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(19) **United States**(12) **Patent Application Publication****Walther et al.**(10) **Pub. No.: US 2006/0040499 A1**(43) **Pub. Date:****Feb. 23, 2006**(54) **IN SITU SURFACE CONTAMINANT  
REMOVAL FOR ION IMPLANTING**(52) **U.S. Cl. .... 438/689; 315/111.81; 118/723 R;  
156/345.1; 216/58**(76) **Inventors: Steve Walther, Andover, MA (US);  
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(US); Ukyo Jeong, Andover, MA (US)**(57) **ABSTRACT**

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Inc.****35 Dory Road****Gloucester, MA 01930 (US)**(21) **Appl. No.: 10/922,710**(22) **Filed: Aug. 20, 2004****Publication Classification**(51) **Int. Cl.****H01L 21/302 (2006.01)****C23F 1/00 (2006.01)****C03C 25/68 (2006.01)**

Methods and apparatus that introduce, within the ion implant chamber or an isolated chamber in communication therewith, the capability to remove contaminants and oxide surface layers on a wafer surface prior to ion implantation, are disclosed. The mechanisms for removal of contaminants include conducting: a low energy plasma etch, heating the wafer and application of ultraviolet illumination, either in combination or individually. As a result, implantation can occur immediately after the cleaning/preparation process without the contamination potential of exposure of the wafer to an external environment. The preparation allows for the removal of surface contaminants, such as water vapor, organic materials and surface oxides.

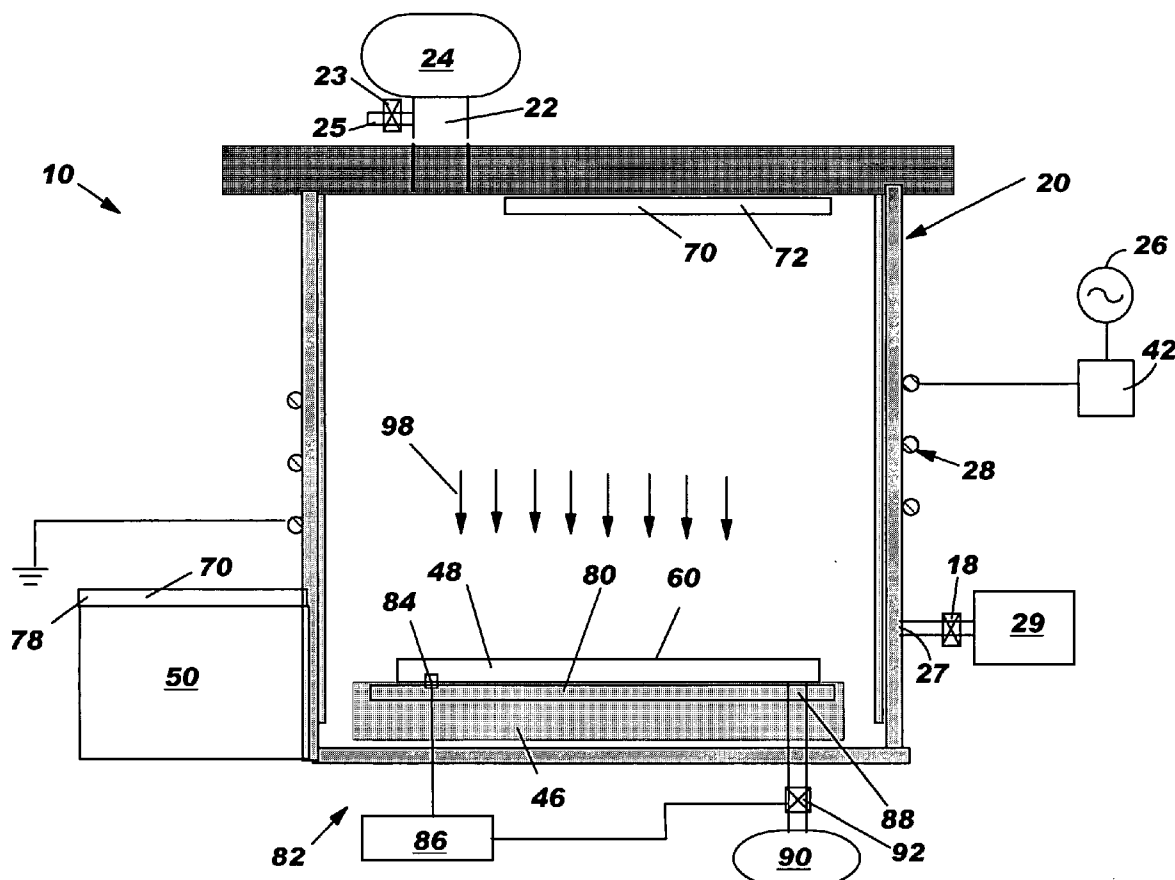


FIG. 1

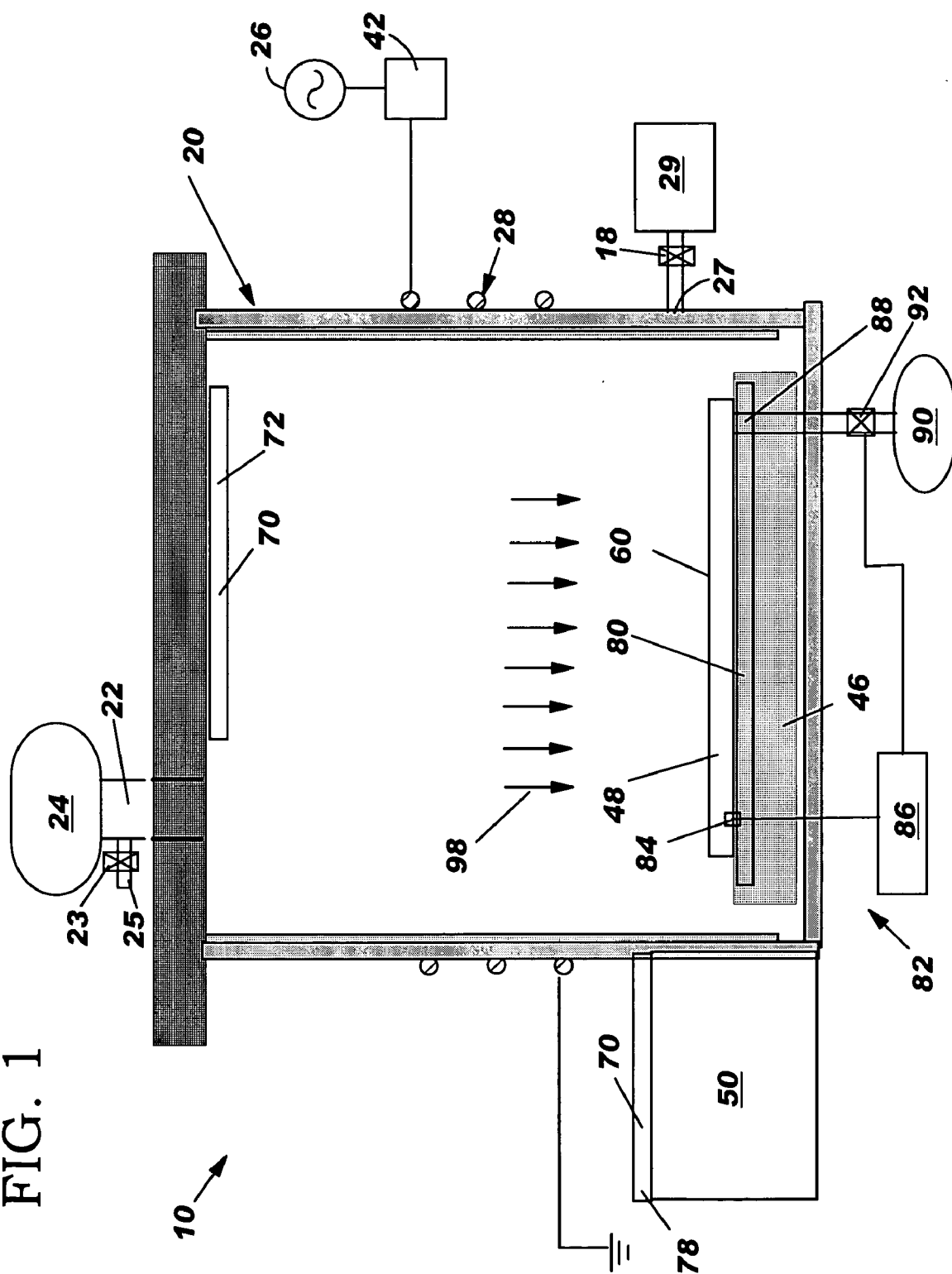
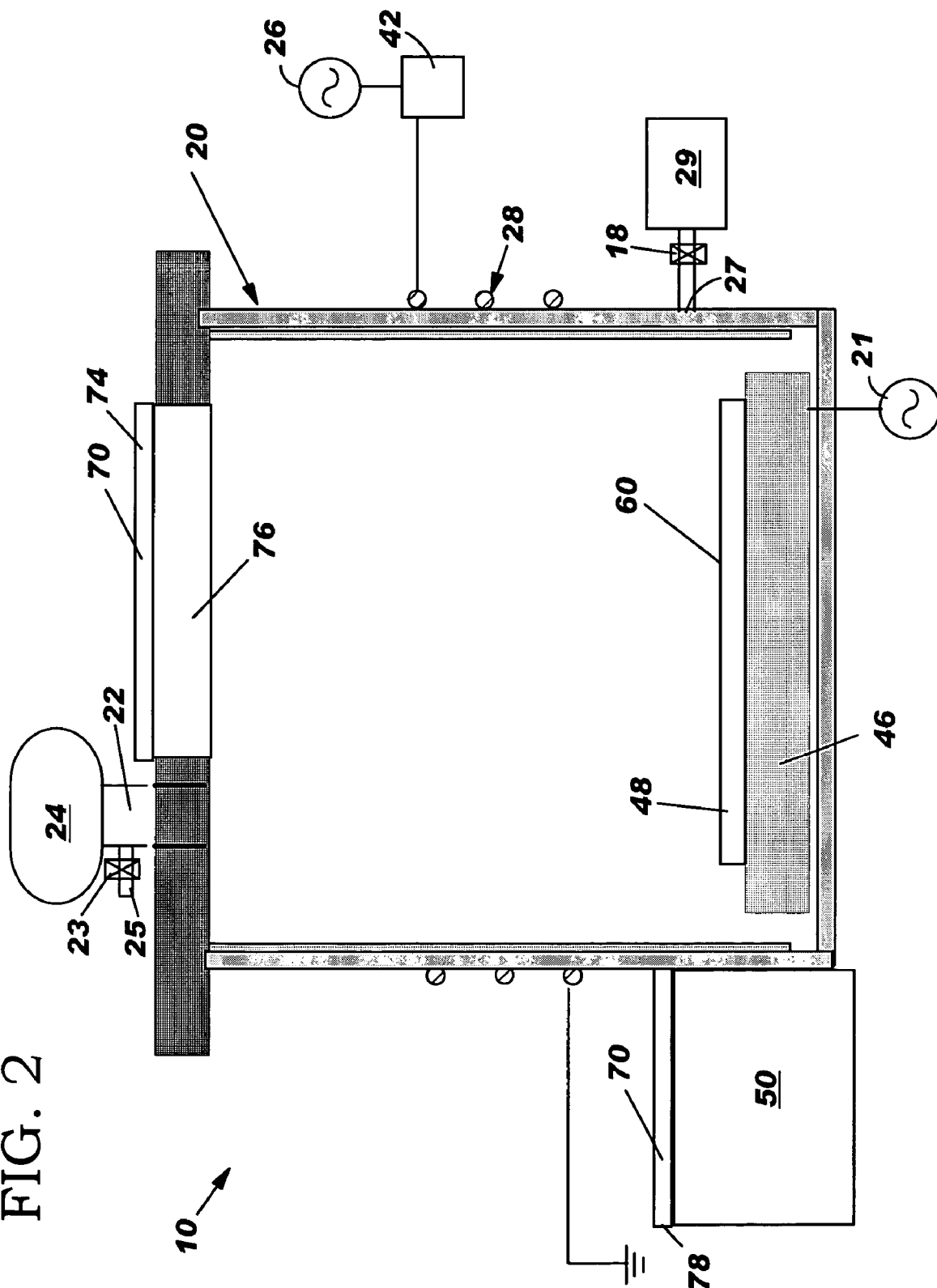


FIG. 2



## IN SITU SURFACE CONTAMINANT REMOVAL FOR ION IMPLANTING

### BACKGROUND OF THE INVENTION

#### [0001] 1. Technical Field

[0002] The present invention relates generally to ion implantation, and more particularly, to in situ surface contaminant removal for ion implanting.

#### [0003] 2. Related Art

[0004] Semiconductor wafers that are to be ion implanted typically have contaminant materials and oxides on the wafer surface. These materials can contaminate the implant process and cause dose non-uniformity and reduced dose retained in the silicon.

[0005] Conventional surface preparation procedures include pre-cleaning techniques that are external to an ion implantation chamber. One of these approaches includes stripping of native oxide from the wafer, and exposing the wafer to a high vacuum environment to allow water vapor to evaporate off of the wafer surface. Unfortunately, externally removing oxides still allows for oxide re-growth as the wafer is transported to the implant tool. Accordingly, the performance of devices on the wafer may be limited by the external environment in which they are cleaned. In addition, since the external environment is typically not controlled, the repeatability of the transport conditions also may affect performance.

[0006] In view of the foregoing, there is a need in the art for a way to prepare a wafer surface for ion implantation in situ.

### SUMMARY OF THE INVENTION

[0007] The invention includes a method and apparatus that introduce, within the ion implant chamber or an isolated chamber in communication therewith, the capability to remove contaminants and oxide surface layers on a wafer surface prior to ion implantation. The mechanisms for removal of contaminants include conducting: a low energy plasma etch, heating the wafer and application of ultraviolet illumination, either in combination or individually. As a result, implantation can occur immediately after the cleaning/preparation process without the contamination potential of exposure of the wafer to an external environment. The preparation allows for the removal of surface contaminants, such as water vapor, organic materials and surface oxides.

[0008] A first aspect of the invention is directed to an ion implanting apparatus comprising: an implant chamber; means for generating ions for implanting a wafer in the chamber; and means for removing contaminants from a surface of the wafer in situ within the implant chamber.

[0009] A second aspect of the invention is directed to a method of removing contaminants from a surface of a wafer in situ of an ion implant apparatus, the method comprising: placing the wafer in an isolated chamber that is in communication with an implant chamber; and removing contaminants from a surface of the wafer in situ within one of the isolated chamber and the implant chamber.

[0010] A third aspect of the invention is directed to a method of removing contaminants from a surface of a wafer,

the method comprising: placing the wafer in an isolated chamber that is in communication with an implant chamber; and removing contaminants from a surface of the wafer in situ within one of the isolated chamber and the implant chamber by conducting at least one of: exposing the surface to ultraviolet (UV) illumination; heating a platen that holds the wafer in the implant chamber; and controlling a radio frequency (RF) source of the implant chamber to conduct a low energy plasma etch

[0011] The foregoing and other features of the invention will be apparent from the following more particular description of embodiments of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The embodiments of this invention will be described in detail, with reference to the following figures, wherein like designations denote like elements, and wherein:

[0013] **FIG. 1** shows an ion implant apparatus according to a first embodiment of the invention.

[0014] **FIG. 2** shows an ion implant apparatus according to a second embodiment of the invention.

### DETAILED DESCRIPTION OF THE INVENTION

[0015] Referring to the attached drawings, **FIG. 1** shows an ion implant apparatus **10** according to the invention. Apparatus **10** includes an implant chamber **20** configured to receive a process gas **22** from a gas source **24**. A gas pressure controller **25** may be provided by, for example, a combination of upstream controller and variable position throttle valve **23**. An exhaust port **27** is coupled to one or more vacuum pump(s) **29**. Pressure controller **25** operates to maintain implant chamber **20** pressure to a set value by fixing exhaust conductance and varying process gas **22** flow rate in a feedback loop to allow for changing gas demand. A radio frequency (RF) source **26** is configured to resonate radio frequency currents in a radio frequency antenna **28**, which pass into implant chamber **20** and excite and ionize process gas **22** to generate plasma within the chamber. RF source **26** is coupled, via an impedance match **42**, to antenna **28** that surrounds implant chamber **20**. RF source **26** can be either pulsed or continuous. Apparatus **10** also includes a platen **46** for holding a semiconductor wafer **48**, to be implanted within implant chamber **20**. In an alternative embodiment, ion implant apparatus **10** may function using a glow discharge system in which a pulsed DC voltage (negative) is applied to the cathode (platen **46**) as one would do anyway for implant. Under suitable conditions of this wafer bias voltage and process gas **22** pressure (e.g., for  $-5$  kV and  $15$  mTorr of  $\text{BF}_3$ ) a glow discharge plasma is created. This is a pulsed plasma as the wafer bias is a pulsed signal. The pulsed wafer bias voltage is typically applied to platen **46** with the other conductive chamber components connected to electrical ground. The plasma may also be created by biasing a third electrode synchronously with the wafer bias, which may be used in cases where the wafer bias is too small to create the plasma. The pulsed DC voltage applied depends on the desired implant energy and process gas **22** used. In this case, RF source **26** is not necessary. In another alternative embodiment, the above-described plasma immersion ion implanter devices may be replaced by, for example, a

low energy beamline implanter (not shown). In any case, an isolated chamber **50** that is sealed for transport of wafers **48** to implant chamber **20** is also included. Isolated chamber **50** can include any now known or later developed load locks or wafer handler chambers.

[0016] The invention also includes a number of mechanisms for removing contaminants from a surface **60** of wafer **48**.

[0017] A first mechanism includes exposing wafer **48** to ultraviolet light. In this case, one or more ultraviolet illumination devices **70** may be employed for exposing surface **60** to ultraviolet (UV) illumination. In one embodiment, as shown in **FIG. 1**, a UV illumination device **72** is mounted within implant chamber **20**. However, in another embodiment, as shown in **FIG. 2**, a UV illumination device **74** is mounted externally of process chamber **20** and transmits UV light through a window **76** of process chamber **20**. In another embodiment, a UV illumination device **78** may also be mounted to transmit UV light into isolated chamber **50** so that a wafer **48** may be de-contaminated during transport. Alternatively, to the above-described embodiments that transmit UV light into implant chamber **20**, UV light may also be produced by RF source **26** resonating radio frequency currents to produce a UV emitting plasma, or by the above-described glow discharge system producing a UV emitting plasma. Removal of contaminants under any of the UV light exposure embodiments also preferably includes exposing wafer **48** to a vacuum of better than  $1 \times 10^{-5}$  Torr (pressure equal to that value or less) by one or more vacuum pump(s) **29**. When UV light is used in isolated chamber **50**, a vacuum may also be applied therein in a conventional fashion.

[0018] A second mechanism for removing contaminants from surface **60** includes, as shown in **FIG. 1**, heating wafer **48**. In one embodiment, this mechanism is implemented by heating platen **46** so as to heat wafer **48** in implant chamber **20**. It should be recognized, however, that a variety of other mechanisms may be implemented to heat wafer **48**, and the invention should not be limited other than as set out in the attached claims. In the former case, platen **46** may be provided with a heater **80** such as one or more embedded heating coils. This mechanism may also include a temperature controller **82** for heater **80** including a thermocouple **84** and a heater controller **86**. A gas portal **88** may also be provided for introducing a gas **90** between platen **46** and wafer **48** to improve heat transfer. Gas **90** flow may be controlled by heater controller **86** by controlling a valve **92**. Removal of contaminants by heating wafer **48** also preferably includes exposing wafer **48** to a high vacuum of better than  $1 \times 10^{-5}$  Torr (pressure equal to that value or less) by one or more vacuum pump(s) **29**.

[0019] A third mechanism for removing contaminants includes, as shown in **FIG. 1**, controlling RF source **26** to conduct a low energy plasma etch **98**. Alternatively, a pulsed glow discharge approach may be implemented that conducts a low energy plasma etch **98**. In either case, low energy plasma etch **98** uses no greater than  $-1000$  V of wafer bias, with a suitable etching process gas (e.g.,  $\text{NF}_3$ ,  $\text{SiF}_4$ ,  $\text{BF}_3$ ,  $\text{F}_2$ ,  $\text{H}_2$  etc.). In one example, low energy plasma etch **98** may use one of:  $\text{BF}_3$ ,  $\text{NF}_3$  and  $\text{F}_2$  as a plasma gas source for a subsequent  $\text{BF}_3$  plasma implantation. The duration process

may be controlled by monitoring the wafer pulsing current to detect the change in secondary electron emission as the wafer surface is altered.

[0020] A method of removing contaminants from a surface of a wafer **46** according to the invention includes placing wafer **48** in isolated chamber **50** that is in communication with implant chamber **20**, and then removing contaminants from surface **60** of wafer **48** in situ within one of isolated chamber **50** and implant chamber **20**. The removing step includes conducting at least one of: exposing surface **60** to ultraviolet (UV) illumination; heating wafer **48**; and controlling RF source **26** of implant chamber **20** to conduct low energy plasma etch **98**.

[0021] While this invention has been described in conjunction with the specific embodiments outlined above, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, the embodiments of the invention as set forth above are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. An ion implanting apparatus comprising:
  - an implant chamber;
  - means for generating ions for implanting a wafer in the chamber; and
  - means for removing contaminants from a surface of the wafer in situ within the implant chamber.
2. The apparatus of claim 1, wherein the contaminant removing means includes means for exposing the surface to ultraviolet (UV) illumination.
3. The apparatus of claim 2, wherein the exposing means is mounted externally of the implant chamber and includes a UV illumination device to transmit UV light through a window of the implant chamber.
4. The apparatus of claim 2, wherein the exposing means includes one of an internally-mounted UV illumination device and means for producing an ion plasma configured to emit UV light.
5. The apparatus of claim 4, wherein the producing means includes one of:
  - a) a radio frequency (RF) source configured to resonate radio frequency currents in a radio frequency antenna to pass into the implant chamber and excite and ionize a process gas to generate plasma within the implant chamber; and
  - b) a direct current (DC) pulse generator for generating a pulsed DC voltage in a wafer cathode to excite and ionize the process gas to generate plasma within the implant chamber.
6. The apparatus of claim 2, wherein the exposing means further includes means for exposing the wafer to a vacuum of better than  $1 \times 10^{-5}$  Torr.
7. The apparatus of claim 1, wherein the contaminant removing means includes a heater for heating the wafer.
8. The apparatus of claim 7, further comprising a temperature controller for the heater.
9. The apparatus of claim 7, further comprising a gas portal for introducing a gas between a platen that holds the wafer and the wafer to improve heat transfer.

**10.** The apparatus of claim 1, wherein the contaminant removing means includes means for conducting a low energy plasma etch.

**11.** The apparatus of claim 10, wherein the low energy plasma etch uses no greater than  $-1000$  V of wafer bias.

**12.** The apparatus of claim 10, wherein the low energy plasma etch includes using one of:

$\text{BF}_3$ ,  $\text{NF}_3$  and  $\text{F}_2$  as a plasma for a subsequent  $\text{BF}_3$  plasma implantation.

**13.** The apparatus of claim 10, wherein the ion generating means includes at least one of:

a) a radio frequency (RF) source configured to resonate radio frequency currents in a radio frequency antenna to pass into the implant chamber and excite and ionize a process gas to generate plasma within the implant chamber; and

b) a direct current (DC) pulse generator for generating a pulsed DC voltage in a wafer cathode to excite and ionize the process gas to generate plasma within the implant chamber.

**14.** A method of removing contaminants from a surface of a wafer in situ of an ion implant apparatus, the method comprising:

placing the wafer in an isolated chamber that is in communication with an implant chamber; and

removing contaminants from a surface of the wafer in situ within one of the isolated chamber and the implant chamber.

**15.** The method of claim 14, wherein the contaminant removing step includes exposing the surface to ultraviolet (UV) illumination.

**16.** The method of claim 15, wherein the exposing step includes exposing the surface to UV light through a window of one of the isolated chamber and the implant chamber.

**17.** The method of claim 15, wherein the exposing step includes exposing the surface to one of an internally-mounted UV illumination device and means for producing a UV light emitting plasma.

**18.** The method of claim 17, wherein the producing means includes one of:

a) a radio frequency (RF) source configured to resonate radio frequency currents in a radio frequency antenna to pass into the implant chamber and excite and ionize a process gas to generate plasma within the implant chamber; and

b) a direct current (DC) pulse generator for generating a pulsed DC voltage in a wafer cathode to excite and ionize the process gas to generate plasma within the implant chamber.

**19.** The method of claim 15, wherein the exposing step further includes exposing the wafer to a vacuum of better than  $1 \times 10^{-5}$  Torr.

**20.** The method of claim 14, wherein the contaminant removing step includes heating the wafer.

**21.** The method of claim 20, wherein the heating step includes heating a platen that holds the wafer in the implant chamber, and further comprising controlling a temperature of the heating.

**22.** The method of claim 20, further comprising introducing a gas between the platen and the wafer to improve heat transfer.

**23.** The method of claim 14, wherein the contaminant removing step includes controlling a radio frequency (RF) source of the implant chamber to conduct a low energy plasma etch.

**24.** The method of claim 23, wherein the low energy plasma etch uses no greater than  $-1000$  V wafer bias.

**25.** The method of claim 23, wherein the low energy plasma etch includes using one of:  $\text{BF}_3$ ,  $\text{NF}_3$  or  $\text{F}_2$  as a plasma for a subsequent  $\text{BF}_3$  plasma implantation.

**26.** A method of removing contaminants from a surface of a wafer, the method comprising:

placing the wafer in an isolated chamber that is in communication with an implant chamber; and

removing contaminants from a surface of the wafer in situ within one of the isolated chamber and the implant chamber by conducting at least one of:

exposing the surface to ultraviolet (UV) illumination;

heating a platen that holds the wafer in the implant chamber; and

controlling a radio frequency (RF) source of the implant chamber to conduct a low energy plasma etch.

**27.** The method of claim 26, wherein the exposing step includes exposing the surface to UV light through a window of one of the isolated chamber and the process chamber.

**28.** The method of claim 26, wherein the exposing step includes exposing the surface to one of an internally-mounted UV illumination device and means for producing UV light emitting plasma.

**29.** The method of claim 28, wherein the producing means includes one of:

a) a radio frequency (RF) source configured to resonate radio frequency currents in a radio frequency antenna to pass into the implant chamber and excite and ionize a process gas to generate plasma within the implant chamber; and

b) a direct current (DC) pulse generator for generating a pulsed DC voltage in a wafer cathode to excite and ionize the process gas to generate plasma within the implant chamber.

**30.** The method of claim 26, wherein the heating step further includes controlling a temperature of the heating.

**31.** The method of claim 26, wherein the heating step further includes introducing a gas between the platen and the wafer to improve heat transfer.

**32.** The method of claim 26, wherein the controlling step includes using no greater than  $0.1$  V.

**33.** The method of claim 26, wherein the controlling step includes using one of:  $\text{BF}_3$ ,  $\text{NF}_3$  or  $\text{F}_2$  as a source gas for a subsequent  $\text{BF}_3$  plasma implantation.

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