US 20050098264A1

(19) **United States**

(12) **Patent Application Publication**

Wolf et al.

(10) **Pub. No.: US 2005/0098264 A1**

(43) **Pub. Date: May 12, 2005**

(54) **MOLECULAR AIRBORNE CONTAMINANTS (MACS) FILM REMOVAL AND WAFER SURFACE SUSTAINING SYSTEM AND METHOD**

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(21) Appl. No.: **10/966,125**

(22) Filed: **Oct. 14, 2004**

Related U.S. Application Data

(60) Provisional application No. 60/511,209, filed on Oct. 14, 2003.

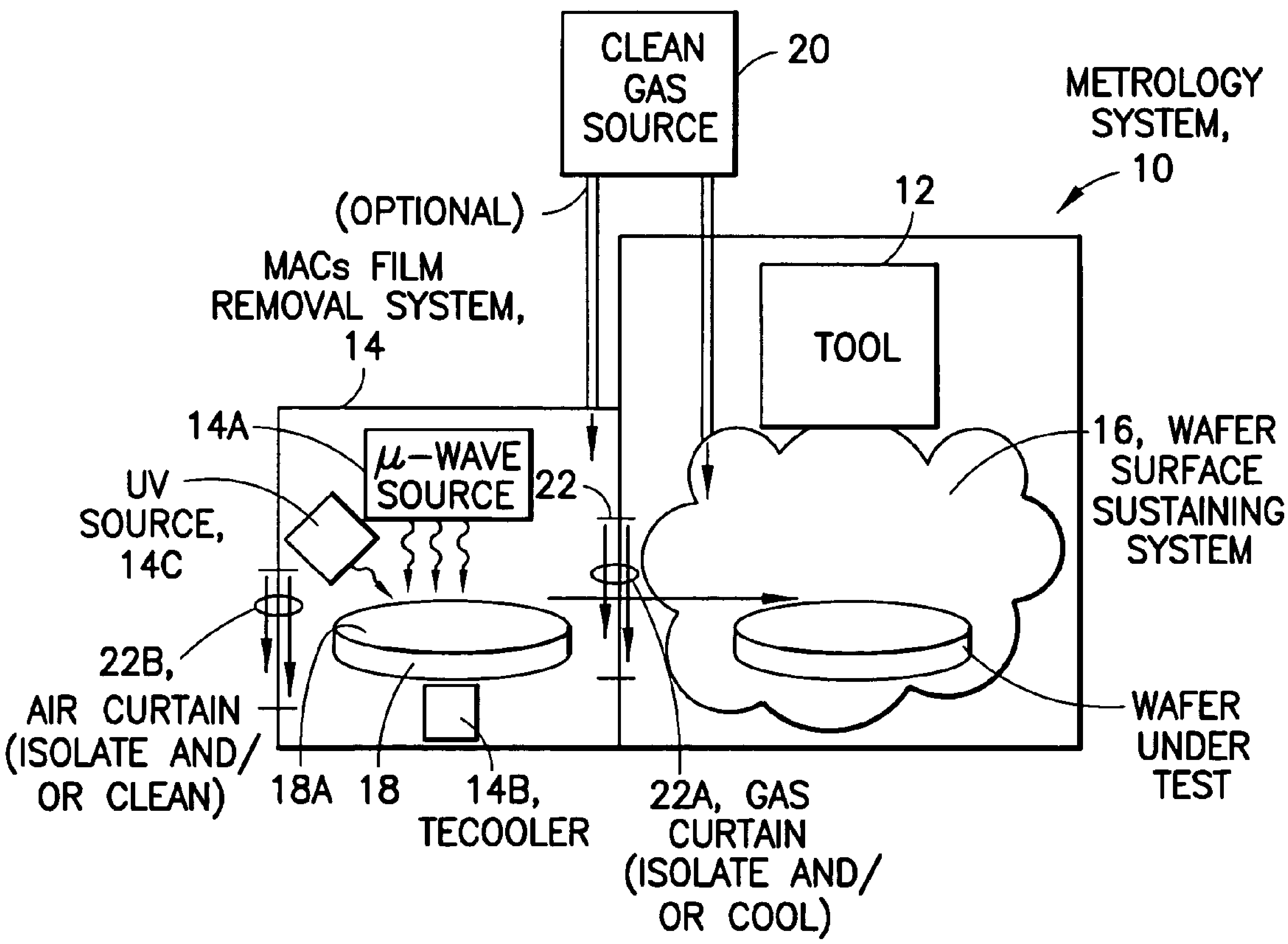
Publication Classification

(51) Int. Cl.[7] **C23F 1/00**; C25F 1/00

(52) U.S. Cl. **156/345.32**; 134/1.1; 134/2

(57) **ABSTRACT**

A MACs mitigation system includes a MACs film removal sub-system **(14)** and a wafer surface sustaining sub-system **(16)** for sustaining or maintaining the cleaned surface **(18A)** of a wafer **(18)** in a substantially MACs-free condition for some predetermined period of time, such as the typical amount of time required after MACs film removal to perform a desired measurement on the wafer using a metrology tool **(12)**. The MACs film removal sub-system can comprise a source **(14A)** of microwave energy that beneficially both heats and dissociates the chemical constituents of the MACs film. The wafer surface sustaining sub-system can be co-located with a measurement stage portion of the metrology tool, and preferably includes an atmosphere provided by a source **(20)** of clean gas.



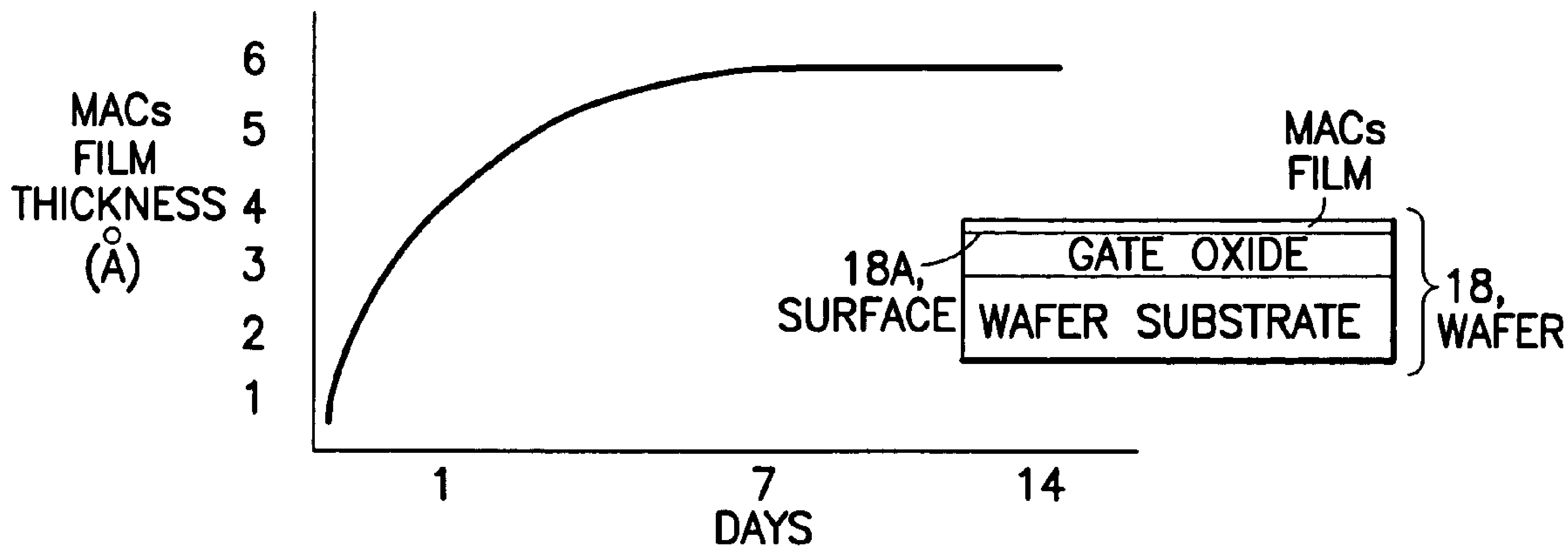

MACs
FILM
THICKNESS
(Å)
6
5
4
3
2
1
1
7
14
DAYS
MACs
FILM
GATE OXIDE
18A,
SURFACE
WAFER SUBSTRATE
18,
WAFER

FIG.1

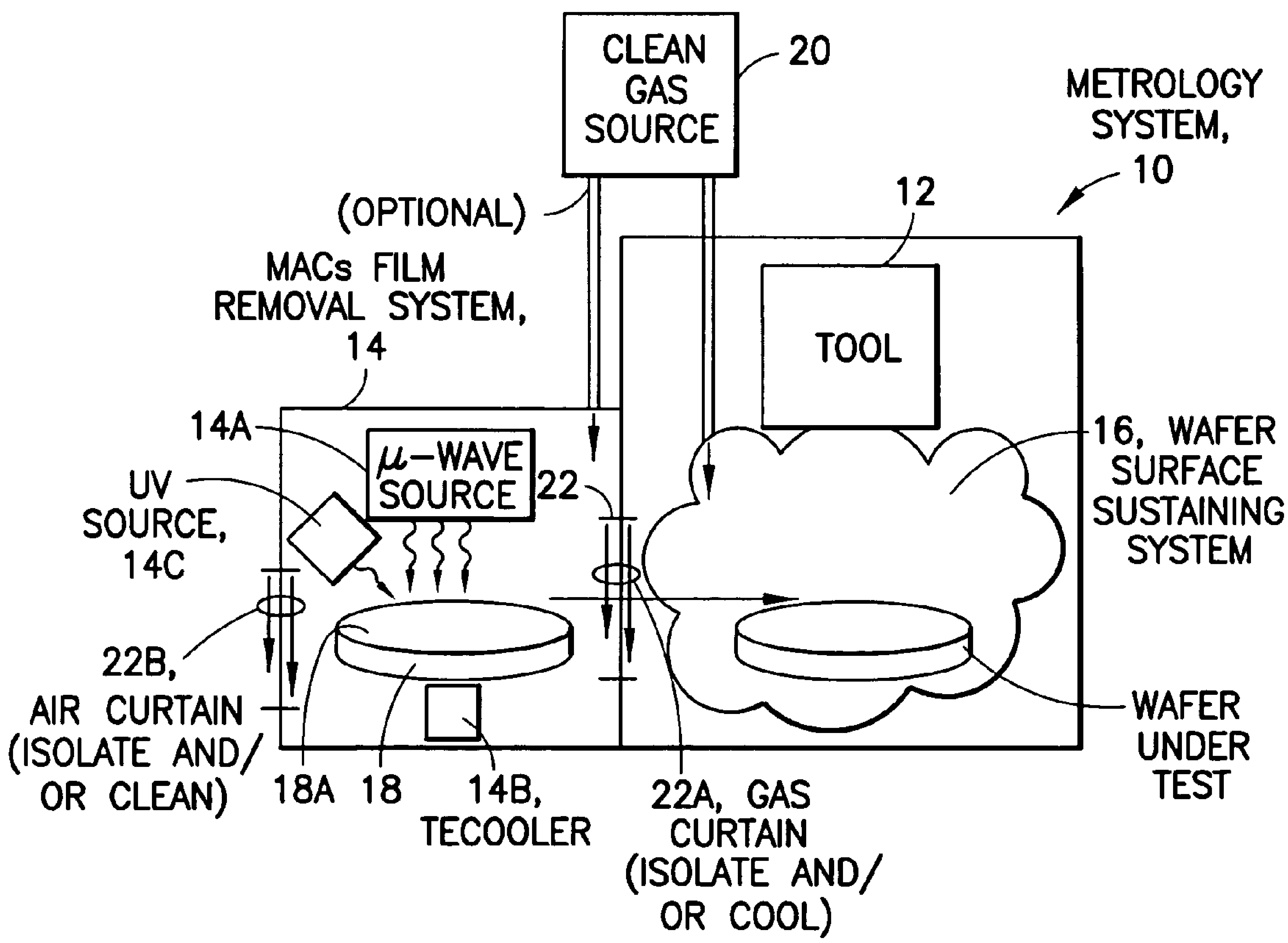

CLEAN
GAS
SOURCE
20
METROLOGY
SYSTEM,
10
12
(OPTIONAL)
MACs FILM
REMOVAL SYSTEM,
14
TOOL
14A
μ-WAVE
SOURCE
22
16, WAFER
SURFACE
SUSTAINING
SYSTEM
UV
SOURCE,
14C
22B,
AIR CURTAIN
(ISOLATE AND/
OR CLEAN)
18A
18
14B,
TECOOLER
22A, GAS
CURTAIN
(ISOLATE AND/
OR COOL)
WAFER
UNDER
TEST

FIG.2

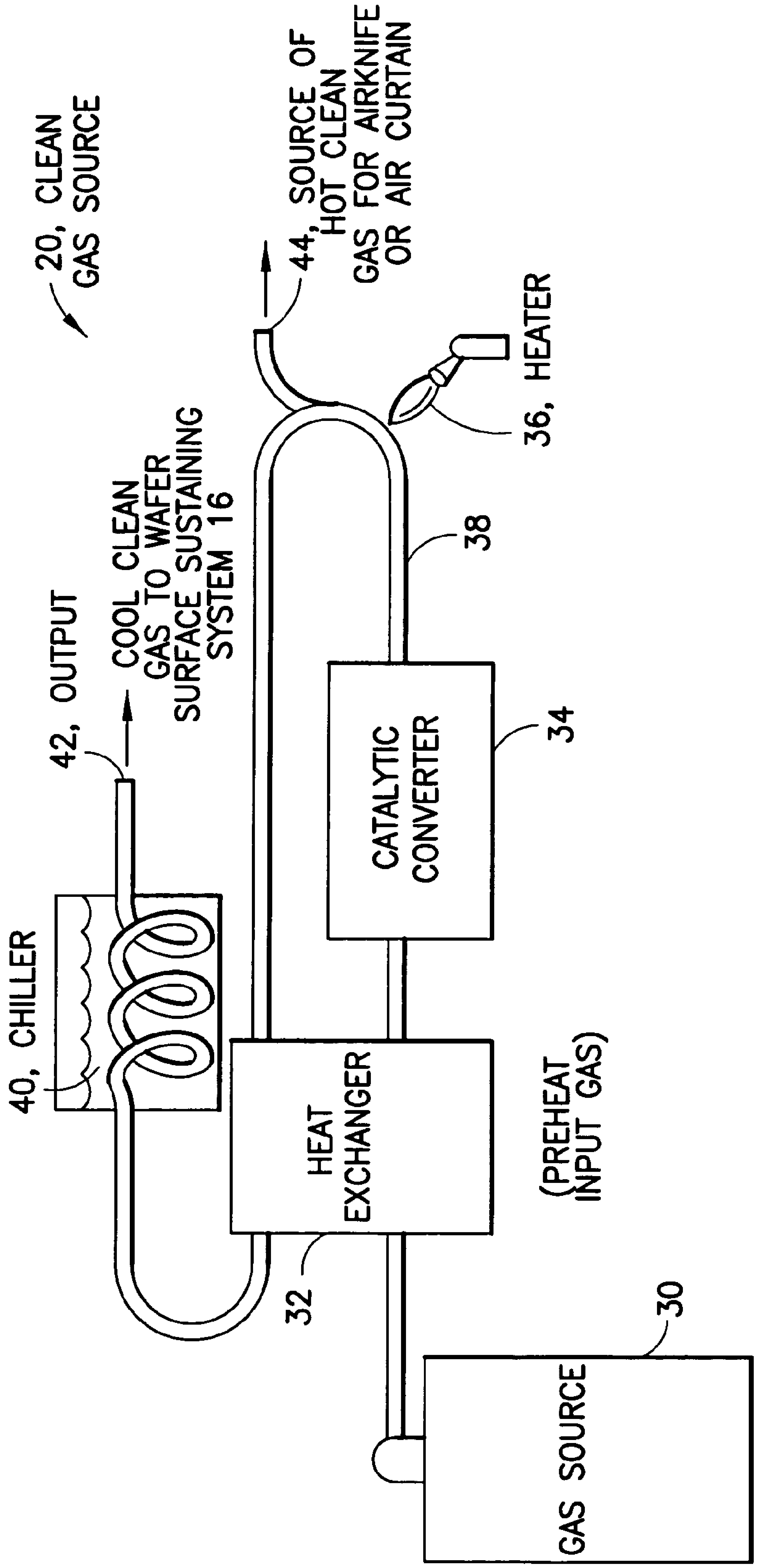

20, CLEAN GAS SOURCE
44, SOURCE OF HOT CLEAN GAS FOR AIRKNIFE OR AIR CURTAIN
36, HEATER
38
42, OUTPUT
COOL CLEAN GAS TO WAFER SURFACE SUSTAINING SYSTEM 16
40, CHILLER
CATALYTIC CONVERTER
34
HEAT EXCHANGER
(PREHEAT INPUT GAS)
32
30
GAS SOURCE

FIG.3

MOLECULAR AIRBORNE CONTAMINANTS (MACS) FILM REMOVAL AND WAFER SURFACE SUSTAINING SYSTEM AND METHOD

CLAIM OF PRIORITY FROM COPENDING PROVISIONAL PATENT APPLICATION

[0001] This patent application claims priority under 35 U.S.C. §119(e) from Provisional Patent Application No. 60/511,209, filed Oct. 14, 2003, the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] This invention relates generally to semiconductor wafer metrology systems and methods and, more specifically, relates to methods and apparatus for removing a MACs layer or film from a surface of a wafer prior to a metrology operation, and for inhibiting the formation of another MACs film subsequent to the removal of the MACs film and the start of the metrology operation.

BACKGROUND

[0003] The measurement of thin transparent layers for semiconductor applications is an important part of the fabrication process for advanced transistors. As the geometry and layer thicknesses of modem transistor devices decrease, the process control requirements become more stringent. For example, modem transistors require a gate oxide (e.g., SiO_2) layer thickness in the sub-30 Angstrom regime.

[0004] It is known that when a gate oxide layer is exposed to the atmosphere both water and hydrocarbons adhere to the surface of the layer, causing an immediate growth of a contaminant film at the rate of a few tenths of an Angstrom per hour (see **FIG. 1**). These surface contaminates are also known as molecular airborne contaminants (MACs), and the resulting contamination film as a MACs film. Since at present the refractive index of the contamination is not known, the MACs film thickness is measured as if the film had the refractive index of the underlying oxide layer. Several techniques for removing MACs are known in the art, including thermal, photo-thermal, and other techniques. For example, U.S. Pat. No. 6,624,393 B2, "Method and Apparatus for Preparing Semiconductor Wafers for Measurement", Howell et al., discloses a wafer-cleaning module for removing contaminants from a semiconductor wafer prior to measurement in a metrology tool. The cleaning module includes a heating chamber that includes a heater plate for heating the wafer by conduction. A separate cooling chamber is provided to cool the wafer. The system is controlled so that the heating cycle, cooling cycle and the time periods between these cycles and the measurement cycle are uniform for all wafers.

[0005] Also by example, U.S. Pat. No. 6,325,078 B2, "Apparatus and Method for Rapid Photo-Thermal Surface Treatment", Kamieniecki, discloses a system for surface treating a semiconductor wafer that includes a surface treatment chamber and a source of radiation. The semiconductor wafer is disposed inside the chamber and is illuminated with radiation sufficient to create or generate a plurality of electron-hole pairs near the surface of the wafer. This technique is said to desorb ions and molecules adsorbed on the surface of the wafer.

[0006] Once the MACs film is removed, however, the re-growth of the MACs film on the wafer surface begins anew. Further, and referring again to **FIG. 1**, it can be seen that during the initial stage of MACs film growth the growth rate is the most rapid.

[0007] The gate oxide layer measurement problems that arise due to the presence of the MACs film have to do with the relative apparent thickness of the MACs film as a fraction of the total (desired) layer thickness. As the desired layer(s) become thinner (e.g., when a gate oxide layer is required to have a thickness of less than 30 Angstroms), the percent of the total layer thickness due to the presence of the MACs film becomes substantial. These effects cause the most difficulty for metrology tool calibration and matching, but also complicate and detrimentally affect tool acceptance qualification, tool monitoring and overall process control. As but one example, if a metrology tool is expected to exhibit some stringent degree of repeatability of layer thickness measurements (e.g., less than one tenth Angstrom) over a period of, for example several days, and if a MACs film is continually increasing in thickness on a test wafer over the same period of time (e.g., starting at an initial rate of a few tenths of an Angstrom per hour), then the required degree of layer thickness measurement repeatability will be impossible to meet. Furthermore, it becomes very difficult to ascertain whether the metrology tool is operating within its required parameters, or whether there may actually be a tool-related repeatability problem.

[0008] Thus, given that the repeatability of an advanced metrology system, such as an ellipsometry-based metrology tool system, may be **0.04** Angstroms for a period of five days, it can be appreciated that it is most desirable to remove the MACs film, and to also sustain the underlying wafer surface in a MACs-free condition, to a degree that is better than the repeatability level of the metrology tool. The effectiveness of the MACs film removal system should thus be substantially better than the repeatability of the metrology tool, and the wafer surface sustaining system should have the ability to maintain the surface state to be essentially MACs-free for at least the duration of the longest typical tool measurement. Since the longest measurement may last up to **10** minutes or more, a system is needed that will maintain the clean surface of the wafer for at least that duration of time. Without the surface sustaining system, the MACs film removal system alone will operate so as to de-stabilize the wafer surface, resulting in the MACs film being in its most rapid state of re-growth (see **FIG. 1** once again) as soon as the MACs film is removed.

[0009] Proposed solutions to this problem to date include aggressive methods to drive off the MACs film by baking the wafer. However, the amount of heating required may cause problems for process wafers since the temperatures required are in excess of 100 degrees C. What is needed is a process compatible method that will quickly remove the MACs from a wafer surface, and then sustain the surface in a MACs free state for the duration of the longest typical measurement run.

[0010] Additionally, in order to be compatible with current metrology, the process compatible MACs film removal method should not impede the throughput of the system. For example, the conduction-based heater plate approach may require some number of minutes to heat the wafer surface sufficiently to drive off a MACs film. Further, in order to achieve process compatibility, the method should also have a low thermal and UV exposure level. Furthermore, the MACs film removal process should not generate undesirable environmental effects, such as excessive amounts of ozone that can be generated by UV radiation-based MACs film removal techniques.

[0011] The use of microwave plasmas and microwave energy for the general pre-heating, as well as cleaning, of semiconductor wafers is known. Reference can be made, as examples, to U.S. Pat. No. 5,449,411, "Microwave Plasma Processing Apparatus", Fukuda et al., and to U.S. Patent No.: **5,261,965**, "Semiconductor Wafer Cleaning Using Condensed-Phase Processing", Moslehi. This latter U.S. Patent describes a method and system for semiconductor wafer cleaning within a condensed-phase processing environment that is based on first cooling the semiconductor wafer to a predetermined temperature (e.g., −100 degrees Celsius to −150 degrees Celsius) in order to condense a liquid film on the surface of the semiconductor wafer from a condensable process gas or gas mixture (e.g., water, alcohol, HCl, HF and Cl). Thermally activated surface reactions are then promoted in order to rapidly evaporate the liquid film from the semiconductor wafer surface using a high peak power, short pulse duration energy source, such as a pulsed microwave source. This process is said to both dissolve surface contaminants and produce drag forces sufficiently large to remove particulates and other surface contaminants from the surface of the semiconductor wafer. The method and system are said to be capable of removing various organic, metallic, native oxide, and particulate contaminants from the surface of the wafer. The method and system can be used for both pre-process and post-process wafer cleaning.

[0012] At least one disadvantage of the Moslehi technique is the requirement to cool the wafer in the presence of the condensable process gas or gas mixture in order to form the liquid film layer of the wafer surface.

[0013] What is thus needed is a method to remove the MACs-based contamination layer from the surface of a wafer, and to also then sustain the wafer surface in a substantially MACs-free state to prevent or inhibit the formation of another MACs film prior to making a desired metrology measurement or measurements.

[0014] Based on the foregoing discussion, it should be apparent that there are a number of problems with the existing conduction heating, optical energy and microwave energy wafer cleaning systems, as well as with maintaining a cleaned wafer in a condition that inhibits the rapid re-growth of another MACs film. Prior to this invention these problems were not adequately addressed.

SUMMARY OF THE PREFERRED EMBODIMENTS

[0015] The foregoing and other problems are overcome, and other advantages are realized, in accordance with the presently preferred embodiments of these teachings. Disclosed in accordance with embodiments of this invention is a MACs mitigation system that comprises a first system for removing a MACs film from a surface of a wafer by directing energy towards the surface, and a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time.

[0016] Also disclosed in accordance with embodiments of this invention is a metrology system that includes a metrology tool and a MACs mitigation system that comprises a first system for removing a MACs film from a surface of a wafer by directing energy towards the surface and a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time.

[0017] Also disclosed in accordance with embodiments of this invention is a MACs mitigation system that comprises a first system for removing a MACs film from a surface of a wafer, where the first system comprises a MACs removal means having directed energy means; and a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time at least equal to the time required after MACs film removal to perform a desired measurement on the wafer using a metrology tool.

[0018] Also disclosed in accordance with embodiments of this invention is a MACs removal system that comprises a source that provides a stream of gas that is directed towards a surface of a wafer for removing a MACs film from the surface.

[0019] Also disclosed in accordance with embodiments of this invention is a method to inhibit formation of a MACs film on a surface, comprising removing a MACs film from the surface by directing energy towards the surface; and maintaining the surface in a substantially MACs-free condition for some predetermined period of time during which a procedure is performed on or through the surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The foregoing and other aspects of these teachings are made more evident in the following Detailed Description of the Preferred Embodiments, when read in conjunction with the attached Drawing Figures, wherein:

[0021] **FIG. 1** is graph showing the increase in thickness of a MACs film as a function of time;

[0022] **FIG. 2** is an overall metrology system block diagram, where the metrology system includes a MACs film removal station or sub-system, and a wafer surface sustaining station or sub-system; and

[0023] **FIG. 3** is a block diagram of a system for providing clean gas to the wafer surface sustaining station, and possibly also to the MACs film removal station.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Reference may be had to commonly assigned U.S. Pat. Nos. 6,519,045; 6,621,582; 6,504,618, 6,256,097; and 5,166,752, incorporated by reference herein in their entireties, for describing various aspects of metrology systems and methods for performing at least reflectometry-based and ellisometry-based measurements. Interferometry-based measurements are also within the scope of these teachings.

[0025] For example, commonly-assigned U.S. Pat. No. 6,519,045 describes in part a thickness metrology apparatus and method for accurately determining the actual thickness of thin dielectric film on a semiconductor wafer. As described in the commonly-assigned U.S. Patent the wafer is subjected to a heat treatment, such as baking at a heating station of the apparatus, to cause desorption of organic compounds from the film. The treated wafer is transferred to a measurement stage where the thickness of the film is measured by an ellipsometer, for example. The actual thickness of the film is determined from the measured thickness and a change in the measured film thickness as a function of time for the film due to absorption of organic compounds onto the film following desorption of organic compounds therefrom. U.S. Pat. No. 6,519,045 also describes the use of an optional inert atmosphere system, whether in the form of purging the wafer with inert gas or in the form of a vacuum chamber, that serves to extend the period of time during which the actual thickness of the thin film oxide on the wafer can be measured without the accumulation of organic compounds on the surface of the wafer causing an increase in the measured thickness of the oxide layer. The duration of this extended period of time is said to range up to tens of minutes. In the absence of the inert atmosphere system, there is a stable thickness time of approximately three minutes.

[**0026**] Referring now to **FIG. 2**, there is shown a metrology system **10** in accordance with embodiments of this invention that has a metrology tool or instrument **12**, such as an ellipsometer tool, and a MACs film removal system **14** and a wafer surface sustaining system **16**. As used herein the wafer surface sustaining system **16** is considered to be some means that is suitable for inhibiting the regrowth of a MACs film on a surface **18A** of a wafer **18** from which a MACs film was removed by the MACs film removal system **14**, or by some other technique, such as by processing the wafer **18** in such a manner as to drive off a pre-existing MACs film. The wafer surface sustaining system **16** is preferably co-located with the tool **12** measurement stage for maintaining the surface **18A** of wafer **18** substantially free of MACs layer re-growth, after the MACs layer is removed by the MACs film removal system **14**, both prior to and during the operation of the metrology tool **12**. The MACs film removal system is also preferably located within the region of the surface sustaining environment such that there are no contaminants available to re-contaminate the surface of the wafer **18**.

[**0027**] In **FIG. 2** the MACs film removal system **14** can comprise hot clean gas comprised of air, or N_2, or some other suitable gas or mixture of gases, including one containing ozone, where "clean" refers to a complete or at least partial absence of hydrocarbons and/or water and/or any other substance that is capable of promoting the growth of a MACs film on the surface **18A** of the substrate **18**. The hot clean gas can be applied as one or more jets, or by an air knife, and can be used to remove or aid in the removal of the MACs film.

[**0028**] The MACs film removal system **14** can also include a source **14A** of microwave energy, such as a magnetron or a klystron having an operating frequency in a range of about 1 GHz to about 10 GHz, and an output power in a range of about 10^2-10^5 Watts. One suitable embodiment uses a magnetron operating at a frequency of about 2.4 GHz and an output power of about 1 KW. Under these conditions a 20 second exposure of the wafer **18** to the microwave energy has been found to be sufficient to remove substantially all of the MACs film from the surface **18A** of the wafer **18**. This contrasts very favorably with the several minutes required to bake off the MACs film using the conduction-based hot plate approach. The use of microwave energy is not believed to generate or create any electron-hole pairs in the semiconductor material of the wafer **18**. The wafer **18** appears to the microwave energy at the frequencies of interest as a resistive element, and any already available free electrons in the semiconductor wafer **18** are caused to move within the wafer crystalline lattice by the oscillating electrical field of the microwave energy, thereby generating heat in the wafer **18** (e.g., it has been found that the surface **18A** of the wafer **18** is raised to about 250 degrees Celsius after 20 seconds of microwave energy exposure at 2.4 GHz and an output power of about 1 KW). The heating effect is, however, also felt directly by the overlying gate oxide layer and by the MACs film disposed atop the gate oxide layer. Thus, the use of the microwave source **14A** can more rapidly drive off the MACs by both heating the wafer **18** and the contaminating molecules themselves. The use of the microwave energy is also believed to directly heat and/or dissociate at least some of the organic molecules found in the MACs film, or heat to such an extent that an oxygen takes place on at least some of the organic molecules found in the MACs film, thereby even more effectively removing the MACs film from the surface **18A** of the wafer **18**. If desired, the wafer **18** can be maintained on a cool surface, such as on a thermoelectric (TE). cooler **14B**, during the RF excitation. In this case it is clearly just the MACs film, and possibly also the underlying gate oxide layer, that are raised significantly in temperature by the RF microwave energy.

[**0029**] The MACs film removal system **14** can also comprise ozone enriched water, a hot-plate, and/or a UV light source **14C**.

[**0030**] The wafer surface sustaining system **16** can have an atmosphere comprised of a chemically clean gas or gas mixture, such as N_2, or air, or an ozone-enriched air or nitrogen atmosphere at ambient or elevated temperatures. A source **20** of chemically clean gas can be shared between the removal system **14** and the sustaining system **16**, such that each is subject to the same environment, and can comprise a chemical filter and/or a system that "burns" or converts, via a catalytic converter (e.g., one based on platinum or palladium metal), any remaining hydrocarbons and other contaminates to gases. In this regard it is noted that most if not all organic materials of interest to this invention burn at or below about 300 degrees Celsius, and that the hot gas can be cooled by expansion and a heat exchanger **32** (see **FIG. 3**, discussed below). In this embodiment any residual heat from the catalytic reaction may be used to warm the gas for the removal system **14** and/or the sustaining system **16**. The residual heat from the catalytic system may be removed via the heat exchanger **32**, such as one located between the gas input and output so as to both pre-heat the input gas and cool the output gas.

[**0031**] Reference in this regard can be made to **FIG. 3**, which shows that the source **20** of chemically clean gas may comprise a gas source **30** (e.g., a cylinder of purified clean air or nitrogen), the heat exchanger **32**, a catalytic converter **34**, a heater **36** (e.g., a gas torch or an electrical heating element) thermally coupled to a gas flow line **38** for combusting any remaining impurities in the gas flow, and a chiller **40** (such as a water bath or some other heat removal means) for reducing the temperature of the clean gas flow to a desired temperature for at least one of cooling the wafer **18**, after the MACs film removal operation, and maintaining the wafer **18** at a temperature that is suitable for operation of the metrology tool **12** (e.g., less than about 30 degrees Celsius). In accordance with an aspect of this invention the gas at the output **42** of the gas delivery system shown in **FIG. 3** is ultra-clean, and is used to form the atmosphere in the wafer surface sustaining system **16** for inhibiting the re-growth of a MACs film prior to the operation of the metrology tool **12**, and possibly also in the MACs film removal system **14**, as was noted above. Another output **44** can be taken before the heat exchanger **32** and chiller **40** to provide a source of hot clean gas for the air knife and or hot air curtain **22**B, if used.

[**0032**] The source **20** of chemically clean gas can also comprise an ozone assisted chemical reaction, and a method of producing the clean gas can be a part of a method for producing ozone for use in the ozone-enriched air or other gas.

[**0033**] A wafer removal system **22** of the metrology system **10**, between the MACs film removal system **14** and the surface sustaining system **16**, can include a clean air or gas curtain **22**A. This can be placed at an entrance to the environment of the sustaining system **16** (e.g., at the entrance to the measurement stage area of the metrology tool **12**). In this case the wafer measurement environment that forms a part of the metrology tool **12** can thus be treated to remove contaminants. For example, the clean gas delivery tubing can be treated to remove contaminants, such as by using a chemical filter, or a thermal process to burn off contaminates, and/or a catalytic converter to trap and remove contaminates, as was described above with respect to **FIG. 3**.

[**0034**] In one presently preferred embodiment the MACs film removal system **14** includes a radio frequency (RF) device, such as a microwave source, that simultaneously heats the surface adsorbed contaminants (the MACs film) and the wafer **18**. The RF heating device can be designed as a wafer pass-through system, and it may include a second integral clean air curtain **22**B that isolates the atmosphere of the removal system **14** from the ambient atmosphere by excluding external air, as well as possibly facilitating the removal of the MACs film (such as with the heated air knife) as the wafer **18** is placed within the removal system **14**. The first air curtain **22**A can also be used to facilitate the cooling of the wafer **18** prior to the start of a metrology operation, so that the wafer temperature is within a range of acceptable temperatures for operation of the metrology tool. The use of the air curtain or air stream **22**A to cool the wafer **18** prior to the measurement can be used to beneficially eliminate a separate cooling stage at the output of the MACs film removal system **14**.

[**0035**] While it is known in the prior art to employ a stream of air for preventing the entry of ambient air into a chamber, the use of an air curtain or stream or knife for MACs film removal, and for the other related purposes described herein, has not, to the knowledge of the inventors, been previously proposed or used. Reference with regard to one prior art technique can be made to U.S. Pat. No. 6,056,544, "Apparatus for Baking Resists on Semiconductor Wafers", Cho. This U.S. Patent describes an apparatus for baking resists on semiconductor wafers that is capable of preventing cold air from entering the interior of the baking chamber during a baking process. This is accomplished by controlling the temperature of ambient air surrounding the baking chamber to equal the internal temperature of the baking chamber. The control is achieved by providing a hot air supply unit and nozzles. The hot air supply unit generates hot air heated to a desired temperature and supplies the generated hot air to the nozzles that are arranged near the baking chamber. The nozzles inject the hot air onto the outer surface of the baking chamber. The nozzles may be arranged around the entrance ofthe baking chamber where a wafer to be baked is loaded. In this case, the nozzles are said to inject heated air onto opposite surfaces of a wafer being loaded or unloaded. The baking apparatus may have a configuration including a cooling chamber, a feeding chamber and a baking chamber. In this case, the baking apparatus carries out a baking process in a sealed condition.

[**0036**] Based on the foregoing description, it can be appreciated that in one aspect thereof this invention provides a MACs mitigation system that includes a MACs film removal sub-system and a wafer surface sustaining sub-system (i.e., a sub-system for sustaining or maintaining the cleaned surface of the wafer in a substantially MACs-free condition for some predetermined period of time, such as the typical amount of time required after MACs film removal to perform a desired measurement on the wafer using a metrology tool).

[**0037**] In another aspect thereof this invention provides a MACs removal system where a MACs film is removed by a hot air knife that flows a dry, clean gas. If desired, a rinse with de-ionized (DI) water may precede the use of the hot air knife.

[**0038**] In another aspect thereofthis invention provides a MACs removal system where a MACs film is removed by radio frequency energy, either alone or in combination with a clean gas.

[**0039**] In another aspect thereof this invention there is provided a MACs removal system where a MACs film is removed by a combination of a hot, clean gas and optical excitation, preferably ultraviolet (UV) light excitation, such as Vacuum UV (VUV).

[**0040**] In a further aspect thereof this invention provides a system where a wafer surface sustaining environment involves chemically filtered gas that is integrated into a metrology tool.

[**0041**] In a still further aspect thereof this invention provides a MACs removal and a wafer surface sustaining system where the sustaining and removal systems are linked such that the hot gas knife acts also as an air curtain for excluding MACs-contaminated gasses out of the sustaining environment.

[**0042**] In another aspect thereof this invention provides a MACs film removal system where thermal energy is applied to the wafer surface via an air knife, and where the thermal insult to the wafer is reduced. Since the MACs effectively boil off, most of the energy applied goes into the desorption until the MACs film is completely removed. The air knife also serves as a barrier to contaminated air that would otherwise enter the measurement environment.

[**0043**] In accordance with embodiments of this invention there is provided a MACs mitigation system that includes a first system for removing a MACs film from a surface of a wafer and a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time. The predetermined period of time is at least equal to the time required after MACs film removal to perform a desired measurement on the wafer using a metrology tool. The first system may comprise a source of microwave energy that is directed towards the MACs film. Preferably the source of microwave energy both heats and dissociates chemical constituents of the MACs film. The first system can also comprise a source of heated gas that is directed towards the MACs film (e.g., as in an air knife embodiment), and/or it can comprise a source of ultraviolet radiation that is directed towards the MACs film. In a presently preferred embodiment the second system is co-located with a measurement stage portion of the metrology tool, and comprises an atmosphere provided by a source of clean gas, where "clean" refers to a complete or at least partial absence of hydrocarbons and/or water and/or any other substance that is capable of promoting the growth of a MACs film on the surface of the substrate.

[0044] Also disclosed herein in accordance with further embodiments of this invention is a metrology system that includes a metrology tool, such as an ellipsometer or a reflectometer, and a MACs mitigation system. The MACs mitigation system includes a first system for removing a MACs film from a surface of a wafer and a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time.

[0045] Also disclosed herein in accordance with further embodiments of this invention is a MACs mitigation system that includes a first system for removing a MACs film from a surface of a wafer using any suitable means, including one or more of thermal, optical, and chemical means, and a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time at least equal to the time required after MACs film removal to perform a desired measurement on the wafer using a metrology tool.

[0046] As non-limiting examples, the thermal means can comprise one or more of RF energy, a hot plate that heats the MACs film by conduction via the wafer, and a source of heated gas that is directed towards the MACs film. The optical means may comprise a source of ultraviolet optical energy, such as a lamp or a laser.

[0047] The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the best method and apparatus presently contemplated by the inventors for carrying out the invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. As but some examples, the use of other similar or equivalent temperatures, wafers, layer thicknesses and the like may be attempted by those skilled in the art. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention.

[0048] Further, while this invention has been described in the context of an ellipsometer metrology tool, the teachings herein apply as well to reflectometry-based metrology tools.

[0049] Further still, some of the features of the present invention could be used to advantage without the corresponding use of other features. For example, the MACs film removal system **14** could be used without the wafer surface sustaining system **16**, if the start of the wafer measurement can be assured to occur within some short period of time, and if a received wafer is guaranteed to be free of a MACs film (e.g., a wafer that has just undergone high temperature processing), then the wafer surface sustaining system **16** could be used without the MACs film removal system **14**. As such, the foregoing description should be considered as merely illustrative of the principles of the present invention, and not in limitation thereof.

What is claimed is:

1. A molecular airborne contaminates (MACs) mitigation system comprising:

a first system for removing a MACs film from a surface of a wafer by directing energy towards the surface; and

a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time.

2. A MACs mitigation system as in claim 1, where the predetermined period of time is at least equal to the time required after MACs film removal to perform a desired measurement sequence or a series of measurements on the wafer using a metrology tool.

3. A MACs mitigation system as in claim 1, where said first system comprises a source of microwave energy that is directed towards the MACs film.

4. A MACs mitigation system as in claim 3, where the source of microwave energy both heats and dissociates chemical constituents of the MACs film.

5. A MACs mitigation system as in claim 1, where said first system further comprises a source of heated or clean, dry gas that is directed towards the MACs film.

6. A MACs mitigation system as in claim 1, where said first system comprises a source of ultraviolet radiation that is directed towards the MACs film.

7. A MACs mitigation system as in claim 1, where said first system comprises a source of microwave energy that is directed towards the MACs film, and a source of heated or dry, clean gas that is directed towards the MACs film.

8. A MACs mitigation system as in claim 1, where said first system comprises a source of microwave energy that is directed towards the MACs film, and a source of ultraviolet radiation that is directed towards the MACs film.

9. A MACs mitigation system as in claim 1, where said first system comprises a source of microwave energy that is directed towards the MACs film, a source of heated or clean, dry gas that is directed towards the MACs film; and a source of ultraviolet radiation that is directed towards the MACs film.

10. A MACs mitigation system as in claim 1, where said second system is co-located with a measurement stage portion of the metrology tool, and comprises an atmosphere provided by a source of clean gas characterized by a complete or partial absence of at least one of hydrocarbons, water and any other substance capable of promoting the growth of a MACs film on the surface of the substrate.

11. A MACs mitigation system as in claim 1, where said first system and said second system are subject to the same environment.

12. A metrology system, comprising:

a metrology tool; and

a molecular airborne contaminates (MACs) mitigation system comprising a first system for removing a MACs film from a surface of a wafer by directing energy towards the surface and a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time.

13. A metrology system as in claim 12, where said second system is co-located with a measurement stage portion of said metrology tool and comprises an atmosphere provided by a source of clean gas characterized by a complete or at least partial absence of at least one of hydrocarbons, water and any other substance that is capable of promoting the growth of a MACs film on the surface of the substrate.

14. A metrology system as in claim 12, where said metrology tool comprises an ellipsometer.

15. A metrology system as in claim 12, where said metrology tool comprises a reflectometer.

16. A molecular airborne contaminates (MACs) mitigation system comprising:

a first system for removing a MACs film from a surface of a wafer comprising MACs removal means comprised of directed energy means; and

a second system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time at least equal to the time required after MACs film removal to perform a desired measurement on the wafer using a metrology tool.

17. A MACs mitigation system as in claim 16, where said directed energy means comprises a source of RF energy.

18. A MACs mitigation system as in claim 16, where said directed energy means comprises a source of ultraviolet optical energy.

19. A MACs mitigation system as in claim 16, where said directed energy means comprises a jet of heated gas.

20. A MACs mitigation system as in claim 16, where said directed energy means comprises a curtain of heated gas.

21. A MACs mitigation system as in claim 16, further comprising means for cooling said wafer at least during operation of said first system.

22. A MACs mitigation system as in claim 16, where at least one of an entrance to or an exit from said first system comprises a curtain of gas.

23. A MACs mitigation system as in claim 16, further comprising a hot plate that heats the MACs film by conduction via the wafer.

24. A molecular airborne contaminates (MACs) removal system, comprising a source providing a stream of gas that is directed towards a surface of a wafer for removing a MACs film from the surface.

25. A MACs removal system as in claim 24, where said source provides chemically clean gas.

26. A MACs removal system as in claim 24, where said source provides ozone-enriched gas.

27. A MACs removal system as in claim 24, where said source provides chemically clean gas that is also provided to a MACs film formation inhibiting system.

28. A MACs removal system as in claim 24, where said source provides chemically clean gas and comprises a catalytic converter to remove at least hydrocarbons.

29. A MACs removal system as in claim 28, where heat generated from a catalytic reaction is used to warm the gas.

30. A MACs removal system as in claim 24, where said source comprises a heat exchanger.

31. A MACs removal system as in claim 24, further comprising a heater thermally coupled to a gas flow path for producing a heated gas flow at least for combusting impurities in the gas flow.

32. A MACs removal system as in claim 31, further comprising a chiller for reducing the temperature of the heated gas flow for at least one of cooling the wafer and maintaining the wafer at a temperature that is suitable for operation of a metrology tool.

33. A MACs removal system as in claim 24, further comprising an ozone generator for generating an ozone-enriched stream of gas.

34. A MACs removal system as in claim 24, further comprising a MACs film formation inhibiting system for sustaining the surface of the wafer in a substantially MACs-free condition for some predetermined period of time at least equal to the time required after MACs film removal to perform a desired measurement on the wafer using a metrology tool.

35. A method to inhibit formation of a molecular airborne contaminates (MACs) film on a surface, comprising: removing a MACs film from the surface by directing energy towards the surface; and maintaining the surface in a substantially MACs-free condition for some predetermined period of time during which a procedure is performed on or through the surface.

36. A method as in claim 35, where the predetermined period of time is at least equal to the time required after MACs film removal to perform at least one measurement on a wafer using a metrology tool.

37. A method as in claim 35, where removing includes directing microwave energy towards the MACs film.

38. A method as in claim 37, where the microwave energy is selected to both heat the MACs film and dissociate at least one chemical constituent of the MACs film.

39. A method as in claim 35, where removing includes directing at least one of heated gas towards the MACs film, and dry, clean gas towards the MACs film.

40. A method as in claim 35, where removing includes directing ultraviolet radiation towards the MACs film.

41. A method as in claim 35, where removing includes directing microwave energy towards the MACs film, and directing at least one of heated gas, and dry, clean gas towards the MACs film.

42. A method as in claim 35, where removing includes directing microwave energy towards the MACs film, and directing ultraviolet radiation towards the MACs film.

43. A method as in claim 35, where removing includes directing microwave energy towards the MACs film, directing at least one of heated gas, and dry, clean gas towards the MACs film, and directing ultraviolet radiation towards the MACs film.

44. A method as in claim 35, where maintaining occurs at a location associated with a measurement stage portion of a metrology tool, and comprises providing an atmosphere from a source of gas having a complete or at least partial absence of at least one of hydrocarbons, water and any other substance that is capable of promoting the growth of a MACs film on the surface.

45. A method as in claim 35, where removing and maintaining are carried out within the same environment.

46. A method as in claim 35, where said procedure comprises a measurement procedure that is performed on a surface associated with a semiconductor wafer.

47. A method as in claim 35, where said procedure comprises an ellipsometry-based metrology procedure that is performed on or through a surface associated with a semiconductor wafer.

48. A method as in claim 35, where said procedure comprises a reflectometry-based metrology procedure that is performed on or through a surface associated with a semiconductor wafer.

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