

merges with the feedstock gas 40 to form the discharging fluid 50. The discharging fluid 50 is then passed through apertures 56a, 58a in the dielectric plates 56, 58. The electric field strength within the apertures 56a, 58a is high and it shapes the discharging fluid 50. For example, by using suitable sizes and shapes of the apertures 56a, 58a, the plasma 45 in the discharging fluid 50 is concentrated or expanded in area. With multiple dielectrics plates or tubes 56, 58 being stacked together and coupled with the discharging fluid 50, the plasma 45 is guided to flow in different directions (ie. in-directly) from the electrode 36 to the work pieces 32. The dielectric members 56, 58 with small apertures 56a, 58a allow the plasma 45 and the discharging fluid 50 to pass through. Thus the ion energy, density of the plasma 45 and discharging fluid 50 are accordingly controlled. As seen earlier, the dielectric members 56, 58 also assist in guiding or directing the plasma 45 so that the discharging fluid 50 covers the workpiece 32 surface including the workpiece surface inside the cleaning chamber 34.

[0039] An enlarged photographic view of a wire bonder's wedge is illustrated in FIG. 7A. FIG. 7B is a scanning electron microscope (SEM) image of the edge that is contaminated with usage. FIG. 7C shows SEM images of the same wedge before and after cleaning by the SPC, together with contaminant signatures.

[0040] An enlarged photographic view of probe-card tips is illustrated in FIG. 8A. FIG. 8B is an SEM image of one of the probes that is contaminated with usage. FIG. 8C is an SEM image of the same probe after cleaning by the SPC 30, 130.

[0041] Several embodiments are illustrated at FIGs. 9A-9C for G-SPC with a single feedstock gas inlet 38. FIG. 9A shows the feedstock gas inlet 38 and outlet 42 at the same horizontal level and closer to the electrode 36 while being further away from the workpiece 32. FIG. 9B shows the feedstock gas inlet 38 and outlet 42 at the same horizontal level and centrally located between the electrode 36 and the workpiece 32. FIG. 9C shows the feedstock gas inlet 38 and outlet 42 at the same horizontal level and closer to the workpiece 32 while being further away from the electrode 36.

[0042] Several embodiments are illustrated at FIGs. 10A-10C for G-SPC with multiple feedstock gas inlets 38. FIG. 10A shows one set of the feedstock gas inlet 38b and outlet 42b at the same horizontal level and closer to the electrode 36 while another such set 38a, 42a respectively closer to the work piece 32. FIG. 10B shows one set of feedstock gas inlet 38a

[0046] Ions, radicals and neutral species at the electrode 36 including the same elements of the workpiece 32 are also transferred onto the surface of workpiece 32 to replace the contaminants. This reconditions the surface and recovers the structure distortion caused by the removal of embedded contaminants. The localized heating will also anneal the surface *in-situ* and repair the internal structure of the workpiece 32 as discussed earlier.

[0047] Advantageously, the SPC cleaning apparatus is small. FIG. 12A shows the electrode 36 of the SPC is mounted onto a handler 20 and the electrode 36 is configured to be inserted into a cavity of a test socket 32 for semiconductor testing; the space in the socket cavity between the test socket 32 and electrode 36 thus forms a cleaning chamber 34. In FIG. 12A, the feedstock 40 gas inlet and suction line for removing contaminants are not shown. FIG. 12B shows an SEM image of a pin 33 in the Kelvin test socket before SPC, together with an analysis of the surface contamination. FIG. 12C shows an SEM image of the Kelvin test socket pin after SPC, together with an analysis of the surface contamination. FIG. 12C shows that the SPC system has been effective in removing tin contamination on pins in a test socket. FIGs. 12D and 12E are also SEM images of the Kelvin pin before and after SPC.

[0048] FIG. 13A shows a schematic of a SPC system 130 according to another embodiment of the present invention. As shown in FIG. 13A, the SPC system 130 includes a cleaning chamber 34, an electrode 36 connected to a power generator 44, a floating electrode 160 disposed between the electrode 36 and the workpiece 32 to generate a plasma 145. The floating electrode 160 is electrically isolated and has a floating potential relative to the power generator 44; schematically, a network R (made up of resistor, inductor and capacitor) is shown connected to ground or a bias. In use, the plasma 145 generated between the floating electrode 160 and the workpiece 32 inside the cleaning chamber 34 has low ion energy. As in the above embodiments, the cleaning chamber is at atmospheric pressure. The plasma 145 is different from that in the NTP shown in FIG. 3 and has low ion bombardment energies and plasma damage to the workpiece is suppressed. In the space between the electrode 36 and the floating electrode 160, there may or may not be any plasma present. In one embodiment, the floating electrode 160 is made from a metal; in another embodiment, the floating electrode 160 is made of ceramic, semiconductor or electric insulator. When the floating electrode is metallic, it can be connected to ground or tuning to a bias via the network R of resistor, inductor and capacitor; in this way, the electric field and ion energy in the cleaning chamber

can be controlled. Large area uniformity in plasma discharge is achieved by charge compensation via the floating electrodes and tuning the network R of resistor, inductor and capacitor.

[0049] FIG. 13B shows a variation of the SPC system. This SPC system 130a is similar to the above except that there are two floating electrodes 160, 160a. These floating electrodes 160, 160a are thin flat plates; in another embodiment of the SPC system 130b, as shown in FIG. 13C, the floating electrodes 160, 160a are grid meshes or plates with perforations, which are advantageous for use with a feedstock gas 40.

[0050] The above SPC system 130, 130a-130b is suitable for localized plasma cleaning on the workpiece 32 has a small cross-sectional area, such as a pin or probe. Advantageously, the surrounding area near a tip of the pin or probe is also cleaned during SPC. For large area plasma cleaning, a feedstock gas 40 is supplied into the cleaning chamber 34, as shown by a SPC system 130c in FIG. 14A. The feedstock gas 40 provides ions and inert gas radicals to enhance the plasma cleaning process and to spread plasma cleaning over a large surface of the workpiece 32. It is possible that there are two or more feedstock gases 40 are fed into the cleaning chamber 34. As in the above embodiments, the feedstock gas can be a single element or a mixture of gases.

[0051] FIG. 14B shows a SPC system 130d according to another embodiment. This SPC system 130d is similar to the above SPC system 130c except that the plasma 145 is now guided by deflectors 170 onto the workpiece 32. To remove contaminants dislodged from the workpiece, a suction nozzle 180 is provided near the workpiece.

[0052] The above SPC systems 30, 130, 130a-130d are applied in a dry cleaning chamber 34. FIG. 15 shows a SPC system 230 being configured with the cleaning chamber containing a liquid medium 234, where external connections to the floating electrodes 160, 160a and electrodes are not shown in the figure. As shown in FIG. 15, floating electrodes 160, 160a are immersed inside the liquid medium 234 between the electrode 36 and workpiece 32. The cleaning chamber is filled with a liquid medium, such as, water. In an embodiment, salt ions, such as potassium or sodium ions, are added into the liquid medium by dissolving in it a salt. An advantage of this embodiment is the plasma cleaning process uses both salt ions and water

CLAIMS:

1. A non-thermal soft plasma cleaning system comprising:
a cleaning chamber containing a fluid at atmospheric pressure;
an electrode disposed in the cleaning chamber, wherein the electrode is connected to a power generator through a power matching unit; and
a dielectric member disposed adjacent to the electrode to guide or direct a plasma generated between the electrode and a workpiece to reach the workpiece in a sweeping direction;
wherein the workpiece is cleaned by the plasma without causing any plasma damage.
2. The non-thermal soft plasma cleaning system according to claim 1, wherein the dielectric member has an aperture, so that the plasma goes through the aperture to reach the workpiece in the sweeping direction.
3. The non-thermal soft plasma cleaning system according to claim 1, wherein the fluid in the cleaning chamber is air or a gas; further comprising a feedstock gas to combine with the plasma into a discharging fluid flow, to guide the plasma to the workpiece, and to expand a cleaning area, with the feedstock gas adding plasma species into the plasma.
4. The non-thermal soft plasma cleaning system according to claim 3, further comprising a second dielectric member with an aperture, with the second dielectric member being disposed perpendicular to the dielectric member to constitute a plasma guiding and amplifying component.
5. The non-thermal soft plasma cleaning system according to claim 3, further comprising a second dielectric member with a second aperture, with the second dielectric member being disposed parallel to the dielectric member such that the (first) aperture is not in line with the second aperture, so as to constitute a plasma guiding and amplifying component.
6. The non-thermal soft plasma cleaning system according to any one of claims 1-5, further comprising a floating electrode disposed in the cleaning chamber, wherein the

floating electrode is connected to a tuning network of resistor, inductor and capacitor, with the tuning network connected to ground or a bias to further control over both an electric field component and ion energy in the plasma.

7. The non-thermal soft plasma cleaning system according to claim 6 comprising two or more floating electrodes.

8. The non-thermal soft plasma cleaning system according to claim 6 or 7, wherein the floating electrode is a plate, a plate with perforations or a grid mesh

9. The non-thermal soft plasma cleaning system according to any one of claims 6-8, further comprising a deflector to preionise, guide or direct the discharging fluid in the cleaning chamber to the workpiece.

10. The non-thermal soft plasma cleaning system according to any one of claims 1-9, wherein the workpiece is a test socket and a cavity of the test socket forms the cleaning chamber.

11. The non-thermal soft plasma cleaning system according to any one of claims 1-9, wherein the workpiece is a wire bonder wedge, a pin of a probe card for testing semiconductor devices, a pin of a test socket for testing semiconductor devices or other devices susceptible to plasma ion damage.

12. The non-thermal soft plasma cleaning system according to claim 3, wherein the feedstock gas is an inert gas, nitrogen, hydrogen, compressed air, liquid carbon dioxide or liquid nitrogen.

13. The non-thermal soft plasma cleaning system according to claim 1, wherein the fluid in the cleaning chamber is a liquid.

14. The non-thermal soft plasma cleaning system according to claim 13, wherein the liquid is water, solvent or a chemical solution.

15. The non-thermal soft plasma cleaning system according to claim 14, further comprising salt ions dissolved in the water.
16. The non-thermal soft plasma cleaning system according to claim 13, further comprising an inlet for injecting water or solvent with salt ions or a chemical solution into the cleaning chamber.
17. The non-thermal soft plasma cleaning system according to claim 16, further comprising an inlet for injecting a feedstock gas into the cleaning chamber.
18. The non-thermal soft plasma cleaning system according to claim 13, further comprising a floating electrode disposed between the electrode and the workpiece, with the floating electrode being connected to a tuning network of resistor, inductor and capacitor to provide further control over both an electric field component and ion energy in the plasma; and wherein the floating electrode is made of a metal, ceramic, a semiconductor or an electric insulator.
19. The non-thermal soft plasma cleaning system according to claim 1, further comprising a second dielectric member, which is disposed to further guide or direct the plasma to reach the workpiece in the sweeping direction.
20. The non-thermal soft plasma cleaning system according to claim 18, wherein the metallic floating electrode is a plate, a plate with perforations or a grid mesh.
21. A non-thermal soft plasma cleaning system comprising:
 - a cleaning chamber containing a fluid at atmospheric pressure;
 - an electrode disposed in the cleaning chamber, wherein the electrode is connected to a power generator through a power matching unit; and
 - a plasma guiding and amplifying component disposed near the electrode, wherein the plasma guiding and amplifying component comprises a first dielectric member with a first aperture and a second dielectric member with a second aperture, such that the first and second apertures are not inline, so that a path of a plasma generated between the electrode and a workpiece is substantially indirect.

22. The non-thermal soft plasma cleaning system according to claim 21, further comprising a feedstock gas, which combines with the plasma to form a discharging fluid flow,
23. The non-thermal soft plasma cleaning system according to claim 22, further comprising a deflector to guide or direct the discharging fluid in the cleaning chamber to the workpiece.
24. The non-thermal soft plasma cleaning system according to any one of claims 21-23, wherein the fluid in the cleaning chamber is air, gas or liquid.
25. The non-thermal soft plasma cleaning system according to claim 24, wherein when the fluid is a liquid, the fluid comprises a salt solution.