

TITLE OF INVENTION

Method and apparatus for deposition removal and precision cleaning of high purity ceramic process kits used in nanoscale semiconductor manufacturing.

1. BACKGROUND OF THE INVENTION

1.1. Field of the Invention

The present invention described herein relates in general to a method and apparatus for deposition removal, precision recycle cleaning and retexturing of high purity ceramic kits used in semiconductor production equipment, and more particularly, to a method which provide an innovative chemical and mechanical processing method that selectively and completely removes the organic, inorganic and metallic contaminants by-products which adhere to the surface of the high purity ceramic process kits, without damaging or destroying the surfaces of the ceramic process kits. And more particularly, the present invention relates to a method of removing organic contaminants, metal element contaminants, particle contaminants and the like from a ceramic process kits and the like, which is parts of semiconductor processing equipment, and which is required to have a high purity.

1.2. Description of the Related Art

As semiconductor device geometry continues to shrink from currently at about 0.18 μ m to nanoscale of 70nm, and the increases of wafer sizes, there is a need for more advanced material with higher density, purity as well as good particle and/or metal contamination control.

In nanoscale semiconductor manufacturing, a combination of extreme purity and excellent high temperature properties make high purity ceramic an ideal material for processing silicon wafers. These high purity ceramic materials are inorganic materials, and their crystal structures are made of metallic ions; not only that they have excellent strength at high temperatures, heat resistance, wear resistance, resistance to chemicals, and the like, but also resistance to physical and chemical attack, including erosion, corrosion and/or erosion-corrosion, thus creates the low contamination environment required for achieving high wafer yields and reliability and the overall equipment effectiveness.

In view of the high purity requirements for nanoscale wafer fabrication, there is a critical need for regular maintenance and precision cleaning to ensure proper performance of the equipment and process kits prior to putting it into production service. The high purity ceramic parts used in semiconductor equipment such as etching process and chemical vapor deposition process require regular maintenance and cleaning not only to ensure proper performance and capability of the equipment, but also to increase the overall equipment effectiveness and efficiency.

There are many related issues to be addressed in precision cleaning of high purity ceramic process kits, such as the capability and cleanliness requirement of the process kits, the compatibility of the cleaning process with the material/coating of the process kits, the sequence and interaction effects of wet chemistries process, and the effectiveness, usability and operability of the cleaned part.

Thus, a principal object of the present invention is to provide effective method(s) and apparatus of cleaning contaminants from ceramic surfaces in nanoscale wafer fabrication without corroding the surfaces of the ceramic process kit, and more particularly, to a method which provide an innovative chemical method that selectively and completely removes contaminants from high purity ceramic process kits surfaces without irreversibly damaging the ceramic and surface morphology and the structural integrity of the ceramic process kits.

1.3. References

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2. SUMMARY OF THE PRESENT INVENTION

The fabrication of nanoscale semiconductor devices requires the use of high purity ceramic process kits having a high level of surface purity, whether those kits are new or reconditioned. The present invention includes a Best-Known-Method (BKM) and apparatus for deposition removal and precision cleaning of high purity ceramic process kits using chemical and mechanical processing. Preferably, the process kits are cleaned using the best-known-method using both mechanical cleaning such as high pressure water-jet cleaning, clean-dry-air blowing, bead blasting, CO₂ cleaning, and oven air baking, etc., as well as chemical stripping by exposing it to the different mix-acids and chemical solvents in order to remove the organic/inorganic and metallic impurities by-products, stains, adhesions and contaminants by-products on the semiconductor production equipment parts or process kits, without damaging or destroying the surfaces of the ceramic process kits.

The present invention provides a Best-Known-Method (BKM) and apparatus for recycle cleaning of high purity ceramic process kits using mechanical and mixed chemical processing. Specifically, the mixed chemical cleaning method is designed such that while organic and inorganic contaminants being oxidized and dissolved away by use of the strong acid, the surface of the ceramic process kit is slightly etched by the fluorine-containing compound to establish a chemophobic surface so that etching residues and foreign particles can be removed. Preferably, the ceramic process kits are cleaned using the best-known-method using chemical processing by exposing it to the different mix-acids and chemical solvents in order to remove the organic/inorganic and metallic impurities by-products, stains, adhesions and contaminants by-products during wafer fabrication, without damaging or destroying the surfaces of the high purity ceramic process kits. The types and concentration of the chemical solutions such as mix-acids, solvents may vary according to the particular contaminants build-up on the ceramic process kit and other factors such as the part material type and its reactivity with respect to the cleaning chemical.

The present invention provides a method and apparatus for completely removing all process organic/inorganic, foreign particulate matter and metallic impurities by-products deposits from ceramic process kits materials as well as metallic contaminants such as aluminum, aluminum melt, nickel, stainless steel, titanium, tantalum and copper as well as elemental contaminants such as Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gallium, Germanium, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Sodium, Strontium, Tin, Titanium, Tungsten, Vanadium, Zinc and Zirconium used in the wafer fabrication.

In one embodiment of the present invention, a best-known-method (BKM) for precision cleaning of a contaminated semiconductor ceramic process kit, in which the precision cleaning method and process includes the steps of:

- (a) Incoming acceptance inspection – this is the incoming inspection method carried out to ensure a detail, proper and thorough inspection of all components of the ceramic process kits. The method generally includes receiving the ceramic process kits in protective boxes; and then dismantling the ceramic process kit carefully; and then laying out the ceramic process kits in proper sequence; and then examining the ceramic process kits for damage; inspecting the ceramic process kits to identify areas which may trap contamination and cause a virtual system leak; and the categorizing the ceramic process kits into the required recycle cleaning processes.
- (b) Mechanical Processing – This is a precision mechanical cleaning method using bead-blast cleaning and/or in combination with CO2 pellet-blast cleaning. These mechanical physical cleaning is carried out by either by the bead blasting machine and/or the CO2 blast apparatus, with suitable sizes of blasting media to strip-off deposition film to achieve the surface roughness requirements. The method generally includes setting up for deposition removal by mechanical cleaning method in the masking areas; and then masking the ceramic process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical processing; and then blasting the process kit with suitable blasting media to achieve the surface roughness requirements; and then blowing to clean the process kit surface with high pressure compressed clean-dry-air; and then inspecting the surface roughness and conditions of the process kit after the mechanical blasting; and then repeating the above-mentioned steps, until the surface roughness is achieved; in addition, the ceramic surface of the process kit may be exposed to CO2 pellets to remove any polymer residues by a combination of thermal shock and physical bombardment; and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then removing the blasting plaster and aluminum foil on the process kit surface for the next process.
- (c) Pre-Chemical Processing within a Class 10,000 Clean Room Environment – This is a pre-chemical cleaning method carried out in a controlled environment to remove gross organic/inorganic and metallic deposited contaminants. The method includes water-jetting the ceramic process kit with pressured city water-jet to remove any gross contamination (if necessary); and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then wiping the ceramic process kit with 2-propanol to remove any residues; and rinsing the ceramic process kit with deionized water; and then submerging the ceramic process kit into acetone solution; and then removing the ceramic process kit from the tank; and rinsing the ceramic process kit with deionized water; and then blowing dry the ceramic process kit with nitrogen

gas or clean-dry-air; and then soaking the ceramic process kit with the aqueous mixed alkaline chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a overflow rinse tank containing ultra-pure deionized water with ultrasonic cleaning to facilitate effective fluid exchange; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the surface cleanliness and signs of contamination, faulty cleaning or damage; and the pre-chemical cleaning sequence is repeated until the ceramic process kit is cleaned.

- (d) Chemical Processing within a Class 10,000 Clean Room Environment – This is a precision chemical cleaning method carried out within a class 10,000 clean room environment to remove organic/inorganic and metallic deposited contaminants. The method generally includes immersing or submerging the ceramic process kit with the aqueous acid chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then re-immersing or submerging the ceramic process kit into a tank with ‘chemical” aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then again re-immersing or submerging the ceramic process kit into a tank with ‘chemical” aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the ceramic process kit; and then inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage; and then repeating until the ceramic process kit is cleaned.
- (e) Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment - This is a final class 100 cleaning, baking and certification method to ensure and verify that the ceramic process kits are free from organic/inorganic, metallic and particulate impurities and that the physical surface morphology remains intact. The method generally includes rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water; and then re-rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then baking and drying of the ceramic process kit using a class 100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooling the ceramic process kit before taking out from the oven; and then inspecting and confirming the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits; and then testing the cleanliness of the physical surface of the ceramic process kits to ensure that it is

“clean” after a cleaning procedure is completed; and then certifying the results of inspection per the guidelines established; and then repeating the above-mentioned steps until the ceramic process kit is cleaned; and then assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes; and then final inspecting and documenting the critical dimensions of the assembled ceramic process kits.

- (f) Packaging and Identification within a Class 100 Clean Room Environment - This is the packaging, identification and shipment method to ensure the ceramic process kits are identified and packed carefully to ensure that it remains clean and free from damage. The method generally includes packing and vacuum sealing the ceramic process kit using an inner class 100 nylon bag and an outer poly bag; and then inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit; and then confirming the quantity of the kits and generating a correct packing list according to the delivery order with proper labeling of the ceramic process kits; and then packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.

In another embodiment, the present invention in one aspect relates to precision cleaning method and process for a contaminated ceramic process kit in which the cleaning method and process includes the steps of:

(a) Mechanical Processing

- (i) Setting up for deposition removal by mechanical cleaning method in the masking areas;
- (ii) Masking the process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical blasting;
- (iii) Blasting the process kit with suitable bead blasting media to achieve the surface roughness requirements;
- (iv) Blowing to clean the process kit surface with high pressure compressed clean-dry-air;
- (v) Inspecting the surface roughness and conditions of the process kit after the mechanical blasting;

- (vi) Repeating the above-mentioned steps, until the surface roughness is achieved;
- (vii) Blasting the ceramic kit with suitable CO₂ pellets to remove any polymer residues by a combination of thermal shock and physical bombardment;
- (viii) spraying the ceramic process kit with pressured deionized water jet to remove any residue;
- (ix) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (x) Removing the blasting plaster and aluminum foil on the process kit surface.

(b) Pre-Chemical Processing within a Class10,000 Clean Room Environment.

- (i) water-jetting the ceramic process kit with pressured city water-jet to remove any gross contamination (if necessary);
- (ii) spraying the ceramic process kit with pressured deionized water jet to remove any residue;
- (iii) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (iv) wiping the ceramic process kit with 2-propanol to remove any residues;
- (v) rinsing the ceramic process kit with deionized water;
- (vi) submerging the ceramic process kit into acetone solution;
- (vii) removing the ceramic process kit from the acetone solution tank;
- (viii) rinsing the ceramic process kit with deionized water;
- (ix) blowing dry the ceramic process kit with nitrogen gas or clean-dry-air;
- (x) submerge the ceramic process kit into a tank with an aqueous mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water (H₂O₂:NH₄OH:H₂O);
- (xi) removing the ceramic process kit from the mixed-chemical solution tank;
- (xii) rinsing the ceramic process kit in a overflow rinse tank containing deionized water with ultrasonic cleaning to facilitate effective fluid exchange rinsing the

ceramic process kit in an overflow rinse tank containing ultrasonic system and de-ionized water;

- (xiii) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (xiv) inspecting the quality of the cleaning method by checking the surface cleanliness and conditions of the ceramic process kit, as well as inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage;
- (xv) cleaning sequence is repeated until the ceramic process kit is cleaned;

(c) Chemical Processing within a Class10,000 Clean Room Environment.

- (i) immersing or submerging the ceramic process kit with an aqueous chemical solution containing Hydrochloric acids (HCL) until all stains have been removed;
- (ii) removing the ceramic process kit from the Hydrochloric acids (HCL) chemical tank;
- (iii) rinsing the ceramic process kit in an overflow rinse tank containing de-ionized water;
- (iv) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (v) immersing or submerging the ceramic process kit into a tank with ‘HPC-Clean chemical’ comprises of Nitric acids and Hydrogen fluoride aqueous mix-acid solution;
- (vi) removing the ceramic process kit from the ‘HPC-Clean” aqueous mixed-acid tank;
- (vii) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing de-ionized water;
- (viii) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (ix) repeating the above-mentioned “HPC-Clean” steps at least one time on precision chemical cleaning until the contaminants are substantially removed from the ceramic process kits, and with the proviso that the ceramic process kit may not be in contact with the chemical solution for a time greater than one cumulative hours;

- (x) inspecting the quality by checking the surface cleanliness and conditions of the ceramic process kit, as well as inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage.

(d) Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment.

- (i) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing ultra pure de-ionized water;
- (ii) rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water;
- (iii) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing ultra pure de-ionized water;
- (iv) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (v) baking and drying of the ceramic process kit using a class 100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process;
- (vi) cooling the ceramic process kit within a class 100 clean-room before taking out from the oven;
- (vii) inspecting and confirming the ceramic process kits on the surface areas for the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits;
- (viii) measuring the surface cleanliness of the ceramic process kit surface using the surface particle counter and the Inductively Coupled Plasma - Mass Spectrometry (ICPMS) method;
- (ix) repeating the above-mentioned steps until the ceramic process kit is cleaned;
- (x) assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes. The assembled ceramic process kit is final inspected and critical dimensions measured and documented. The kits, which need not be assembled, are put back to the place designated for final packaging after inspection;

(e) Packaging and Identification within a Class 100 Clean Room Environment

- (i) packaging and vacuum sealing the ceramic process kit within a class 100 clean-room using a double bags vacuum pack;
- (ii) inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit within a class 100 clean-room;
- (iii) confirming the quantity of the kits and generate a correct packing list according to the delivery order with proper labeling of the ceramic process kits;
- (iv) packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit and comply with customer specification before delivery shipment to customer.

In another embodiment, another aspect of this invention relates to a method of increasing the overall equipment effectiveness of a semiconductor production equipment, whereby the ceramic process kit is contaminated with a contaminated species deriving from a semiconductor process, in which the precision cleaning method comprising:

- (a) Incoming acceptance inspection – this is the incoming inspection method carried out to ensure a detail, proper and thorough inspection of all components of the ceramic process kits. The method generally includes receiving the ceramic process kits in protective boxes; and then dismantling the ceramic process kit carefully; and then laying out the ceramic process kits in proper sequence; and then examining the ceramic process kits for damage; inspecting the ceramic process kits to identify areas which may trap contamination and cause a virtual system leak; and the categorizing the ceramic process kits into the required recycle cleaning processes.
- (b) Mechanical Processing – This is a precision mechanical cleaning method using bead-blast cleaning and/or in combination with CO2 pellet-blast cleaning. These mechanical physical cleaning is carried out by either by the bead blasting machine and/or the CO2 blast apparatus, with suitable sizes of blasting media to strip-off deposition film to achieve the surface roughness requirements. The method generally includes setting up for deposition removal by mechanical cleaning method in the masking areas; and then masking the ceramic process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical processing; and then blasting the process kit with suitable blasting media to achieve the surface roughness requirements; and then blowing to clean the process kit surface with high pressure compressed clean-dry-air; and then inspecting the surface roughness and conditions of the process kit after the mechanical blasting; and then repeating the above-mentioned steps, until the surface roughness is achieved; in addition, the ceramic

surface of the process kit may be exposed to CO₂ pellets to remove any polymer residues by a combination of thermal shock and physical bombardment; and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then removing the blasting plaster and aluminum foil on the process kit surface for the next process.

- (c) Pre-Chemical Processing within a Class 10,000 Clean Room Environment – This is a pre-chemical cleaning method carried out in a controlled environment to remove gross organic/inorganic and metallic deposited contaminants. The method includes water-jetting the ceramic process kit with pressured city water-jet to remove any gross contamination (if necessary); and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then wiping the ceramic process kit with 2-propanol to remove any residues; and rinsing the ceramic process kit with deionized water; and then submerging the ceramic process kit into acetone solution; and then removing the ceramic process kit from the tank; and rinsing the ceramic process kit with deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then soaking the ceramic process kit with the aqueous mixed alkaline chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a overflow rinse tank containing ultra-pure deionized water with ultrasonic cleaning to facilitate effective fluid exchange; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the surface cleanliness and signs of contamination, faulty cleaning or damage; and the pre-chemical cleaning sequence is repeated until the ceramic process kit is cleaned.
- (d) Chemical Processing within a Class 10,000 Clean Room Environment – This is a precision chemical cleaning method carried out within a class 10,000 clean room environment to remove organic/inorganic and metallic deposited contaminants. The method generally includes immersing or submerging the ceramic process kit with the aqueous acid chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then re-immersing or submerging the ceramic process kit into a tank with ‘chemical’ aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then again re-immersing or submerging the ceramic process kit into a tank with ‘chemical’ aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the ceramic process kit; and then

inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage; and then repeating until the ceramic process kit is cleaned.

- (e) Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment - This is a final class 100 cleaning, baking and certification method to ensure and verify that the ceramic process kits are free from organic/inorganic, metallic and particulate impurities and that the physical surface morphology remains intact. The method generally includes rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water; and then re-rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then baking and drying of the ceramic process kit using a class 100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooling the ceramic process kit before taking out from the oven; and then inspecting and confirming the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits; and then testing the cleanliness of the physical surface of the ceramic process kits to ensure that it is “clean” after a cleaning procedure is completed; and then certifying the results of inspection per the guidelines established; and then repeating the above-mentioned steps until the ceramic process kit is cleaned; and then assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes; and then final inspecting and documenting the critical dimensions of the assembled ceramic process kits.
- (f) Packaging and Identification within a Class 100 Clean Room Environment - This is the packaging, identification and shipment method to ensure the ceramic process kits are identified and packed carefully to ensure that it remains clean and free from damage. The method generally includes packing and vacuum sealing the ceramic process kit using an inner class 100 nylon bag and an outer poly bag; and then inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit; and then confirming the quantity of the kits and generating a correct packing list according to the delivery order with proper labeling of the ceramic process kits; and then packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.

The ceramic kits cleaned using the inventive process have been found to have a surface contaminant particle density of no more than about 0.3 μm per square centimeter. In addition, the ceramic kits have also been found to have a surface trace metal contaminant concentration of no more than about 300 surface concentration ($\times 10^{10}$ atoms/ cm^2), as analyzed by ICPMS (inductively-coupled plasma mass spectrometry) for metal contamination such as Aluminum,

Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gallium, Germanium, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Sodium, Strontium, Tin, Titanium, Tungsten, Vanadium, Zinc and Zirconium, following application of this invention.

The present invention best-known-method and apparatus advantageously remove the organic and inorganic and metallic impurities by-products without damaging the original high purity ceramic process kit material or surface morphology.

Another role of the present invention is to offers a reliable, quantifiable and efficient means to attain consistent quality in all stages of recycle cleaning processes.

Another role of the present invention is to help engineers and workers to work consistently by providing a disciplined approach and a consistent best-known-method process knowledge and document the recycle cleaning work and knowledge.

Other aspects, features and advantages of the invention will be more fully apparent from the ensuing disclosure and appended claims.

3. OBJECTS AND ADVANTAGES OF THE PRESENT INVENTION

Accordingly, several objects and advantages of the present invention are of great benefits to the semiconductor manufacturing companies:

- (a) Maximize semiconductor processing equipment availability, performance efficiency, and rate of quality for optimal equipment effectiveness value and improved nanoscale wafer fabrication productivity.
- (b) Improve the rate of quality by reducing the effects of semiconductor processing equipment failure such as scrap and rework.
- (c) Reduce the bottleneck of semiconductor processing equipment throughput for improved factory wafer capacity, which can reduce the need for redundant equipment ceramic process kits.
- (d) Reduce frequent repair, shorter repair time, fewer spare parts, and lower field service cost, which all improve factory operating costs.

By implementing this invention, engineers can increase recycle cleaning process yields, increase process quality and performance, achieve faster time-to-delivery, and increase customer satisfaction, etc. The most critical advantage of this invention is improved cycle times, reduces contamination and at the same time increased overall equipment effectiveness (i.e. availability, performance efficiency, and rate of quality.)

Another object of the present invention is to provide a method of precision cleaning of a high purity ceramic kits to, easily and within a short period of time, remove organic and inorganic impurities which are present on the surface and in the vicinity of the surface of the ceramic kits so that the ceramic kits can be used in various parts of semiconductors and electronic parts.

Further objects and advantages of this invention will become apparent from a consideration of the drawings and the ensuing description.

4. SCOPE OF THE PRESENT INVENTION

The scope of the present invention covers all ultra-high vacuum, and high vacuum-related manufacturing. This is a critical precision cleaning technology for the ultra-high, and high vacuum-related manufacturing method such as semiconductor, flat panel display and mass storage manufacturing because not only that it increases the equipment effectiveness, efficiency, availability and equipment recovery times but also it decreases the total cost of ownership, production cost and spares inventory holdings.

This invention can be applied to the deposition removal and recycle cleaning of new and used high purity ceramic components and assemblies, such as focus ring, bell jars, electrostatic chucks, focus rings, shadow rings, chambers, lift pins, domes, end effectors, liners, supports, injector ports, manometer ports, screen plates, heaters, and vacuum chucks, wafer transfer hand, a chamber dome and clamp ring, parts of the apparatus for manufacturing the liquid crystal display device such as a mask plate, etc. This invention in general extends far beyond the semiconductor industry. Many applications in biological, medical, aerospace, imaging, automotive, pharmaceutical, etc. In nanoscale fabrication that need is increased by more than one order of magnitude.

The scope of this invention covers a method and apparatus for deposition removal and recycle cleaning technology using chemical and mechanical processing to clean high purity ceramic process kits used in nanoscale semiconductor manufacturing.

This invention may be used to process any number of types of parts having ceramic surfaces, including, without limitation, parts having surfaces comprised of alumina, aluminum oxide (Al₂O₃), silicon carbide (SiC), silicon nitride (Si₃N₄), yttria (Y₂O₃), zirconia (ZrO₂), aluminum nitride (AlN), and quartz, Spinel, and parts having chemical vapor deposited ceramic coatings, plasma spray ceramic coatings, and anodized ceramic coatings.

Additionally, a system and method are provided for establishing criteria to verify that the ceramic process kits are clean with respect to organic, metallic and particulate impurities and establishing criteria to verify that the physical surface morphology remains intact.

Accordingly, the scope of the present invention should be determined not by the embodiments illustrated, but by the appended claims and their legal equivalents.

5. BRIEF DESCRIPTION OF THE DRAWINGS

The above and other advantages of the invention will become more apparent from the following description taken in conjunction with the accompanying drawings wherein like references refer to like parts and wherein:

FIGURE 1 illustrates the process flowchart for deposition removal and precision cleaning of high purity ceramic process kits in accordance with the present invention.

FIGURE 2 illustrates the layout of the apparatus and the physical workflow in accordance with the present invention.

FIGURE 3 shows the cleanliness level of the ceramic surface and the effectiveness of the present invention using Inductively Coupled Plasma - Mass Spectrometry (ICPMS) method.

6. DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be described in further detail with reference to the accompanying drawings.

The concept of the present invention is based on the convergence and unification of various mechanical and mixed chemical processing techniques. The idea behind this is to provide effective ultra-clean treatment of contaminated ceramic process kits made of high purity ceramic materials. These high purity ceramic process kits are specifically used in semiconductor production equipment for etching and chemical vapour deposition process, although not limited to these processes.

This invention is the result of extensive experimental investigations using robust engineering techniques to identify and optimized the critical parameters (incorporating noise factors) on the effective aqueous chemical cleaning methods such as the sequence of reactive solutions used, the ratio of chemicals in each solution, process temperature, the wetting of contaminate surface, as well as chemical solution degradation due to reactant depletion and solution contamination, as well as the facilities, apparatus and fixtures used.

One aspect of the invention provides effective treatment of contaminated ceramic process kits to remove process-related contaminants, such as reagent residues, and reaction byproducts of reagents used in the active processing carried out in the nanoscale wafer fabrication. The primary process contamination on the ceramic process kit includes partially fluorinated hydrocarbons, elemental contaminants such as Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gallium, Germanium, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Sodium, Strontium, Tin, Titanium, Tungsten, Vanadium, Zinc and Zirconium used in the wafer fabrication. The contaminants may further comprise free iron, oxide scale, rust, grease, oil, carbonaceous and other residual chemical films, soil, particles, metal chips, and dirt.

6.1. Chemical Solutions and Mechanical Techniques Used in Present Invention

In this present invention, the chemical cleaning chemistries and acid solutions typically used for contaminant removal and recycling cleaning for the high purity ceramic process kits are Potassium Hydroxide (KOH), Hydrochloric acids (HCL), Nitric acids (HNO₃), mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water (H₂O₂:NH₄OH:H₂O), mix-acids Nitric acids and Hydrogen fluoride (HNO₃ and HF).

In this present invention, the acid solution comprises at least one acid and may be employed in any suitable concentration that removes contaminants without causing damage to the ceramic substrate. The most preferred mix-acid chemical solutions, the mix-acid species is nitric acid with a concentration preferably in a range of from about 8% to about 10% by weight, based on

the total weight of the aqueous acid solution. The mixed-acid solution may further comprise hydrogen fluoride in a concentration from about 1% to about 5% by weight. In a specific application of the cleaning process, the mixed-acid solution comprises about 10% of nitric acid and 1% hydrogen fluoride.

The weight percentage of each chemical is not limited to that specified above. For example, the amount of hydrogen fluoride may be determined according to the desired cleaning time and etching rate. If the concentration of nitric acid is too high, the stability of the cleaning solution decreases and the rate of etching caused by hydrogen fluoride decreases. Although it is conceivable to mix hydrogen fluoride and other chemicals at the same time, this leads to a decrease in the etching ability of the cleaning solution after a long time has elapsed after mixing. In view of this, it is desired that other chemicals are mixed beforehand and hydrogen fluoride is added to the mixed acids just before cleaning. In the process of the present invention, the ceramic surface to be cleaned is immersed in the liquid or the surface can be sprayed or flooded with the liquid. Generally, optimum results are obtained when the ceramic surface is immersed in the chemical.

In this present invention, the cleaning solution may comprise of at least one strong acid such as Hydrochloric acids (HCL) and Nitric acids (HNO_3), fluorine compound chemical solution such as hydrogen fluoride, an oxidizer such as hydrogen peroxide. The use of these chemicals and mixed chemical solutions allows the surface of the ceramic process kit can be etched so that the foreign particles adhering to the surface can be easily liberated, and at the same time permits the concurrent oxidation, dissolution and removal of organic and inorganic substances to be performed in the same cleaning step.

In this present invention, the types of precision mechanical cleaning techniques typically used for deposition removal and recycling cleaning are:

- (a) Clean-Dry-Air Blowing - This technique involves a jet of clean-dry-air compressed air or inert gas with particulate filtration at or near the point of delivery is used to remove particulates and liquids, particularly from blind holes, as well as surface dust.
- (b) High Pressure Water-jetting - This technique involves a jet of high-pressure water-jet to remove particulates and liquids, particularly from blind holes, as well as surface dust.
- (c) Bead Blasting - This technique involves a jet of alumina or silica or some other inert material in the form of small beads is directed onto a surface to physically strips deposited contaminants.
- (d) CO_2 Cleaning - This non-impact technique uses a jet of pellets or liquid Carbon Dioxide which is directed onto the surface to physically strips deposited contaminants.

(e) Ultrasonic Cleaning - This non-impact technique uses ultrasonic system which is directed onto the surface to remove particulates.

(f) Oven Air Baking - This technique involves baking process kits components at normal bake temperatures in air to reduce outgassing rates.

6.2. The Best-Known-Method of the present invention.

FIGURE 1 illustrates the overall generalized flowchart of the present invention, i.e. method and apparatus for deposition removal and precision cleaning of high purity ceramic process kits used in nanoscale semiconductor manufacturing.

In one embodiment of the present invention, a best-known-method (BKM) for precision cleaning of a contaminated semiconductor ceramic process kit, in which the cleaning method and process includes the steps of:

6.2.1. Incoming Acceptance Inspection

- (a) receiving the ceramic process kits in protective boxes from customers;
- (b) dismantling the ceramic process kit carefully and laying out the ceramic process kits in proper sequence on a table;
- (c) examining the ceramic process kits for damages, for example all ceramic surfaces shall be free of pitting, scale, cracks and indentations, all knife edges and vacuum sealing faces shall be checked to ensure that there are no scratches, pits, or any evidence of rolling, peeling or inclusions or any other defects that may cause sealing problems leading to vacuum leaks, all weld regions shall be free from scale, voids, blow holes, etc.
- (d) inspecting the ceramic process kits to identify areas which may trap contamination and cause a virtual system leak.;
- (e) documenting the conditions of the ceramic process kits using guidelines established, digital photographs and pictures taken as well as critical data are logged.
- (f) categorizing and preparing the ceramic process kits into the required recycle cleaning processes.

Mechanical Processing - deposition removal and precision cleaning by physical method

- (a) setting up for deposition removal by mechanical cleaning method in the masking areas;

- (b) masking the ceramic process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical blasting;
- (c) blasting the ceramic process kit with suitable blasting media such as white oxidized aluminum with a pressure of 3kg/cm^2 to 4.2 kg/cm^2 to achieve the surface roughness requirements;
- (d) blowing to clean the ceramic process kit surface with high pressure compressed clean-dry-air (dry, oil-free, and filtered at the point of use with a 0.1 micron filter);
- (e) inspecting the surface roughness and conditions of the ceramic process kit after the mechanical blasting;
- (f) repeating the above-mentioned steps, until the ceramic surface roughness is achieved;
- (g) blasting the ceramic process kit with suitable CO₂ media such as dry ice pellets (pellet size range 0.2 mm to 0.8 mm) or liquid with a pressure of 3kg/cm^2 to 4.2 kg/cm^2 for about 10-15 minutes, to remove any polymer residues by a combination of thermal shock and physical bombardment;
- (h) spraying the ceramic process kit with pressured (8 to 10 kg/cm^2) deionized water jet (resistivity 2-16 Mega Ohm/cm or higher) for 5 to 10 minutes to remove any residues. Operator must start wear dual latex gloves and use teflon fixture to handle the ceramic process kit.
- (i) blowing dry the ceramic process kit with clean (ultra-filtered to 0.1 micron or better) pressured (about 8 to 10 kg/cm^2) nitrogen gas or clean-dry-air for 5 to 10 minutes.
- (j) removing the blasting plaster and aluminum foil on the process kit surface.

6.2.2. Pre-Chemical Processing within a Class 10,000 Clean Room Environment

- (a) water-jetting the ceramic process kit with pressured (about 30 bar to 40 bar) city water for 5 to 10 minutes to remove any gross contamination (if necessary).
- (b) spraying the ceramic process kit with pressured (8 to 10 kg/cm^2) deionized water jet (resistivity 2-16 Mega Ohm/cm or higher) for 5 to 10 minutes to remove any residues. Operator must start wear dual latex gloves and use teflon fixture to handle the ceramic process kit.
- (c) blowing dry the ceramic process kit with clean (ultra-filtered to 0.1 micron or better) pressured (about 8 to 10 kg/cm^2) nitrogen gas or clean-dry-air for 5 to 10 minutes.

- (d) wiping the ceramic process kit on every surface with 2-propanol (100% semiconductor grade) to remove any residues.
- (e) rinsing the ceramic process kit with deionized water (resistivity 2-16 Mega Ohm/cm or higher) for 5 to 10 minutes from top to bottom.
- (f) submerging the ceramic process kit into acetone solution (100% semiconductor grade) for 5 to 10 minutes with a teflon fixture to hold the ceramic process kit. Use polyester sealed wipers to clean the ceramic process kit if necessary.
- (g) removing the ceramic process kit from the acetone solution tank together with the teflon fixture.
- (h) rinsing the ceramic process kit with deionized water (resistivity 2-16 Mega Ohm/cm or higher) for 5 –10 minutes from top to bottom.
- (i) blowing dry the ceramic process kit with clean (ultra-filtered to 0.1 micron or better) pressured (about 8 to 10 kg/cm²) nitrogen gas or clean-dry-air for 5 to 10 minutes.
- (j) submerging the ceramic process kit using a teflon fixture into a tank with an aqueous mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water (H₂O₂:NH₄OH:H₂O), wherein the amount of Hydrogen Peroxide, Ammonium Hydroxide and Water (H₂O₂:NH₄OH:H₂O) in said aqueous chemical solution is in the ratio of 1:1:2 by weight, based on the total weight of the solution, for 30 minutes until all stains have been removed. Ensure that the chemical solution contacts all surfaces.
- (k) removing the ceramic process kit from the aqueous mixed-chemical solution tank together with the teflon fixture.
- (l) rinsing the ceramic process kit using a teflon fixture in a overflow rinse tank containing deionized water with ultrasonic cleaning to facilitate effective fluid exchange rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system (40KHz/600W) and de-ionized water (resistivity 2-16 Mega Ohm/cm or higher) for 30 minutes, preferably at least three rinsing to ensure removal of all acid cleaning solution. The de-ionized water is ultra-filtered to remove all particles down to 0.1 um or better. All utensils that contact the rinse tanks and contents are rinsed with de-ionized water.
- (m)blowing dry the ceramic process kit with clean (ultra-filtered to 0.1 micron or better) pressured (about 8 to 10 kg/cm²) nitrogen gas or clean-dry-air for 5 minutes.
- (n) inspecting the quality of the cleaning method by checking the surface cleanliness and conditions of the ceramic process kit, as well as inspecting the ceramic process kit for signs

of contamination, faulty cleaning or damage. The ceramic process kit is visually inspected for cleanliness using a portable microscope.

- (o) Pre-chemical cleaning sequence is repeated until the ceramic process kit is cleaned.

6.2.3. Chemical Processing within a Class 10,000 Clean Room Environment

- (a) immersing or submerging the ceramic process kit with an aqueous chemical solution containing Hydrochloric acids (4 to 8% HCL) by weight, based on the total weight of the solution, for 30 minutes until all stains have been removed. Ensure that the acid solution contacts all surfaces.
- (b) removing the ceramic process kit from the Hydrochloric acids tank together with the teflon fixture.
- (c) rinsing the ceramic process kit with a teflon fixture in an overflow rinse tank containing de-ionized water (resistivity of 16 Mega Ohm/cm or higher) for 15 minutes. Preferably, the tanks are kept covered to prevent air particulates from contaminating the de-ionized water. Ensure all trapped air is removed from the internal area of the ceramic process kit.
- (d) blowing dry the ceramic process kit with clean (ultra-filtered to 0.1 micron or better) pressured (about 8 to 10 kg/cm²) nitrogen gas or clean-dry-air for 5 minutes.
- (e) re-immersing or submerging the ceramic process kit using a teflon fixture into a tank with 'HPC-Clean chemical' comprising of Nitric acids and Hydrogen fluoride (1%HF and 10%HNO₃) aqueous mix-acid solution for 15 minutes; wherein the aqueous "HPC-Clean" mix-acid solution of chemical stripping for ceramic process kits comprises Nitric acids and Hydrogen fluoride, wherein the amount of Hydrogen fluoride in said aqueous "HPC-Clean" mix-acid solution is from about 1% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 10% by weight, based on the total weight of the solution.
- (f) removing the ceramic process kit from the 'HPC-Clean" aqueous mixed-acid tank together with the teflon fixture.
- (g) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing de-ionized water (resistivity of 16 Mega Ohm/cm or higher) for about 5-10 minutes, and at about several minutes' intervals, preferably about every 5 minutes, preferably at least three rinsing to ensure removal of all acid cleaning solution. Again ensure all trapped air is removed from the internal area of the ceramic process kit.

- (h) blowing dry the ceramic process kit with clean (ultra-filtered to 0.1 micron or better) pressured (about 8 to 10 kg/cm²) nitrogen gas or clean-dry-air for 5 to 10 minutes.
- (i) repeating the above-mentioned “HPC-Clean” steps at least one time on precision chemical cleaning until the contaminants are substantially removed from the ceramic process kits, and with the proviso that the ceramic process kit may not be in contact with the chemical solution for a time greater than one cumulative hours. Once ceramic process kit components have started the cleaning process, they should complete the cycle without a break. If it is unavoidable that a delay occurs between stages, then care must be exercised that the component is thoroughly dry before storage, and all seal faces and ports must be covered. There should never be a break between any chemical cleaning stage and the subsequent water washing stage.
- (j) inspecting the quality by checking the surface cleanliness and conditions of the ceramic process kit, as well as inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage. The ceramic process kit is visually inspected for cleanliness using a portable microscope.

6.2.4. Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment

- (a) handling of all final cleaning activity must be carried out in class 100 clean-room environment. Once the cleaning process has started, components and assemblies can only be handled with talcum free latex, clean room gloves. Gloved hands that touch clean parts must not touch anything else. Immediately replace any glove which has touched an unclean surface, i.e., hair, clothing, bench, etc.
- (b) rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing ultra pure de-ionized water (resistivity of 18 Mega Ohm/cm or higher) for about 5-10 minutes, and at about several minutes' intervals, preferably about every 5 minutes, preferably at least three rinsing to ensure removal of all acid cleaning solution. Again ensure all trapped air is removed from the internal area of the ceramic process kit.
- (c) rinsing the ceramic process kit in an overflow rinse tank containing of ultrasonic system (40KHz/600W) and ultra pure de-ionized (resistivity of 18 Mega Ohm/cm or higher) water for 60 minutes within a class 100 clean-room. The ultra pure de-ionized water is ultra-filtered to remove all particles down to 0.1 um or better.
- (d) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing ultra pure de-ionized water (resistivity of 18 Mega Ohm/cm or higher) for

about 5-10 minutes. Again ensure all trapped air is removed from the internal area of the ceramic process kit.

- (e) blowing dry the ceramic process kit with high pressured (about 8 to 10 kg/cm²) nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better) for 5 to 10 minutes within a class 100 clean-room environment.
- (f) baking and drying of the ceramic process kit using a class 100 dust free air oven within a class 100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process. The baking of the ceramic process kits for a sufficient temperature of about 110°C and a sufficient time of about 60 to 80 minutes is to remove substantially all absorbed cleaning solution. The class 100 dust free air oven should be of sufficient size to accommodate the ceramic process kits and the kits should be kept away from the oven wall by jig and fixtures.
- (g) cooling the ceramic process kit within a class 100 clean-room before taking out from the oven.
- (h) inspecting and confirming the ceramic process kits on the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits.
- (i) measuring the surface particle count to ensure the surface cleanliness of the process kit surface within a class100 clean-room. The criteria for a clean process kit includes, in addition to examining visually clean and measuring the surface for particle count. The criteria for a surface particle test for the process kit materials is generally less than about 5 particles/cm² as measured by surface particle detector. Typically, a particle size of about 0.3 microns is used as a criteria particle size to test for using a surface particle detector such as QIII Plus by Pentagon technology. The physical surface morphology of the process kits is tested to ensure that it is intact after a cleaning procedure is completed. The cleaning of process kits are certified and include results of visual inspection and inspection per the guidelines established;
- (j) testing the cleanliness of the physical surface of the ceramic process kits to ensure that it is “clean” after a cleaning procedure is completed. The cleaning of ceramic process kits are certified and include results of visual inspection and inspection per the guidelines established. The criteria for a clean ceramic process kit includes, in addition to examining the ceramic kit is visually clean, but also measuring the cleanliness of the ceramic process kits using Inductively Coupled Plasma - Mass Spectrometry (ICPMS) method to ensure that it is clean after a cleaning procedure is completed. The ceramic surface cleanliness is determined by extracting the surface contamination from the “cleaned” process kit coupon with a mixed chemical solutions of 2% ultra-pure hydrofluoric acid and 2% ultra-pure

hydrogen peroxide, and then the extract is analyzed by ICPMS (inductively-coupled plasma mass spectrometry) for metal contamination such as Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gallium, Germanium, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Sodium, Strontium, Tin, Titanium, Tungsten, Vanadium, Zinc and Zirconium.

- (k) assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes within a class 100 clean-room. The assembled ceramic process kit is final inspected and critical dimensions measured and documented. The kits, which need not be assembled, are put back to the place designated for final packaging after inspection.

6.2.5. Packaging and Identification within a Class 100 Clean Room Environment

- (a) packaging and vacuum sealing the ceramic process kit within a class 100 clean-room using a double bags vacuum pack. The inner bag is a anti-static nylon bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment. The outer bag is a normal polyethylene bag of thickness 0.12mm. Before packaging, verify all parts are dry. After the component has been cleaned and baked, it must be packed carefully to ensure that it remains clean and free from damage, protect all seal faces and/or knife edges with clean used metal gaskets where possible, and cover all ports with strong clean new aluminum foil and plastic covers. Small items should be wrapped in clean aluminum foil and sealed in a polyethylene bag, under dry nitrogen gas or clean-dry-air if possible.
- (b) inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit within a class 100 clean-room.
- (c) confirming the quantity of the kits and generate a correct packing list according to the delivery order with proper labeling of the ceramic process kits. All ceramic process kits are identified per specific drawing note, and the identification must be visible through any packaging or on the outside of the package.
- (d) packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit and comply with customer specification before delivery shipment to customer.

6.3. The apparatus of the present invention.

The recycle cleaning process shall be performed with equipment and facilities capable of monitoring, controlling and recording all critical parameters that affect the quality as defined in this specification. These parameters include but are not limited to processing time, composition, and temperature of chemical baths, method of rinsing, resistivity of rinsing water and operations of ultrasonic equipment. A certified process shall be established, documented and maintained.

FIGURE 2 is an illustration of the layout of the apparatus and physical workflow for the cleaning of ceramic process kits with the present invention.

It will therefore be appreciated that the apparatus for cleaning of ceramic process kits in accordance with the present invention includes equipment and facilities such as:

- (a) De-ionized (DI) water: The source of de-ionized water have a specific resistivity of no less than 16 M Ohm-cm as determined in accordance with ASTM D1125. A proper UV light module is installed for bacteria control. At point of use, DI water used for rinsing and cleaning (except for drag out rinse) have a minimum specific resistivity of 2.0 M Ohm-cm.
- (b) Compressed Nitrogen gas gas or clean-dry-air or Air: Nitrogen gas gas or clean-dry-air or air used to dry components shall be dry, oil-free, and filtered at the point of use with a 0.1 mm filter. The filters are replaced regularly and a maintenance record should be documented.
- (c) Critical Chemicals: In-coming critical chemicals such as 2-propanol, Acetone, Hydrochloric acids (HCL), Nitric acids (HNO_3), mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$), mix-acids Nitric acids and Hydrogen fluoride (HNO_3 and HF) shall be semiconductor grade 2 and monitored for mobile ion/heavy metal levels. Maximum acceptable levels for ion contamination and heavy metals shall be established which correlate to the requirements with maintained records indicating in-coming chemical purity.
- (d) Clean-room: A Class 100 or better clean-room as defined in FED-STD-209 shall be employed for final cleaning, drying, final inspection and packaging. The operation, housekeeping, and monitoring of clean-room shall be in compliance with IES-RP-CC026 and IES-RP-CC018. The equipment required for this present invention include Class 100 clean room oven and Class 100 clean room de-ionized (DI) water rinse tanks with ultrasonic cleaning.
- (e) Process tanks: Chemical tanks for cleaning shall be monitored regularly for adequate control of chemical compositions, cleanliness and temperature. All chemical baths for cleaning shall be properly filtered and free of any visible surface films or scum. Tanks are covered when

not in use. The chemical tanks and DI water in immersion tanks are properly agitated by oil-free clean dry air or nitrogen gas or clean-dry-air and mechanical agitation is used to prevent contaminating by particles or hydrocarbons. The equipment required for the present invention are: (i) one pressured water-jet rinse tank, (ii) one acetone solution tank, (iii) one mixed-chemical solution tank (iv) one HCL chemical solution tank (v) two mix-acid tank for HF and HNO₃; (vi) two ultra pure de-ionized (DI) water rinse tanks with overflow and ultrasonic cleaning; (vii) two de-ionized (DI) water overflow rinse tanks, (viii) three ultra pure de-ionized (DI) water overflow rinse tanks.

Preferably, process equipment shall be adequately equipped and constructed of materials that will not damage or contaminate components during processing. The tanks are fabricated from polypropylene and have sufficient dimensions to completely hold the ceramic process kits and allowing for submerging thereof. More preferably, the dimensions of the tanks are design and built between 800-1000mm in length, 800-1000mm in width, and of sufficient height to provide at least a 300-600mm depth of any liquid therein. In operation, the level of mix-acids, chemical solutions or solvent in the container must be at least of sufficient quantity and depth to wet the surfaces of the ceramic process kits to create a “cleaning” effect.

The selection of the appropriate type of container or tank for the cleaning systems tends to be important. The container must be fabricated from any material that remains un-corroded in the presence of mix-acids or chemical solutions and preferably the container is fabricated of heat resistant glass or stainless steel.

The primary constituents of the rinse baths may include heavy metal waste concentration and as such, acid bath solution and rinse water should be disposed in an environmentally safe method.

FIGURE 3 illustrate the cleanliness level of the physical surface of the ceramic process kits using Inductively Coupled Plasma - Mass Spectrometry (ICPMS) method. The inductively coupled plasma - mass spectrometry (ICPMS) is a well-known method for trace element analysis because of its sub-parts-per-trillion detection limits and multi-element, multi-isotope capability. The surface cleanliness is determined by extracting the surface contamination from the process kit coupon with a mixed solution of 2% hydrofluoric acid and 2% hydrogen peroxide, and then the extract is analyzed by ICPMS (inductively-coupled plasma mass spectrometry). The amount of metal determined is expressed in terms of the number of atoms per unit area of the sample used for extraction (atoms/square cm). The concentration of metal in the sample was determined by ICPMS in the following manner. A small amount of a chemical reagents consisting of a 50:50 mixture of 2% ultra-pure hydrofluoric acid and 2% ultra-pure hydrogen peroxide is dropped onto the surface of the process kit coupon to be analyzed. The solution on the coupon surface is allowed to stand for about 10 minutes and then recovered. The concentration of metal was analyzed by ICPMS, and the figures are expressed in terms of the number of metal atoms per unit area of the process kit. The apparatus used for ICPMS was run

under the condition such as Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gallium, Germanium, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Sodium, Strontium, Tin, Titanium, Tungsten, Vanadium, Zinc and Zirconium. The results clearly show that the metal contaminations of the major elements are extremely low, thus the present invention is effective in recycle cleaning of ceramic process kits as illustrated in FIGURE 3.

It will therefore be appreciated that a method and apparatus for cleaning of semiconductor ceramic process kits in accordance with a preferred embodiment of this present invention includes:

- (a) Incoming acceptance inspection – this is the incoming inspection method carried out to ensure a detail, proper and thorough inspection of all components of the ceramic process kits. The method generally includes receiving the ceramic process kits in protective boxes; and then dismantling the ceramic process kit carefully; and then laying out the ceramic process kits in proper sequence; and then examining the ceramic process kits for damage; inspecting the ceramic process kits to identify areas which may trap contamination and cause a virtual system leak; and the categorizing the ceramic process kits into the required recycle cleaning processes.
- (b) Mechanical Processing – This is a precision mechanical cleaning method using bead-blast cleaning and/or in combination with CO₂ pellet-blast cleaning. These mechanical physical cleaning is carried out by either by the bead blasting machine and/or the CO₂ blast apparatus, with suitable sizes of blasting media to strip-off deposition film to achieve the surface roughness requirements. The method generally includes setting up for deposition removal by mechanical cleaning method in the masking areas; and then masking the ceramic process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical processing; and then blasting the process kit with suitable blasting media to achieve the surface roughness requirements; and then blowing to clean the process kit surface with high pressure compressed clean-dry-air; and then inspecting the surface roughness and conditions of the process kit after the mechanical blasting; and then repeating the above-mentioned steps, until the surface roughness is achieved; in addition, the ceramic surface of the process kit may be exposed to CO₂ pellets to remove any polymer residues by a combination of thermal shock and physical bombardment; and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then removing the blasting plaster and aluminum foil on the process kit surface for the next process.
- (c) Pre-Chemical Processing within a Class 10,000 Clean Room Environment – This is a pre-chemical cleaning method carried out in a controlled environment to remove gross

organic/inorganic and metallic deposited contaminants. The method includes water-jetting the ceramic process kit with pressured city water-jet to remove any gross contamination (if necessary); and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then wiping the ceramic process kit with 2-propanol to remove any residues; and rinsing the ceramic process kit with deionized water; and then submerging the ceramic process kit into acetone solution; and then removing the ceramic process kit from the tank; and rinsing the ceramic process kit with deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then soaking the ceramic process kit with the aqueous mixed alkaline chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a overflow rinse tank containing ultra-pure deionized water with ultrasonic cleaning to facilitate effective fluid exchange; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the surface cleanliness and signs of contamination, faulty cleaning or damage; and the pre-chemical cleaning sequence is repeated until the ceramic process kit is cleaned.

- (d) Chemical Processing within a Class 10,000 Clean Room Environment – This is a precision chemical cleaning method carried out within a class 10,000 clean room environment to remove organic/inorganic and metallic deposited contaminants. The method generally includes immersing or submerging the ceramic process kit with the aqueous acid chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then re-immersing or submerging the ceramic process kit into a tank with ‘chemical’ aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then again re-immersing or submerging the ceramic process kit into a tank with ‘chemical’ aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the ceramic process kit; and then inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage; and then repeating until the ceramic process kit is cleaned.
- (e) Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment - This is a final class 100 cleaning, baking and certification method to ensure and verify that the ceramic process kits are free from organic/inorganic, metallic and particulate impurities and that the physical surface morphology remains intact. The method generally includes rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and

ultra pure de-ionized water; and then re-rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then baking and drying of the ceramic process kit using a class 100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooling the ceramic process kit before taking out from the oven; and then inspecting and confirming the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits; and then testing the cleanliness of the physical surface of the ceramic process kits to ensure that it is “clean” after a cleaning procedure is completed; and then certifying the results of inspection per the guidelines established; and then repeating the above-mentioned steps until the ceramic process kit is cleaned; and then assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes; and then final inspecting and documenting the critical dimensions of the assembled ceramic process kits.

- (f) Packaging and Identification within a Class 100 Clean Room Environment - This is the packaging, identification and shipment method to ensure the ceramic process kits are identified and packed carefully to ensure that it remains clean and free from damage. The method generally includes packing and vacuum sealing the ceramic process kit using an inner class 100 nylon bag and an outer poly bag; and then inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit; and then confirming the quantity of the kits and generating a correct packing list according to the delivery order with proper labeling of the ceramic process kits; and then packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.

Having thus described illustrative embodiments of the invention, it will be apparent that various alterations, modifications and improvements will readily occur to those skilled in the art. Such obvious alterations, modifications and improvements, though not expressly described above, are nonetheless intended to be implied and are within the spirit and scope of the invention. Accordingly, the foregoing discussion is intended to be illustrative only, and not limiting; the invention is limited and defined only by the following claims and equivalents thereto.

While the invention has been shown and described with reference to specific features, aspects and embodiments herein, it will be appreciated that the invention is susceptible of a wide variety of other embodiments, features and implementations consistent with the disclosure herein, and the invention and claims hereafter set forth are therefore to be broadly construed and interpreted, within the spirit and scope of the foregoing disclosure.

7. THE CLAIMS

What is claimed is:

1. A Best-Known-Method on recycle cleaning for a semiconductor ceramic process kit to remove contaminant residue and species deriving from a semiconductor process, the Best-Known-Method comprising the steps of:

(a) Incoming acceptance inspection – this is the incoming inspection method carried out to ensure a detail, proper and thorough inspection of all components of the ceramic process kits. The method generally includes receiving the ceramic process kits in protective boxes; and then dismantling the ceramic process kit carefully; and then laying out the ceramic process kits in proper sequence; and then examining the ceramic process kits for damage; inspecting the ceramic process kits to identify areas which may trap contamination and cause a virtual system leak; and the categorizing the ceramic process kits into the required recycle cleaning processes.

(b) Mechanical Processing – This is a precision mechanical cleaning method using bead-blast cleaning and/or in combination with CO₂ pellet-blast cleaning. These mechanical physical cleaning is carried out by either by the bead blasting machine and/or the CO₂ blast apparatus, with suitable sizes of blasting media to strip-off deposition film to achieve the surface roughness requirements. The method generally includes setting up for deposition removal by mechanical cleaning method in the masking areas; and then masking the ceramic process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical processing; and then blasting the process kit with suitable blasting media to achieve the surface roughness requirements; and then blowing to clean the process kit surface with high pressure compressed clean-dry-air; and then inspecting the surface roughness and conditions of the process kit after the mechanical blasting; and then repeating the above-mentioned steps, until the surface roughness is achieved; in addition, the ceramic surface of the process kit may be exposed to CO₂ pellets to remove any polymer residues by a combination of thermal shock and physical bombardment; and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then removing the blasting plaster and aluminum foil on the process kit surface for the next process.

(c) Pre-Chemical Processing within a Class 10,000 Clean Room Environment – This is a pre-chemical cleaning method carried out in a controlled environment to remove gross organic/inorganic and metallic deposited contaminants. The method includes water-jetting the ceramic process kit with pressured city water-jet to remove any gross contamination (if necessary); and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then

wiping the ceramic process kit with 2-propanol to remove any residues; and rinsing the ceramic process kit with deionized water; and then submerging the ceramic process kit into acetone solution; and then removing the ceramic process kit from the tank; and rinsing the ceramic process kit with deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then soaking the ceramic process kit with the aqueous mixed alkaline chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a overflow rinse tank containing ultra-pure deionized water with ultrasonic cleaning to facilitate effective fluid exchange; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the surface cleanliness and signs of contamination, faulty cleaning or damage; and the pre-chemical cleaning sequence is repeated until the ceramic process kit is cleaned.

(d) Chemical Processing within a Class 10,000 Clean Room Environment – This is a precision chemical cleaning method carried out within a class 10,000 clean room environment to remove organic/inorganic and metallic deposited contaminants. The method generally includes immersing or submerging the ceramic process kit with the aqueous acid chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then re-immersing or submerging the ceramic process kit into a tank with ‘chemical” aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then again re-immersing or submerging the ceramic process kit into a tank with ‘chemical” aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the ceramic process kit; and then inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage; and then repeating until the ceramic process kit is cleaned.

(e) Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment - This is a final class 100 cleaning, baking and certification method to ensure and verify that the ceramic process kits are free from organic/inorganic, metallic and particulate impurities and that the physical surface morphology remains intact. The method generally includes rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water; and then re-rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then baking and drying of the ceramic process kit using a class 100 dust free air oven to remove water vapor, chemicals and spouts traps during the

cleaning process; and then cooling the ceramic process kit before taking out from the oven; and then inspecting and confirming the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits; and then testing the cleanliness of the physical surface of the ceramic process kits to ensure that it is “clean” after a cleaning procedure is completed; and then certifying the results of inspection per the guidelines established; and then repeating the above-mentioned steps until the ceramic process kit is cleaned; and then assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes; and then final inspecting and documenting the critical dimensions of the assembled ceramic process kits.

(f) Packaging and Identification within a Class 100 Clean Room Environment - This is the packaging, identification and shipment method to ensure the ceramic process kits are identified and packed carefully to ensure that it remains clean and free from damage. The method generally includes packing and vacuum sealing the ceramic process kit using an inner class 100 nylon bag and an outer poly bag; and then inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit; and then confirming the quantity of the kits and generating a correct packing list according to the delivery order with proper labeling of the ceramic process kits; and then packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.

2. The process of claim 1, wherein the contaminant on the ceramic process kits comprises a contaminant species selected from the group consisting of partially elemental tantalum, fluorinated hydrocarbons, elemental silicon, as well as elemental contaminants such as Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gallium, Germanium, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Sodium, Strontium, Tin, Titanium, Tungsten, Vanadium, Zinc and Zirconium used in the wafer fabrication. Other common contaminants include air formed oxides of silicon and germanium, free iron, oxide scale, rust, grease, oil, carbonaceous and other residual chemical films, soil, particles, metal chips, and dirt.
3. The process of claim 1(a), wherein the incoming acceptance inspection step comprises receiving, dismantling, laying out the kits, documenting with digital pictures, data logging critical dimension, inspecting and examining the ceramic for damage, and categorize and separate into different recycle cleaning process routings.

4. The process of claim 1(b), wherein the mechanical stripping comprises setting up and masking the process kits with different blasting plaster and aluminum foil to protect critical surfaces from mechanical blasting.
5. The process of claim 1(b), wherein the blasting media used for mechanical processing is white oxidized aluminum and is carried out with a blasting pressure of 3 to 5 kg/cm² to achieve the required surface roughness.
6. The process of claim 1(b), wherein the process kit is cleaned with suitable CO₂ media such as dry ice pellets (pellet size range 0.2 mm to 0.8 mm) or liquid with a pressure of 3kg/cm² to 4.2 kg/cm² for about 10-15 minutes, to remove any polymer residues by a combination of thermal shock and physical bombardment;
7. The process of claim 1(b), wherein the process kit is cleaned with pressured (8 to 10 kg/cm²) de-ionized water of resistivity of 16 Mega Ohm/cm or higher and is ultra-filtered to remove all particles down to 0.1 um or better.
8. The process of claim 1(b), wherein the process kit is cleaned and dried using high pressure ionized clean dry air (dry, oil-free, and filtered at the point of use with a 0.1 micron filter), and is carried out at a pressure range of about 60 bar to 110 bar.
9. The process of claim 1(c), wherein the ceramic process kit is cleaned with water-jet to remove any gross residues; wherein the cleaning is carried out at a high-pressure in the range of from about 30 bar to about 40 bar.
10. The process of claim 1(c), wherein the ceramic process kit surface areas are wiped cleaned with 2-propanol chemical (100% semiconductor 2 purity) on a lint free cloth to remove any residues.
11. The process of claim 1(c), wherein the ceramic process kit is rinsed with de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution;
12. The process of claim 11, wherein the de-ionized water resistivity of 16 Mega Ohm/cm or higher and is ultra-filtered to remove all particles down to 0.1 um or better.
13. The process of claim 11, wherein the process kits is rinsed in an overflow rinse tank for about 5 to about 10 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
14. The process of claim 1(c), wherein the aqueous chemical solution of chemical cleaning for the ceramic process kit comprises Acetone (semiconductor grade 2) to remove any residues.

15. The process of claim 14, wherein the Acetone (semiconductor grade 2) chemical cleaning is carried out for a contacting time of from about 5 minutes, and is carried out for not longer than 30 cumulative minutes.
16. The process of claim 1(c), wherein the aqueous chemical solution of chemical cleaning comprises mix-chemical solution Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$);
17. The process of claim 16, wherein the amount of Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) in said aqueous chemical solution is in the ratio of 1:1:2 by weight, based on the total weight of the solution.
18. The process of claim 17, wherein the Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) chemical cleaning is carried out for a contacting time of from about 30 to 45 minutes until all stains have been removed, and is carried out for not longer than one cumulative hour.
19. The process of claim 1(c), wherein the ceramic process kits are rinsed in an overflow rinse tank containing ultrasonic system and de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution.
20. The process of claim 19, wherein the ultrasonic system is 40KHz/600W.
21. The process of claim 19, wherein the de-ionized water is filtered to remove all particles down to 0.1 μm .
22. The process of claim 19, wherein the ceramic process kits is rinsed in an overflow deionized water rinse tank with ultrasonic system for about 30 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
23. The process of claim 19, wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 μm or better.
24. The process of claim 1(c), wherein the ceramic process kit is cleaned and dried using pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better), and is carried out at a pressure range of about 6 kg/cm^2 to 8 kg/cm^2 .
25. The process of claim 1(d), wherein the ceramic process kits are chemically cleaned and inspected within a class10,000 clean-room.
26. The process of claim 1(d), wherein the aqueous chemical solution of chemical cleaning comprises chemical solution Hydrochloric acids (HCL).

27. The process of claim 26, wherein the amount of Hydrochloric acids (HCL) in said aqueous acid solution is from about 6% to 8% by weight, based on the total weight of the solution.
28. The process of claim 26, wherein the Hydrochloric acids (HCL) chemical cleaning is carried out for a contacting time of from about 30 to 45 minutes, and is carried out for not longer than one cumulative hour.
29. The process of claim 1(d), wherein the aqueous "HPC-Clean" mix-acid solution of chemical cleaning for ceramic process kits comprises of Hydrofluoric Acid (HF) and Nitric Acid (HNO₃);
30. The process of claim 29, wherein the amount of Hydrofluoric Acid in said aqueous "HPC-Clean" mix-acid solution is from about 1% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 10% by weight, based on the total weight of the solution.
31. The process of claim 29, wherein the "HPC-Clean" chemical cleaning is carried out for a contacting time of from about 15 to 30 minutes, and is carried out for not longer than one cumulative hour.
32. The process of claim 1(d), wherein the ceramic process kits is rinsed in an overflow deionized water rinse tank for about 5 to about 10 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
33. The process of claim 32, wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 um or better.
34. The process of claim 1(d), wherein the ceramic process kit is cleaned and dried using pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better), and is carried out at a pressure range of about 6 kg/cm² to 8 kg/cm².
35. The process of claim 1(d), wherein the quality of the ceramic process kit is visually inspected for cleanliness using a portable microscope.
36. The process of claim 1(e), wherein the ceramic process kits are final cleaned, baked and certified within a class 100 clean-room.
37. The process of claim 1(e), wherein the ceramic process kits is multiple-rinsed with ultra pure deionised water in an overflow rinse tank for about 5 to about 10 minutes.

38. The process of claim 37 wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 um or better.
39. The process of claim 1(e), wherein the ceramic process kit is rinsed in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution, within a class 100 clean-room environment.
40. The process of claim 39, wherein the ultrasonic system is 40KHz/600W.
41. The process of claim 39, wherein the de-ionized water is controlled at a resistivity of 18 Mega Ohm/cm or higher and is ultra-filtered to remove all particles down to 0.1 um or better.
42. The process of claim 39, wherein the ceramic process kits is rinsed in an overflow rinse tank with ultrasonic system for about 60 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
43. The process of claim 1(e), wherein the ceramic process kit is cleaned and dried with pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better) within a class 100 clean-room environment.
44. The process of claim 1(e), wherein the ceramic process kit is baked and dried using a class 100 dust free air oven within a class 100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process.
45. The process of claim 44, wherein the ceramic process kits is baked for a sufficient temperature of about 100°C to 110°C and a sufficient time of about 60 to 80 minutes, to remove substantially all absorbed cleaning solution.
46. The process of claim 44, wherein the class 100 dust free air oven should be of sufficient size to accommodate the ceramic process kits and the kits should be kept away from the oven wall by jig and fixtures.
47. The process of claim 44, the ceramic process kit is cooled before taking out from the oven within a class 100 clean-room environment.
48. The process of claim 1(e), wherein the cleanliness of the physical surface of the ceramic process kits is tested using Inductively Coupled Plasma - Mass Spectrometry (ICPMS) method to ensure that it is “clean” after a cleaning procedure is completed.

49. The process of claim 1(f), wherein the ceramic process kit is packed and vacuum-sealed within a class 100 clean-room environment using a double bags vacuum pack.
50. The process of claim 50, wherein the inner bag is a anti-static nylon bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment.
51. The process of claim 50, wherein the outer bag is a normal polyethylene bag of thickness 0.12mm.
52. The process of claim 1(f), wherein the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, is inspected to ensure a complete vacuum seal packing of the ceramic process kit within a class 100 clean-room environment.
53. The process of claim 1(f), wherein the quantity of the kits is confirmed and a correct packing list according to the delivery order is generated with proper labeling of the ceramic process kits.
54. The process of claim 1(f), wherein the ceramic process kits are packed into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.
55. A chemical method and process for recycling cleaning for a contaminated ceramic process kit made of high purity ceramic, and is contaminated with contaminant species from a semiconductor production process, in which the recycling cleaning method and process includes the steps of:
 - (a) Pre-Chemical Processing within a Class 10,000 Clean Room Environment.
 - (i) water-jetting the ceramic process kit with pressured city water-jet to remove any gross contamination (if necessary);
 - (ii) spraying the ceramic process kit with pressured deionized water jet to remove any residue.
 - (iii) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
 - (iv) wiping the ceramic process kit with 2-propanol to remove any residues;
 - (v) rinsing the ceramic process kit with deionized water;
 - (vi) submerging the ceramic process kit into acetone solution;
 - (vii) removing the ceramic process kit from the acetone solution tank;

- (viii) rinsing the ceramic process kit with deionized water;
- (ix) blowing dry the ceramic process kit with nitrogen gas or clean-dry-air;
- (x) submerge the ceramic process kit into a tank with an aqueous mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$);
- (xi) removing the ceramic process kit from the mixed-chemical solution tank;
- (xii) rinsing the ceramic process kit in a overflow rinse tank containing deionized water with ultrasonic cleaning to facilitate effective fluid exchange rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and de-ionized water;
- (xiii) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (xiv) inspecting the quality of the cleaning method by checking the surface cleanliness and conditions of the ceramic process kit, as well as inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage;
- (xv) cleaning sequence is repeated until the ceramic process kit is cleaned.

(b) Chemical Processing within a Class 10,000 Clean Room Environment.

- (i) immersing or submerging the ceramic process kit with an aqueous chemical solution containing Hydrochloric acids (HCL) until all stains have been removed;
- (ii) removing the ceramic process kit from the Hydrochloric acids (HCL) chemical tank;
- (iii) rinsing the ceramic process kit in an overflow rinse tank containing de-ionized water;
- (iv) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (v) immersing or submerging the ceramic process kit into a tank with ‘HPC-Clean chemical’ comprises of Nitric acids and Hydrogen fluoride aqueous mix-acid solution;
- (vi) removing the ceramic process kit from the ‘HPC-Clean’ aqueous mixed-acid tank;

- (vii) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing de-ionized water;
- (viii) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (ix) repeating the above-mentioned “HPC-Clean” steps at least one time on precision chemical cleaning until the contaminants are substantially removed from the ceramic process kits, and with the proviso that the ceramic process kit may not be in contact with the chemical solution for a time greater than one cumulative hours;
- (x) inspecting the quality by checking the surface cleanliness and conditions of the ceramic process kit, as well as inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage.

(c) Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment.

- (i) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing ultra pure de-ionized water;
- (ii) rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water;
- (iii) re-rinsing the ceramic process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing ultra pure de-ionized water;
- (iv) blowing dry the ceramic process kit with pressured nitrogen gas or clean-dry-air;
- (v) baking and drying of the ceramic process kit using a class 100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process;
- (vi) cooling the ceramic process kit within a class 100 clean-room before taking out from the oven;
- (vii) inspecting and confirming the ceramic process kits on the surface areas for the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits;
- (viii) measuring the surface particle count to ensure the surface cleanliness of the process kit surface within a class100 clean-room;
- (ix) measuring the surface cleanliness of the ceramic process kit surface using the ICPMS method;
- (x) repeating the above-mentioned steps until the ceramic process kit is cleaned;

- (xi) assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes. The assembled ceramic process kit is final inspected and critical dimensions measured and documented. The kits, which need not be assembled, are put back to the place designated for final packaging after inspection.
- (d) Packaging and Identification within a Class 100 Clean Room Environment
- (i) packaging and vacuum sealing the ceramic process kit within a class 100 clean-room using a double bags vacuum pack;
 - (ii) inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit within a class 100 clean-room;
 - (iii) confirming the quantity of the kits and generate a correct packing list according to the delivery order with proper labeling of the ceramic process kits;
 - (iv) packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit and comply with customer specification before delivery shipment to customer.
56. The process of claim 55(a), wherein the ceramic process kits are pre-cleaned and inspected within a within a class 10,000 clean-room.
57. The process of claim 55(a), wherein the ceramic process kit is cleaned with water-jet to remove any gross residues; wherein the cleaning is carried out at a high-pressure in the range of from about 30 bar to about 40 bar.
58. The process of claim 55(a), wherein the ceramic process kit surface areas are wiped cleaned with 2-propanol chemical (100% semiconductor grade 2 purity) on a lint free cloth to remove any residues.
59. The process of claim 55(a), wherein the ceramic process kit is rinsed with de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution;
60. The process of claim 59, wherein the de-ionized water resistivity of 16 Mega Ohm/cm or higher and is ultra-filtered to remove all particles down to 0.1 um or better.
61. The process of claim 59, wherein the process kits is rinsed in an overflow rinse tank for about 5 to about 10 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.

62. The process of claim 55(a), wherein the aqueous chemical solution of chemical cleaning for the ceramic process kit comprises Acetone (semiconductor grade 2) to remove any residues.
63. The process of claim 62, wherein the Acetone (semiconductor grade 2) chemical cleaning is carried out for a contacting time of from about 5 minutes, and is carried out for not longer than 30 cumulative minutes.
64. The process of claim 55(a), wherein the aqueous chemical solution of chemical cleaning comprises mix-chemical solution Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$);
65. The process of claim 64, wherein the amount of Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) in said aqueous chemical solution is in the ratio of 1:1:2 by weight, based on the total weight of the solution.
66. The process of claim 64, wherein the Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) chemical cleaning is carried out for a contacting time of from about 30 minutes until all stains have been removed, and is carried out for not longer than one cumulative hour.
67. The process of claim 55(a), wherein the ceramic process kits are rinsed in an overflow rinse tank containing ultrasonic system and de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution.
68. The process of claim 67, wherein the ultrasonic system is 40KHz/600W.
69. The process of claim 67, wherein the de-ionized water is ultra-filtered to remove all particles down to 0.1 μm or better.
70. The process of claim 67, wherein the ceramic process kits is rinsed in an overflow rinse tank with ultrasonic system for about 30 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
71. The process of claim 67, wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 μm or better.
72. The process of claim 55(a), wherein the ceramic process kit is cleaned and dried using pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better), and is carried out at a pressure range of about 6 kg/cm^2 to 8 kg/cm^2 .

73. The process of claim 55(b), wherein the ceramic process kits are chemically cleaned and inspected within a class 10,000 clean-room.
74. The process of claim 55(b), wherein the aqueous chemical solution of chemical cleaning comprises chemical solution Hydrochloric acids (HCL).
75. The process of claim 74, wherein the amount of Hydrochloric acids (HCL) in said aqueous acid solution is from about 6% to 8% by weight, based on the total weight of the solution.
76. The process of claim 74, wherein the Hydrochloric acids (HCL) chemical cleaning is carried out for a contacting time of from about 30 minutes, and is carried out for not longer than one cumulative hour.
77. The process of claim 55(b), wherein the aqueous "HPC-Clean" mix-acid solution of chemical cleaning for ceramic process kits comprises of Hydrofluoric Acid (HF) and Nitric Acid (HNO₃);
78. The process of claim 77, wherein the amount of Hydrofluoric Acid in said aqueous "HPC-Clean" mix-acid solution is from about 1% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 10% by weight, based on the total weight of the solution.
79. The process of claim 78, wherein the "HPC-Clean" chemical cleaning is carried out for a contacting time of from about 15 to 30 minutes, and is carried out for not longer than one cumulative hour.
80. The process of claim 55(b), wherein the ceramic process kits is rinsed in an overflow rinse deionized water tank for about 5 to about 10 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
81. The process of claim 80, wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 um or better.
82. The process of claim 55(b), wherein the ceramic process kit is cleaned and dried using pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better), and is carried out at a pressure range of about 6 kg/square cm to 8 kg/square cm.
83. The process of claim 55(b), wherein the quality of the ceramic process kit is visually inspected for cleanliness using a portable microscope.
84. The process of claim 55(c), wherein the ceramic process kits are final cleaned, baked and certified within a class 100 clean-room.

85. The process of claim 55(c), wherein the ceramic process kits is multiple-rinsed with ultra pure de-ionised water in an overflow rinse tank for about 5 to about 10 minutes.
86. The process of claim 85 wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 um or better.
87. The process of claim 55(c), wherein the ceramic process kit is rinsed in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution, within a class 100 clean-room environment.
88. The process of claim 87, wherein the ultrasonic system is 40KHz/600W.
89. The process of claim 87, wherein the de-ionized water is controlled at a resistivity of 18 Mega Ohm/cm or higher and is ultra-filtered to remove all particles down to 0.1 um or better.
90. The process of claim 87, wherein the ceramic process kits is rinsed in an overflow ultra pure de-ionized water rinse tank with ultrasonic system for about 60 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
91. The process of claim 55(c), wherein the ceramic process kit is cleaned and dried with pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better) within a class 100 clean-room environment.
92. The process of claim 55(c), wherein the ceramic process kit is baked and dried using a class 100 dust free air oven within a class 100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process.
93. The process of claim 92, wherein the ceramic process kits is baked for a sufficient temperature of about 110°C and a sufficient time of about 60 to 80 minutes, to remove substantially all absorbed cleaning solution.
94. The process of claim 92, wherein the class 100 dust free air oven should be of sufficient size to accommodate the ceramic process kits and the kits should be kept away from the oven wall by jig and fixtures.
95. The process of claim 92, the ceramic process kit is cooled before taking out from the oven within a class 100 clean-room environment.

96. The process of claim 55(c), wherein the cleanliness of the physical surface of the ceramic process kits is tested using Inductively Coupled Plasma - Mass Spectrometry (ICPMS) method to ensure that it is “clean” after a cleaning procedure is completed.
97. The process of claim 55(c), wherein the ceramic process kit is packed and vacuum-sealed within a class 100 clean-room environment using a double bags vacuum pack.
98. The process of claim 97, wherein the inner bag is a anti-static nylon bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment.
99. The process of claim 97, wherein the outer bag is a normal polyethylene bag of thickness 0.12mm.
100. The process of claim 55(d), wherein the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, is inspected to ensure a complete vacuum seal packing of the ceramic process kit within a class 100 clean-room environment.
101. The process of claim 55(d), wherein the quantity of the kits is confirmed and a correct packing list according to the delivery order is generated with proper labeling of the ceramic process kits.
102. The process of claim 55(d), wherein the ceramic process kits are packed into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.
103. A method of increasing the overall equipment effectiveness and availability of a semiconductor equipment, in which comprises of a ceramic process kits that is contaminated with contaminant species deriving from a semiconductor process, the method comprising:
 - (a) Incoming acceptance inspection – this is the incoming inspection method carried out to ensure a detail, proper and thorough inspection of all components of the ceramic process kits. The method generally includes receiving the ceramic process kits in protective boxes; and then dismantling the ceramic process kit carefully; and then laying out the ceramic process kits in proper sequence; and then examining the ceramic process kits for damage; inspecting the ceramic process kits to identify areas which may trap contamination and cause a virtual system leak; and the categorizing the ceramic process kits into the required recycle cleaning processes.
 - (b) Mechanical Processing – This is a precision mechanical cleaning method using bead-blast cleaning and/or in combination with CO₂ pellet-blast cleaning. These mechanical physical cleaning is carried out by either by the bead blasting machine and/or the CO₂ blast apparatus, with suitable sizes of blasting media to strip-off

deposition film to achieve the surface roughness requirements. The method generally includes setting up for deposition removal by mechanical cleaning method in the masking areas; and then masking the ceramic process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical processing; and then blasting the process kit with suitable blasting media to achieve the surface roughness requirements; and then blowing to clean the process kit surface with high pressure compressed clean-dry-air; and then inspecting the surface roughness and conditions of the process kit after the mechanical blasting; and then repeating the above-mentioned steps, until the surface roughness is achieved; in addition, the ceramic surface of the process kit may be exposed to CO₂ pellets to remove any polymer residues by a combination of thermal shock and physical bombardment; and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then removing the blasting plaster and aluminum foil on the process kit surface for the next process.

- (c) Pre-Chemical Processing within a Class 10,000 Clean Room Environment – This is a pre-chemical cleaning method carried out in a controlled environment to remove gross organic/inorganic and metallic deposited contaminants. The method includes water-jetting the ceramic process kit with pressured city water-jet to remove any gross contamination (if necessary); and then spraying the ceramic process kit with pressured deionized water jet; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then wiping the ceramic process kit with 2-propanol to remove any residues; and rinsing the ceramic process kit with deionized water; and then submerging the ceramic process kit into acetone solution; and then removing the ceramic process kit from the tank; and rinsing the ceramic process kit with deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then soaking the ceramic process kit with the aqueous mixed alkaline chemical solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a overflow rinse tank containing ultra-pure deionized water with ultrasonic cleaning to facilitate effective fluid exchange; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the surface cleanliness and signs of contamination, faulty cleaning or damage; and the pre-chemical cleaning sequence is repeated until the ceramic process kit is cleaned.
- (d) Chemical Processing within a Class 10,000 Clean Room Environment – This is a precision chemical cleaning method carried out within a class 10,000 clean room environment to remove organic/inorganic and metallic deposited contaminants. The method generally includes immersing or submerging the ceramic process kit with the aqueous acid chemical solution; and then removing the ceramic process kit from the

tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then re-immersing or submerging the ceramic process kit into a tank with ‘chemical” aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then again re-immersing or submerging the ceramic process kit into a tank with ‘chemical” aqueous mix-acid solution; and then removing the ceramic process kit from the tank; and then rinsing the ceramic process kit in a rinse tank containing deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air; and then inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the ceramic process kit; and then inspecting the ceramic process kit for signs of contamination, faulty cleaning or damage; and then repeating until the ceramic process kit is cleaned.

- (e) Final Cleaning, Baking and Certification within a Class 100 Clean Room Environment - This is a final class 100 cleaning, baking and certification method to ensure and verify that the ceramic process kits are free from organic/inorganic, metallic and particulate impurities and that the physical surface morphology remains intact. The method generally includes rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then rinsing the ceramic process kit in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water; and then re-rinsing the ceramic process kit in a rinse tank containing ultra pure deionized water; and then blowing dry the ceramic process kit with nitrogen gas or clean-dry-air ; and then baking and drying of the ceramic process kit using a class 100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooling the ceramic process kit before taking out from the oven; and then inspecting and confirming the non-existent of stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the ceramic process kits; and then testing the cleanliness of the physical surface of the ceramic process kits to ensure that it is “clean” after a cleaning procedure is completed; and then certifying the results of inspection per the guidelines established; and then repeating the above-mentioned steps until the ceramic process kit is cleaned; and then assembling the ceramic process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes; and then final inspecting and documenting the critical dimensions of the assembled ceramic process kits.
- (f) Packaging and Identification within a Class 100 Clean Room Environment - This is the packaging, identification and shipment method to ensure the ceramic process kits are identified and packed carefully to ensure that it remains clean and free from

damage. The method generally includes packing and vacuum sealing the ceramic process kit using an inner class 100 nylon bag and an outer poly bag; and then inspecting the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, to ensure a complete vacuum seal packing of the ceramic process kit; and then confirming the quantity of the kits and generating a correct packing list according to the delivery order with proper labeling of the ceramic process kits; and then packing into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.

104. The process of claim 103, wherein the contaminant on the ceramic process kits comprises a contaminant species selected from the group consisting of partially elemental tantalum, fluorinated hydrocarbons, elemental silicon, as well as elemental contaminants such as Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gallium, Germanium, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Sodium, Strontium, Tin, Titanium, Tungsten, Vanadium, Zinc and Zirconium used in the wafer fabrication. Other common contaminants include air formed oxides of silicon and germanium, free iron, oxide scale, rust, grease, oil, carbonaceous and other residual chemical films, soil, particles, metal chips, and dirt.
105. The process of claim 103(a), wherein the incoming acceptance inspection step comprises receiving, dismantling, laying out the kits, documenting with digital pictures, data logging critical dimension, inspecting and examining the ceramic for damage, and categorize and separate into different recycle cleaning process routings.
106. The process of claim 103(b), wherein the ceramic process kits are pre-cleaned and inspected within a within a class10,000 clean-room.
107. The process of claim 103(b), wherein the ceramic process kit is cleaned with water-jet to remove any gross residues; wherein the cleaning is carried out at a high-pressure in the range of from about 30 bar to about 40 bar.
108. The process of claim 103(b), wherein the ceramic process kit surface areas are wiped cleaned with 2-propanol chemical (100% semiconductor grade 2 purity) on a lint free cloth to remove any residues.
109. The process of claim 103(b), wherein the ceramic process kit is rinsed with deionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution;
110. The process of claim 109, wherein the de-ionized water resistivity of 16 Mega Ohm/cm or higher and is ultra-filtered to remove all particles down to 0.1 um or better.

111. The process of claim 109, wherein the process kits is rinsed in an overflow rinse tank for about 5 to about 10 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
112. The process of claim 103(b), wherein the aqueous chemical solution of chemical cleaning for the ceramic process kit comprises Acetone (semiconductor grade 2) to remove any residues.
113. The process of claim 112, wherein the Acetone (semiconductor grade 2) chemical cleaning is carried out for a contacting time of from about 5 minutes, and is carried out for not longer than 30 cumulative minutes.
114. The process of claim 103(b), wherein the aqueous chemical solution of chemical cleaning comprises mix-chemical solution Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$);
115. The process of claim 114, wherein the amount of Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) in said aqueous chemical solution is in the ratio of 1:1:2 by weight, based on the total weight of the solution.
116. The process of claim 114, wherein the Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) chemical cleaning is carried out for a contacting time of from about 30 minutes until all stains have been removed, and is carried out for not longer than one cumulative hour.
117. The process of claim 103(b), wherein the ceramic process kits are rinsed in an overflow rinse tank containing ultrasonic system and de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution.
118. The process of claim 117, wherein the ultrasonic system is 40KHz/600W.
119. The process of claim 117, wherein the de-ionized water is ultra-filtered to remove all particles down to 0.1 μm or better.
120. The process of claim 117, wherein the ceramic process kits is rinsed in an overflow deionized water rinse tank with ultrasonic system for about 30 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
121. The process of claim 117, wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 μm or better.

122. The process of claim 103(b), wherein the ceramic process kit is cleaned and dried using pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better), and is carried out at a pressure range of about 6 kg/square cm to 8 kg/square cm.
123. The process of claim 103(c), wherein the ceramic process kits are chemically cleaned and inspected within a class 10,000 clean-room.
124. The process of claim 103(c), wherein the aqueous chemical solution of chemical cleaning comprises chemical solution Hydrochloric acids (HCL).
125. The process of claim 124, wherein the amount of Hydrochloric acids (HCL) in said aqueous acid solution is from about 6% to 8% by weight, based on the total weight of the solution.
126. The process of claim 124, wherein the Hydrochloric acids (HCL) chemical cleaning is carried out for a contacting time of from about 30 minutes, and is carried out for not longer than one cumulative hour.
127. The process of claim 103(c), wherein the aqueous "HPC-Clean" mix-acid solution of chemical cleaning for ceramic process kits comprises of Hydrofluoric Acid (HF) and Nitric Acid (HNO₃);
128. The process of claim 127, wherein the amount of Hydrofluoric Acid in said aqueous "HPC-Clean" mix-acid solution is from about 1% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 10% by weight, based on the total weight of the solution.
129. The process of claim 127, wherein the "HPC-Clean" chemical cleaning is carried out for a contacting time of from about 15 to 30 minutes, and is carried out for not longer than one cumulative hour.
130. The process of claim 103(c), wherein the ceramic process kits is rinsed in an overflow deionized water rinse tank for about 5 to about 10 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
131. The process of claim 130, wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 um or better.
132. The process of claim 103(c), wherein the ceramic process kit is cleaned and dried using pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better), and is carried out at a pressure range of about 6 kg/cm² to 8 kg/cm².

133. The process of claim 103(c), wherein the quality of the ceramic process kit is visually inspected for cleanliness using a portable microscope.
134. The process of claim 103(d), wherein the ceramic process kits are final cleaned, baked and certified within a class 100 clean-room.
135. The process of claim 103(d), wherein the ceramic process kits is multiple-rinsed with ultra pure deionised water in an overflow rinse tank for about 5 to about 10 minutes.
136. The process of claim 135 wherein deionized water used for rinsing is controlled at a resistivity of 16 Mega Ohm/cm or higher and ultra-filtered to substantially remove all particles down to 0.1 um or better.
137. The process of claim 103(d), wherein the ceramic process kit is rinsed in an overflow rinse tank containing ultrasonic system and ultra pure de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution, within a class 100 clean-room environment.
138. The process of claim 137, wherein the ultrasonic system is 40KHz/600W.
139. The process of claim 137, wherein the de-ionized water is controlled at a resistivity of 18 Mega Ohm/cm or higher and is ultra-filtered to remove all particles down to 0.1 um or better.
140. The process of claim 137, wherein the ceramic process kits is rinsed in an overflow rinse tank with ultrasonic system for about 60 minutes, with multiple dippings in a drained, cleaned and refilled rinse tank.
141. The process of claim 103(d), wherein the ceramic process kit is cleaned and dried with pressured nitrogen gas or clean-dry-air (dry, oil-free, and ultra-filtered to 0.1 micron or better) within a class 100 clean-room environment.
142. The process of claim 103(d), wherein the ceramic process kit is baked and dried using a class 100 dust free air oven within a class 100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process.
143. The process of claim 142, wherein the ceramic process kits is baked for a sufficient temperature of about 110°C and a sufficient time of about 60 to 80 minutes, to remove substantially all absorbed cleaning solution.
144. The process of claim 142, wherein the class 100 dust free air oven should be of sufficient size to accommodate the ceramic process kits and the kits should be kept away from the oven wall by jig and fixtures.

145. The process of claim 142, the ceramic process kit is cooled before taking out from the oven within a class 100 clean-room environment.
146. The process of claim 103(d), wherein the cleanliness of the physical surface of the ceramic process kits is tested using Inductively Coupled Plasma - Mass Spectrometry (ICPMS) method to ensure that it is “clean” after a cleaning procedure is completed.
147. The process of claim 103(e), wherein the ceramic process kit is packed and vacuum-sealed within a class 100 clean-room environment using a double bags vacuum pack.
148. The process of claim 147, wherein the inner bag is a anti-static nylon bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment.
149. The process of claim 147, wherein the outer bag is a normal polyethylene bag of thickness 0.12mm.
150. The process of claim 103(e), wherein the condition of the vacuum pack such as leaking and breakage of the anti-static polyethylene bag, is inspected to ensure a complete vacuum seal packing of the ceramic process kit within a class 100 clean-room environment.
151. The process of claim 103(e), wherein the quantity of the kits is confirmed and a correct packing list according to the delivery order is generated with proper labeling of the ceramic process kits.
152. The process of claim 103(e), wherein the ceramic process kits are packed into a proprietary-designed container box with cushion designated to properly protect and secure the ceramic process kit before delivery shipment to customer.
153. The apparatus for recycle cleaning of semiconductor ceramic process kits in comprises of the equipment and facilities such as: (a) De-ionized water source; (b) compressed nitrogen gas or clean-dry-air; (c) Class 10000/1000/100 clean-rooms; (d) Process Tanks; (e) high pressure water-jet; (f) ultrasonic systems; (g) vacuum pack system; (h) quality control equipment.
154. The apparatus of claim 153(a), wherein the source of de-ionized water have a specific resistivity of no less than 18 Mega Ohm-cm as determined in accordance with ASTM D1125, with a proper UV light module is installed for bacteria control, and at point of use, de-ionised water used for rinsing and cleaning have a minimum specific resistivity of 2 Mega Ohm-cm or higher.
155. The process of claim 154, wherein the de-ionized water used for various stages of rinsing referenced in this invention meet the following requirements: (a) for drag-out rinse: Rinse by spray or immersion is acceptable by using cold de-ionized water with specific resistivity

of no less than 2 Mega Ohm-cm, (b) for spray rinse: use cold de-ionized water with specific resistivity of no less than 2 M Ohm-cm,

156. The apparatus of claim 153(b), wherein the Nitrogen gas or clean-dry-air used to dry components shall be dry, oil-free, and filtered at the point of use with a 0.1 mm filter.
157. The apparatus of claim 153(c), wherein the equipment required include Class 100 clean room oven and Class 100 clean room ultra pure deionized (DI) water rinse tanks with ultrasonic cleaning.
158. The apparatus of claim 153(d), wherein the equipment required are properly agitated by oil-free clean dry air or nitrogen gas or clean-dry-air and mechanical agitation is used to prevent contaminating by particles, and includes: (i) one pressured water-jet rinse tank, (ii) one acetone solution tank, (iii) one mixed-chemical solution tank (iv) one HCL chemical solution tank (v) two mix-acid tank for HF and HNO₃; (vi) two ultra pure de-ionized (DI) water rinse tanks with overflow and ultrasonic cleaning; (vii) two de-ionized (DI) water overflow rinse tanks, (viii) three ultra pure de-ionized (DI) water overflow rinse tanks.
159. The apparatus of claim 158, wherein the tanks are fabricated from polypropylene and have sufficient dimensions to completely hold the ceramic process kits and allowing for submerging thereof. More preferably, the dimensions of the tanks are design and built between 800-1000mm in length, 800-1000mm in width, and of sufficient height to provide at least a 300-600mm depth of any liquid therein. In operation, the level of mix-acids, chemical solutions or solvent in the container must be at least of sufficient quantity and depth to wet the surfaces of the ceramic process kits to create a "cleaning" effect.