

TITLE OF INVENTION

Method and apparatus for deposition removal and recycle cleaning of copper interconnect semiconductor process kits.

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 and recycle cleaning of process kits for copper interconnect semiconductor production equipment, and more particularly, to a method and system which provide an innovative chemical and mechanical processing method that selectively and completely removes the organic, inorganic and metallic impurities by-products, stains, adhesions as well as contaminants by-products on the semiconductor production equipment parts or process kits, without damaging or destroying the surfaces of the process kits.

1.2. Description of the Related Art

In the field of semiconductor manufacturing, various semiconductor production equipment and process kits are used to perform processes, such as film formation, etching, oxidation, and diffusion, on a target substrate, e.g., a semiconductor wafer. One of the primary steps in the manufacturing of semiconductor devices is the continuous formation of a thin film on a semiconductor substrate to form a film of solid material by a deposition process using high vacuum semiconductor production equipment. These semiconductor production equipment are generally classified as deposition equipment according to their methods of forming thin films. These deposition equipment can be further classified as a PVD (Physical Vapor Deposition) sputtering method using a sputtering phenomenon under reduced pressure, a vacuum evaporation method using an evaporation phenomenon, a plasma CVD (Chemical Vapor Deposition) method using low temperature gas decomposition by plasma, a thermal CVD method using heat decomposition of a gas, a photo-CVD method for decomposing a gas by energy of short wavelength light or ultraviolet rays, and the like. These semiconductor production equipment requires process kits, which usually consist of a set of individual

components assembled together, and they are used to prevent sputtered material from depositing on the walls and other parts of the chamber.

During the thin film deposition process, a metal such as Ti, Al or Cu, or a metal compound such as WSi, TiN or TiSi is deposited through the vacuum to form a thin film onto the semiconductor substrate. However, during these thin film deposition processes, organic, inorganic and metallic impurities by-products are deposited on the surfaces of the process kits as well. The sputtered material deposits not only on the wafer substrate, but also on surrounding parts of the process kits such as the chamber, shields, cover ring, disc, depo ring, etc. Thus, the continuous use of such deposition equipment will cause the process kits to become coated with the sputtered material and, due to build up of material and eventually results in flaking of the deposited materials. When the thickness of the by-product increases, the by-product cracks and peels off for example due to a change in the processing parameters. Consequently, the peeled by-product will cause particle contamination during the deposition process, resulting in deposition failure and defects

Furthermore, the accumulation of these contaminants by-products on the surfaces of the process kits will cause problems in semiconductor manufacturing such as contaminating wafers with particles, as well as organic and metallic impurities affecting the process chemistries. These contamination, if not properly and adequately removed, could cause irreversibly damaged and reduced lifespan of the process kits, chemical reactions and explosions, false readings of instruments, or inaccurate measurements which ultimately could result in a malfunction or total failure of the system or device. Once flaking and particle generation has begun, the process kits must be disassembled and the various parts cleaned or replaced. Therefore, the continuous use of the deposition equipment creates 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.

However, most semiconductor process kits are made from a combination of stainless steel or aluminum, and may contained copper, titanium, beryllium, ceramics of various sorts, and various other materials. In order to clean a semiconductor process kits to the highest standards so that it is capable of working at high vacuum with very low levels of contaminants in the residual vacuum, careful consideration must be given to how the process kit is to be cleaned and cleaning process must not damage the component being cleaned. The cleaning method should, not only completely remove the contaminants, but also remove particles and metallic impurities without corroding, damaging or altering the process kits material and surface morphology. In addition, multiple parameters such as hardness, porosity, thermal coefficient of expansion, conductivity, noise effects, chemical permeability and corrosion resistance, etc., must also be

considered to formulate an effective and appropriate cleaning methods and recipes. Therefore, what is needed is a method and apparatus for completely removing all process organic and inorganic deposits from metal process kits materials as well as metallic contaminants such as aluminum, aluminum melt, nickel, stainless steel, titanium, tantalum and copper.

Further, the precision cleaning method must be effective with appropriate apparatus, cleaning methods and recipes to remove organic contaminants as well as particles and metallic impurities without changing the chemical structure of the metallic, quartz or ceramic surface. Otherwise the precision cleaning process will thereby corrode, damage or alter the process kits material and surface morphology, which consequently resulted in irreversibly damaged and the lifetime of the process kit is significantly shortened

Additionally, what is needed is to establish criteria to verify that the process kits are clean with respect to organic, metallic and particulate impurities and to establish criteria to verify that the physical surface morphology remains intact. There are two different approaches to determining whether or not a surface is clean. The more fundamental one is to perform a chemical analysis of some sort on the surface to determine what is there. The second approach is more pragmatic and simply seeks to measure the properties of interest. To study the effects of precision cleaning treatments, engineer should measure in a systematic way how the properties of interest change. Unfortunately, few such systematic studies have been undertaken and published, so there are poor statistics on the efficacy of precision cleaning processes.

There are many related issues to be addressed in assessing a precision cleaning method, 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 deposition removal process, and the effectiveness, usability and operability of the cleaned part. Therefore, each deposition removal and recycling precision cleaning process for different process kits must be custom-made for the specific process kits and component, exposed surfaces and nature of contamination as well as process compatibility.

Thus, a principal object of the present invention is to provide some effective methods and apparatus for deposition removal and recycle cleaning of process kits for semiconductor production equipment, and more particularly, to a method and system which provide an innovative chemical and mechanical processing method that selectively and completely removes contaminants from process kits surfaces without irreversibly damaging the process kits and surface morphology of the process kits.

1.3. References

1. ASTM D 1125 - Test Methods for Electrical Conductivity and Resistivity of Water.
2. ASTM D 1193 - Standard Specification for Reagent Water.
3. ASTM E 1151 - Practice for Ion Chromatography Terms and Relationship.
4. ASTM E 1559 - Contamination Outgassing Characteristics of Spacecraft Materials.
5. FED-STD-209 - Airborne Particulate Cleanliness Classes in Clean-rooms and Clean Zones.
6. IES-RP-CC018 – Clean-room Housekeeping – Operating and Monitoring Procedures.
7. IES-RP-CC026 – Clean-room Operations.
8. US EPA Method 300.0 - Determination of Inorganic Anions by Ion Chromatography.
9. US EPA Method 300.7 - Dissolved Sodium, Ammonium, Potassium, Magnesium, and Calcium in Wet Deposition by Chemically Suppressed Ion Chromatography.

2. SUMMARY OF THE PRESENT INVENTION

The present invention includes a Best-Known-Method (BKM) and apparatus for deposition removal and recycle cleaning of copper interconnect semiconductor 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 process kits. The present invention provides a method and apparatus for completely removing all process organic/inorganic and metallic impurities by-products deposits from process kits materials as well as metallic contaminants such as aluminum, aluminum melt, nickel, stainless steel, titanium, tantalum and copper used in the making of semiconductor process kits.

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

(a) Acceptance Inspection – receiving, incoming inspection to thoroughly examine, dismantle, and data documented with digital pictures; and then categorize and separate into the required deposition removal and recycle cleaning processes such as the chemical-method and mechanical-method. Any gross contaminations are removed by washing out, swabbing or rinsing with high-pressure city water or any general-purpose solvent.

(b) Chemical Stripping – This is a precision chemical cleaning method to strip-off or dissolve organic/inorganic and metallic deposited contaminants according to the process kits materials and type of deposited contaminants. The method generally includes immersing or submerging the process kit into a tank with an aqueous mixed-acid solution; and then removing the process kit from the mix-acid tank; and then rinsing the process kit in an overflow rinse tank containing warm city water; and then water-jetting the process kit surface with high pressure city water to remove any residues; and then re-immersing or submerging the process kit into a tank with ‘bright dip’ aqueous mix-acid solution; and then removing the process kit from the ‘bright dip’ aqueous mixed-acid tank; and then re-rinsing the process kit in an overflow rinse tank containing warm city water; and then water-jetting the process kit surface with high pressure city

water to remove any residues; and then repeating until contaminants are substantially removed from the process kits; and then rinsing the process kit in an overflow rinse tank containing warm de-ionized water; and then blowing dry the process kit with high pressure compressed clean-dry-air; and then inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the process kit; and then inspecting the process kit for signs of contamination, faulty cleaning or damage; and then repeating until the process kit is cleaned.

(c) Mechanical Stripping – This is a precision mechanical cleaning method using blasting machine with suitable blasting media to strip-off deposition film to achieve the surface roughness requirements and appropriate adhesion between the process kit substrate and the coating film. The method generally includes setting up for deposition removal by mechanical cleaning method in the masking areas; and then masking the process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical blasting; 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; and then removing the blasting plaster and aluminum foil on the process kit surface for the next process.

(d) Thin-film Thermal Coating – This is a precision thermal spraying method using a thermal spray system with a suitable deposition media and proprietary-optimized spraying techniques to achieve the thickness and surface roughness requirements to prevent particle issues during usage. The method generally includes masking with thermal plaster and aluminum foil to protect critical surface from thermal spray; and then spraying to coat the process kit surface with proprietary-optimized spraying parameters (current, voltage, speed, distance) according to the deposition media and the thickness and 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 thermal spraying; and then repeating the above-mentioned steps, until the surface roughness is achieved; and then removing the thermal plaster and aluminum foil on the process kit surface for the next process.

(e) Post-Processes Class1000 Cleaning and Inspection – This is a post-processes overall cleaning and inspection method to ensure the quality of the deposition removal and recycling cleaning method is achieved. The method generally includes blowing to clean on the process kit surface to remove particles using high pressure compressed clean-dry-air; and then wiping to clean the non-blasted/sprayed process kit surface areas with some solvents; and then cleaning the process kit with high pressure water-jet system; and then rinsing the process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water; and then cleaning

the process kit with high pressure de-ionized water-jet system; and then blowing dry the process kit with high pressure compressed clean-dry-air; and then inspecting the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition, as well as for stain, dirt, defect and fracture; and then inspecting the quality of the deposition removal and recycling cleaning method by checking the surface cleanliness and conditions of the process kit; and then repeating the above-mentioned steps, until the process kit is cleaned.

(f) Final Class100 Cleaning, Baking and Certification - This is a final class100 cleaning, baking and certification method to ensure and verify that the 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 process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water within a class100 clean-room; and then blowing dry the process kit with high pressure compressed clean-dry-air within a class 100 clean-room environment; and then baking and drying of the process kit using a class100 dust free air oven within a class100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooling the process kit within a class100 clean-room before taking out from the oven; and then inspecting and confirming the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film as well as 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 process kits; and then measuring the surface particle count to ensure the surface cleanliness of the process kit surface within a class100 clean-room; and then testing the physical surface morphology of the process kits to ensure that it is intact 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 process kit is cleaned and surface particle count is achieved; and then assembling the process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes within a class100 clean-room; and then final inspecting and documenting the critical dimensions of the assembled process kits.

(g) Packaging, Identification and Shipment - This is the packaging, identification and shipment method to ensure the 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 process kit within a class 100 clean-room using a double bags vacuum pack; 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 process kit within a class100 clean-room; and then confirming the quantity of the kits and generating a correct packing list according to the delivery order with proper labeling of the process kits; and then packing into a proprietary-

designed container box with cushion designated to properly protect and secure the process kit before delivery shipment to customer.

In another embodiment, the present invention in one aspect relates to a deposition removal and recycling cleaning method for a contaminated process kit made of either stainless steel, titanium, or ceramic materials, in which the deposition removal and recycling cleaning process includes the steps of:

(a) Incoming acceptance inspection to receive, dismantle, examine and digital data log the process kit and categorize and separate them into chemical-method and mechanical-method. Pre-processes cleaning of the process kit to remove gross contamination by high pressure washing out, swabbing or rinsing with city water, if necessary;

(b) Chemical Stripping

- (i) Immersing or submerging the process kit into a tank with an aqueous mixed-acid solution;
- (ii) Removing the process kit from the mix-acid tank;
- (iii) Rinsing the process kit in an overflow rinse tank containing warm city water;
- (iv) Water-jetting the process kit surface with high pressure city water to remove any residues;
- (v) Re-immersing or submerging the process kit into a tank with 'bright dip' aqueous mix-acid solution;
- (vi) Removing the process kit from the 'bright dip' aqueous mixed-acid tank;
- (vii) Re-rinsing the process kit in an overflow rinse tank containing warm city water;
- (viii) Water-jetting the process kit surface with high pressure city water to remove any residues;
- (ix) Repeating the above-mentioned steps on precision chemical cleaning until the contaminants are substantially removed from the process kits, and with the proviso that the process kit may not be in contact with the chemical solution for a time greater than five cumulative hours;
- (x) Rinsing the process kit in an overflow rinse tank containing warm de-ionized;

- (xi) Blowing dry the process kit with high pressure compressed clean-dry-air;
- (xii) Inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the process kit, as well as inspecting the process kit for signs of contamination, faulty cleaning or damage;
- (xiii) Repeating the above-mentioned steps, until the process kit is cleaned.

(c) Mechanical Stripping

- (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 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) Removing the blasting plaster and aluminum foil on the process kit surface.

(d) Thin-film Thermal Coatings

- (i) Masking with thermal plaster and aluminum foil to protect critical surface from thermal spray;
- (ii) Spraying to coat the process kit surface with proprietary-optimized spraying parameters (current, voltage, speed, distance) according to the deposition media and the thickness and surface roughness requirements;
- (iii) Blowing to clean the process kit surface with high pressure compressed clean-dry-air;

- (iv) Inspecting the surface roughness and conditions of the process kit after the thermal spraying;
- (v) Repeating the above-mentioned steps, until the surface roughness is achieved;
- (vi) Removing the thermal plaster and aluminum foil on the process kit surface.

(e) Post-Processes Class1000 Cleaning and Inspection

- (i) Blowing to clean on the process kit surface to remove particles using high pressure compressed clean-dry-air;
- (ii) Wiping to clean the non-blasted/sprayed process kit surface areas with some solvents;
- (iii) Cleaning the process kit with high pressure water-jet system;
- (iv) Rinsing the process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water;
- (v) Cleaning the process kit with high pressure de-ionized water-jet system;
- (vi) Blowing dry the process kit with high pressure compressed clean-dry-air;
- (vii) Inspecting the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition as well as inspecting the process kits for stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the process kits;
- (viii) Inspecting the quality of the deposition removal and recycling cleaning method by checking the surface cleanliness and conditions of the process kit;
- (ix) Repeating the above-mentioned steps, until the process kit is cleaned.

(f) Final Class100 Cleaning, Baking and Certification

- (i) Rinsing the process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water within a class 100 clean-room;
- (ii) Blowing dry the process kit with high pressure compressed clean-dry-air within a class 100 clean-room environment;

- (iii) Baking and drying of the process kit using a class100 dust free air oven within a class 100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process;
- (iv) Cooling the process kit within a class 100 clean-room before taking out from the oven;
- (v) Inspecting and confirming the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition;
- (vi) 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 process kits;
- (vii) Measuring the surface particle count to ensure the surface cleanliness of the process kit surface within a class 100 clean-room;
- (viii) Testing the physical surface morphology of the process kits to ensure that it is intact after a cleaning procedure is completed;
- (ix) Certifying the results of inspection per the guidelines established;
- (x) Repeating the above-mentioned steps until the process kit is cleaned and surface particle count is achieved;
- (xi) Assembling the 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;
- (xii) Inspecting and documenting the critical dimensions of the process kits;
- (xiii) Placing the process kits designated for final packaging after inspection.

(g) Packaging, Identification and Shipment

- (i) Packing and vacuum sealing the 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 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 process kits;
- (iv) Packing into a proprietary-designed container box with cushion designated to properly protect and secure the process kit and comply with customer specification before delivery shipment to customer.

In another embodiment, another aspect of the invention relates to a process for deposition removal and recycle cleaning of a contaminated process kit made of stainless steel, titanium, or ceramic materials, comprising the steps of:

(a) Chemical Stripping

- (i) Immerging or submerging the process kit into a tank with an aqueous mixed-acid solution. The types and concentration of the chemical solutions such as mix-acids, solvents may vary according to the particular contaminants build-up on the process kit and other factors such as the part material type and its reactivity with respect to the cleaning chemical;
- (ii) For the process kits contaminated with Copper-related contaminants, submerge it into a tank with an aqueous acid solution containing Nitric Acid (30% - 40% HNO_3) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (iii) For the process kits contaminated with Aluminum-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (iv) For the process kits contaminated with Titanium-related contaminants, submerge it into a tank with an aqueous mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$), 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 7:1:7 by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (v) For the process kits contaminated with Titanium-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide

(15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;

- (vi) For the process kits contaminated with Tantalum-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (vii) Removing the process kit from the mix-chemical tank;
- (viii) Rinsing the process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing warm (temperature 45-50°C) city water for about 5-10 minutes, and at about several minutes' intervals, preferably about every 5 minutes. Again ensure all trapped air is removed from the internal area of the process kit;
- (ix) Water-jetting the process kit surface with high-pressure (110 bar) city water to remove any residues;
- (x) Re-immersing or submerging the process kit into a tank with 'bright dip' (2%HF and 18%HNO₃) aqueous mix-acid solution for 2 seconds; wherein the aqueous "bright dip" mix-acid solution of chemical stripping for process kits comprises Hydrofluoric Acid (HF) and Nitric Acid (HNO₃), wherein the amount of Hydrofluoric Acid in said aqueous "bright dip" mix-acid solution is from about 2% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 18% by weight, based on the total weight of the solution;
- (xi) Removing the process kit from the 'bright dip' aqueous mixed-acid tank;
- (xii) Re-rinsing the process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing warm (temperature 45-50°C) city water 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 process kit;
- (xiii) Water-jetting the process kit surface with high-pressure (110 bar) city water to remove any residues;

- (xiv) Repeating the above-mentioned steps on precision chemical cleaning until the contaminants are substantially removed from the process kits, and with the proviso that the process kit may not be in contact with the chemical solution for a time greater than five cumulative hours;
- (xv) Rinsing the process kit in an overflow rinse tank containing warm (45-50°C) de-ionized water for 15 minutes. Preferably, the tanks are kept covered to prevent air particulates from contaminating the de-ionized water;
- (xvi) Blowing dry the process kit with high pressure compressed clean-dry-air;
- (xvii) Inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the process kit, as well as inspecting the process kit for signs of contamination, faulty cleaning or damage. The process kit is visually inspected for cleanliness using a portable microscope;
- (xviii) Repeating the above-mentioned steps, until the process kit is cleaned. Once process kit components have started the deposition removal and 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;

(b) Mechanical Stripping

- (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 blasting media such as white oxidized aluminum with a pressure of 3kg/cm^2 to achieve the surface roughness requirements;
- (iv) Blowing to clean the 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);

- (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) Removing the blasting plaster and aluminum foil on the process kit surface.

(c) Thin-film Thermal Coatings

- (i) Masking with thermal plaster and aluminum foil to protect critical surface from thermal spray;
- (ii) Spraying to coat the process kit surface with proprietary-optimized spraying parameters (current, voltage, speed, distance) according to the deposition media and the thickness (0.18-0.25mm) and surface roughness ($>18\mu\text{m}$) requirements;
- (iii) Blowing to clean the 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);
- (iv) Inspecting the surface roughness and conditions of the process kit after the thermal spraying. The surface roughness is measured by a surface profilometer. A change of less than about 35 Ra is considered an acceptable amount of surface roughness;
- (v) Repeating the above-mentioned steps, until the surface roughness is achieved;
- (vi) Removing the thermal plaster and aluminum foil on the process kit surface.

(d) Post-Processes Class1000 Cleaning and Inspection

- (i) Blowing to clean on the process kit surface to remove particles using high pressure compressed clean-dry-air (dry, oil-free, and filtered at the point of use with a 0.1 micron filter);
- (ii) Wiping to clean the non-blasted/sprayed process kit surface areas with some solvents, preferably hand polishing using fine mesh alumina in an isopropyl alcohol on a lint free cloth or with ScotchBrite (Alumina loaded Grade A);
- (iii) Cleaning the process kit with high-pressure (60 bar) water-jet system;
- (iv) Rinsing the process kit in an overflow rinse tank containing four sets of ultrasonic system (40KHz/1800W) and warm de-ionized water (temperature 45-50°C),

preferably at least three rinsing to ensure removal of all acid cleaning solution. The de-ionized water is filtered to remove all particles down to 0.1 μm . All utensils that contact the rinse tanks and contents are rinsed with de-ionized water;

- (v) Cleaning the process kit with high-pressure (60 bar) de-ionized (resistivity of 2 M Ohm-cm or higher) water-jet system;
- (vi) Blowing dry the process kit with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter);
- (vii) Inspecting the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition, as well as inspecting the process kits for stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the process kits;
- (viii) Inspecting the quality of the deposition removal and recycling cleaning method by checking the surface cleanliness and conditions of the process kit. The process kit is visually inspected for cleanliness using a portable microscope;
- (ix) Repeating the above-mentioned steps, until the process kit is cleaned.

(e) Final Class100 Cleaning, Baking and Certification

- (i) Handling of all post cleaning activity such as assembly or leak checking must be carried out in class 100 clean-room environments. 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;
- (ii) Rinsing the process kit in an overflow rinse tank containing four sets of ultrasonic system (40KHz/1800W) and warm de-ionized water (temperature 45-50°C, and resistivity of 2 M Ohm-cm or higher), preferably at least three rinsing to ensure removal of all acid cleaning solution. The de-ionized water is filtered to remove all particles down to 0.1 μm . All utensils that contact the rinse tanks and contents are rinsed with de-ionized water;

- (iii) Blowing dry the process kit with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter) within a class 100 clean-room environment. An Isopropylalcohol (IPA) or de-ionized water (DI) moistened clean room wipe is used to remove fingerprints, water marks etc;
- (iv) Baking and drying of the process kit using a class100 dust free air oven within a class 100 clean-room environments to remove water vapor, chemicals and spouts traps during the cleaning process. The baking of the 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 class100 dust free air oven should be of sufficient size to accommodate the process kits and the kits should be kept away from the oven wall by jig and fixtures;
- (v) Cooling the process kit within a class 100 clean-room before taking out from the oven;
- (vi) Inspecting and confirming the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition. In addition, 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 process kits;
- (vii) 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;
- (viii) Repeating the above-mentioned steps until the process kit is cleaned and surface particle count is achieved;

- (ix) Assembling the process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes within a class100 clean-room. The assembled 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.

In another embodiment, another aspect of this invention relates to a method of increasing the overall equipment effectiveness of a semiconductor production equipment, (the semiconductor production equipment comprises of process kits made from a combination different materials such as stainless steel or aluminum, copper, titanium, beryllium, ceramics of various sorts, and various other materials), whereby the process kit is contaminated with a contaminated species deriving from a semiconductor process, in which the deposition removal and recycling cleaning method comprising:

(a) Acceptance inspection process whereby all components of the process kits are received, dismantled, documented, thoroughly examined for damage, categorized and separated into the required deposition removal and recycle cleaning processes such as the chemical-method and mechanical-method; and then cleaned with high pressure water-jet is used to remove any gross contamination, if necessary.

(b) Chemical stripping process whereby the process kit is immersed into a tank with an aqueous mixed-acid solution (according to the particular contaminants build-up on the process kit); and then removed and rinsed in an overflow rinse tank containing warm city water; and then cleaned with high pressure water-jet to remove any residues; and then re-immersed into a tank with 'bright dip' aqueous mix-acid solution; and then removed and re-rinsed in an overflow rinse tank containing warm city water; and then dried with high pressure compressed clean-dry-air; and then inspected for surface cleanliness and signs of contamination, faulty cleaning or damage; and then re-rinsed in an overflow rinse tank containing warm de-ionized water; and then blow dried with high pressure compressed clean-dry-air; and the chemical stripping sequence is repeated until the process kit is cleaned.

(c) Mechanical stripping process whereby the process kit is masked with blasting plaster and aluminum foil to protect critical surfaces; and then blasted with suitable blasting media to achieve the surface roughness requirements; and then cleaned with high pressure compressed clean-dry-air; and then inspected for surface roughness and conditions of the process kit after the mechanical blasting; and the mechanical stripping sequence is repeated until the surface roughness is achieved.

(d) Thin-film thermal coating process whereby the process kit is masked with thermal plaster and aluminum foil to protect critical surface; and then sprayed with a suitable deposition media and proprietary-optimized spraying techniques to achieve the thickness and surface roughness; and then cleaned with high pressure compressed clean-dry-air; and then inspected for surface roughness and conditions of the process kit after the thin-film thermal spraying; and the thin-film thermal coating is repeated until the surface roughness and thickness is achieved.

(e) Post-Processes Class1000 cleaning and inspection process whereby the process kit is cleaned using high pressure compressed clean-dry-air; and any non-blasted/sprayed surface area is cleaned with some solvents; and then cleaned with high pressure water-jet system; and then rinsed in an overflow rinse tank containing ultrasonic system and warm de-ionized water; and then cleaned with high pressure de-ionized water-jet system; and then dried with high pressure compressed clean-dry-air; and then inspected for non-peeling of coated film, stain, dirt, defect and fracture, surface cleanliness and signs of contamination, faulty cleaning or damage; and the sequence is repeated if the inspection indicates the presence of visible contaminants.

(f) Final Class100 cleaning, baking and certification process whereby the process kit is rinsed in an overflow rinse tank containing ultrasonic system and warm de-ionized water within a class 100 clean-room; and then dried with high pressure compressed ionized clean dry air; and then touched up with clean room wipe (if necessary); and then baked and dried with a class100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooled within the dust free air oven before taking out from the oven; and then measured the surface particle count to ensure the surface cleanliness of the process kit; and then tested for the physical surface morphology of the process kits to ensure that it is intact after a cleaning procedure is completed; and the sequence is repeated until the process kit is cleaned and surface particle count is achieved; and then certified the process kits with the results of visual inspection per the guidelines established; and then assembled according to the standard procedures, working instruction sheets and recipes within a class 100 clean-room environment; and then inspected for the presence of visible contaminants, confirmed and measured the critical dimensions of the assembled process kits before sending for vacuum packaging.

(g) Packaging, identification and shipment process whereby the process kit is packed and vacuum sealed within a class 100 clean-room environment using a double bags vacuum pack with inner bag is a blue anti-static polyethylene bag and the outer bag is a white normal polyethylene bag; and then inspected for the condition of the vacuum pack to ensure a complete vacuum seal packing of the process kit within a class 100 clean-room environment; and then verified for quantity and a correct packing list with proper labeling and identification of the

process kits; and then packed and secured into a proprietary-designed container box before delivery to customer.

The present invention also can be used to clean process kits made of materials such as aluminum (Al), titanium (Ti) and stainless steel (SUS) metal parts, ceramic parts, and quartz parts. The present invention best-known-method and apparatus advantageously remove the organic and inorganic and metallic impurities by-products without damaging the original process kit material or surface morphology.

In addition, the present invention establishes criteria to verify that the process kits are clean with respect to organic, metallic and particulate impurities and establishes criteria to verify that the physical surface morphology remains intact in terms of surface roughness, hardness, thickness and microstructure.

Another role of the present invention is to offers a reliable, quantifiable and efficient means to attain consistent quality in all stages of deposition removal and 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 deposition removal and 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) Prevent deposited layer from peeling off and possible particle reduction.
- (b) Maximize equipment availability, performance efficiency, and rate of quality for optimal equipment effectiveness value and improved factory productivity.
- (c) Improve factory operational teamwork for improved operational management and efficiency.
- (d) Improve rate of quality by reducing the effects of equipment failure (wafer scrap and rework).
- (e) Improve bottleneck wafer equipment throughput for improved factory wafer capacity, which can reduce the need for redundant equipment process kits.
- (f) More productive to find permanent solutions and to eliminate recurring equipment failures.
- (g) Less 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 deposition removal and recycle cleaning process yields, increase process quality and performance, achieve faster time-to-delivery, and increase customer satisfaction, etc.

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, and high vacuum-related manufacturing. This is a critical 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. 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.)

This invention can be applied to the deposition removal and recycle cleaning of new and used components and assemblies, such as shields, platens, stainless liners, shutters, process chamber doors, transfer plates, rotating drums, process chambers, box coaters, CVD and PVD parts, load lock chambers, shielding, valves, ion sources, diffusion pumps, ion pumps, wave guides, etc., for the semiconductor, disk drive, biomedical, flat panel display and related industries.

This invention can be applied to process kits used in sputtering, deposition and plasma CVD, etching equipment, as well as ceramics and metal parts around deposition areas, including but not limited to: (a) aluminum (Al), titanium (Ti) and stainless steel (SUS) metal parts deposition removal, recycle cleaning technology; (b) Ceramic parts deposition removal, precision cleaning technology; (c) Quartz parts deposition removal, precision cleaning technology.

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

Additionally, a system and method are provided for establishing criteria to verify that the 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 flowchart for deposition removal and recycle cleaning of the copper interconnect semiconductor process kits using chemical and mechanical processing in accordance with the present invention.

FIGURE 2 illustrates the layout of the apparatus for deposition removal and recycle cleaning of copper interconnect semiconductor process kits with the present invention.

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 both a chemical and mechanical processing techniques. The idea behind this is to provide effective ultra-clean treatment of contaminated process kits made of stainless steel, titanium or ceramics materials. These process kits are specifically used in semiconductor production equipment for deposition process. Thus, primary process contamination on the process kits includes partially metallic contaminants such as aluminum, aluminum melt, nickel, stainless steel, titanium, tantalum and copper used in the making of semiconductor process kits. The contaminants may further comprise free iron, oxide scale, rust, grease, oil, carbonaceous and other residual chemical films, soil, particles, metal chips, and dirt.

This invention is the result of some 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.

6.1. Chemical Solutions and Mechanical Techniques Used in Present Invention

In this present invention, the types of aqueous chemical cleaning chemistries typically used for deposition removal and recycling cleaning are:

(a) Acidic chemical cleaners - Common acid materials include mineral acids (hydrochloric, sulfuric, nitric), chromic acid, carboxylic acids, and other organic acids.

(b) Alkaline chemical cleaners - Alkaline-cleaning solutions can be formulated by adding such materials as sodium or potassium hydroxide, carbonate, bicarbonate, phosphate, silicate, or other similar materials. It is important to keep in mind that sodium hydroxide, like other alkaline metal hydroxides, lacks the good buffering capacity of, for example, carbonates, and is very corrosive.

(c) Chemical builders - The primary function of builders is to provide a buffer, or "reserve," of pH lending material without changing the desired pH. In this manner, cleaners can establish a longer "lifetime" by not neutralizing immediately when placed in contact with certain

contaminants. Components such as silicates serve a dual function in that they can act as both builders and corrosion inhibitors, as in the case of polysilicates.

In this present invention, the chemical acid solutions typically used for deposition removal and recycling cleaning is chosen according to the process kits made with the following materials:

(a) Stainless Steel: Hydrochloric acids (HCL), Nitric acids (HNO_3), Potassium Hydroxide (KOH), 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 (HNO_3 and HF).

(b) Aluminum: Potassium Hydroxide (KOH), 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 (HNO_3 and HF).

(c) Titanium: 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 (HNO_3 and HF).

(d) Copper: 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 (HNO_3 and HF).

(e) Ceramics: mix-acids (HNO_3 and HF), Potassium Hydroxide (KOH), mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$).

In this present invention, the aqueous chemical cleaning chemistries typically used for deposition removal and recycling cleaning of:

(a) Organics contaminants removal – the mix-acid solutions such as mix-acids (HNO_3 and HF), Potassium Hydroxide (KOH), mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) is used to oxidize organic constituents to make more water soluble species.

(b) Metals contaminants removal - the mix-acid solutions such as Hydrochloric acids (HCL), Nitric acids (HNO_3), Potassium Hydroxide (KOH), mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) is used to accept electron density from an anion in solution to form an inorganic complex or coordination compound that is soluble in water.

(c) Particle contaminants removal - the mix-acid solutions such as mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$) is used to create large repulsive force between particles to produce a cleaning action.

In this present invention, for the most preferred mix-acid chemical solutions, the mix-acid species is nitric acid with a concentration preferably in a range of from about 25% to about 30% by weight, based on the total weight of the aqueous acid solution. The mixed-acid solution may further comprise hydrofluoric acid in a concentration from about 18% to about 20% by weight. In a specific application of the cleaning process, the mixed-acid solution comprises about 30% of nitric acid and 18% HF.

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 metal films.

(d) CO₂ Cleaning - This non-impact technique uses a jet of liquid Carbon Dioxide which is directed onto the surface to remove particulates and some hydrocarbon films.

(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 (110°C) in air to reduce outgassing rates.

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

FIGURES 1 illustrates the overall generalized flowchart of the present invention, i.e. Method and apparatus for deposition removal and recycle cleaning of semiconductor process kits.

The deposition removal and cleaning method for the process kits such as stainless steel processing chambers, contaminated with elemental metallic contaminants such as aluminum, aluminum melt, nickel, stainless steel, titanium, tantalum and copper, may include any or all of the following steps:

6.2.1. Acceptance Inspection

- (a) All components of the process kits are dismantled, documented with digital pictures taken as well as critical data are logged;
- (b) All components of the process kits are thoroughly examined for damage e.g. all vacuum 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;
- (c) All components of the process kits are thoroughly inspected to identify areas which may trap contamination and cause a virtual system leak such as blind holes, re-entrant volumes, crevices and cracks are examples of areas that must be thoroughly examined and cleaned;
- (d) All components of the process kits are cleaned with a high-pressure compressed air line to remove any debris. Any gross contaminations are removed by washing out, swabbing or rinsing with high-pressure city water or any general-purpose solvent;
- (e) All components of the process kits are categorized and separated into the required deposition removal and recycle cleaning processes such as the chemical-method and mechanical-method.

6.2.2. Chemical Stripping - deposition removal and recycle cleaning by chemical method

- (a) Immerging or submerging the process kit into a tank with an aqueous mixed-acid solution. The types and concentration of the chemical solutions such as mix-acids, solvents may vary according to the particular contaminants build-up on the process kit and other factors such as the part material type and its reactivity with respect to the cleaning chemical. Adjust the dipping time according to the thickness of the membrane.;
- (b) For the process kits contaminated with Copper-related contaminants, submerge it into a tank with an aqueous acid solution containing Nitric Acid (30% - 40% HNO_3) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (c) For the process kits contaminated with Aluminum-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-

65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;

(d) For the process kits contaminated with Titanium-related contaminants, submerge it into a tank with an aqueous mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$), 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 7:1:7 by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;

(e) For the process kits contaminated with Titanium-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;

(f) For the process kits contaminated with Tantalum-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;

(g) Removing the process kit from the mix-chemical tank;

(h) Rinsing the process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing warm (temperature 45-50°C) city water for about 5-10 minutes, and at about several minutes' intervals, preferably about every 5 minutes. Again ensure all trapped air is removed from the internal area of the process kit;

(i) Water-jetting the process kit surface with high-pressure (110 bar) city water to remove any residues;

(j) Re-immersing or submerging the process kit into a tank with 'bright dip' (2%HF and 18% HNO_3) aqueous mix-acid solution for 2 seconds; wherein the aqueous "bright dip" mix-acid solution of chemical stripping for process kits comprises Hydrofluoric Acid (HF) and Nitric Acid (HNO_3), wherein the amount of Hydrofluoric Acid in said aqueous "bright dip" mix-acid solution is from about 2% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 18% by weight, based on the total weight of the solution;

(k) Removing the process kit from the 'bright dip' aqueous mixed-acid tank;

- (l) Re-rinsing the process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing warm (temperature 45-50°C) city water 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 process kit;
- (m) Water-jetting the process kit surface with high-pressure (110 bar) city water to remove any residues;
- (n) Repeating the above-mentioned steps on precision chemical cleaning until the contaminants are substantially removed from the process kits, and with the proviso that the process kit may not be in contact with the chemical solution for a time greater than five cumulative hours;
- (o) Rinsing the process kit in an overflow rinse tank containing warm (temperature 45-50°C) de-ionized water for 15 minutes. Preferably, the tanks are kept covered to prevent air particulates from contaminating the de-ionized water;
- (p) Blowing dry the process kit with high pressure compressed clean-dry-air;
- (q) Inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the process kit, as well as inspecting the process kit for signs of contamination, faulty cleaning or damage. The process kit is visually inspected for cleanliness using a portable microscope;
- (r) Repeating the above-mentioned steps, until the process kit is cleaned. Once process kit components have started the deposition removal and 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.

6.2.3. Mechanical Stripping - deposition removal and recycle cleaning by mechanical method

- (a) Setting up for deposition removal by mechanical cleaning method in the masking areas;
- (b) Masking the process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical blasting;

- (c) Blasting the process kit with suitable blasting media such as white oxidized aluminum with a pressure of 3kg/cm^2 to achieve the surface roughness requirements;
- (d) Blowing to clean the 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 process kit after the mechanical blasting;
- (f) Repeating the above-mentioned steps, until the surface roughness is achieved;
- (g) Removing the blasting plaster and aluminum foil on the process kit surface.

6.2.4. Thermal Spray Coating – Thin-film coating process.

- (a) Masking with thermal plaster and aluminum foil to protect critical surface from thermal spray;
- (b) Spraying to coat the process kit surface with proprietary-optimized spraying parameters (current, voltage, speed, distance) according to the deposition media and the thickness (0.18-0.25mm) and surface roughness ($>18\mu\text{m}$) requirements;
- (c) Blowing to clean the 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);
- (d) Inspecting the surface roughness and conditions of the process kit after the thermal spraying. The surface roughness is measured by a surface profilometer. A change of less than about 35 Ra is considered an acceptable amount of surface roughness;
- (e) Repeating the above-mentioned steps, until the surface roughness is achieved;
- (f) Removing the thermal plaster and aluminum foil on the process kit surface.

6.2.5. Post-Processes Class1000 Cleaning and Inspection.

- (a) Blowing to clean on the process kit surface to remove particles using high pressure compressed clean-dry-air (dry, oil-free, and filtered at the point of use with a 0.1 micron filter);

- (b) Wiping to clean the non-blasted/sprayed process kit surface areas with some solvents, preferably hand polishing using fine mesh alumina in an isopropyl alcohol on a lint free cloth or with ScotchBrite (Alumina loaded Grade A);
- (c) Cleaning the process kit with high-pressure (60 bar) water-jet system;
- (d) Rinsing the process kit in an overflow rinse tank containing four sets of ultrasonic system (40KHz/1800W) and warm de-ionized water (temperature 45-50°C), preferably at least three rinsing to ensure removal of all acid cleaning solution. The de-ionized water is filtered to remove all particles down to 0.1 um. All utensils that contact the rinse tanks and contents are rinsed with de-ionized water;
- (e) Cleaning the process kit with high pressure (60 bar) de-ionized (resistivity of 2 M Ohm-cm or higher) water-jet system;
- (f) Blowing dry the process kit with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter);
- (g) Inspecting the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition, as well as inspecting the process kits for stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the process kits;
- (h) Inspecting the quality of the deposition removal and recycling cleaning method by checking the surface cleanliness and conditions of the process kit. The process kit is visually inspected for cleanliness using a portable microscope;
- (i) Repeating the above-mentioned steps, until the process kit is cleaned.

6.2.6. Final Class100 Cleaning, Baking and Certification

- (a) Handling of all post cleaning activity such as assembly or leak checking must be carried out in class100 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 process kit in an overflow rinse tank containing four sets of ultrasonic system (40KHz/1800W) and warm (temperature 45-50°C) de-ionized (resistivity of 2 M Ohm-cm or

higher) water within a class100 clean-room, preferably at least three rinsing to ensure removal of all acid cleaning solution. The de-ionized water is filtered to remove all particles down to 0.1 um. All utensils that contact the rinse tanks and contents are rinsed with de-ionized water;

(c) Blowing dry the process kit with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter) within a class100 clean-room environment. An Isopropylalcohol (IPA) or de-ionized water (DI) moistened clean room wipe is used to remove fingerprints, water marks etc;

(d) Baking and drying of the process kit using a class100 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 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 class100 dust free air oven should be of sufficient size to accommodate the process kits and the kits should be kept away from the oven wall by jig and fixtures;

(e) Cooling the process kit within a class100 clean-room before taking out from the oven;

(f) Inspecting and confirming the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition. In addition, 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 process kits;

(g) 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;

(h) Repeating the above-mentioned steps until the process kit is cleaned and surface particle count is achieved;

(i) Assembling the process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes within a class100 clean-room. The assembled 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.

6.2.7. Packaging, Identification and Shipment

(a) Packing and vacuum sealing the process kit within a class100 clean-room using a double bags vacuum pack. The inner bag is a blue anti-static polyethylene bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment. The outer bag is a white 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 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 process kit within a class100 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 process kits. All 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 process kit and comply with customer specification before delivery shipment to customer.

6.3. The apparatus of the present invention.

The deposition removal and 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 for deposition removal and recycle cleaning of semiconductor process kits with the present invention.

It will therefore be appreciated that the apparatus for recycle cleaning of semiconductor 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 M Ohm-cm. DI 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 DI water with specific resistivity of no less than 0.2 M Ohm-cm, (b) for spray rinse: Power spray blind holes, creases, and non-welded seams by using cold DI water with specific resistivity of no less than 2 M Ohm-cm, (c) for hot rinse: immerse in hot DI bath of temperature of 45-50°C with minimum resistivity of 2 M Ohm-cm. DI water in immersion tanks shall be overflowing.

(b) Blasting Media: Aluminum Oxide, Al_2O_3 , is used unless otherwise specified. The use of garnet is prohibited unless otherwise specified. The cleanliness and effectiveness of such media shall be controlled so the processed components will meet the requirements specified.

(c) Compressed Nitrogen or Air: Nitrogen 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.

(d) Clean-room: A Class100 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 Class100 clean room oven and Class100 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 and mechanical agitation is used to prevent contaminating by particles or hydrocarbons. The equipment required for the present invention are : (i) two mix-acid tank for HF and HNO_3 ; (ii) two chemical solution tank; (iii) one mix-acid tank for “bright dip” aqueous mix-chemical solution; (iv) two warm city water overflow rinse tanks; (v) two high pressure

water-jet rinse tanks; (vi) two de-ionized (DI) water rinse tanks with ultrasonic cleaning; (vii) two de-ionized (DI) water 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 process kits and allowing for submerging thereof. More preferably, the dimensions of the tanks are design and built between 600-1000mm in length, 600-1000mm 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 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 tank may be incorporated with a heat source coupled to the tank to “warm or heat” up the mix-acid or chemical solutions or de-ionised water content inside the tank to above ambient or "room" temperature by some known heating means such as a resistance-heating device. Preferably, the heated tank should include a thermocouple to monitor the temperature within the tank for safety reasons.

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

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

(a) Acceptance inspection process whereby all components of the process kits are received, dismantled, documented, thoroughly examined for damage, categorized and separated into the required deposition removal and recycle cleaning processes such as the chemical-method and mechanical-method; and then cleaned with high pressure water-jet is used to remove any gross contamination, if necessary.

(b) Chemical stripping process whereby the process kit is immersed into a tank with an aqueous mixed-acid solution (according to the particular contaminants build-up on the process kit); and

then removed and rinsed in an overflow rinse tank containing warm city water; and then cleaned with high pressure water-jet to remove any residues; and then re-immersed into a tank with 'bright dip' aqueous mix-acid solution; and then removed and re-rinsed in an overflow rinse tank containing warm city water; and then dried with high pressure compressed clean-dry-air; and then inspected for surface cleanliness and signs of contamination, faulty cleaning or damage; and then re-rinsed in an overflow rinse tank containing warm de-ionized water; and then blow dried with high pressure compressed clean-dry-air; and the chemical stripping sequence is repeated until the process kit is cleaned.

(c) Mechanical stripping process whereby the process kit is masked with blasting plaster and aluminum foil to protect critical surfaces; and then blasted with suitable blasting media to achieve the surface roughness requirements; and then cleaned with high pressure compressed clean-dry-air; and then inspected for surface roughness and conditions of the process kit after the mechanical blasting; and the mechanical stripping sequence is repeated until the surface roughness is achieved.

(d) Thin-film thermal coating process whereby the process kit is masked with thermal plaster and aluminum foil to protect critical surface; and then sprayed with a suitable deposition media and proprietary-optimized spraying techniques to achieve the thickness and surface roughness; and then cleaned with high pressure compressed clean-dry-air; and then inspected for surface roughness and conditions of the process kit after the thin-film thermal spraying; and the thin-film thermal coating is repeated until the surface roughness and thickness is achieved.

(e) Post-Processes Class1000 cleaning and inspection process whereby the process kit is cleaned using high pressure compressed clean-dry-air; and any non-blasted/sprayed surface area is cleaned with some solvents; and then cleaned with high pressure water-jet system; and then rinsed in an overflow rinse tank containing ultrasonic system and warm de-ionized water; and then cleaned with high pressure de-ionized water-jet system; and then dried with high pressure compressed clean-dry-air; and then inspected for non-peeling of coated film, stain, dirt, defect and fracture, surface cleanliness and signs of contamination, faulty cleaning or damage; and the sequence is repeated if the inspection indicates the presence of visible contaminants.

(f) Final Class100 cleaning, baking and certification process whereby the process kit is rinsed in an overflow rinse tank containing ultrasonic system and warm de-ionized water within a class100 clean-room; and then dried with high pressure compressed ionized clean dry air; and then touched up with clean room wipe (if necessary); and then baked and dried with a class100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooled within the dust free air oven before taking out from the oven; and then

measured the surface particle count to ensure the surface cleanliness of the process kit; and then tested for the physical surface morphology of the process kits to ensure that it is intact after a cleaning procedure is completed; and the sequence is repeated until the process kit is cleaned and surface particle count is achieved; and then certified the process kits with the results of visual inspection per the guidelines established; and then assembled according to the standard procedures, working instruction sheets and recipes within a class100 clean-room environment; and then inspected for the presence of visible contaminants, confirmed and measured the critical dimensions of the assembled process kits before sending for vacuum packaging.

(g) Packaging, identification and shipment process whereby the process kit is packed and vacuum sealed within a class100 clean-room environment using a double bags vacuum pack with inner bag is a blue anti-static polyethylene bag and the outer bag is a white normal polyethylene bag; and then inspected for the condition of the vacuum pack to ensure a complete vacuum seal packing of the process kit within a class100 clean-room environment; and then verified for quantity and a correct packing list with proper labeling and identification of the process kits; and then packed and secured into a proprietary-designed container box before delivery 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 deposition removal and recycle cleaning for a copper interconnect semiconductor process kit to remove contaminant residue and species deriving from a semiconductor process, the Best-Known-Method comprising the steps of:

(a) Acceptance Inspection – receiving, incoming inspection to thoroughly examine, dismantle, and data documented with digital pictures; and then categorize and separate into the required deposition removal and recycle cleaning processes such as the chemical-method and mechanical-method. Any gross contaminations are removed by washing out, swabbing or rinsing with high-pressure city water or any general-purpose solvent.

(b) Chemical Stripping – This is a precision chemical cleaning method to strip-off or dissolve organic/inorganic and metallic deposited contaminants according to the process kits materials and type of deposited contaminants. The method generally includes immersing or submerging the process kit into a tank with an aqueous mixed-acid solution; and then removing the process kit from the mix-acid tank; and then rinsing the process kit in an overflow rinse tank containing warm city water; and then water-jetting the process kit surface with high pressure city water to remove any residues; and then re-immersing or submerging the process kit into a tank with ‘bright dip’ aqueous mix-acid solution; and then removing the process kit from the ‘bright dip’ aqueous mixed-acid tank; and then re-rinsing the process kit in an overflow rinse tank containing warm city water; and then water-jetting the process kit surface with high pressure city water to remove any residues; and then repeating until contaminants are substantially removed from the process kits; and then rinsing the process kit in an overflow rinse tank containing warm de-ionized water; and then blowing dry the process kit with high pressure compressed clean-dry-air; and then inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the process kit; and then inspecting the process kit for signs of contamination, faulty cleaning or damage; and then repeating until the process kit is cleaned.

(c) Mechanical Stripping – This is a precision mechanical cleaning method using blasting machine with suitable blasting media to strip-off deposition film to achieve the surface roughness requirements and appropriate adhesion between the process kit substrate and the coating film. The method generally includes setting up for deposition removal by mechanical cleaning method in the masking areas; and then masking the process kit with blasting plaster and aluminum foil to protect critical surfaces from mechanical blasting; 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; and then removing the blasting plaster and aluminum foil on the process kit surface for the next process.

(d) Thin-film Thermal Coating – This is a precision thermal spraying method using a thermal spray system with a suitable deposition media and proprietary-optimized spraying techniques to achieve the thickness and surface roughness requirements to prevent particle issues during usage. The method generally includes masking with thermal plaster and aluminum foil to protect critical surface from thermal spray; and then spraying to coat the process kit surface with proprietary-optimized spraying parameters (current, voltage, speed, distance) according to the deposition media and the thickness and 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 thermal spraying; and then repeating the above-mentioned steps, until the surface roughness is achieved; and then removing the thermal plaster and aluminum foil on the process kit surface for the next process.

(e) Post-Processes Class1000 Cleaning and Inspection – This is a post-processes overall cleaning and inspection method to ensure the quality of the deposition removal and recycling cleaning method is achieved. The method generally includes blowing to clean on the process kit surface to remove particles using high pressure compressed clean-dry-air; and then wiping to clean the non-blasted/sprayed process kit surface areas with some solvents; and then cleaning the process kit with high pressure water-jet system; and then rinsing the process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water; and then cleaning the process kit with high pressure de-ionized water-jet system; and then blowing dry the process kit with high pressure compressed clean-dry-air; and then inspecting the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition, as well as for stain, dirt, defect and fracture; and then inspecting the quality of the deposition removal and recycling cleaning method by checking the surface cleanliness and conditions of the process kit; and then repeating the above-mentioned steps, until the process kit is cleaned.

(f) Final Class100 Cleaning, Baking and Certification - This is a final class100 cleaning, baking and certification method to ensure and verify that the 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 process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water within a class 100 clean-room; and then blowing dry the process kit with high pressure compressed clean-dry-air within a class 100

clean-room environment; and then baking and drying of the process kit using a class100 dust free air oven within a class 100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooling the process kit within a class 100 clean-room before taking out from the oven; and then inspecting and confirming the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film as well as 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 process kits; and then measuring the surface particle count to ensure the surface cleanliness of the process kit surface within a class100 clean-room; and then testing the physical surface morphology of the process kits to ensure that it is intact 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 process kit is cleaned and surface particle count is achieved; and then assembling the 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; and then final inspecting and documenting the critical dimensions of the assembled process kits.

(g) Packaging, Identification and Shipment - This is the packaging, identification and shipment method to ensure the 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 process kit within a class 100 clean-room using a double bags vacuum pack; 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 process kit within a class 100 clean-room; and then confirming the quantity of the kits and generating a correct packing list according to the delivery order with proper labeling of the process kits; and then packing into a proprietary-designed container box with cushion designated to properly protect and secure the process kit before delivery shipment to customer.

2. The process of claim 1, wherein the contaminant on the process kits comprises a contaminant species selected from the group consisting of partially elemental copper, elemental aluminum, elemental tantalum, elemental titanium, fluorinated hydrocarbons, elemental silicon, elemental germanium, the common 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 acceptance inspection step comprises receiving, dismantling, taking digital pictures, data logging critical dimension, categorize and separate into different deposition removal and recycle cleaning process routings.

4. The process of claim 1(b), wherein the aqueous acid solution of chemical stripping for Copper-related contaminant deposits comprises Nitric Acid (HNO_3).
5. The process of claim 4, wherein the amount of Nitric Acid (HNO_3) in said aqueous acid solution is from about 30% to 40% by weight, based on the total weight of the solution.
6. The process of claim 1(b), wherein the aqueous chemical solution of chemical stripping for Aluminum-related contaminant deposits comprises Potassium Hydroxide (KOH).
7. The process of claim 6, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is from 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.
8. The process of claim 1(b), wherein the aqueous chemical solution of chemical stripping for Titanium-related contaminant deposits comprises mix-chemical solution Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$).
9. The process of claim 8, 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 7:1:7 by weight, based on the total weight of the solution.
10. The process of claim 1(b), wherein the aqueous chemical solution of chemical stripping for Tantalum-related contaminant deposits comprises Potassium Hydroxide (KOH).
11. The process of claim 10, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is about 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.
12. The process of claim 1(b), wherein the aqueous “bright dip” mix-acid solution of chemical stripping for process kits comprises Hydrofluoric Acid (HF) and Nitric Acid (HNO_3).
13. The process of claim 12, wherein the amount of Hydrofluoric Acid in said aqueous “bright dip” mix-acid solution is from about 2% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 18% by weight, based on the total weight of the solution.
14. The process of claim 1(b), wherein the chemical stripping is carried out at a temperature in the range of from about 25°C to about 65°C.
15. The process of claim 1(b), wherein the chemical stripping is carried out for a contacting time of from about 60 to 120 minutes, and is carried out for not longer than five cumulative hours.

16. The process of claim 1(b), 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 and is carried out at a temperature of about 45°C to 50°C.
17. The process of claim 1(b), wherein the process kits is cleaned with water-jet to remove any residues; wherein the cleaning is carried out at a high-pressure in the range of from about 90 bar to about 110 bar.
18. The process of claim 1(b), wherein the process kits is multiple-rinsed with warm de-ionised water in an overflow rinse tank for about 5 to about 10 minutes.
19. The process of claim 18, wherein the temperature of the de-ionized water is heated up to a temperature of about 45°C to 50°C.
20. The process of claim 18, wherein deionized water used for rinsing is controlled at a resistivity of 2 M Ohm-cm or higher and filtered to substantially remove all particles down to 0.1 um.
21. The process of claim 1(b), wherein the process kit is cleaned and dried using high pressure ionized clean dry air, and is carried out at a pressure range of about 60 bar to 110 bar.
22. The process of claim 1(c), 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.
23. The process of claim 1(c), wherein the blasting media used for mechanical stripping is white oxidized aluminum and is carried out with a blasting pressure of 3kg/cm² to achieve the required surface roughness.
24. The process of claim 1(c), 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.
25. The process of claim 1(d), wherein the thermal spray coating comprises setting up and masking the process kits with different thermal plaster and aluminum foil to protect critical surfaces from thermal spray processes.
26. The process of claim 1(d), wherein the thermal spray parameters used for thermal spray process are the current is 300A, the voltage is 29V, the speed is 90rpm, the distance is 30cm, to achieve the required surface roughness and thickness.

27. The process of claim 1(d), 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.
28. The process of claim 1(e), wherein the process kits are post-process cleaned and inspected within a class1000 clean-room.
29. The process of claim 1(e), 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.
30. The process of claim 1(e), wherein the non-blasted/sprayed process kit surface areas are wiped cleaned with fine mesh alumina in an isopropyl alcohol on a lint free cloth or with ScotchBrite (Alumina loaded Grade A).
31. The process of claim 1(e), wherein the water-jet used for removing any residues is carried out at a high pressure in the range of about 60 bar.
32. The process of claim 1(e), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution.
33. The process of claim 32, wherein the ultrasonic system is 40KHz/1800W.
34. The process of claim 32, wherein the temperature of the de-ionized water is heated up to 45-50°C.
35. The process of claim 32, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.
36. The process of claim 32, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.
37. The process of claim 1(e), wherein the process kit is dried with high pressure compressed ionized clean dry, oil-free, and filtered at the point of use with a 0.1 micron filter air.
38. The process of claim 1(e), wherein the quality of the process kit is visually inspected for cleanliness using a portable microscope.

39. The process of claim 1(f), wherein the process kits are final cleaned, baked and certified within a class100 clean-room.
40. The process of claim 1(f), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution, within a class100 clean-room environment.
41. The process of claim 40, wherein the ultrasonic system is 40KHz/1800W.
42. The process of claim 40, wherein the temperature of the de-ionized water is set to 45-50°C.
43. The process of claim 40, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.
44. The process of claim 40, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.
45. The process of claim 1(f), wherein the process kit is cleaned and dried with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter) within a class100 clean-room environment.
46. The process of claim 1(f), wherein the process kit is baked and dried using a class100 dust free air oven within a class100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process;
47. The process of claim 46, wherein the 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.
48. The process of claim 46, wherein the class100 dust free air oven should be of sufficient size to accommodate the process kits and the kits should be kept away from the oven wall by jig and fixtures.
49. The process of claim 46, the process kit is cooled before taking out from the oven within a class100 clean-room environment.
50. The process of claim 1(f), wherein the surface cleanliness of the process kit surface is measured using a surface particle tester or equipment, within a class100 clean-room environment.

51. The process of claim 50, wherein the acceptable criteria for the process kit surface cleanliness is generally less than about 5 particles/cm², based on particle size of about 0.3 microns, as measured by surface particle detector, such as QIII Plus by Pentagon technology.

52. The process of claim 50, wherein the physical surface morphology of the process kits is tested to ensure that it is intact after a cleaning procedure is completed.

53. The process of claim 1(g), wherein the process kit is packed and vacuum-sealed within a class100 clean-room environment using a double bags vacuum pack;

54. The process of claim 53, wherein the inner bag is a blue anti-static polyethylene bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment.

55. The process of claim 53, wherein the outer bag is a white normal polyethylene bag of thickness 0.12mm.

56. The process of claim 1(g), 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 process kit within a class100 clean-room environment.

57. The process of claim 1(g), 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 process kits.

58. The process of claim 1(g), wherein the process kits are packed into a proprietary-designed container box with cushion designated to properly protect and secure the process kit before delivery shipment to customer.

59. A method on deposition removal and recycling cleaning for a contaminated process kit made of stainless steel, titanium, or ceramic materials, and is contaminated with contaminant species from a semiconductor production process, in which the deposition removal and recycling cleaning process includes the steps of:

(a) Incoming acceptance inspection to receive, dismantle, examine and digital data log the process kit and categorize and separate them into chemical-method and mechanical-method. Pre-processes cleaning of the process kit to remove gross contamination by high pressure washing out, swabbing or rinsing with city water, if necessary;

(b) Chemical Stripping

(i) Immerging or submerging the process kit into a tank with an aqueous mixed-acid solution;

- (ii) Removing the process kit from the mix-acid tank;
- (iii) Rinsing the process kit in an overflow rinse tank containing warm city water;
- (iv) Water-jetting the process kit surface with high pressure city water to remove any residues;
- (v) Re-immersing or submerging the process kit into a tank with ‘bright dip’ aqueous mix-acid solution;
- (vi) Removing the process kit from the ‘bright dip’ aqueous mixed-acid tank;
- (vii) Re-rinsing the process kit in an overflow rinse tank containing warm city water;
- (viii) Water-jetting the process kit surface with high pressure city water to remove any residues;
- (ix) Repeating the above-mentioned steps on precision chemical cleaning until the contaminants are substantially removed from the process kits, and with the proviso that the process kit may not be in contact with the chemical solution for a time greater than five cumulative hours;
- (x) Rinsing the process kit in an overflow rinse tank containing warm de-ionized;
- (xi) Blowing dry the process kit with high pressure compressed clean-dry-air;
- (xii) Inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the process kit, as well as inspecting the process kit for signs of contamination, faulty cleaning or damage;
- (xiii) Repeating the above-mentioned steps, until the process kit is cleaned.

(c) Mechanical Stripping

- (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 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) Removing the blasting plaster and aluminum foil on the process kit surface.

(d) Thin-film Thermal Coating

- (i) Masking with thermal plaster and aluminum foil to protect critical surface from thermal spray;
- (ii) Spraying to coat the process kit surface with proprietary-optimized spraying parameters (current, voltage, speed, distance) according to the deposition media and the thickness and surface roughness requirements;
- (iii) Blowing to clean the process kit surface with high pressure compressed clean-dry-air;
- (iv) Inspecting the surface roughness and conditions of the process kit after the thermal spraying;
- (v) Repeating the above-mentioned steps, until the surface roughness is achieved;
- (vi) Removing the thermal plaster and aluminum foil on the process kit surface.

(e) Post-Processes Class1000 Cleaning and Inspection

- (i) Blowing to clean on the process kit surface to remove particles using high pressure compressed clean-dry-air;
- (ii) Wiping to clean the non-blasted/sprayed process kit surface areas with some solvents;
- (iii) Cleaning the process kit with high pressure water-jet system;
- (iv) Rinsing the process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water;

- (v) Cleaning the process kit with high pressure de-ionized water-jet system;
- (vi) Blowing dry the process kit with high pressure compressed clean-dry-air;
- (vii) Inspecting the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition as well as inspecting the process kits for stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the process kits;
- (viii) Inspecting the quality of the deposition removal and recycling cleaning method by checking the surface cleanliness and conditions of the process kit;
- (ix) Repeating the above-mentioned steps, until the process kit is cleaned.

(f) Final Class100 Cleaning, Baking and Certification

- (i) Rinsing the process kit in an overflow rinse tank containing ultrasonic system and warm de-ionized water within a class100 clean-room;
- (ii) Blowing dry the process kit with high pressure compressed clean-dry-air within a class100 clean-room environment;
- (iii) Baking and drying of the process kit using a class100 dust free air oven within a class100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process;
- (iv) Cooling the process kit within a class100 clean-room before taking out from the oven;
- (v) Inspecting and confirming the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition;
- (vi) 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 process kits;
- (vii) Measuring the surface particle count to ensure the surface cleanliness of the process kit surface within a class100 clean-room;

- (viii) Testing the physical surface morphology of the process kits to ensure that it is intact after a cleaning procedure is completed;
- (ix) Certifying the results of inspection per the guidelines established;
- (x) Repeating the above-mentioned steps until the process kit is cleaned and surface particle count is achieved;
- (xi) Assembling the process kits together when proper cleanliness levels are achieved, according to the standard procedures, working instruction sheets and recipes within a class100 clean-room;
- (xii) Inspecting and documenting the critical dimensions of the process kits;
- (xiii) Placing the process kits designated for final packaging after inspection.

(g) Packaging, Identification and Shipment

- (i) Packing and vacuum sealing the process kit within a class100 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 process kit within a class100 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 process kits;
- (iv) Packing into a proprietary-designed container box with cushion designated to properly protect and secure the process kit and comply with customer specification before delivery shipment to customer.

60. The process of claim 59(a), wherein the acceptance inspection step comprises receiving, dismantling, taking digital pictures, data logging critical dimension, categorize and separate into different deposition removal and recycle cleaning process routings.

61. The process of claim 59(b), wherein the aqueous acid solution of chemical stripping for Copper-related contaminant deposits comprises Nitric Acid (HNO_3).

62. The process of claim 61, wherein the amount of Nitric Acid (HNO_3) in said aqueous acid solution is from about 30% to 40% by weight, based on the total weight of the solution.

63. The process of claim 59(b), wherein the aqueous chemical solution of chemical stripping for Aluminum-related contaminant deposits comprises Potassium Hydroxide (KOH).
64. The process of claim 63, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is from 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.
65. The process of claim 59(b), wherein the aqueous chemical solution of chemical stripping for Titanium-related contaminant deposits comprises mix-chemical solution Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$).
66. The process of claim 65, 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 7:1:7 by weight, based on the total weight of the solution.
67. The process of claim 59(b), wherein the aqueous chemical solution of chemical stripping for Tantalum-related contaminant deposits comprises Potassium Hydroxide (KOH).
68. The process of claim 67, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is about 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.
69. The process of claim 59(b), wherein the aqueous “bright dip” mix-acid solution of chemical stripping for process kits comprises Hydrofluoric Acid (HF) and Nitric Acid (HNO_3).
70. The process of claim 69, wherein the amount of Hydrofluoric Acid in said aqueous “bright dip” mix-acid solution is from about 2% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 18% by weight, based on the total weight of the solution.
71. The process of claim 59(b), wherein the chemical stripping is carried out at a temperature in the range of from about 25°C to about 65°C.
72. The process of claim 59(b), wherein the chemical stripping is carried out for a contacting time of from about 60 to 120 minutes, and is carried out for not longer than five cumulative hours.
73. The process of claim 59(b), 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 and is carried out at a temperature of about 45°C to 50°C.

74. The process of claim 59(b), wherein the process kits is cleaned with water-jet to remove any residues; wherein the cleaning is carried out at a high-pressure in the range of from about 90 bar to about 110 bar.

75. The process of claim 59(b), wherein the process kits is multiple-rinsed with warm de-ionised water in an overflow rinse tank for about 5 to about 10 minutes.

76. The process of claim 75, wherein the temperature of the de-ionized water is heated up to a temperature of about 45°C to 50°C.

77. The process of claim 75, wherein deionized water used for rinsing is controlled at a resistivity of 2 M Ohm-cm or higher and filtered to substantially remove all particles down to 0.1 μm .

78. The process of claim 59(b), wherein the process kit is cleaned and dried using high pressure ionized clean dry air, and is carried out at a pressure range of about 60 bar to 110 bar.

79. The process of claim 59(c), 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.

80. The process of claim 59(c), wherein the blasting media used for mechanical stripping is white oxidized aluminum and is carried out with a blasting pressure of $3\text{kg}/\text{cm}^2$ to achieve the required surface roughness.

81. The process of claim 59(c), 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.

82. The process of claim 59(d), wherein the thermal spray coating comprises setting up and masking the process kits with different thermal plaster and aluminum foil to protect critical surfaces from thermal spray processes.

83. The process of claim 59(d), wherein the thermal spray parameters used for thermal spray process are the current is 300A, the voltage is 29V, the speed is 90rpm, the distance is 30cm, to achieve the required surface roughness and thickness.

84. The process of claim 59(d), 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.

85. The process of claim 59(e), wherein the process kits are post-process cleaned and inspected within a class1000 clean-room.
86. The process of claim 59(e), 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.
87. The process of claim 59(e), wherein the non-blasted/sprayed process kit surface areas are wiped cleaned with fine mesh alumina in an isopropyl alcohol on a lint free cloth or with ScotchBrite (Alumina loaded Grade A).
88. The process of claim 59(e), wherein the water-jet used for removing any residues is carried out at a high pressure in the range of about 60 bar.
89. The process of claim 59(e), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution.
90. The process of claim 89, wherein the ultrasonic system is 40KHz/1800W.
91. The process of claim 89, wherein the temperature of the de-ionized water is heated up to 45-50°C.
92. The process of claim 89, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.
93. The process of claim 89, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.
94. The process of claim 59(e), wherein the process kit is dried with high pressure compressed ionized clean dry, oil-free, and filtered at the point of use with a 0.1 micron filter air.
95. The process of claim 59(e), wherein the quality of the process kit is visually inspected for cleanliness using a portable microscope.
96. The process of claim 59(f), wherein the process kits are final cleaned, baked and certified within a class100 clean-room.
97. The process of claim 59(f), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three

rinsing to ensure removal of all acid cleaning solution, within a class100 clean-room environment.

98. The process of claim 97, wherein the ultrasonic system is 40KHz/1800W.

99. The process of claim 97, wherein the temperature of the de-ionized water is set to 45-50°C.

100. The process of claim 97, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.

101. The process of claim 97, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.

102. The process of claim 59(f), wherein the process kit is cleaned and dried with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter) within a class100 clean-room environment.

103. The process of claim 59(f), wherein the process kit is baked and dried using a class100 dust free air oven within a class100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process;

104. The process of claim 103, wherein the 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.

105. The process of claim 103, wherein the class100 dust free air oven should be of sufficient size to accommodate the process kits and the kits should be kept away from the oven wall by jig and fixtures.

106. The process of claim 103, the process kit is cooled before taking out from the oven within a class100 clean-room environment.

107. The process of claim 59(f), wherein the surface cleanliness of the process kit surface is measured using a surface particle tester or equipment, within a class100 clean-room environment.

108. The process of claim 107, wherein the acceptable criteria for the process kit surface cleanliness is generally less than about 5 particles/cm², based on particle size of about 0.3 microns, as measured by surface particle detector, such as QIII Plus by Pentagon technology.

109. The process of claim 107, wherein the physical surface morphology of the process kits is tested to ensure that it is intact after a cleaning procedure is completed.

110. The process of claim 59(g), wherein the process kit is packed and vacuum-sealed within a class100 clean-room environment using a double bags vacuum pack;

111. The process of claim 110, wherein the inner bag is a blue anti-static polyethylene bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment.

112. The process of claim 110, wherein the outer bag is a white normal polyethylene bag of thickness 0.12mm.

113. The process of claim 59(g), 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 process kit within a class100 clean-room environment.

114. The process of claim 59(g), 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 process kits.

115. The process of claim 59(g), wherein the process kits are packed into a proprietary-designed container box with cushion designated to properly protect and secure the process kit before delivery shipment to customer.

116. A process for deposition removal and recycling cleaning of a contaminated process kit made of either stainless steel, titanium, or ceramic materials, and is contaminated with contaminant species from a semiconductor production process, comprising the steps of:

(a) Chemical Stripping

- (i) Immerging or submerging the process kit into a tank with an aqueous mixed-acid solution. The types and concentration of the chemical solutions such as mix-acids, solvents may vary according to the particular contaminants build-up on the process kit and other factors such as the part material type and its reactivity with respect to the cleaning chemical;
- (ii) For the process kits contaminated with Copper-related contaminants, submerge it into a tank with an aqueous acid solution containing Nitric Acid (30% - 40% HNO_3) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;

- (iii) For the process kits contaminated with Aluminum-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (iv) For the process kits contaminated with Titanium-related contaminants, submerge it into a tank with an aqueous mixed-chemical solution of Hydrogen Peroxide, Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$), 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 7:1:7 by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (v) For the process kits contaminated with Titanium-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (vi) For the process kits contaminated with Tantalum-related contaminants, submerge it into a tank with an aqueous chemical solution containing Potassium Hydroxide (15% KOH at 60-65°C) by weight, based on the total weight of the solution, for 1-2 hours until all stains have been removed. Ensure that the acid solution contacts all surfaces;
- (vii) Removing the process kit from the mix-chemical tank;
- (viii) Rinsing the process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing warm (temperature 45-50°C) city water for about 5-10 minutes, and at about several minutes' intervals, preferably about every 5 minutes. Again ensure all trapped air is removed from the internal area of the process kit;
- (ix) Water-jetting the process kit surface with high-pressure (110 bar) city water to remove any residues;
- (x) Re-immersing or submerging the process kit into a tank with 'bright dip' (2%HF and 18% HNO_3) aqueous mix-acid solution for 2 seconds; wherein the aqueous "bright dip" mix-acid solution of chemical stripping for process kits comprises

Hydrofluoric Acid (HF) and Nitric Acid (HNO₃), wherein the amount of Hydrofluoric Acid in said aqueous “bright dip” mix-acid solution is from about 2% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 18% by weight, based on the total weight of the solution;

- (xi) Removing the process kit from the ‘bright dip’ aqueous mixed-acid tank;
- (xii) Re-rinsing the process kit in an overflow (to facilitate effective fluid exchange) rinse tank containing warm (temperature 45-50°C) city water 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 process kit;
- (xiii) Water-jetting the process kit surface with high-pressure (110 bar) city water to remove any residues;
- (xiv) Repeating the above-mentioned steps on precision chemical cleaning until the contaminants are substantially removed from the process kits, and with the proviso that the process kit may not be in contact with the chemical solution for a time greater than five cumulative hours;
- (xv) Rinsing the process kit in an overflow rinse tank containing warm (40-50°C) de-ionized water for 15 minutes. Preferably, the tanks are kept covered to prevent air particulates from contaminating the de-ionized water;
- (xvi) Blowing dry the process kit with high pressure compressed clean-dry-air;
- (xvii) Inspecting the quality of the recycling cleaning method by checking the surface cleanliness and conditions of the process kit, as well as inspecting the process kit for signs of contamination, faulty cleaning or damage. The process kit is visually inspected for cleanliness using a portable microscope;
- (xviii) Repeating the above-mentioned steps, until the process kit is cleaned. Once process kit components have started the deposition removal and 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.

(b) Mechanical Stripping

- (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 blasting media such as white oxidized aluminum with a pressure of 3kg/cm^2 to achieve the surface roughness requirements;
- (iv) Blowing to clean the 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);.
- (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) Removing the blasting plaster and aluminum foil on the process kit surface.

(c) Thin-film Thermal Coating

- (i) Masking with thermal plaster and aluminum foil to protect critical surface from thermal spray;
- (ii) Spraying to coat the process kit surface with proprietary-optimized spraying parameters (current, voltage, speed, distance) according to the deposition media and the thickness (0.18-0.25mm) and surface roughness ($>18\mu\text{m}$) requirements;
- (iii) Blowing to clean the 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);
- (iv) Inspecting the surface roughness and conditions of the process kit after the thermal spraying. The surface roughness is measured by a surface profilometer. A change of less than about 35 Ra is considered an acceptable amount of surface roughness;

- (v) Repeating the above-mentioned steps, until the surface roughness is achieved;
- (vi) Removing the thermal plaster and aluminum foil on the process kit surface.

(d) Post-Processes Class1000 Cleaning and Inspection

- (i) Blowing to clean on the process kit surface to remove particles using high pressure compressed clean-dry-air (dry, oil-free, and filtered at the point of use with a 0.1 micron filter);
- (ii) Wiping to clean the non-blasted/sprayed process kit surface areas with some solvents, preferably hand polishing using fine mesh alumina in an isopropyl alcohol on a lint free cloth or with ScotchBrite (Alumina loaded Grade A);
- (iii) Cleaning the process kit with high pressure (60 bar) water-jet system;
- (iv) Rinsing the process kit in an overflow rinse tank containing four sets of ultrasonic system (40KHz/1800W) and warm de-ionized water (temperature 45-50°C), preferably at least three rinsing to ensure removal of all acid cleaning solution. The de-ionized water is filtered to remove all particles down to 0.1 um. All utensils that contact the rinse tanks and contents are rinsed with de-ionized water;
- (v) Cleaning the process kit with high pressure (60 bar) de-ionized (resistivity of 2 M Ohm-cm or higher) water-jet system;
- (vi) Blowing dry the process kit with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter);
- (vii) Inspecting the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition, as well as inspecting the process kits for stain, dirt, defect and fracture such as scratch and dent as well as to the particular inner edge of the process kits;
- (viii) Inspecting the quality of the deposition removal and recycling cleaning method by checking the surface cleanliness and conditions of the process kit. The process kit is visually inspected for cleanliness using a portable microscope;
- (ix) Repeating the above-mentioned steps, until the process kit is cleaned.

(e) Final Class100 Cleaning, Baking and Certification

- (i) Handling of all post cleaning activity such as assembly or leak checking must be carried out in class 100 clean-room environments. 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;
- (ii) Rinsing the process kit in an overflow rinse tank containing four sets of ultrasonic system (40KHz/1800W) and warm de-ionized water (temperature 45-50°C), preferably at least three rinsing to ensure removal of all acid cleaning solution. The de-ionized water is filtered to remove all particles down to 0.1 um. All utensils that contact the rinse tanks and contents are rinsed with de-ionized water;
- (iii) Blowing dry the process kit with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter) within a class 100 clean-room environments. An Isopropylalcohol (IPA) or deionized water (DI) moistened clean room wipe is used to remove fingerprints, water marks etc;
- (iv) Baking and drying of the process kit using a class100 dust free air oven within a class 100 clean-room environments to remove water vapor, chemicals and spouts traps during the cleaning process. The baking of the 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 class100 dust free air oven should be of sufficient size to accommodate the process kits and the kits should be kept away from the oven wall by jig and fixtures;
- (v) Cooling the process kit within a class 100 clean-room before taking out from the oven;
- (vi) Inspecting and confirming the process kits on the surface treatment areas such as the coated surface, blasted surface, non-coated surface, to ensure non-peeling of coated film and condition. In addition, 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 process kits;

- (vii) Measuring the surface particle count to ensure the surface cleanliness of the process kit surface within a class 100 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;
- (viii) Repeating the above-mentioned steps until the process kit is cleaned and surface particle count is achieved;
- (ix) Assembling the 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 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.

117. The process of claim 116(a), wherein the aqueous acid solution of chemical stripping for Copper-related contaminant deposits comprises Nitric Acid (HNO₃).

118. The process of claim 117, wherein the amount of Nitric Acid (HNO₃) in said aqueous acid solution is from about 30% to 40% by weight, based on the total weight of the solution.

119. The process of claim 116(a), wherein the aqueous chemical solution of chemical stripping for Aluminum-related contaminant deposits comprises Potassium Hydroxide (KOH).

120. The process of claim 119, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is from 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.

121. The process of claim 116(a), wherein the aqueous chemical solution of chemical stripping for Titanium-related contaminant deposits comprises mix-chemical solution Hydrogen Peroxide Ammonium Hydroxide and Water (H₂O₂:NH₄OH:H₂O).

122. The process of claim 121, 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 7:1:7 by weight, based on the total weight of the solution.

123. The process of claim 116(a), wherein the aqueous chemical solution of chemical stripping for Tantalum-related contaminant deposits comprises Potassium Hydroxide (KOH).

124. The process of claim 123, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is about 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.

125. The process of claim 116(a), wherein the aqueous “bright dip” mix-acid solution of chemical stripping for process kits comprises Hydrofluoric Acid (HF) and Nitric Acid (HNO_3).

126. The process of claim 125, wherein the amount of Hydrofluoric Acid in said aqueous “bright dip” mix-acid solution is from about 2% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 18% by weight, based on the total weight of the solution.

127. The process of claim 116(a), wherein the chemical stripping is carried out at a temperature in the range of from about 25°C to about 65°C.

128. The process of claim 116(a), wherein the chemical stripping is carried out for a contacting time of from about 60 to 120 minutes, and is carried out for not longer than five cumulative hours.

129. The process of claim 116(a), 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 and is carried out at a temperature of about 45°C to 50°C.

130. The process of claim 116(a), wherein the process kits is cleaned with water-jet to remove any residues; wherein the cleaning is carried out at a high-pressure in the range of from about 90 bar to about 110 bar.

131. The process of claim 116(a), wherein the process kits is multiple-rinsed with warm de-ionised water in an overflow rinse tank for about 5 to about 10 minutes.

132. The process of claim 131, wherein the temperature of the de-ionized water is heated up to a temperature of about 45°C to 50°C.

133. The process of claim 131, wherein deionized water used for rinsing is controlled at a resistivity of 2 M Ohm-cm or higher and filtered to substantially remove all particles down to 0.1 μm .

134. The process of claim 116(a), wherein the process kit is cleaned and dried using high pressure ionized clean dry air, and is carried out at a pressure range of about 60 bar to 110 bar.

135. The process of claim 116(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.

136. The process of claim 116(b), wherein the blasting media used for mechanical stripping is white oxidized aluminum and is carried out with a blasting pressure of $3\text{kg}/\text{cm}^2$ to achieve the required surface roughness.

137. The process of claim 116(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.

138. The process of claim 116(c), wherein the thermal spray coating comprises setting up and masking the process kits with different thermal plaster and aluminum foil to protect critical surfaces from thermal spray processes.

139. The process of claim 116(c), wherein the thermal spray parameters used for thermal spray process are the current is 300A, the voltage is 29V, the speed is 90rpm, the distance is 30cm, to achieve the required surface roughness and thickness.

140. The process of claim 116(c), 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.

141. The process of claim 116(d), wherein the process kits are post-process cleaned and inspected within a class1000 clean-room.

142. The process of claim 116(d), 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.

143. The process of claim 116(d), wherein the non-blasted/sprayed process kit surface areas are wiped cleaned with fine mesh alumina in an isopropyl alcohol on a lint free cloth or with ScotchBrite (Alumina loaded Grade A).

144. The process of claim 116(d), wherein the water-jet used for removing any residues is carried out at a high pressure in the range of about 60 bar.

145. The process of claim 116(d), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution.

146. The process of claim 145, wherein the ultrasonic system is 40KHz/1800W.

147. The process of claim 145, wherein the temperature of the de-ionized water is heated up to 45-50°C.

148. The process of claim 145, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.

149. The process of claim 145, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.

150. The process of claim 116(d), wherein the process kit is dried with high pressure compressed ionized clean dry, oil-free, and filtered at the point of use with a 0.1 micron filter air.

151. The process of claim 116(d), wherein the quality of the process kit is visually inspected for cleanliness using a portable microscope.

152. The process of claim 116(e), wherein the process kits are final cleaned, baked and certified within a class100 clean-room.

153. The process of claim 116(e), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution, within a class100 clean-room environment.

154. The process of claim 153, wherein the ultrasonic system is 40KHz/1800W.

155. The process of claim 153, wherein the temperature of the de-ionized water is set to 45-50°C.

156. The process of claim 153, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.

157. The process of claim 153, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.

158. The process of claim 116(e), wherein the process kit is cleaned and dried with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter) within a class100 clean-room environment.

159. The process of claim 116(e), wherein the process kit is baked and dried using a class100 dust free air oven within a class100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process;

160. The process of claim 159, wherein the 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.

161. The process of claim 159, wherein the class100 dust free air oven should be of sufficient size to accommodate the process kits and the kits should be kept away from the oven wall by jig and fixtures.

162. The process of claim 159, the process kit is cooled before taking out from the oven within a class100 clean-room environment.

163. The process of claim 116(e), wherein the surface cleanliness of the process kit surface is measured using a surface particle tester or equipment, within a class100 clean-room environment.

164. The process of claim 163, wherein the acceptable criteria for the process kit surface cleanliness is generally less than about 5 particles/cm², based on particle size of about 0.3 microns, as measured by surface particle detector, such as QIII Plus by Pentagon technology.

165. The process of claim 163, wherein the physical surface morphology of the process kits is tested to ensure that it is intact after a cleaning procedure is completed.

166. A method of increasing the overall equipment effectiveness and availability of a semiconductor equipment, in which comprises of a process kits that is contaminated with contaminant species deriving from a semiconductor process, the method comprising:

(a) Acceptance inspection process whereby all components of the process kits are received, dismantled, documented, thoroughly examined for damage, categorized and separated into the required deposition removal and recycle cleaning processes such as the chemical-method and mechanical-method; and then cleaned with high pressure water-jet is used to remove any gross contamination, if necessary.

(b) Chemical stripping process whereby the process kit is immersed into a tank with an aqueous mixed-acid solution (according to the particular contaminants build-up on the process kit); and then removed and rinsed in an overflow rinse tank containing warm city water; and then cleaned with high pressure water-jet to remove any residues; and then re-immersed into a tank with 'bright dip' aqueous mix-acid solution; and then removed and re-rinsed in an overflow rinse tank containing warm city water; and then dried with high pressure compressed clean-dry-air; and then inspected for surface cleanliness and signs of contamination, faulty cleaning or damage; and then re-rinsed in an overflow rinse tank containing warm de-ionized water; and then blow dried with high pressure compressed clean-dry-air; and the chemical stripping sequence is repeated until the process kit is cleaned.

(c) Mechanical stripping process whereby the process kit is masked with blasting plaster and aluminum foil to protect critical surfaces; and then blasted with suitable blasting media to achieve the surface roughness requirements; and then cleaned with high pressure compressed clean-dry-air; and then inspected for surface roughness and conditions of the process kit after the mechanical blasting; and the mechanical stripping sequence is repeated until the surface roughness is achieved.

(d) Thin-film thermal coating process whereby the process kit is masked with thermal plaster and aluminum foil to protect critical surface; and then sprayed with a suitable deposition media and proprietary-optimized spraying techniques to achieve the thickness and surface roughness; and then cleaned with high pressure compressed clean-dry-air; and then inspected for surface roughness and conditions of the process kit after the thin-film thermal spraying; and the thin-film thermal coating is repeated until the surface roughness and thickness is achieved.

(e) Post-Processes Class1000 cleaning and inspection process whereby the process kit is cleaned using high pressure compressed clean-dry-air; and any non-blasted/sprayed surface area is cleaned with some solvents; and then cleaned with high pressure water-jet system; and then rinsed in an overflow rinse tank containing ultrasonic system and warm de-ionized water; and

then cleaned with high pressure de-ionized water-jet system; and then dried with high pressure compressed clean-dry-air; and then inspected for non-peeling of coated film, stain, dirt, defect and fracture, surface cleanliness and signs of contamination, faulty cleaning or damage; and the sequence is repeated if the inspection indicates the presence of visible contaminants.

(f) Final Class100 cleaning, baking and certification process whereby the process kit is rinsed in an overflow rinse tank containing ultrasonic system and warm de-ionized water within a class 100 clean-room; and then dried with high pressure compressed ionized clean dry air; and then touched up with clean room wipe (if necessary); and then baked and dried with a class100 dust free air oven to remove water vapor, chemicals and spouts traps during the cleaning process; and then cooled within the dust free air oven before taking out from the oven; and then measured the surface particle count to ensure the surface cleanliness of the process kit; and then tested for the physical surface morphology of the process kits to ensure that it is intact after a cleaning procedure is completed; and the sequence is repeated until the process kit is cleaned and surface particle count is achieved; and then certified the process kits with the results of visual inspection per the guidelines established; and then assembled according to the standard procedures, working instruction sheets and recipes within a class 100 clean-room environment; and then inspected for the presence of visible contaminants, confirmed and measured the critical dimensions of the assembled process kits before sending for vacuum packaging.

(g) Packaging, identification and shipment process whereby the process kit is packed and vacuum sealed within a class 100 clean-room environment using a double bags vacuum pack with inner bag is a blue anti-static polyethylene bag and the outer bag is a white normal polyethylene bag; and then inspected for the condition of the vacuum pack to ensure a complete vacuum seal packing of the process kit within a class 100 clean-room environment; and then verified for quantity and a correct packing list with proper labeling and identification of the process kits; and then packed and secured into a proprietary-designed container box before delivery to customer.

167. The process of claim 166(a), wherein the acceptance inspection step comprises receiving, dismantling, taking digital pictures, data logging critical dimension, categorize and separate into different deposition removal and recycle cleaning process routings.

168. The process of claim 166(b), wherein the aqueous acid solution of chemical stripping for Copper-related contaminant deposits comprises Nitric Acid (HNO_3).

169. The process of claim 168, wherein the amount of Nitric Acid (HNO_3) in said aqueous acid solution is from about 30% to 40% by weight, based on the total weight of the solution.

170. The process of claim 166(b), wherein the aqueous chemical solution of chemical stripping for Aluminum-related contaminant deposits comprises Potassium Hydroxide (KOH).

171. The process of claim 170, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is from 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.

172. The process of claim 166(b), wherein the aqueous chemical solution of chemical stripping for Titanium-related contaminant deposits comprises mix-chemical solution Hydrogen Peroxide Ammonium Hydroxide and Water ($\text{H}_2\text{O}_2:\text{NH}_4\text{OH}:\text{H}_2\text{O}$).

173. The process of claim 172, 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 7:1:7 by weight, based on the total weight of the solution.

174. The process of claim 166(b), wherein the aqueous chemical solution of chemical stripping for Tantalum-related contaminant deposits comprises Potassium Hydroxide (KOH).

175. The process of claim 174, wherein the amount of Potassium Hydroxide (KOH) in said aqueous chemical solution is about 15% by weight, based on the total weight of the solution; wherein is carried out at temperature in the range of from about 60°C to about 65°C.

176. The process of claim 166(b), wherein the aqueous “bright dip” mix-acid solution of chemical stripping for process kits comprises Hydrofluoric Acid (HF) and Nitric Acid (HNO_3).

177. The process of claim 176, wherein the amount of Hydrofluoric Acid in said aqueous “bright dip” mix-acid solution is from about 2% by weight, based on the total weight of the solution, and the amount of Nitric Acid in said solution is from about 18% by weight, based on the total weight of the solution.

178. The process of claim 166(b), wherein the chemical stripping is carried out at a temperature in the range of from about 25°C to about 65°C.

179. The process of claim 166(b), wherein the chemical stripping is carried out for a contacting time of from about 60 to 120 minutes, and is carried out for not longer than five cumulative hours.

180. The process of claim 166(b), 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 and is carried out at a temperature of about 45°C to 50°C.

181. The process of claim 166(b), wherein the process kits is cleaned with water-jet to remove any residues; wherein the cleaning is carried out at a high-pressure in the range of from about 90 bar to about 110 bar.

182. The process of claim 166(b), wherein the process kits is multiple-rinsed with warm de-ionised water in an overflow rinse tank for about 5 to about 10 minutes.

183. The process of claim 182, wherein the temperature of the de-ionized water is heated up to a temperature of about 45°C to 50°C.

184. The process of claim 182, wherein deionized water used for rinsing is controlled at a resistivity of 2 M Ohm-cm or higher and filtered to substantially remove all particles down to 0.1 μm .

185. The process of claim 166(b), wherein the process kit is cleaned and dried using high pressure ionized clean dry air, and is carried out at a pressure range of about 60 bar to 110 bar.

186. The process of claim 166(c), 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.

187. The process of claim 166(c), wherein the blasting media used for mechanical stripping is white oxidized aluminum and is carried out with a blasting pressure of $3\text{kg}/\text{cm}^2$ to achieve the required surface roughness.

188. The process of claim 166(c), 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.

189. The process of claim 166(d), wherein the thermal spray coating comprises setting up and masking the process kits with different thermal plaster and aluminum foil to protect critical surfaces from thermal spray processes.

190. The process of claim 166(d), wherein the thermal spray parameters used for thermal spray process are the current is 300A, the voltage is 29V, the speed is 90rpm, the distance is 30cm, to achieve the required surface roughness and thickness.

191. The process of claim 166(d), 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.

192. The process of claim 166(e), wherein the process kits are post-process cleaned and inspected within a class1000 clean-room.

193. The process of claim 166(e), 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.

194. The process of claim 166(e), wherein the non-blasted/sprayed process kit surface areas are wiped cleaned with fine mesh alumina in an isopropyl alcohol on a lint free cloth or with ScotchBrite (Alumina loaded Grade A).

195. The process of claim 166(e), wherein the water-jet used for removing any residues is carried out at a high pressure in the range of about 60 bar.

196. The process of claim 166(e), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three rinsing to ensure removal of all acid cleaning solution.

197. The process of claim 196, wherein the ultrasonic system is 40KHz/1800W.

198. The process of claim 196, wherein the temperature of the de-ionized water is heated up to 45-50°C.

199. The process of claim 196, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.

200. The process of claim 196, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.

201. The process of claim 166(e), wherein the process kit is dried with high pressure compressed ionized clean dry, oil-free, and filtered at the point of use with a 0.1 micron filter air.

202. The process of claim 166(e), wherein the quality of the process kit is visually inspected for cleanliness using a portable microscope.

203. The process of claim 166(f), wherein the process kits are final cleaned, baked and certified within a class100 clean-room.

204. The process of claim 166(f), wherein the process kits are rinsed in an overflow rinse tank containing four sets of ultrasonic system and warm de-ionized water, preferably at least three

rinsing to ensure removal of all acid cleaning solution, within a class100 clean-room environment.

205. The process of claim 204, wherein the ultrasonic system is 40KHz/1800W.

206. The process of claim 204, wherein the temperature of the de-ionized water is set to 45-50°C.

207. The process of claim 204, wherein the de-ionized water is filtered to remove all particles down to 0.1 um.

208. The process of claim 204, wherein the process kit is cleaned with high pressure de-ionized water-jet system; wherein the water-jet pressure is controlled at about 60 bar and the resistivity of the de-ionised water is controlled at 2 M Ohm-cm or higher.

209. The process of claim 166(f), wherein the process kit is cleaned and dried with high pressure compressed clean-dry-air (ionized clean dry air must be dry, oil-free, and filtered at the point of use with a 0.1 micron filter) within a class100 clean-room environment.

210. The process of claim 166(f), wherein the process kit is baked and dried using a class100 dust free air oven within a class100 clean-room environment to remove water vapor, chemicals and spouts traps during the cleaning process;

211. The process of claim 210, wherein the 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.

212. The process of claim 210, wherein the class100 dust free air oven should be of sufficient size to accommodate the process kits and the kits should be kept away from the oven wall by jig and fixtures.

213. The process of claim 210, the process kit is cooled before taking out from the oven within a class100 clean-room environment.

214. The process of claim 166(f), wherein the surface cleanliness of the process kit surface is measured using a surface particle tester or equipment, within a class100 clean-room environment.

215. The process of claim 214, wherein the acceptable criteria for the process kit surface cleanliness is generally less than about 5 particles/cm², based on particle size of about 0.3 microns, as measured by surface particle detector, such as QIII Plus by Pentagon technology.

216. The process of claim 214, wherein the physical surface morphology of the process kits is tested to ensure that it is intact after a cleaning procedure is completed.

217. The process of claim 166(g), wherein the process kit is packed and vacuum-sealed within a class100 clean-room environment using a double bags vacuum pack;

218. The process of claim 217, wherein the inner bag is a blue anti-static polyethylene bag of thickness 0.12mm with clean lint free material to prevent damage during handling or shipment.

219. The process of claim 217, wherein the outer bag is a white normal polyethylene bag of thickness 0.12mm.

220. The process of claim 166(g), 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 process kit within a class100 clean-room environment.

221. The process of claim 166(g), 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 process kits.

222. The process of claim 166(g), wherein the process kits are packed into a proprietary-designed container box with cushion designated to properly protect and secure the process kit before delivery shipment to customer.

223. The apparatus for deposition removal and recycle cleaning of semiconductor process kits in comprises of the equipment and facilities such as: (a) De-ionized water source; (b) Blasting Media; (c) Compressed Nitrogen or Air; (d) Class 1000/100 Clean-room; (e) Process Tanks; (f) Thermal Coating System; (g) High Pressure Water-jet; (h) Ultrasonic systems; (i) Vacuum Pack System; (j) Quality Control Equipment.

224. The apparatus of claim 223(a), wherein 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, with a proper Ultra-Violet 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 M Ohm-cm.

225. The process of claim 224, wherein the DI 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 DI water with specific resistivity of no less than 0.2 M Ohm-cm, (b) for spray rinse: Power spray blind holes, creases, and non-welded seams by using cold DI water with specific resistivity of no less than 2 M Ohm-cm, (c) for hot rinse:

immerse in hot DI bath of 45 to 50°C with minimum resistivity of 2 M Ohm-cm. DI water in immersion tanks shall be overflowing.

226. The apparatus of claim 223(b), wherein the blasting media is Aluminum Oxide, Al₂O₃.

227. The apparatus of claim 223(c), wherein the Nitrogen or air used to dry components shall be dry, oil-free, and filtered at the point of use with a 0.1 mm filter.

228. The apparatus of claim 223(d), wherein the equipment required include Class 100 clean room oven and Class 100 clean room deionized (DI) water rinse tanks with ultrasonic cleaning.

229. The apparatus of claim 223(e), wherein the equipment required are properly agitated by oil-free clean dry air or nitrogen and mechanical agitation is used to prevent contaminating by particles or hydrocarbons, and includes: (a) two mix-acid tank for HF and HNO₃; (b) two chemical solution tank; (c) one mix-acid tank for “bright dip” aqueous mix-chemical solution; (d) two warm city water overflow rinse tanks; (e) two high pressure water-jet rinse tanks; (f) two deionized (DI) water rinse tanks with ultrasonic cleaning; (g) two deionized (DI) water rinse tanks.

230. The apparatus of claim 229, wherein the tanks are fabricated from polypropylene and have sufficient dimensions to completely hold the process kits and allowing for submerging thereof. More preferably, the dimensions of the tanks are design and built between 600-1000mm in length, 600-1000mm 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 process kits to create a “cleaning” effect.

231. The apparatus of claim 229, wherein the tanks tank are incorporated with a heat source coupled to the tank to “warm or heat” up the mix-acid or chemical solutions or de-ionised water content inside the tank to above ambient or "room" temperature by some known heating means such as a resistance-heating device with a thermocouple to monitor the temperature within the tank for safety reasons.