the length of the passage **102**A. The buffer gas ports **176** may be replaced with one or more suitably configured slots.

[**0044**] According to some embodiments, the velocity of the process gas P and the velocity of the buffer gas B through the reaction chamber **106** are substantially the same. For SiC epitaxy, in accordance with some embodiments of the present invention where the length of the reaction chamber **106** is between about 0.1 and 1 m, the velocity of the gases P, B is at least about 1 m/s, and preferably between about 5 and 100 m/s to limit the time for diffusion of the process gas P through the barrier layer **178**.

[**0045**] In order to further promote the integrity of the barrier layer **178** and thereby inhibit diffusion of the process gas P therethrough, the buffer gas B may be provided at a temperature greater than the temperature of the adjacent process gas P. The hotter buffer gas B will naturally segregate from the relatively cooler process gas P along the ceiling surface **120** because of the relative buoyancy of the hotter gas. According to some embodiments, the average temperature of the buffer gas B is at least 10° C. hotter than the average temperature of the process gas in the reaction chamber **106**.

[**0046**] The buffer gas B may be heated using the heater **174**. Additionally or alternatively, the buffer gas B may be heated by heating the ceiling surface **120** to a temperature greater than the temperature or temperatures of the lower surfaces contiguous with the reaction chamber **106** which the process gas P contacts, i.e., by providing a temperature differential between the ceiling surface **120** and the floor, the platter **154** and/or other surfaces contacting the process gas P. That is, the temperature profile in the reaction chamber **106** may be deliberately and selectively maintained as spatially non-uniform (e.g., as a gradient) extending from the ceiling surface **120** to the lower and/or other surfaces contiguous with the reaction chamber **106**. This may be accomplished, for example, by providing greater thermal insulation between the core **142** and the surfaces of the liner **152**, the platter **154** and the substrate **20** contacting the process gas P than is provided between the core **112** and the ceiling surface **120**. For example, the liner **152** and the layer **114** may be suitably relatively constructed (e.g., by selection of material and thickness) to provide desired relative insulative effects. Because the top member **110** and the bottom member **140** are inductively heated, primarily by the resistivity of their graphite cores **112**, **142**, the temperatures of the surfaces of the liner **152**, the platter **154** and the substrate **20** contacting the process gas P are thereby reduced as compared to the temperature of the ceiling surface **120**. The buffer gas B is thus heated at a faster rate than the process gas P. To promote conduction of heat from the core **112** to the ceiling surface **120**, the layer **114** may be directly coated on the core **112** to form a relatively monolithic or unitary top member **110**.

[**0047**] Alternatively or additionally, a temperature differential can be created or increased between the ceiling surface **120** and the other surfaces such as the liner **152** or other lower surfaces by forming the layer **114** (and thus the ceiling surface **120**) from a material having a lower emissivity than the material of the layer **144** and/or of the liner

**152** or other surfaces contacting the process gas P stream. For example, the layer **114** may be formed of TaC (which has an emissivity of about 0.4) and the liner **152** and the platter **154** may be formed of SiC (which has an emissivity of about 0.9). As a result, the layer **114**, and therefore the ceiling surface **120**, will lose comparatively less heat from radiation, resulting in a higher temperature at the ceiling surface **120**. Moreover, parasitic deposits may tend to adhere less well to TaC or other metal carbides than to SiC. As a further advantage, in many applications, a TaC coating will typically be more durable than a SiC coating, which may serve to prolong the service life of the part.

[**0048**] In addition to the barrier effect, the ceiling surface **120** can be heated, for example, in one or more of the manners described above, such that it is sufficiently hotter than the other components in the reaction chamber **106** to induce etching or sublimation of deposits on the ceiling surface **120**. That is, deposits on the relatively hot ceiling surface **120** will tend to etch away or sublime and return to the buffer gas B or the process gas P rather than remaining on the ceiling surface **120**.

[**0049**] As discussed above, the buffer gas B may consist of or include HCl or other active gas to chemically impede the formation of parasitic deposits on the ceiling surface **120** and/or to remove such deposits.

[**0050**] Because the growth of parasitic deposits on the ceiling surface **120** is inhibited or suppressed, greater volumes of process gas P can be flowed through the reaction chamber **106** before cleaning or the like is required. Deposition systems and methods in accordance with the present invention may greatly extend the permissible growth time and layer thickness while improving repeatability and efficiency. Moreover, the reduction in the rate of deposit formation may allow the use of lower ceiling heights, which allows for more efficient use of the process gas and improved thermal uniformity.

[**0051**] While the foregoing deposition system **101** and methods are described as relating to a horizontal, hot wall, CVD, flow through deposition process, various aspects of the present invention may be used in other types of deposition systems and processes. While particular embodiments have been described with reference to "top", "bottom" and the like, other orientations and configurations may be employed in accordance with the invention. For example, the deposition system and process may be a cold wall and/or non-horizontal flow through system and process. The deposition system and process may be a vapor phase epitaxy (VPE), liquid phase epitaxy (LPE), or plasma enhanced CVD (PECVD) deposition system and process rather than a CVD system or process. The present invention is not limited to providing a barrier layer for a ceiling surface of a reaction chamber. The buffer gas supply system may be modified to provide a buffer gas flow along one or more surfaces in addition to or instead of the ceiling surface. For example, the buffer gas supply system may be employed to inhibit parasitic deposits from forming on a lower liner or other surfaces upstream from the substrate **20**, or in other locations where parasitic deposits are problematic.

[**0052**] While the systems and methods have been described in relation to processes for depositing layers on substrates such as semiconductor wafers, the present invention may be employed in processes for depositing layers or the like on other types of substrates. The systems and methods of the present invention may be particularly useful in processes for forming an epitaxial layer on a substrate.

[**0053**] Various other modifications may be made in accordance with the invention. For example, the reaction chamber may be closed at one or both ends rather than providing a through passage. Heating systems may be used other than or in addition to inductive heating.

[**0054**] As used herein a "system" may include one or multiple elements or features. In the claims that follow, the "deposition system", the "deposition control system", the "buffer gas supply system", the "process gas supply system" and the like are not limited to systems including all of the components, aspects, elements or features discussed above or corresponding components, aspects, elements or features.

[**0055**] The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the invention.

**1**. A method for controlling parasitic deposits in a deposition system for depositing a film on a substrate, the deposition system defining a reaction chamber for receiving the substrate and including a process gas in the reaction chamber and an interior surface contiguous with the reaction chamber, the method comprising:

providing a buffer gas to the reaction chamber at a temperature greater than a temperature of the process gas in the reaction chamber; and

flowing the buffer gas to form a flowing gas barrier layer between the interior surface and at least a portion of the process gas, such that the flowing gas barrier layer inhibits contact between the interior surface and components of the process gas.

**2**. The method of claim 1 wherein the step of flowing the buffer gas includes flowing the buffer gas along and in contact with the interior surface.

**3**. The method of claim 1 including flowing the process gas through the reaction chamber in a flow direction, and wherein the step of flowing the buffer gas includes flowing the buffer gas through the reaction chamber in the flow direction.

**4**. The method of claim 3 wherein the step of flowing the buffer gas includes flowing the buffer gas through the reaction chamber at substantially the same velocity as the process gas.

**5**. The method of claim 3 including introducing both the buffer gas and the process gas into the reaction chamber at substantially the same location along the flow direction so as to inhibit turbulence in and mixing between their respective flows.

**6**. The method of claim 1 including flowing the process gas into the reaction chamber through a process gas inlet, and wherein:

the process gas inlet has a smaller cross-sectional area than a cross-sectional area of the reaction chamber so as to define a buffer gas region in the reaction chamber; and

the step of flowing the buffer gas includes flowing the buffer gas into the buffer gas region.

**7**. The method of claim 1 wherein the step of flowing the buffer gas includes providing a substantially laminar flow of the buffer gas along the interior surface.

**8**. The method of claim 1 wherein the interior surface overlies the substrate.

**9**. (canceled)

**10**. The method of claim 1 including heating the buffer gas before introducing the buffer gas into the reaction chamber.

**11**. The method of claim 1 including heating the buffer gas as the buffer gas flows along the interior surface.

**12**. The method of claim 1 including heating the interior surface to a temperature sufficient to promote sublimation of parasitic deposits from the process gas that deposit on the interior surface.

**13**. The method of claim 1 including inductively heating a susceptor member adjacent the interior surface to thereby heat the interior surface.

**14**. The method of claim 1 wherein the step of flowing the buffer gas includes flowing the buffer gas through the reaction chamber at a velocity of at least about 1 m/s.

**15**. The method of claim 14 wherein the step of flowing the buffer gas includes flowing the buffer gas through the reaction chamber at a velocity of between about 5 and 100 m/s.

**16**. The method of claim 1 wherein the buffer gas comprises a noble gas.

**17**. The method of claim 16 wherein the noble gas is selected from the group consisting of argon, helium, neon, krypton, radon, and xenon.

**18**. The method of claim 1 wherein the buffer gas comprises $H_2$, $N_2$, $NH_3$ and/or air.

**19**. The method of claim 1 wherein the buffer gas includes an active material capable of chemically inhibiting the deposition of parasitic deposits on the interior surface and/or removing parasitic deposits from the interior surface.

**20**. The method of claim 19 wherein the active material includes an etchant.

**21**. The method of claim 20 wherein the etchant includes at least one of HCl, $Cl_2$ and a carbon-containing gas.

**22**. The method of claim 1 wherein the deposition system is a chemical vapor deposition (CVD) system.

**23**. The method of claim 22 wherein the deposition system is a hotwall CVD system.

**24**. The method of claim 1 wherein the substrate is a semiconductor substrate.

**25**. The method of claim 24 wherein the substrate comprises a material selected from the group consisting of SiC, sapphire, a Group III nitride, silicon, germanium, and III-V and II-VI compounds and interalloys.

**26**. The method of claim 1 wherein the process gas comprises a reagent selected from the group consisting of $SiH_4$, $C_3H_8$, $C_2H_4$, $Si_2H_6$, $SiCl_4$, $SiH_2Cl_2$, $SiCl_3(CH_3)$, $NH_3$, trimethyl gallium, and trimethyl aluminum.

**27**. The method of claim 1 wherein the process gas is adapted to deposit onto the substrate a layer of material selected from the group consisting of SiC, a Group III nitride, silicon, germanium, and III-V and II-VI compounds and interalloys.

**28-63**. (canceled)

**64**. The method of claim 1 wherein the average temperature of the buffer gas is at least 10° C. hotter than the average temperature of the process gas in the reaction chamber.

**65**. A method for controlling parasitic deposits in a deposition system for depositing a film on a substrate, the deposition system defining a reaction chamber for receiving the substrate and including a process gas in the reaction chamber and an interior surface contiguous with the reaction chamber, the method comprising:

flowing the process gas through the reaction chamber in a flow directions wherein the flow direction is substantially horizontal; and

flowing a buffer gas through the reaction chamber in the flow direction to form a flowing gas barrier layer between the interior surface and at least a portion of the process gas, such that the flowing gas barrier layer inhibits contact between the interior surface and components of the process gas;

wherein the step of flowing the buffer gas includes flowing the buffer gas through the reaction chamber at substantially the same velocity as the process gas; and

wherein the step of flowing the buffer gas includes providing a substantially laminar flow of the buffer gas along the interior surface to at least a location downstream of the substrate.

**66**. The method of claim 65 including introducing both the buffer gas and the process gas into the reaction chamber at substantially the same location along the flow direction so as to inhibit turbulence in and mixing between their respective flows.

**67**. The method of claim 65 including flowing the process gas into the reaction chamber through a process gas inlet, and wherein:

the process gas inlet has a smaller cross-sectional area than a cross-sectional area of the reaction chamber so as to define a buffer gas region in the reaction chamber; and

the step of flowing the buffer gas includes flowing the buffer gas into the buffer gas region.

**68**. (canceled)

**69**. A method for controlling parasitic deposits in a deposition system for depositing a film on a substrate, the deposition system defining a reaction chamber for receiving the substrate and including a process gas in the reaction chamber and an interior surface contiguous with the reaction chamber, the method comprising:

flowing a buffer gas to form a flowing gas barrier layer between the interior surface and at least a portion of the process gas, such that the flowing gas barrier layer inhibits contact between the interior surface and components of the process gas; and

heating the interior surface to a temperature sufficient to promote sublimation of parasitic deposits from the process gas that deposit on the interior surface.

**70**. The method of claim 69 including flowing the process gas through the reaction chamber in a flow direction, and wherein the step of flowing the buffer gas includes flowing the buffer gas through the reaction chamber in the flow direction.

**71**. The method of claim 69 including chemically inhibiting the deposition of parasitic deposits on the interior surface and/or removing parasitic deposits from the interior surface using an active material included in the buffer gas.

**72**. The method of claim 71 wherein the active material includes an etchant.

**73**. The method of claim 72 wherein the etchant includes at least one of HCl, $Cl_2$ and a carbon-containing gas.

**74**. (canceled)

**75**. The method of claim 65 wherein the substrate is a wafer having an exposed surface, the method including positioning the wafer in the reaction chamber such that the exposed surface is disposed horizontally and parallel to the flow direction.

**76**. The method of claim 69 wherein the substrate is a semiconductor wafer.

**77**. The method of claim 76 wherein the wafer comprises a material selected from the group consisting of SiC, sapphire, a Group III nitride, silicon, germanium, and III-V and II-VI compounds and interalloys.

**78**. The method of claim 69 wherein the process gas comprises a reagent selected from the group consisting of $SiH_4$, $C_3H_8$, $C_2H_4$, $Si_2H_6$, $SiCl_4$, $SiH_2Cl_2$, $SiCl_3(CH_3)$, $NH_3$, trimethyl gallium, and trimethyl aluminum.

**79**. The method of claim 69 wherein the process gas is adapted to deposit onto the wafer a layer of material selected from the group consisting of SiC, a Group III nitride, silicon, germanium, and III-V and II-VI compounds and interalloys.

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