

SURFACE PROCESSING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a surface processing method and apparatus for processing the surface of a work piece such as a semiconductor device, a crystal oscillator, a printed wiring board or a wire, for example to improve the solder wettability of the work piece.

Description of the Related Art

One conventional method of cleaning a metal surface by using hydrogen atoms generated by a vacuum plasma known from Japanese Unexamined Patent Publication No. 2-190489 and another conventional method for improving the wettability of a printed wiring board using a vacuum-plasma cleaning technique is known from Japanese Unexamined Patent Publication No. 3-174972.

In another conventional method, the inventor of the present invention has demonstrated a technique, as known from W094/22628, Japanese Patent Application No. 7-2950, in which a plasma formed at, and retained at, atmospheric-pressure, instead of a plasma formed under a vacuum, is used to activate a gas. The wettability of a work to be soldered is improved by the use of a resulting active species such as ions or excited species (W094/22628, Japanese Patent Application No. 7-2950).

In the above processes of using the vacuum plasma and atmospheric-pressure plasma, surface processing is performed by active species excited by the plasma.

When processing a workpiece, a direct discharge processing technique in which a work piece to be processed is exposed to the plasma is not preferred, because the physical characteristics of the workpiece may be damaged, which may be attributed to the plasma. When the work piece to be processed has a metallic surface, a strong concentration of plasma collects at any projecting portion of the surface, and uniform processing over the entire surface cannot be achieved.

In view of these deficiencies in the direct discharge processing techniques, an indirect discharge processing technique has also been proposed in which active species generated in a plasma generator section are guided for processing to a workpiece being processed. The work is positioned in a remote location, and is not directly exposed to the plasma. In this case, no such plasma damage takes place.

However, the active species produced have a relatively short life. Positioning the workpiece to be processed in a remote location from the plasma generator section renders surface processing difficult or impossible and at least substantially reduces the efficiency of processing. Thus, this indirect discharge processing technique places a limitation on the location of the workpiece to be processed, and is therefore not practicable.

SUMMARY OF THE INVENTION

According to the method of the present invention, processing gases including halogen and hydrogen halide are brought into contact with the surface of a workpiece being processed to process the work. A workpiece being processed is surface-processed by a chemical reaction using a processing gas, including highly reactive halogen or hydrogen halide, rather than active species such as fluorine radicals, which have the characteristic of a short life span. Since the work piece being processed is not directly exposed to a plasma, the workpiece will be free from any defects arising from plasma damage. In an exemplary embodiment the halogen and hydrogen halide are typically fluorine gas F_2 and hydrogen fluoride HF .

In an exemplary method of the present invention, the processing gas is preferably produced by decomposing halogen compounds through the decomposition techniques of thermal decomposition, photolysis, decomposition by discharge, and electrolysis, singly or in combination. To this end, the surface processing apparatus of the present invention comprises processing gas generator for producing a processing gas by decomposing a halogen compound by one of the above techniques, and processing gas supplying means for guiding the processing gas to the surface of a workpiece being processed.

Halogen and hydrogen halide are themselves highly reactive and highly corrosive. In the present invention, stable halogen compound is used as a raw material

and is decomposed by one of the above techniques to produce the processing gas. Since the life of halogen or hydrogen halide is not as short as that of active species, the time limitation is not so critical as in the case of active species. This offers a large degree of freedom in the positioning of the workpiece being processed, and the workpiece can be positioned at a remote location.

The use of an organic halogen compound as a raw material halogen compound facilitates handling and reduces danger associated with the compound because of its neutral pH.

Preferred halogen compounds suitable for decomposition through thermal decomposition, photolysis, or decomposition by discharge are NF_3 , SF_6 , CF_4 or NH_4F . These halogen compounds are raw-material gasses, and are supplied to the processing gas generator through a raw-material gas supply.

To decompose the halogen compound, the raw-material gas is preferably decomposed at or at approximately atmospheric pressure by being excited by a pair of electrodes to which a low-frequency AC voltage, of 50 kHz or lower, or a DC voltage is applied. To this end, the processing gas generator of the present invention comprises a power supply that outputs a low-frequency AC voltage source, of 50 kHz or lower, or a DC voltage source, and a plasma generator section having a pair of electrodes to which the voltage is applied, for forming a plasma at or at approximately atmospheric pressure.

When the low-frequency AC voltage or DC voltage is applied between the pair of electrodes, a relatively large peak-to-peak value discharge voltage results, and a reliable discharge is generated without the need for the supply of a plasma generating gas such as helium (He). Thus, using the present invention, generation of a reliable atmospheric-pressure plasma, helium (He) is not necessarily required, and the running cost of the apparatus is reduced.

Decomposition processing of a halogen compound through thermal decomposition, photolysis and discharge is preferably carried out in an atmosphere including water. The presence of moisture permits the halogen compound to be decomposed into hydrogen halide in an efficient manner. Halogen compounds suitable for electrolysis are aqueous solutions of halides that are easy to be electrolyzed.

In any of thermal decomposition, photolysis, decomposition by discharge, and electrolysis, a processing gas is preferably force-fed by a carrier gas to bring the processing gas into contact with a workpiece being processed. In this case, the processing gas is more preferably mixed with the carrier gas after the decomposition process of the halogen compound. By mixing after decomposition, even if a gas containing oxygen is used as a carrier gas, the generation of ozone is not augmented during decomposition. Thus, in the apparatus of this invention, a carrier gas generator means is connected to either a raw-material gas generator or a processing gas generator.

According to an additional embodiment of the surface processing method and apparatus of the invention, instead of the above decomposition techniques, a processing gas is produced by bringing a carrier gas into contact with halogen or hydrogen halide. In this way, a processing gas containing the liquid of either halogen or hydrogen halide is generated to process the work.

The surface processing method of the invention preferably further comprises the steps of force-exhausting a process gas supplied to a workpiece being processed, and a reaction product, and trapping the processing gas or the reaction product while force-exhausting. To this end, the surface processing apparatus of the present invention comprises a forced exhaust and a trap. The processing gas is highly corrosive. The remainder of the unreacted highly corrosive processing gas and any reaction product from the surface processing are trapped during forced exhaustion and recovered without dispersing them into the atmosphere.

The surface processing method of the invention is preferably applied to a process in which the oxide on the surface of a work is replaced with a halogen compound by bringing the processing gas into contact with the surface of a work, thereby improving the solder wettability of the surface of the work.

Workpieces being processed suitable for this sort of process are typically electronic components such as printed circuit boards, integrated circuits (ICs), wires to be soldered, and crystal oscillators.

Accordingly, it is an object of the present invention to provide an improved surface processing method and apparatus which process the surface of a work being processed in a plasma damage-free state, and offer a large degree of freedom in the

positioning of the workpiece being processed.

It is another object of the present invention to provide an improved surface processing method and apparatus, in which a highly reactive processing gas is produced from a stable substance, and the surface of a workpiece being processed is processed by the processing gas.

It is yet another object of the present invention to provide an improved surface processing method and apparatus which process the surface of a workpiece being processed at a reduced running cost and at a reduced consumption rate of the processing gas, and in which relatively costly helium He gas is not required during processing.

It is yet another object of the present invention to provide an improved surface processing method and apparatus which process the surface of a workpiece being processed for improvements while restricting the generation of ozone that oxidizes the workpiece being processed.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specifications and drawings.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the apparatus embodying features of construction, combination(s) of elements and arrangement of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view depicting one embodiment of the processing gas generating unit constructed in accordance with the invention that produces a processing gas through thermal decomposition;

FIG. 2 is a diagrammatic view of another embodiment of the processing gas generating unit constructed in accordance with the invention that produces a processing gas through photolysis;

FIG. 3 is a diagrammatic view depicting another embodiment of the processing gas generating unit constructed in accordance with the invention that produces a processing gas through electric discharge;

FIG. 4 is a diagrammatic view depicting another embodiment of the processing gas generating unit constructed in accordance with the invention that produces a processing gas through photolysis;

FIG. 5 is a diagrammatic view depicting another embodiment of the processing gas generating unit constructed in accordance with the invention that produces a processing gas through contact with a liquid;

FIG. 6 is a diagrammatic view of a surface processing apparatus constructed in accordance with one embodiment of the invention.

FIG. 7 is a diagrammatic view depicting the internal construction of the surface processing unit of FIG. 6;

FIG. 8 is a block diagram depicting the plasma generator section of FIG. 7;

FIG. 9 is a block diagram of a surface processing unit constructed in accordance with an additional embodiment of the invention;

FIG. 10 is a diagrammatic view of an embodiment of the invention in which a processing gas is directly applied to a workpiece;

FIG. 11 is a diagrammatic view depicting the surface processing unit constructed in accordance with yet another embodiment of the invention;

FIG. 12 is a diagrammatic view depicting an embodiment of the invention in which a surface processing unit is incorporated in a line-type processing apparatus;

FIG. 13 is a cross-sectional view depicting the feed and exhaust section of the surface processing unit of FIG. 12;

FIG. 14 is a diagrammatic view depicting an embodiment of the invention in which a surface processing unit is incorporated in a stand-type processing apparatus;

FIG. 15 is a cross-sectional view depicting the feed and exhaust section of the surface processing unit of FIG. 14;

FIG. 16 is a diagrammatic view depicting an embodiment of the invention in which a surface processing unit is incorporated in a cylinder-type processing apparatus;

FIG. 17 is a cross-sectional view depicting the feed and exhaust section of the surface processing unit of FIG. 16;

FIG. 18 is a diagrammatic view depicting an embodiment of the invention in which a surface processing unit is incorporated in a toaster-like surface-processing apparatus;

FIG. 19 is a cross-sectional view depicting the feed and exhaust section of the surface processing unit of FIG. 18; and

FIG. 20 is a diagrammatic view depicting an embodiment of the invention in which the surface processing unit is incorporated in a batch-process type surface processing apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, the surface processing method and apparatus of the invention will be described.

Production method of the processing gas

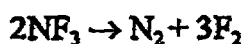
According to the present invention, a processing gas containing a halogen such as Cl_2 , Br_2 , F_2 , I_2 or hydrogen halide such as HF , HCl , HBr and HI , which is highly reactive is brought into contact with a workpiece to be processed so that the highly reactive processing gas processes the surface of the workpiece. To produce such a highly reactive processing gas, one of the techniques illustrated in FIGS. 1 through 5 is used.

FIGS. 1-5 illustrate different embodiments of a processing gas generating unit. Elements which are common to each of FIGS. 1-5 are a processing gas generator container 1 and a processing gas supplying tube 2 for guiding a generated processing gas to the workpiece being processed and are numbered consistently throughout.

Reference is made to FIG. 1 in which a processing gas generating unit 15 constructed in accordance with a first embodiment of the invention is shown. Processing gas generating unit 15 includes a raw-material gas supplying tube 3 for supplying a raw-material halogen compound gas, such as NF_3 , to processing gas generator container 1. A heater 4 disposed adjacent container 1 heats the interior of

processing gas generator container 1. Processing gas formed within processing gas generator container 1 exits through processing gas supply tube 2. In FIG. 1, processing gas generator container 1 thermally decomposes the halogen compound input through raw material gas supplying tube 3 by thermal energy and produces a processing gas containing halogen or hydrogen halide output at supply tube 2.

The minimum temperature required to thermally decompose the raw-material gas NF_3 is 300°C . When the raw-material gas is heated to a temperature of 500°C in this embodiment, a processing gas containing approximately 1000 ppm fluorine gas F_2 is obtained through thermal decomposition. The decomposition process is expressed by the following chemical formula.



A second embodiment of the processing gas generating unit, generally indicated as 16, is depicted in FIG. 2. Unit 16 differs from unit 15 in the use of photolysis to decompose the compounds. Like numbers are utilized to indicate like structures. A processing gas supplying tube 2 and a raw-material gas supplying tube 3 are connected to processing gas generator container 1. For the photolysis process, processing gas generator container 1 contains an ultraviolet lamp 5 for emitting ultraviolet light therein. A halogen compound is used as the raw-material gas and is decomposed through photolysis to produce a processing gas in processing gas generator container 1.

When ultraviolet lamp 5 is set to output ultraviolet radiation of 100 mW/cm^2 and at a wavelength of 400 nm with the raw-material gas being NF_3 , the photolysis expressed by the same chemical formula as that expressed in FIG. 1 takes place, resulting in a processing gas containing approximately 100 ppm fluorine gas F_2 .

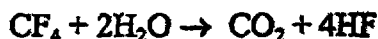
Another embodiment of the processing gas generating unit, generally indicated at 17 is depicted in FIG. 3. Unit 17 is similar to unit 15, like number are used to indicate like structure, the primary difference being the use of a plasma generator in unit 17. Again, processing gas supplying tube 2 and raw-material gas supplying tube 3 are connected to a processing gas generator container 1. To this end, processing gas generator container 1 contains a plasma generator section 6 having a pair of electrodes (not shown). A halogen compound is used as the raw-material gas and is decomposed through discharge under atmospheric pressure or approximately atmospheric pressure to

produce a processing gas in processing gas generator container 1.

In a preferred embodiment utilizing the processing gas generating unit 17, a raw-material gas CF_4 is supplied at a rate of 100 cc/minute, and a voltage having a frequency of approximately 10 kHz is supplied between the pair of electrodes of plasma generator 6. Discharge takes place at a peak-to-peak discharge voltage of 10 kVpp AC. Then, the raw-material gas is decomposed according to the following chemical formula, producing a processing gas containing approximately 800 ppm fluorine F_2 .



When a raw-material gas $\text{CF}_4 + \text{H}_2\text{O}$ is supplied at a rate of 300 cc/minute in unit 17, with the rest of the conditions unchanged from those in the preceding example, the raw-material gas is decomposed according to the following chemical formula, producing a processing gas containing approximately 7200 ppm hydrogen fluoride HF. In this way, hydrogen fluoride is efficiently produced with water added.



The use of a voltage supply having a frequency as low as approximately 10 kHz allows the discharge to take place reliably without the need for a supply of helium. This reduces the running cost involved in decomposition. To maintain a reliable discharge without supplying helium, the peak-to-peak value of the discharge voltage, with a low-frequency supply voltage, needs to be greater than a predetermined level. When the power supply voltage is a DC voltage or an AC voltage having a frequency of 10 kHz, 30 kHz, or 40 kHz, a successful discharge is observed. Thus, a low-frequency AC voltage of 50 kHz or lower or a DC voltage ensures a large peak-to-peak discharge voltage value, as is required by the invention.

Unlike hydrogen halide, halogen compounds decomposed by the processing gas generating units 15, 16, 17, including perfluorocarbon such as CF_4 , $\text{C}_n\text{F}_{(2n+2)}$, HFC such as $\text{C}_2\text{F}_2\text{H}_4$, fluorocarbon such as $\text{C}_2\text{F}_2\text{Cl}_4$, hydrochloric acid based solution such as $\text{C}_2\text{H}_3\text{Cl}_3$, and organic halogen compounds such as halogen of $\text{C}_2\text{F}_2\text{Br}_4$ are advantageous from the standpoint of handling because of their neutral pH. In view of the environment, perfluorocarbon and HFC are most preferably produced.

In the embodiment of processing gas generating unit, generally indicated at 18,

depicted in FIG. 4, the raw material gas supply tube is replaced with an aqueous source of raw-material contained within container 1. Processing gas supplying tube 2 is connected to processing gas generator container 1. Processing gas generator container 1 holds an aqueous solution 3a of halogen compound, for example, an aqueous solution of 2% NaF. Electrodes 8a, 8b connected to voltage source 135 are disposed within container 1 at the regions that are partitioned from each other by a partitioning plate 7. A 24 VDC voltage is applied to electrodes 8a, 8b, and a processing gas containing approximately 1000 ppm fluorine gas F_2 is produced.

Solution 3a of halogen compound is electrolyzed in processing gas generator container 1 to produce a processing gas. Halides suitable for electrolysis, besides NaF, are KF, LiF, CsF, NaCl, KCl, KBr, NaBr and NaI.

In another embodiment depicted in FIG. 5, a processing gas generator unit, generally indicated as 19 is shown, like numbers being utilized to indicate like parts. Container 1 includes an aqueous solution 3a. A carrier gas input port supplies carrier gas to container 1 and aqueous solution 3a through tube 9a. An exit tube 2a is disposed in container 1, proximate solution 3a, and coupled to processing gas supply tube 2. A carrier gas is brought into contact with a solution of halogen or hydrogen halide through tubes 9, 9a to produce a processing gas containing a liquid of halogen or hydrogen halide. By bringing the carrier gas into contact with one of the solutions of HF, HCl, HBr, HI and HCs, a processing gas containing a liquid containing one of these halogen compounds is produced and output through tubes 2a, 2.

Surface processing apparatus for indirect discharge

Reference is now made to FIG. 6 which is a diagrammatic view depicting a surface processing apparatus, generally indicated at 180, for indirect discharge constructed in accordance with one embodiment of the invention. A processing gas generator 30 is provided with a carrier gas and a raw-material gas. Processing gas exits processing gas generator 30 through a processing gas supply tube 20 which extends to a supply section 22. In a preferred embodiment supply section 22 is substantially umbrella shaped to diffuse the processing gas. An exhaust tube 24 is disposed adjacent supply section 22 and is coupled to processing gas generator 30 so that waste gases are

returned to processing gas generator unit 30 which is provided with an exhaust.

A conveyor belt 14 for carrying items to be processed is disposed below supply section 22. A workpiece to be treated, such as an integrated chip (IC) 10 is moved along the conveyor belt into position within supply section 22.

The work to be soldered is depicted as IC 10. ICs 10 placed on a conveyor belt 14 are moved sequentially in the direction from the direction in the page to the direction out of the page of the figure. A lead frame 12 of IC 10 is solder-coated beforehand. The surface of lead frame 12 is covered with tin (Sb), which is oxidized to form tin oxide (SnO). In this embodiment, during processing, tin oxide (SnO) formed on the surface of lead frame 12 is replaced with a halogen compound to improve solder wettability of lead frame 12. To surface process lead frame 12 of IC 10, a supplying connection tube 20 and an exhaust connection tube 24 are utilized.

A processing gas generated in a processing gas generator unit 30 is applied to lead frame 12 of IC 10 through supplying section 22 that is widely opened in an umbrella fashion. The exhaust connection tube 24 sucks in the processing gas, to which the lead frame 12 is exposed, and any reaction product produced as a result of processing, to force-exhaust them.

Reference is made to FIG. 10 in which another embodiment of a surface treatment apparatus, generally indicated as 190 is provided. Surface treatment apparatus 190 is similar to surface treatment apparatus 180, like elements being given like reference numerals, the primary difference being that waste treatment unit 80 is not located within the processing gas generator unit. This embodiment allows for the processing gas to be provided from a first location, and allows the unused processing gas, and any reaction products to be treated to waste treatment unit 80 at a second remote location.

Construction of the gas generator unit 30 will now be described. As shown in FIG. 7, processing gas generator unit 30 comprises a housing 32. A raw-material gas supplying tube 41 is connected to the upstream side of a plasma generator section 60 through a flowmeter 42. The open end of processing gas supplying tube 40 that is connected to the downstream side of the plasma generator section 60 is connected to the supplying connection tube 20. A supplying tube 90 is coupled to processing gas

supplying tube 40 downstream of plasma generator section 60. A raw-material gas containing halogen compound, in a preferred embodiment, CF_4 is introduced into raw-material gas supplying tube 41 from an external source, such as a facility in a plant.

A power supply 50 supplies power to plasma generator 60 to generate a plasma at atmospheric pressure or at approximately atmospheric pressure. The plasma generator section 60 has a pair of opposing electrodes 62a, 62b (FIG. 8) between which a porous insulating body 64 is interposed. Power supply 50 is provided with a plug 52 which may be inserted into a standard socket, and is connected to one electrode 62a. The other electrode 62b is grounded. A relatively low frequency AC voltage, of 50 kHz or lower, or a DC voltage is applied between electrodes 62a, 62b. A waste treatment unit 80 coupled to exhaust connection tube 24 through exhaust tube 70

Power supply 50 is designed to output a relatively low frequency AC voltage. In conventional apparatuses, to generate an atmospheric-pressure plasma, a large amount of helium, which may be relatively easily ionized, is required. Thus, if the frequency of the AC voltage applied between the pair of electrodes were a commercial, conventional frequency of 13.56 MHz, the atmospheric-pressure plasma could not be generated at this AC voltage (the commercial frequency of 13.56 MHz) under an atmosphere of air or N_2 without a relatively expensive helium gas. However, in this embodiment of the invention, by applying a relatively low frequency AC voltage of up to 50 kHz, or a DC voltage, between the pair of electrodes, the atmospheric-pressure plasma is reliably produced without helium gas. A low-frequency AC voltage thus results in a large peak-to-peak voltage, offering energy to be contributed to the generation of plasma.

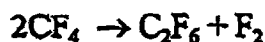
In the invention, the quantity of the processing gas supplied for processing an area of 1 cm^2 of a work is lowered to within a range of 0.01 cc to 50 cc, expensive helium gas was not used as a carrier gas, and the frequency of the AC voltage applied to the plasma generating electrodes is set to be 50 kHz or lower. As a result, the plasma was reliably produced.

Carrier gas supplying tube 90 is connected to processing gas supplying tube 40 at a mid-portion thereof, which is in turn connected to the downstream side of plasma generator section 60. A carrier gas introduced through carrier gas supplying tube 90 may be an inert gas such as N_2 . Alternatively, compressed air may be introduced

through carrier gas supplying tube 90. If compressed air were to be introduced into the plasma generator section 60, oxygen in the compressed air would be excited and ozone would be produced. Lead frame 12 of IC 10 would be exposed to ozone, which would oxidize lead frame 12. Therefore, in this embodiment and in accordance with the invention, carrier gas is mixed with the processing gas at the downstream side of plasma generator section 60 so that the carrier gas forces the processing gas toward lead frame 12, but is not present during plasma generation, and thus does not form ozone.

Housing 32 in surface processing unit 30 is provided with an exhaust tube 70 for force-exhausting the processing gas that has been applied to the lead frame 12. Exhaust tube 70 in surface processing unit 30 is connected to exhaust connection tube 24 of FIG. 6.

Exhaust tube 70 is connected to waste treatment unit 80, which is one example of a trap means. When CF_4 is used as a raw-material gas, it is excited in plasma generator section 60 and decomposes as follows.



The processing gas, containing fluorine gas (F_2), caused by this decomposition contributes to the surface processing of lead frame 12 of IC 10. A portion of the fluorine gas (F_2) is exhausted without contributing to the chemical reaction. However, fluorine gas (F_2) should not be released to the environment because it is a corrosive gas. Waste treatment unit 80 is designed to remove the corrosive component out of the processing gas introduced via the exhaust tube 70 by adsorbing the corrosive component or dissolving the corrosive component into water.

Surface processing method

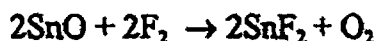
The operation of processing gas generator unit 30 will now be described. In this embodiment, compressed air is used as the carrier gas and a halogen compound such as CF_4 is used as a raw-material gas. The carrier gas and raw-material gas are introduced into carrier gas supplying tube 90 and raw-material gas supplying tube 41, respectively, of surface processing unit 30 by means of an external source which may be a facility in the plant. The flow rates of the raw-material gas and carrier gas are controlled by flow

meters 42, 92 mounted on tubes 41, 90, respectively. In this preferred embodiment, the flow rate of the compressed air as a carrier gas is 20 liters/minute while the flow rate of CF_4 as the raw-material gas is 50 cc/minute. The concentration of the raw-material gas to the carrier gas is preferably less than 0.5% by volume, namely, the corresponding flow rate of the raw material is less than 100 cc/minute and is most preferably $(50 \text{ cc}/20 \text{ liters}) \times 100 = 0.25\%$ by volume.

In this embodiment, the raw-material gas CF_4 is introduced into plasma generator section 60 only after the flow-rate is regulated and fixed within the appropriate range. A relatively low frequency AC voltage, its frequency ranging from 10 to 50 kHz, is applied between the pair of electrodes 62a, 62b disposed in plasma generator section 60. Even if only a small amount of CF_4 as the raw-material gas is used, a plasma is reliably produced at atmospheric pressure or at approximately atmospheric pressure, without the need of helium gas to facilitate plasma generation, because the period of the AC voltage is long.

When CF_4 is used as the raw-material gas, it is excited and decomposed in plasma generator section 60, and fluorine gas F_2 is produced, which is a highly reactive halogen. Carrier gas supplying tube 90 is connected to processing gas supplying tube 40, which is connected to the downstream side of plasma generator section 60. The flow of the carrier gas at a relatively high flow rate of 20 liters/minute is mixed with the produced processing gas to carry the processing gas for feeding and processing during the processing steps.

The mixture of processing gas and carrier gas is delivered through processing gas supplying tube 40 of processing gas generator unit 30 and is applied to the surface of IC 10. This application is made by supplying section 22 via supplying connection tube 20, which is connected to processing gas generator unit 30. Lead frame 12 of IC 10 is surface processed according to the following chemical formula.



The surface of the frame 12 bears an oxide SnO . Through contact with the processing gas, SnO is replaced with halogen compound (SnF_2). Since the IC 10 workpiece is not exposed to plasma, it is free from any damage attributed thereto.

The processing gas and carrier gas mixture applied to lead frame 12 which does not take part in any chemical reactions, and any reaction products are circulated back into surface processing unit 30 via exhaust connection tube 24. In surface processing unit 30, the above gases are guided into waste treatment unit 80 via exhaust tube 70.

Waste treatment unit 80 traps F_2 generated as a result of chemical reactions involving the processing gas by adsorbing or dissolving the F_2 into water to remove highly corrosive components and exhaust the residual gases. A dry-type exhaust gas treatment device, such as KANDEN F-Torr (registered trademark) manufactured by KANTO DENKA KOGYO is preferred as waste treatment unit 80 for removing the corrosive component through adsorption. To dissolve the corrosive components in water for removal, the exhaust gases are simply passed through water.

Thus, even if the processing gas delivered out of waste treatment unit 80 in surface processing unit 30 is force-exhausted through a facility in the plant, pollution problems such as corrosion are precluded since the corrosive aspects of the gas have been removed.

Construction of the surface processing unit

Construction of the processing gas generator unit in accordance with another embodiment of the invention, generally indicated as 100, will now be discussed with reference to FIG. 9, which depicts the processing gas generator unit that is capable of surface processing without using a supply and exhaust facility installed in the plant. Like numbers are utilized to indicate like structures.

Processing gas generator unit 100 depicted in FIG. 9 differs from that of the processing gas generator unit 30 in that surface processing unit 100 further comprises, in addition to the components noted in processing gas generator unit 30, in housing 32, a processing gas cylinder 44 coupled to plasma generator section 60 through flow meter 40. A feed fan 82 for feeding a carrier gas is disposed upstream of flow meter 92 and an exhaust fan 94 disposed downstream of waste treatment unit 80 to exhaust treated gas from housing 32. Fan driving sections 84, 96 are respectively provided for driving each fan. Fan driving sections 84, 96 are connected to the power supply 50.

Processing gas cylinder 44 is filled with a raw-material gas such as CF_4 , and feeds the raw-material gas to plasma generator section 60 via raw-material gas supplying tube 41 and flow meter 42. The concentration of the raw-material gas introduced into plasma generator section 60 as compared to the carrier gas is less than 0.5% by volume, and is acceptably as small as 0.25% by volume, for example, as noted in the prior embodiment. A single gas cylinder 44 therefore is sufficient to process lead frame 12 of a number of ICs 10.

By arranging fan 94 at the front of carrier gas supplying tube 90, air in the plant may be introduced as compressed air and may be used as the carrier gas. By arranging exhaust fan 82 at the downstream side of waste treatment unit 80, ambient gases around IC 10 are force-exhausted through exhaust connection tube 24, exhaust tube 70 and waste treatment unit 80 in gas generator processing unit 30.

Thus, without the need for a separate feed and exhaust facility in the plant, the surface of lead frame 12 of IC 10 may be surface processed by connecting supplying connection tube 20 and exhaust connection tube 24 to surface processing unit 100.

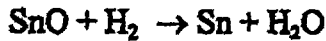
Usable processing gas

The raw-material gas introduced into plasma generator section 60 may be any stable halogen compound, typically CF_4 , as already described. Halogen and hydrogen halide are highly reactive themselves and corrosive. As already described, only after being excited, halogen and hydrogen halide are decomposed into fluorine gas F_2 or the like as a processing gas. Thus, it is more advantageous that a halogen compound such as CF_4 is used as a raw-material gas since it is non-corrosive.

Suitable halogen compounds for use as a raw-material gas are any of perfluorocarbons such as hexafluoroethane, perfluoropropane, and perfluoropentane, and octafluorocyclobutane, tetrafluoroethane, trifluoromethane, monobromotrifluoromethane, tetrachloromethane, trichloromonofluoromethane, dichlorodifluoromethane, chlorotrifluoromethane, sulfur hexafluoride, nitrogen trifluoride, and boron trichloride.

Instead of the above-mentioned halogen-based gases, reducing gas such as hydrogen gas H_2 may also be used, hydrogen gas H_2 is excited in the plasma generator

section 60 for activation, and this processing gas is applied to lead frame 12. The chemical formula in this case is as follows:



The reducing gas H_2 reduces the oxide SnO present on the surface of lead frame 12, thereby enhancing the wettability of lead frame 12. When a reducing gas is used, no corrosive components in the reaction products are generated, and thus the waste treatment unit 80 is dispensed with.

Gases for use as a carrier gas

In the above embodiments, compressed air is used as a carrier gas. Compressed air is advantageous when processing gas generator unit 100 in FIG. 9 is utilized since ambient air, which may be from inside the surrounding plant may be used. When compressed air is used as a carrier gas, however, if it is introduced into plasma generator section 60, ozone is generated in plasma generator section 60, and oxidization of lead frame 12 becomes problematic. For this reason, when using compressed air, carrier gas supplying tube 90 must be joined to processing gas supplying tube 40 on the downstream side of plasma generator section 60.

When an inert gas that is inert to the surface of lead frame 12 is used as a carrier gas, the carrier gas can be introduced into plasma generator section 60. Nitrogen gas N_2 may be used as a relatively inexpensive inert gas.

Additionally, while the use of a carrier gas is preferred in that an active processing gas is forcibly carried toward workpiece 10, the use of a carrier gas is not necessarily required. Without the carrier gas, the atmospheric-pressure plasma needed to activate the surface of the work may be reliably produced by simply supplying, without a carrier gas, a small amount of processing gas within a range of 0.01 cc to 50 cc for processing an area of 1 cm^2 of the workpiece.

Addition of moisture

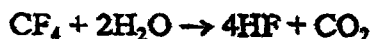
It has been determined that the addition of water as an additive into the plasma generator section 60 increases processing speed. To add water, the raw-material gas is

passed through pure water. Water is added because when CF_4 is used as the raw-material gas, the following reaction takes place in the plasma generator section 60.



Fluorine gas F_2 as an active gas in the above formula expedites the chemical reaction and surface processing speed.

When water is added as an additive into plasma generator section 60 during processing gas formation, the following reaction takes place in plasma generator section 60.



The addition of water increases the generation of an acid such as HF , and this increases the surface processing speed.

The addition of water as an additive not only increases the processing speed, but also restricts the generation of ozone in plasma generator section 60.

The relationship between the amount of ozone (%) generated and humidity is listed in Table 1. In Table 1, the ozone amount generated is a percentage value relative to the ozone amount generated in dry air.

Table 1

Ozone generation (%)			99	95	82	75	61	40	10
Exposure temperature (°C)			-50	-30	-10	0	10	20	30
Moisture g/m ₂			0.060	0.448	2.25	4.85	9.40	17.3	30.3
Temp	10°C	Humidity %	0.05	5	24	50	100	100	100
	20°C		0	3	13	30	55	100	100
	30°C		0	1.5	8	15	31	55	100

Thus, the addition of water as an additive to plasma generator section during formation of the processing gas controls the generation of ozone in plasma generator

section 60 and the oxidization of lead frame 12 is precluded.

As in decomposition through discharge, the addition is equally effective in the thermal decomposition and photolysis methods shown with reference to FIGS. 1 and 2, respectively.

Surface processing unit

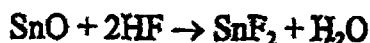
Gas processing generator 19 and the surface processing method of FIG. 5, which process without the use of a plasma generator section, will now be discussed with reference to FIG. 11.

FIG. 11 shows generally the construction of the apparatus, which comprises a processing gas generator unit, indicated generally at 110 to which supplying connection tube 20 and exhaust connection tube 24 are connected, in a manner similar to that as shown in surface processing apparatus 180. Processing gas generator 110 comprises, in a housing 112, a carrier gas supply tube 120 coupled down stream to a carrier gas input by a flow meter 122. A liquid container 130 for adding an aqueous solution 103 is disposed within housing 112. Carrier gas supplying tube 120 comprises a first carrier-gas supplying tube portion 120a positioned at the upstream side of liquid container 130, a second carrier-gas supplying tube portion 120b positioned at the downstream side of the liquid container 130, and a third carrier-gas supplying tube portion 120c that connects first and second carrier-gas supplying tube portions. An entrance tube 120d coupled to tube portion 120c carries carrier gas into container 130. An exit tube 120e coupled to tube portion 120b carries processing gas out of container 130.

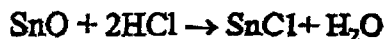
Liquid container 130 holds a solution of hydrogen halide such as HF, HCl. A carrier gas such as N₂ introduced into liquid container 130 via first carrier-gas supplying tube portion 120a and 120d is brought into contact with the liquid and becomes an acidified processing gas. The processing gas is delivered out of liquid container 130 via second carrier-gas supplying tube 120e and 120b, while being forced out through the pressure of the carrier gas itself. The processing gas is thus delivered out of processing gas generating unit 110.

The acidified processing gas is thus applied to lead frame 12 of IC 10 via supplying connection tube 20 and supplying section 22 as shown in FIG. 10. The surface of lead frame 12 is surface processed according to the following chemical formulae, based upon the processing gas used.

When hydrogen fluoride HF is used as a processing gas, surface processing is performed according to the following chemical formula.



When hydrochloric acid HCl is used as a processing gas, surface processing is performed according to the following chemical formula.

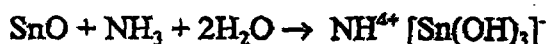


Liquid container 130 may hold an acid liquid such as H_2NO_3 , or basic liquid such as ammonia water. When nitric acid H_2NO_3 is used, surface processing is performed according to the following chemical formula.



Liquid container 130 may hold an acid liquid such as oxalic acid.

When liquid container 130 holds a basic liquid such as ammonia water, surface processing is performed according to the following chemical formula.



The processing gas that has been applied to lead frame 12 is circulated to surface processing gas generator unit 110 via exhaust connection tube 24. The acidified or basic processing gas is a corrosive gas itself, and thus should not be released into the environment. In surface processing unit 110, the processing gas is introduced into waste treatment unit 150, where the corrosive components of the processing gas are removed.

Like processing gas generator unit 100, processing gas generator unit 110 may be designed without the need for the feed and exhaust facility in the plant, namely, may contain a feed fan, an exhaust fan, and fan driving units contained within housing 112.

Types of surface processing units

Referring next to FIGS. 12 through 20, different embodiments for housing gas generators units 30, 100, or surface processing apparatus 110 arranged in a diversity of

configurations with supplying connection tube 20 and exhaust connection tube 24 also arranged in a diversity of configurations are provided.

(1) Line-type surface processing unit

A surface processing apparatus 160 is shown in FIGS. 12 and 13 and is arranged above a conveyor belt 14 so that it faces a workpiece 500 from above. Surface processing unit 160 is provided with a body 161 extending into supplying and exhaust section 162. Body 161 houses a processing gas generator unit. Raw-material gas supply tubes 168 and an exhaust tube 170 are coupled to body 160. Supplying and exhaust section 162 is split into a supplying tube 164 and an exhaust tube 166. In this embodiment, supplying tube 164 is arranged in the center of the section 162, and is surrounded by exhaust tube 166. Exhaust tube 166 is widely opened so that its end is shaped in an umbrella-like fashion.

While workpieces 500 are moved continuously or stepwise by the conveyor belt 14, each workpiece 500 faces supplying and exhaust section 162 of surface processing apparatus 160 to process its surface. With the surface processing unit fixed, the entire surface of each workpiece 500 is processed. A number of workpieces 500 are thus continuously subjected to surface processing.

(2) Stand-type surface processing unit

A surface processing apparatus 200, shown in FIG. 14, comprises a housing 201 having a bottom face to which unit 200 can be fixed. A processing gas generator unit is housed within housing 201. The raw-material gas and/or carrier gas described above are introduced into housing 201 by supply tube 212, and the exhaust gas is output through the waste treatment unit and output by exhaust tube 214. Housing 201 is provided with a supplying connection tube 210 and an exhaust connection tube 230. Supplying connection tube 210 is bent and terminates at a supplying section 220. Supplying section 220 is surrounded by an umbrella-shaped anti-diffusion cover 222 to avoid the diffusion of the processing gas. Exhaust connection tube 230 is provided with an umbrella-shaped exhaust suction section 240 having gradually widening opening toward its upward end facing the anti-diffusion cover 222.

As shown in Figs. 14 and 15, the workpiece to be processed is a wire 250. The insulator sleeve on the end portion of wire 250 is removed. To surface process the end portion of wire 250, a pre-plated end portion 252 of wire 250 is placed just below supplying section 220. In this manner, end portion 252 of wire 250 is processed by the processing gas provided by supplying section 220. The applied processing gas is circulated to the waste treatment unit in housing 201 via exhaust suction section 240 and exhaust connection tube 230.

This stand-type surface processing unit 200 makes a localized atmosphere of the processing gas in air, permitting the surface of a workpiece such as wire 250 to be easily processed.

(3) Cylinder-type surface processing unit

In the embodiment depicted in FIGS. 16 and 17, a surface processing unit 300 is configured in a soldering-iron-like cylindrical housing 301. A processing gas supply unit is disposed in housing 301 and coupled to a supplying connection tube 310 and an exhaust connection tube 320 which are coaxially structured. Raw material gas is input through a supply tube 312. The processing gas is applied to a workpiece 500 from inner supplying connection tube 310, and then guided back into the housing 310 via outer exhaust connection tube 320 after processing. After treatment, exhausted gas is exhausted through exhaust connection tube 320 the end portion of exhaust connection tube 320 is preferably widely opened in an umbrella-fashion so that the exhausting power and area of tube 320 can be expanded, as shown in FIGS. 16 and 17.

The surface processing unit 300 thus configured in such a cylindrical shape can be manually operated and can be moved to process the surface of a diversity of works.

(4) Toaster-like surface processing unit

A surface processing unit 400 is shown in FIGS. 18 and 19, and has one surface on its housing 401, for example the top surface of the housing 401, which is provided with a slit-like socket 410. A processing gas generator unit is disposed within housing 401. Raw-material gas and carrier gas are input to housing 401 through tubes 435, 445 respectively. Through socket 410, a planar workpiece 500 may be inserted. An exhaust

tube 420 is connected to slit-like socket 410. Waste gas is exhausted from housing 401 after treatment through tube 425. A processing gas supplying tube 430 and a carrier gas supplying tube 440 are coupled in fluid communication to socket 410 on both side walls of socket 410.

In this arrangement, the planar workpiece 500 is inserted into slit-like socket 410 opened in the top surface of housing 401. The processing gas is applied to both sides of work 500 to surface process both sides of planar work 500. To surface process only one side of work 500, processing gas supplying tube 430 is opened in only one side wall of socket 410.

(5) Batch-process-type surface processing unit

FIG. 20 depicts a batch-process type surface processing apparatus that allows a large number of workpieces to be processed in a batch. In this apparatus, supplying connection tube 20 and exhaust connection tube 24 connected to processing gas generator unit 30 or 100 or 110 are connected to a batch-process box 450.

Batch-process box 450 accommodates a large number of workpieces 510. Work 510 to be batch-processed may be IC 10, wire 250, planar work 500, a rolled TAB tape, or any combination of any type of workpieces whose surfaces are to be processed.

The batch-process-type surface processing unit surface processes a large number of workpieces at a time. The workpiece surfaces processed according to the surface processing method of the present invention maintains an improved wettability of the work for a relatively long period of time after surface processing. Thus, after batch-processing, excellent soldering characteristics are assured even if the works are stored until actual soldering, rather than immediate soldering after, surface processing.

Example

Tests were conducted to assess the wettability of the workpiece surfaces processed according to the method of the present invention. Referring to Tables 2 and 3, the test results are discussed.

Thirteen days after the deposition of silver on electrodes of a crystal oscillator, the ends of wires to be soldered to the electrodes of the crystal oscillator were surface

processed under a diversity of conditions. The wires were soldered (mounted) to the electrodes on the same day. Table 2 shows the assessment of flow factors of solder.

Table 2

	Plasma Condition			Mount condition		Solder flow result	
	Gas		Time(s)	Full (V)	Pre (V)	Insufficient	Excess
1	No Plasma		-	51.5	41.8	38/48	0/48
2	CF ₄	N ₂	90	51.5	41.8	0/24	1/24
3	CF ₄	N ₂	180	51.5	41.8	0/24	4/24
4	CF ₄	N ₂	90	51.0	41.3	0/24	6/24
5	CF ₄	N ₂	90	49.0	40.0	0/24	8/24
6	CF ₄	N ₂	90	47.0	38.0	12/24	0/24
7	CF ₄	Comp. air	180	51.5	41.8	22/24	0/24
8	CF ₄	N ₂	10	51.5	41.8	0/24	3/24

Test data 1 shows test results without surface processing. In test data 2 through 6 and 8, the raw-material gas was CF₄ (50 cc/minute), the carrier gas was N₂ (20 liters/minute), and water was added by passing CF₄ through pure water. In test data 7, the raw-material gas remained unchanged from test data 2 (CF₄, but the carrier gas was compressed air (20 liters/minute). Plasma was generated at a relatively lower power of 50 to 90 W in test data 2, and at 250 W in test data 3 to 8.

In Table 2, time indicates a total time required to scan a length of 9 cm during processing. Mount conditions show full voltage and preliminary voltage of a soldering iron during soldering.

As can be understood from Table 2, test data 2 through 8 resulted in an improved flow factor of solder in comparison with test data 1 which did not use any surface processing. In particular, test data 2 through 6 and 8, which used N₂ as a carrier gas exhibited excellent results.

Surface-processed wires which were processed under the same condition as that of test data 3 in Table 2 were compared with non-surface-processed wires, and were

tested on an increased number of mounts to assess solder flow failure and electric characteristics of the crystal oscillators. Test results are listed in Table 3.

Table 3.

	Osc. freq. (MHz)	Plasma Present	Results			
			Failure rate in solder flow		Failure rate in electrical characteristic	
1	13.3333	No	45/685	6.57	15/463	3.24%
2	13.3333	Yes	20/594	3.37%	7/461	1.52%
3	16.649	No	83/744	11.16%	23/464	4.96%
4	16.649	Yes	56/820	1.83%	9/473	1.90%

In Table 3, a frequency f_0 is the oscillation frequency of a crystal oscillator. Test data 1 and 3 show test results of non-surface-processed wires and test data 2 and 4 show test results of surface-processed wires. In test data 1 and 2, fourteen days after the deposition of silver on electrodes of crystal oscillators, the wires were soldered (mounted) to the electrodes. In test data 2, surface processing was performed two days before mounting operation. In test data 3 and 4, seventeen days after the deposition of silver on electrodes of crystal oscillators, the wires were soldered (mounted) to the electrodes. In test data 4, surface processing was performed two days before mounting operation.

By comparison of test data 1 with 2 and test data 3 with 4, the surface-processed wires approximately halved solder flow failure rate and electrical characteristics failure rate.

Comparative example 1

The method shown in FIG. 3 uses halogen or hydrogen halide as a processing gas. Halogen compound is decomposed into this halogen or halogen halide by discharge

between a pair of electrodes. The processing gas is exposed to the workpiece through an indirect discharge process in which the work being processed is not directly exposed to a plasma. (A direct discharge process is a known technique in which a work being processed is placed onto one electrode and is exposed to a plasma.)

Table 4 compares test results of solder wettability resulting from 1) the indirect discharge process of this embodiment, 2) the known direct discharge process and 3) unprocessed samples. In the indirect discharge process of this embodiment, the raw-material gas CF_4 was supplied at a rate of 500 cc/minute, and the carrier gas N_2 was supplied at a rate of 20 liters/minute. In the direct discharge process, the raw-material gas CF_4 was supplied at a rate of 500 cc/minute, and the plasma generation gas He was supplied at a rate of 20 liters/minute.

Table 4

	Sample count	Cause of failure and failure count		Failure rate
		Lack of flow	Excess flow	
Non-processed	48	33	0	79.0%
Direct discharge process	231	138	0	60.0%
Indirect discharge process	96	0	19	20.0%

As seen from Table 4, failure rates are substantially improved in the indirect discharge process of this embodiment. The cause of the failures in the indirect discharge process is attributed to excessive flow factor of solder, and solder wettability in the failure cases is still as good or better than that of successful cases.

According to the above test results, the solder flow failure rate in the direct

discharge was improved by only 20% as compared with the unprocessed cases. The reasons for this are as follows. First, a high intensity discharge takes place around the lead end portion of the workpiece, and the workpiece is partially processed. Second, in the direct discharge process in which the gap between the electrodes is as narrow as a few mm, variations in the placement of the workpieces cause variations in the state of the plasma. When a workpiece is subjected to an excessively strong, or an excessive amount of plasma, the work is discolored and the flow of solder is degraded.

Comparative example 2

In the preceding examples, halogen or hydrogen halide is used as a processing gas. In one known method, active species such as fluorine radicals generated in a plasma generator section are guided to a workpiece being processed. The workpieces are placed outside the plasma generator section for processing. In view of the limited life of the active species, the direct discharge process does not permit a large distance between the plasma generator section and the work being processed, compared with the indirect discharge process of the invention. Thus, the indirect discharge process of the invention allows for the placement of the workpieces at a remote location.

The speed of the flow of processing gas was calculated based on the raw-material gas supplying flow rate and tube cross-sectional area, when a standard commercially available 1/4 size (outer diameter 6.35 mm, inner diameter 3.17 mm) pipe is used as a processing gas supplying tube connected to the plasma generator section. With a raw-material gas supplying flow rate of 100 cc/minute, the speed of the processing gas is 21.12 cm/s. Since the life of a fluorine radical is less than 1/1000 second, it would decay 0.0211 cm away from the plasma generator section. With a raw-material gas supplying flow rate of 30 cc/minute, the speed of the processing gas is 6.335 cm/s. Fluorine radical decays 0.063 cm away from the plasma generator section.

In contrast, each of the above embodiments of the invention uses, as a processing gas, halogen or hydrogen halide, allowing a work to be sufficiently apart from a processing gas generator container.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may

be made in carrying out the above method in the construction(s) set forth without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.



WHAT IS CLAIMED IS:

1. A surface processing method comprising the steps of:
producing a processing gas containing halogen or hydrogen halide;
bringing said processing gas into contact with a workpiece being
processed to process the surface of said workpiece.
2. The surface processing method according to claim 1, wherein said halogen
is fluorine.
3. The surface processing method according to claim 1, wherein said
hydrogen halide is hydrogen fluoride.
4. The surface processing method according to claim 1, further comprising
the step of thermally decomposing the halogen compound to produce said processing
gas.
5. The surface processing method, according to claim 1, further comprising
the step of decomposing a halogen compound through photolysis to produce said
processing gas.
6. The surface processing method according to claim 1, further comprising
the step of decomposing a halogen compound through discharge to produce said
processing gas.
7. The surface processing method according to claim 6, wherein said halogen
compound is excited and decomposed by a pair of electrodes to which an AC voltage
having a frequency of 50 kHz or lower, or a DC voltage is applied.
8. The surface processing method according to claim 4, wherein said halogen
compound is an organic halogen compound.
9. The surface processing method, according to claim 5, wherein said
halogen compound is an organic halogen compound.
10. The surface processing method according to claim 6, wherein said halogen
compound is an organic halogen compound.
11. The surface processing method according to claim 7, wherein said halogen
compound is an organic halogen compound.



12. The surface processing method according to claims 4, wherein said halogen compound is one selected from the group of NF_3 , SF_6 , CF_4 and NH_4F .

13. The surface processing method, according to claim 5, wherein said halogen compound is one selected from the group of NF_3 , SF_6 , CF_4 and NH_4F .

14. The surface processing method according to claim 6, wherein said halogen compound is one selected from the group of NF_3 , SF_6 , CF_4 and NH_4F .

15. The surface processing method according to claim 7, wherein said halogen compound is one selected from the group of NF_3 , SF_6 , CF_4 and NH_4F .

16. The surface processing method according to claim 4, wherein the step of decomposing said halogen compound is performed within an atmosphere containing moisture.

17. The surface processing method, according to claim 5, wherein the step of decomposing said halogen compound is performed within an atmosphere containing moisture.

18. The surface processing method according to claim 6, wherein the step of decomposing said halogen compound is performed within an atmosphere containing moisture.

19. The surface processing method according to claim 7, wherein the step of decomposing said halogen compound is performed within an atmosphere containing moisture.

20. The surface processing method according to claim 1, further comprising the step of: decomposing a halogen compound through electrolysis to produce said processing gas.

21. The surface processing method according to claim 20, wherein said halogen compound is a solution of halide.

22. The surface processing method according to claims 1, further comprising the step of decomposing a halogen compound using a combination of decomposition processes selected from thermal decomposition, photolysis, decomposition by discharge, and electrolysis to produce said processing gas.

23. The surface processing method according to claim 1, wherein said processing gas is forcibly fed by a carrier gas to bring said processing gas into contact



with said workpiece being processed.

24. The surface processing method according to claim 23, wherein said carrier gas is mixed with said processing gas after the step of decomposing said halogen compound.

25. The surface processing method according to claim 1, further comprising the step of producing said processing gas containing a liquid of halogen or hydrogen halide by bringing a carrier gas into contact with a solution of halogen or hydrogen halide.

26. The surface processing method according to claims 1, further comprising the steps of exhausting said processing gas applied to said work being processed and a reaction product, and trapping said processing gas and said reaction product during exhausting.

27. The surface processing method according to claim 1, wherein said processing gas is brought into contact with said workpiece being processed, and an oxide on the surface of said workpiece is replaced with a halogen compound in order to improve solder wettability of the surface of said workpiece being processed.

28. The surface processing method according to claim 27, wherein said workpiece being processed is a printed circuit board.

29. The surface processing method according to claim 27, wherein said workpiece being processed is an electronic component.

30. The surface processing method according to claim 29, wherein said electronic component is an integrated circuit, and the surface of said electronic component being processed is a bonding surface of said integrated circuit.

31. The surface processing method according to claim 27, wherein said workpiece being processed is a wire to be soldered.

32. The surface processing method according to claim 27, wherein the surface of said workpiece being processed is an electrode of a crystal oscillator.

33. A surface processing apparatus for processing the surface of a workpiece comprising:

a processing gas generator for producing a processing gas containing halogen or hydrogen halide; and



a processing gas supply for supplying said processing gas from said processing gas producer to the surface of said workpiece being processed.

34. The surface processing apparatus according to claim 33, further comprising a raw-material gas supply for supplying a raw-material gas containing a halogen compound to said processing gas generator, whereby said processing gas generator produces said processing gas by thermally decomposing said halogen compound.

35. The surface processing apparatus according to claim 33 further comprising:

a raw-material gas supply for supplying a raw-material gas containing a halogen compound to said processing gas generator, whereby said processing gas generator produces said processing gas by decomposing said halogen compound through photolysis.

36. A surface processing apparatus according to claim 33 further comprising:
a raw-material gas supply for supplying a raw-material gas containing a halogen compound to said processing gas generator, whereby the processing gas generator produces the processing gas by decomposing said halogen compound through discharge.

37. The surface processing apparatus according to claim 36, wherein said processing gas generator includes a power supply for outputting either a AC voltage of 50 kHz or lower or a DC voltage; and a plasma generator having a pair of electrodes, said power supply coupled to said pair of electrodes for applying said voltage thereto, said electrodes inducing a plasma at approximately the atmospheric pressure.

38. The surface processing apparatus according to claims 33, wherein said processing gas generator decomposes said halogen compound within an atmosphere containing moisture.

39. The surface processing apparatus according to claim 33, wherein said processing gas generator produces said processing gas by electrolyzing a solution containing a halogen compound.

40. The surface processing apparatus according to claim 34, further comprising a carrier gas supply connected to said raw-material gas supply, for supplying



a carrier gas to be mixed with said raw-material gas.

41. The surface processing apparatus according to claim 35, further comprising a carrier gas supply connected to said raw-material gas supply, for supplying a carrier gas to be mixed with said raw-material gas.

42. A surface processing apparatus according to claim 36, further comprising a carrier gas supply connected to said raw-material gas supply, for supplying a carrier gas to be mixed with said raw-material gas.

43. The surface processing apparatus according to claims 38, further comprising a carrier gas supply connected to said raw-material gas supply, for supplying a carrier gas to be mixed with said raw-material gas.

44. The surface processing apparatus according to claim 39, further comprising a carrier gas supply connected to said raw-material gas supply, for supplying a carrier gas to be mixed with said raw-material gas.

45. The surface processing apparatus according to claim 33, further comprising a carrier gas supply, connected to said processing gas supply, for supplying a carrier gas to be mixed with said raw-material gas.

46. The surface processing apparatus according to claim 33, wherein said processing gas generator produces a processing gas containing halogen or hydrogen halide by bringing said carrier gas into contact with a solution of halogen or hydrogen halide.

47. The surface processing apparatus according to claim 33, further comprising an exhaust means for forcibly exhausting said processing gas applied to said workpiece being processed and a reaction product; and a trap for trapping said processing gas and said reaction product before being exhausted.



-34-

ABSTRACT

SURFACE PROCESSING METHOD AND APPARATUS

An improved surface processing method and apparatus for processing the surface of a workpiece which avoids plasma damage and allows a large degree of freedom in the location of the workpiece relative to the processing gas producing apparatus. To improve wettability of the soldering area of a workpiece, a raw-material gas containing a halogen compound preferably including CF_4 is introduced into a plasma generator section in a surface processing unit. Optionally, a carrier gas (other than helium gas) is used to aid in the forwarding of the raw-material gas. In the plasma generator section, the raw-material gas is excited and decomposed by electrodes to which preferably a low frequency AC voltage of 0 to 50 kHz, or a DC voltage is applied, in order to preferably produce a highly reactive fluorine gas F_2 . By bringing the processing gas containing fluorine gas F_2 into contact with the workpiece, the surface of the workpiece is processed. Since fluorine radicals, which have a short life span, are not used, a great deal of freedom is allowed in the workpiece. When air is used as a carrier gas, it is mixed with the raw-material gas after decomposition, to retard the generation of ozone. If halogen compounds are decomposed in an atmosphere containing moisture, hydrogen halide is efficiently produced.

Figure : None

THIS SHEET HAS BEEN
REPLACED

FIGURE 1

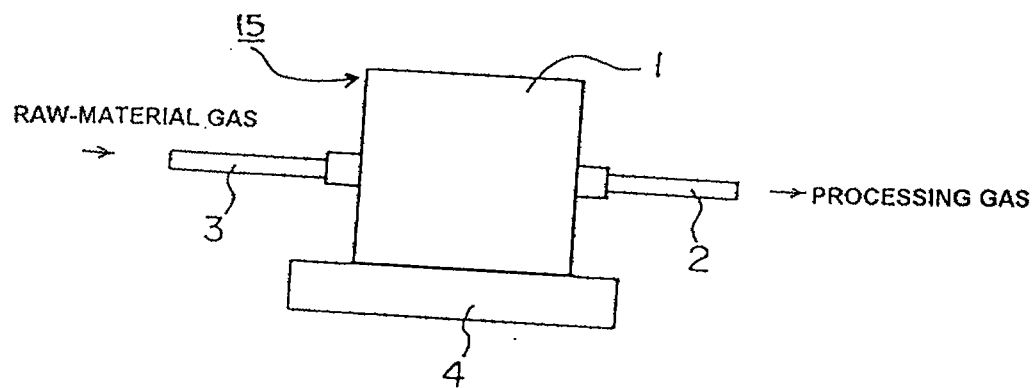


FIGURE 2

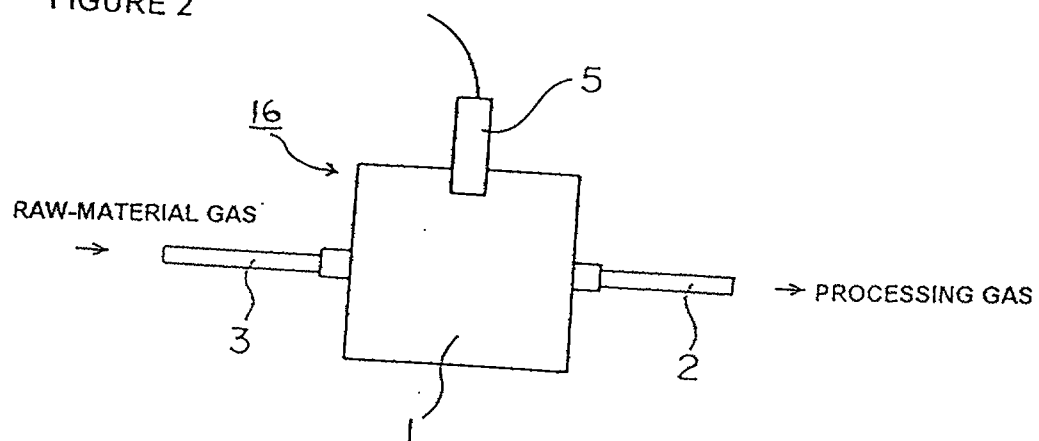


FIGURE 3

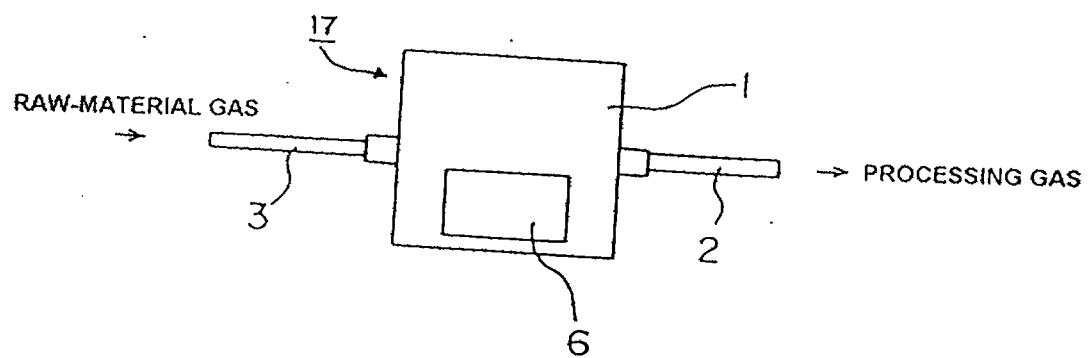


FIGURE 4

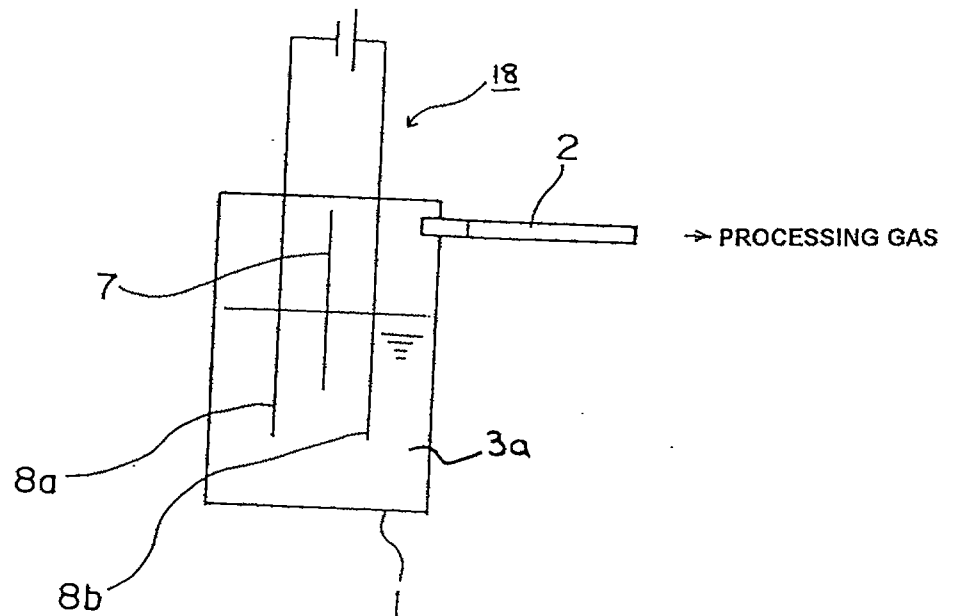
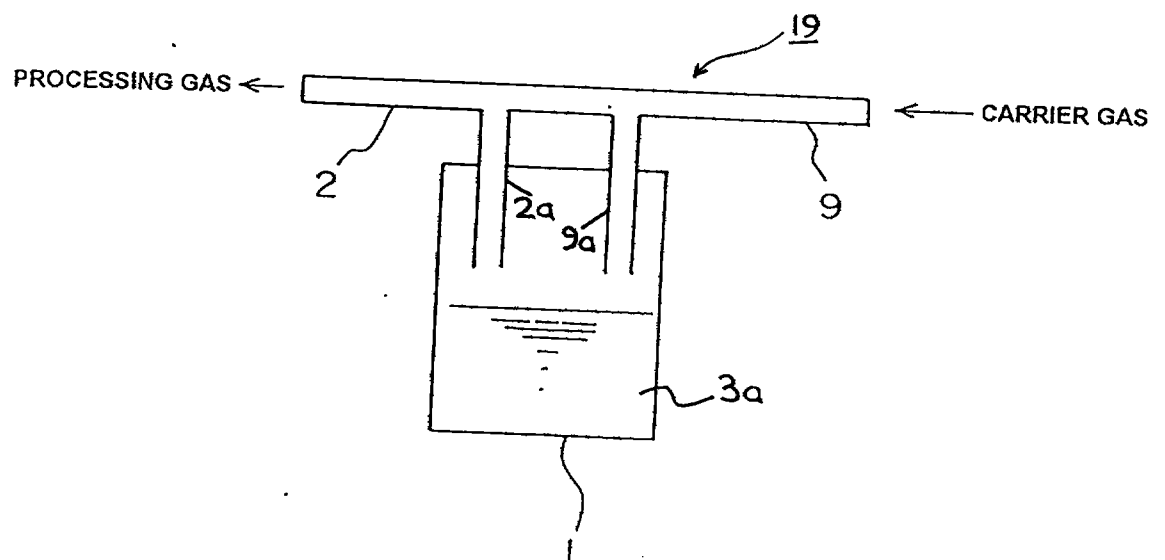


FIGURE 5



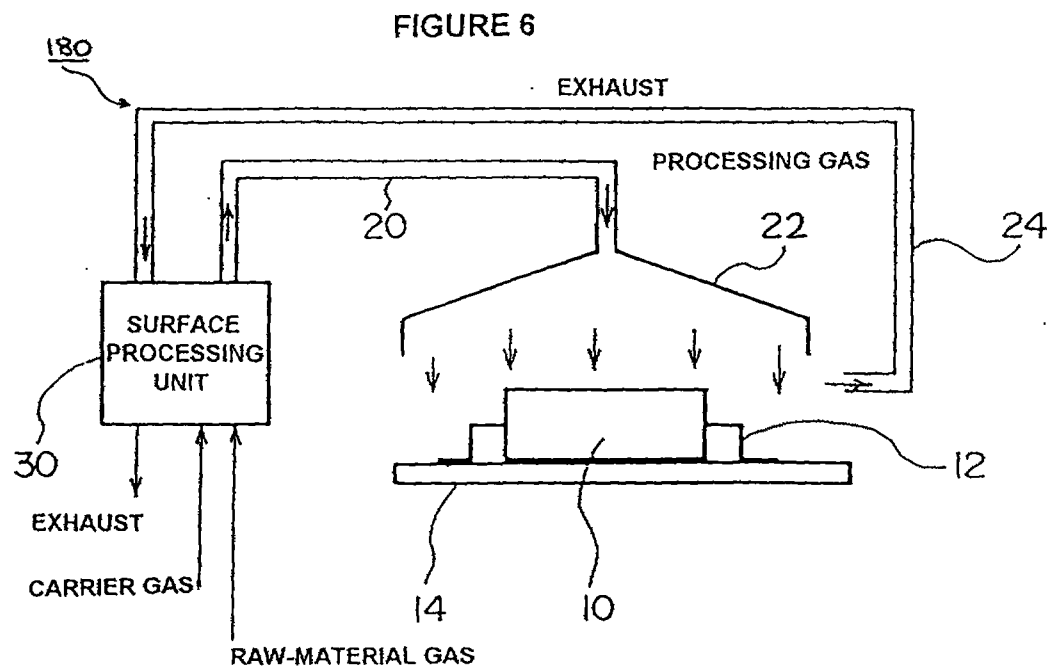


FIGURE 7

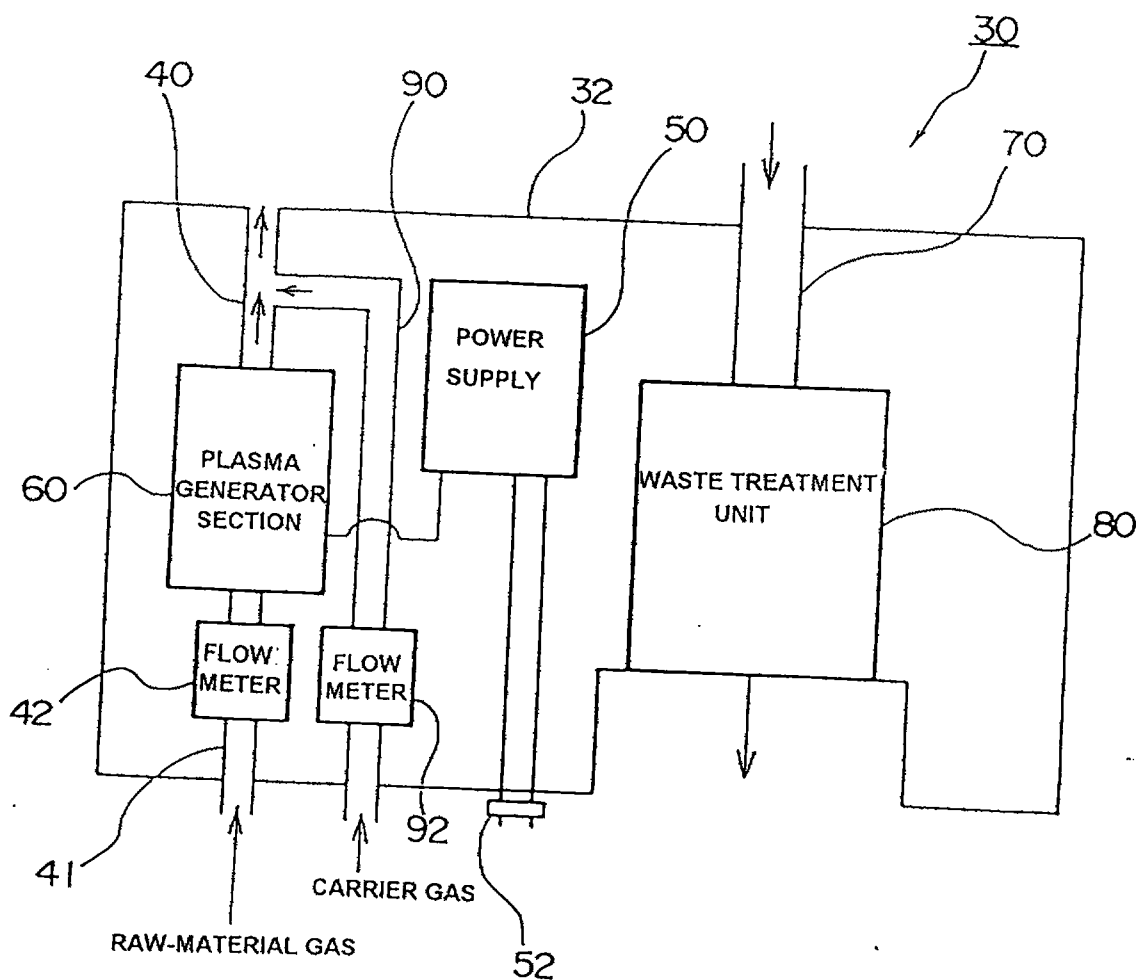


FIGURE 8

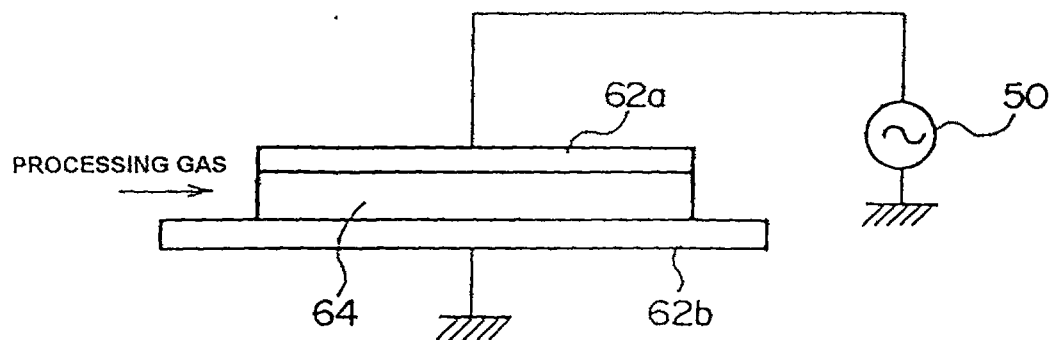


FIGURE 9

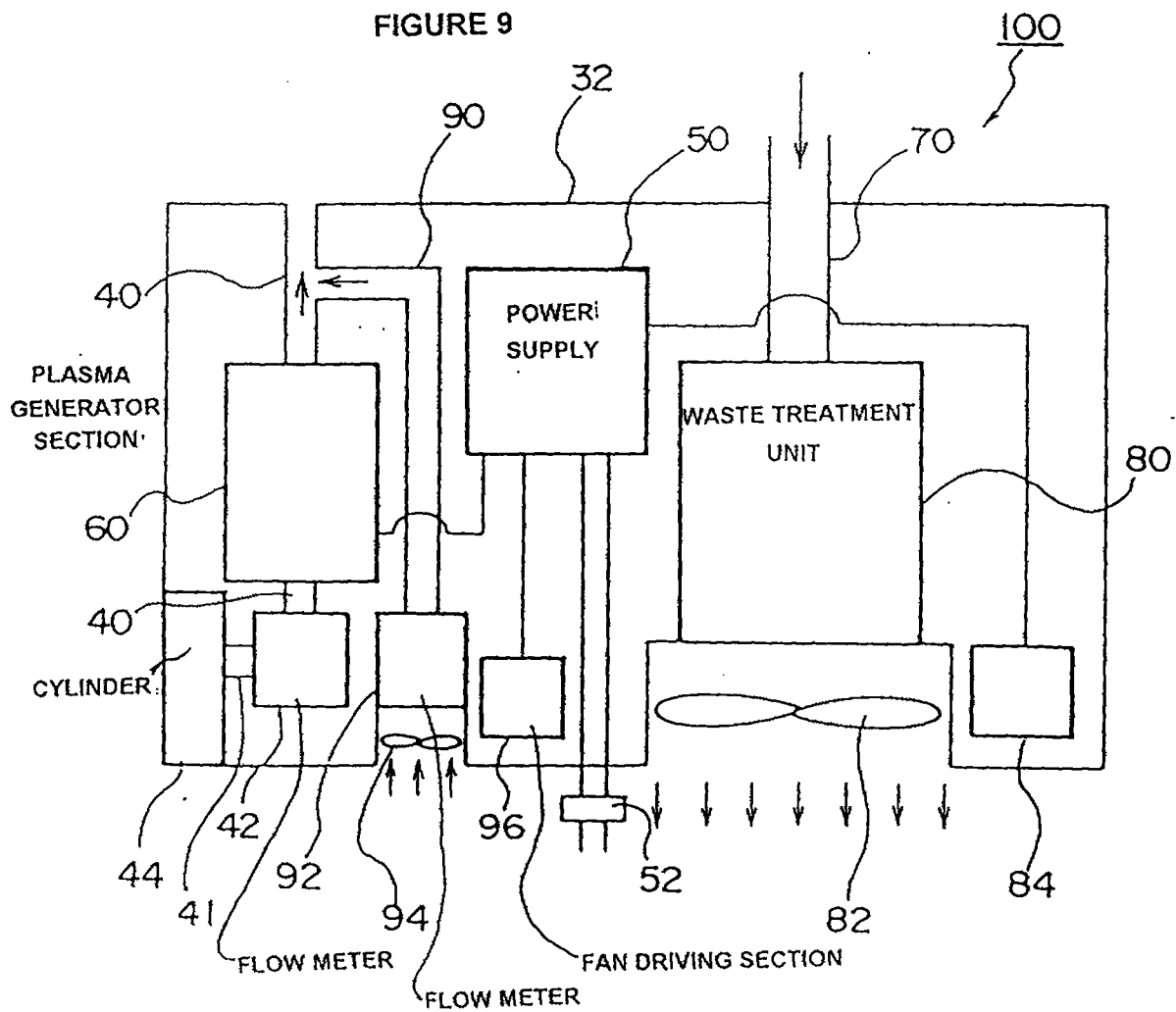


FIGURE 10

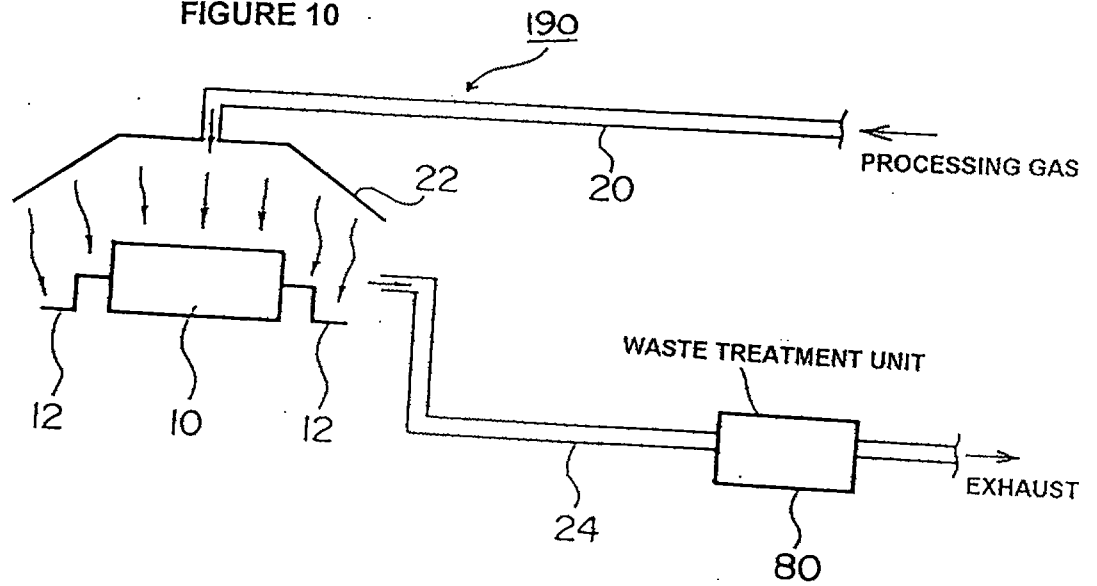


FIGURE 11

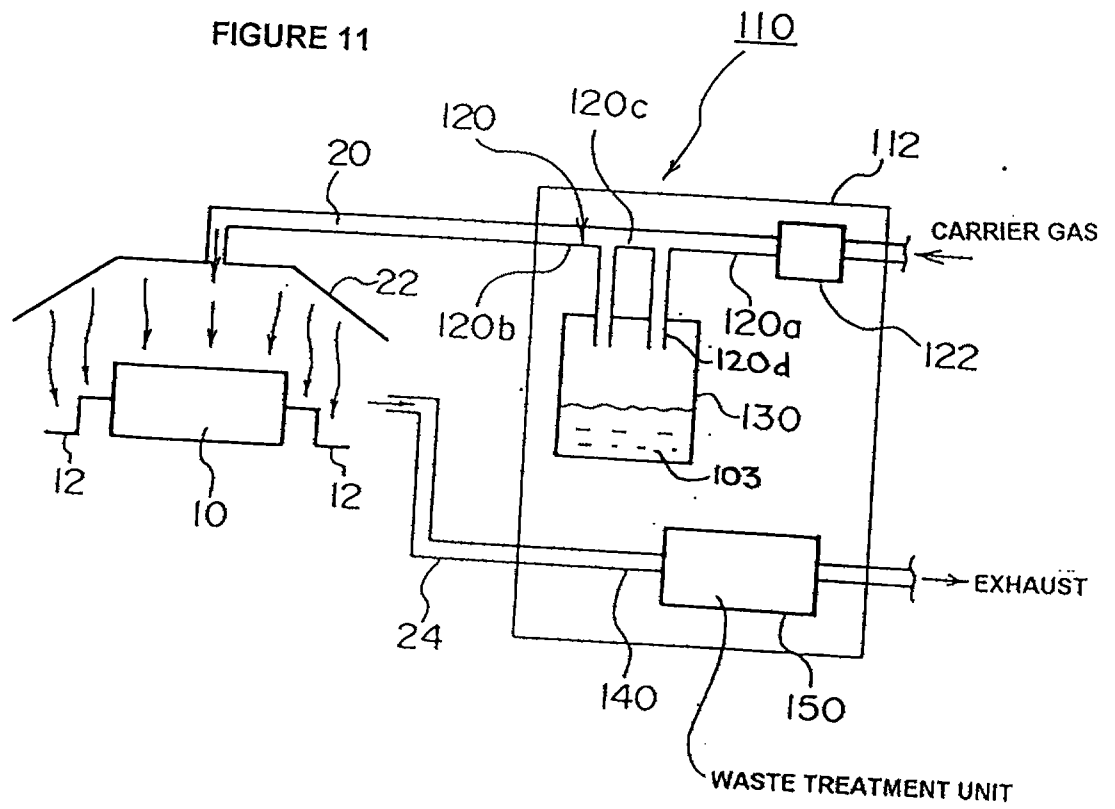


FIGURE 12

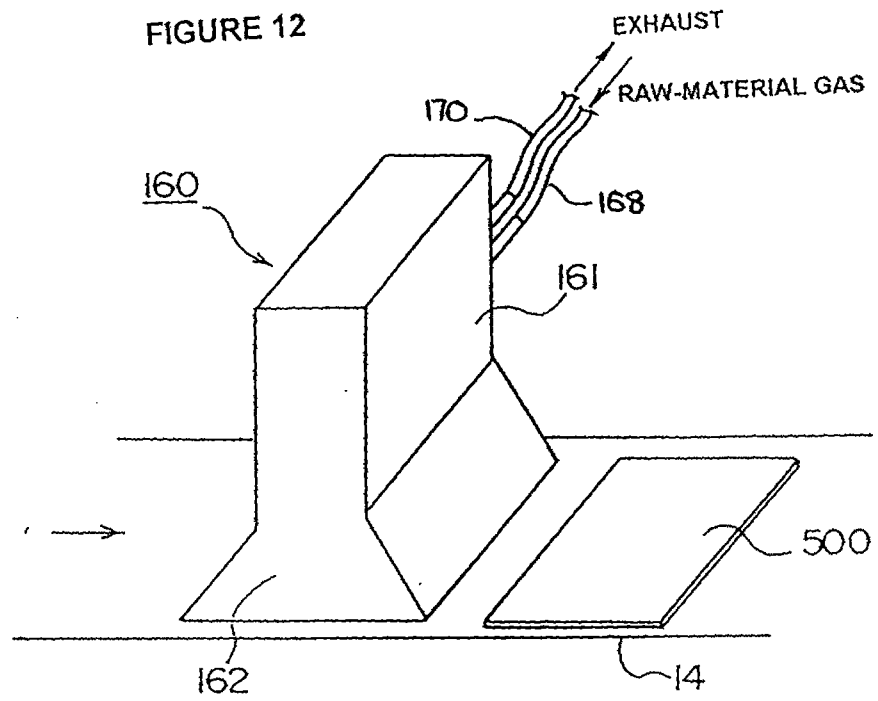


FIGURE 13

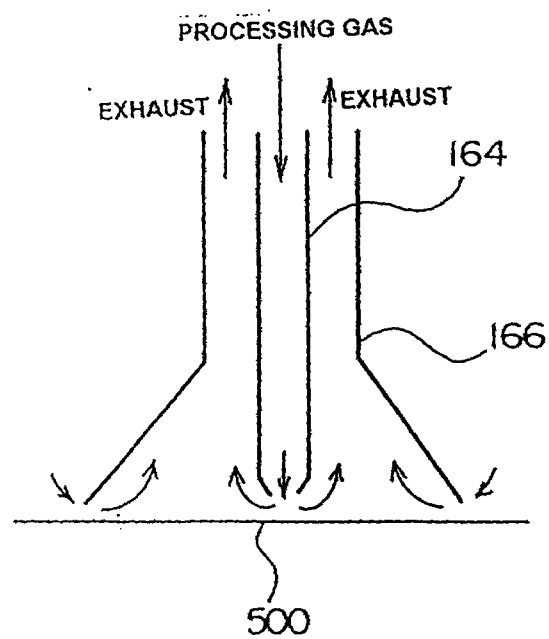


FIGURE 14

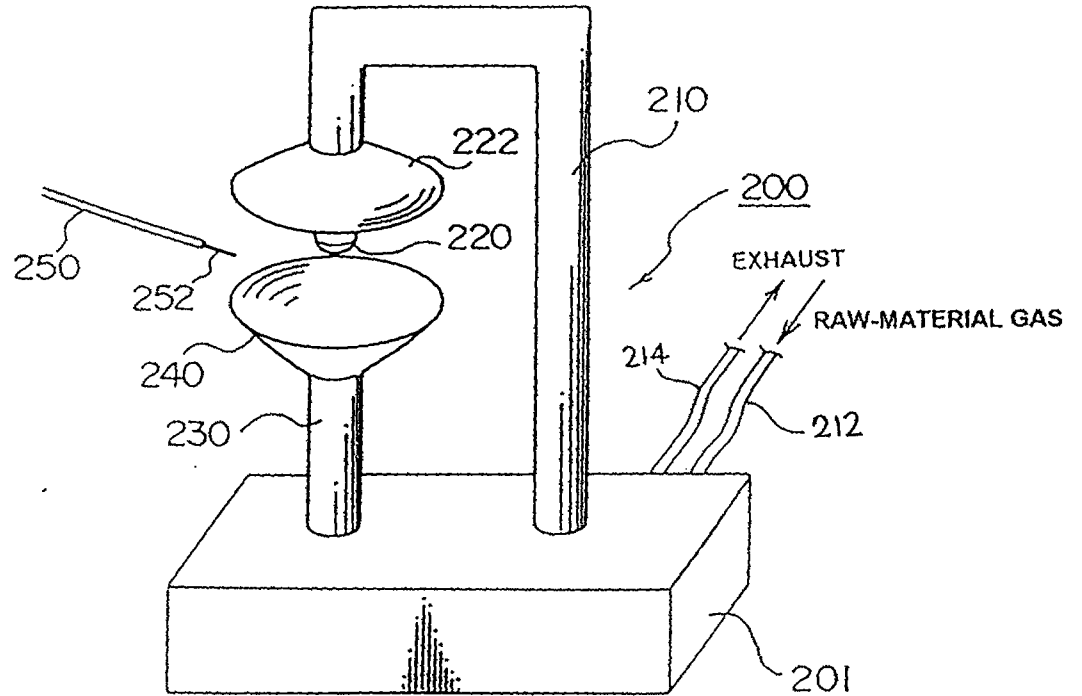


FIGURE 15

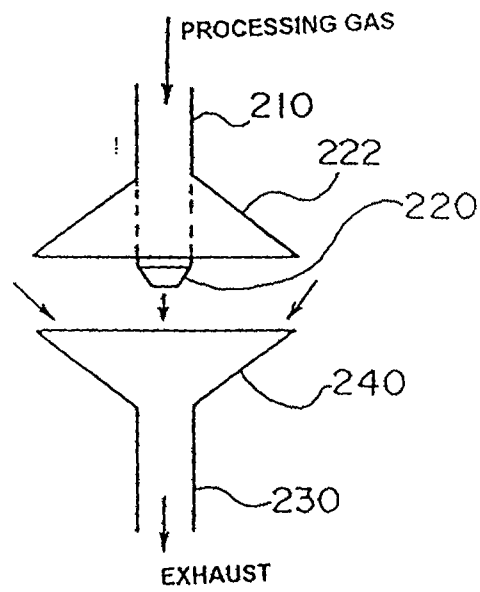


FIGURE 16

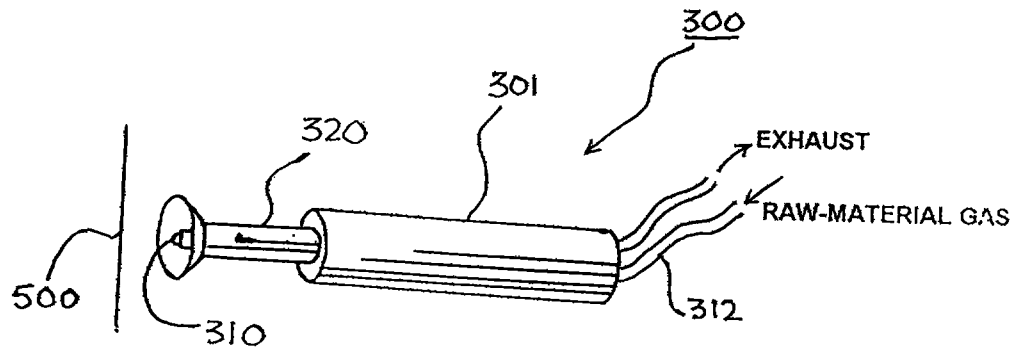


FIGURE 17

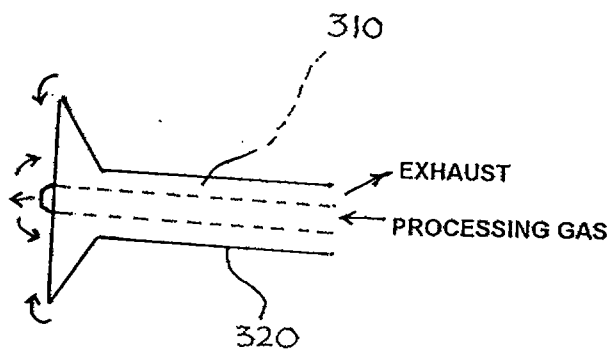


FIGURE 18

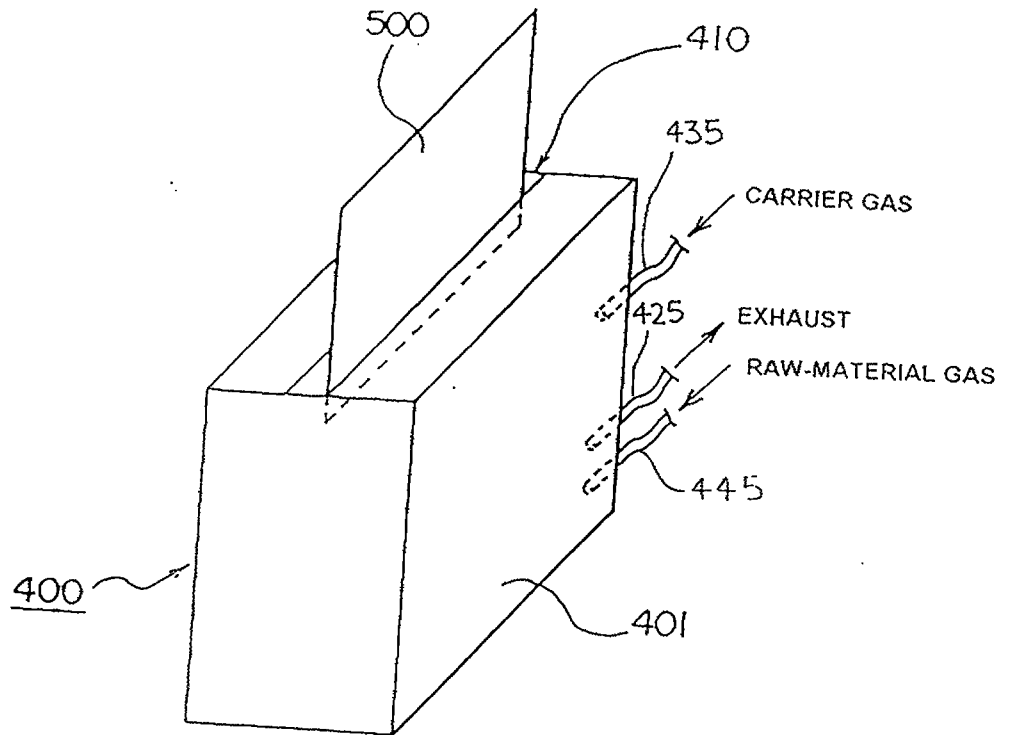


FIGURE 19

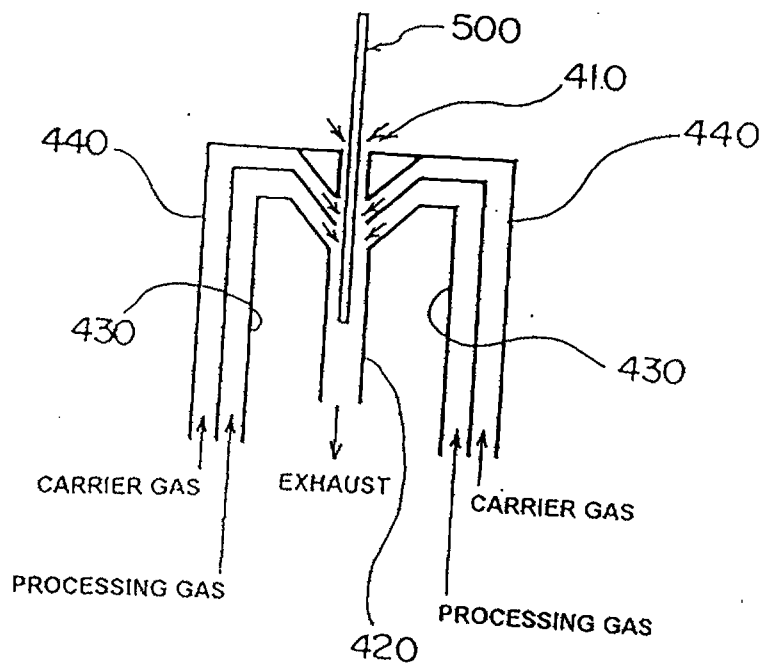
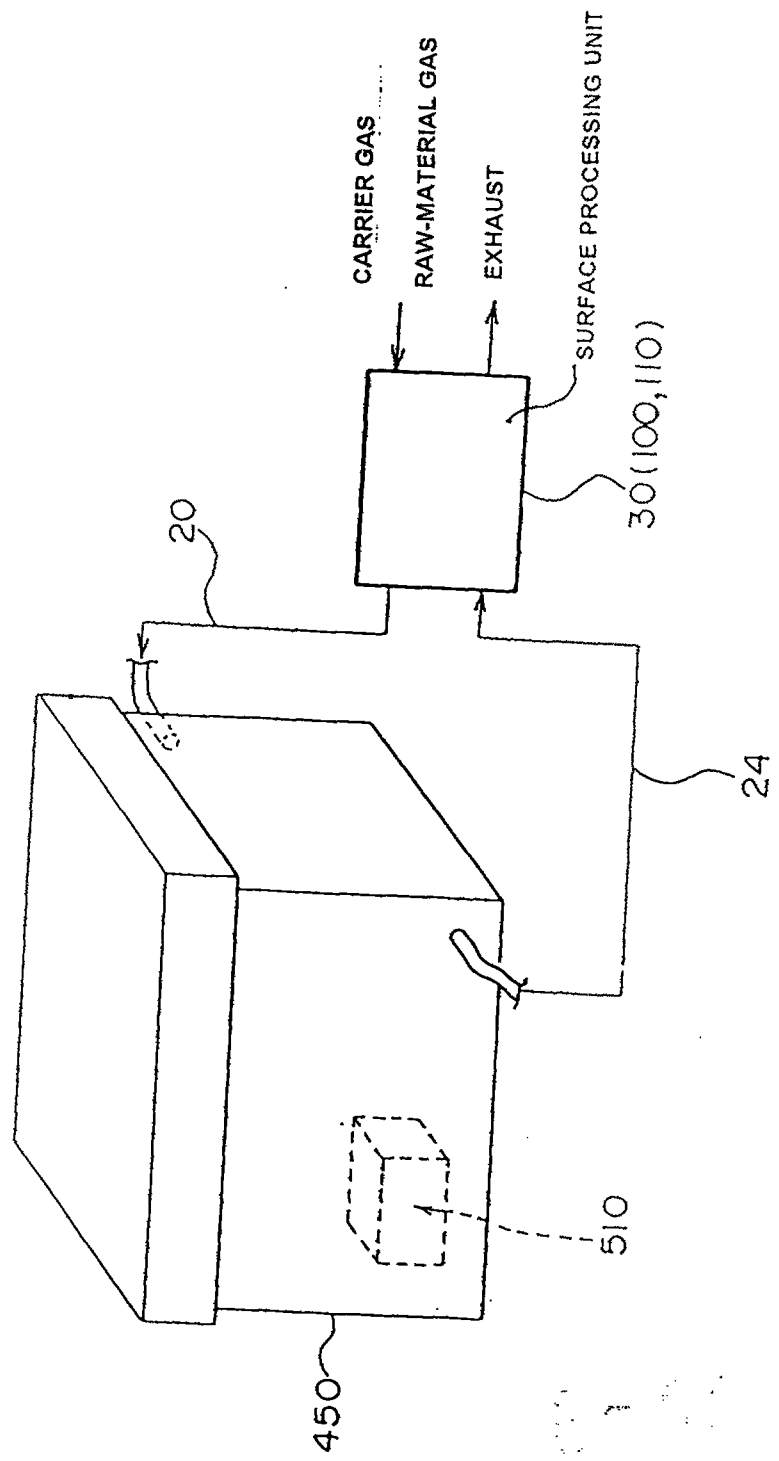


FIGURE 20



- 34 -

ABSTRACT

SURFACE PROCESSING METHOD AND APPARATUS

An improved surface processing method and apparatus for processing the surface of a workpiece which avoids plasma damage and allows a large degree of freedom in the location of the workpiece relative to the processing-gas producing apparatus. A raw-material gas containing a halogen compound preferably including CF_4 is introduced into a plasma generator section in a surface processing unit. In the plasma generator section, the raw-material gas is excited and decomposed by electrodes to which a low frequency AC voltage of 0 to 50 kHz, or a DC voltage is applied, to produce fluorine gas F_2 . By bringing the processing-gas containing fluorine gas F_2 into contact with the workpiece, the surface of the workpiece is processed. Since fluorine radicals, which have a short life span, are not used, a great deal of freedom is allowed in the workpiece.

Figure 6

REPLACEMENT SHEET

14 JAN 1997