AXIC APPLICATION REPORT

PLASMA CLEANING

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PLASMA PROCESSES have many applications in manufacturing and product development, including: dielectric, organic and metallic material processing in IC fabrication; material property modification, such as, wetting, dyeing, printing and adhesion; and material structure modification, such as, surface texture [1]. Two very important applications of plasma are known as plasma cleaning and plasma ashing. Plasma cleaning usually refers to the removal of surface contaminants from a material and plasma ashing refers to the removal (oxidation) of organics.

Quality Control for advanced VLSI device production requires close attention to wafer and process contaminants. Cleaning processes must completely remove residual organics, metallic contaminants, native oxides, and "by process produced" oxides from the wafer. Numerous factors favor dry plasma cleaning over wet chemical cleaning for these kinds of applications. Table 1 outlines some of these factors.

Plasma cleaning techniques can be fine tuned to the substrate material and contaminants that are being removed. Table 2 lists several substrate material/surface cleaning applications with common plasma process parameters [2-6].

A parallel application to plasma cleaning is known as plasma ashing. As noted above, this refers to the removal of organic fractions from materials leaving the inorganic residue. Plasma ashing replaces high temperature and wet ashing. It is often used as a sample preparation step prior to analytical analysis, i.e., organic fractions are removed leaving the inorganic ash for subsequent analysis. Plasma ashing also refers to the removal of organic layers from fabricated materials. In IC produced a common application of plasma ashing is known as resist stripping.

Various plasma configurations are used for plasma cleaning and ashing. A plasma reactor with parallel plate electrodes provides uniform removal due to the good thermal contact that is made between the wafer and the electrode. Placement of wafers on the grounded electrode reduces ion bombardment. Ion bombardment can also be eliminated in cage electrode configurations with the use of a Faraday cup (perforated cylinder) - Figure 1. Another configuration that reduces ion bombardment is the downstream or afterglow reactor - Figure 2. Electrodeless plasma configurations are often used in plasma ashing applications to minimize the possibility of physical sputtering of the sample. For these applications, high RF frequencies of 13.56 MHz or microwave frequencies of 2.45 GHz are typically used to generate the plasma.

TABLE 1
Comparison of wet and dry cleaning of wafers.

Cleaning procedure	Wet process	Dry process
Cleaning of deep trenches (high aspect ratio structures)	• difficulty of getting liquid into and out of small openings, capillary phenomena • not always compatible with VLSI IC'S fabrication • contamination of wafer by wet cleaning medium - not complete removal of trace contamination from the wafer	• gas phase • compatible with VLSI processing • volatilizing of the residual contaminants, • it is easier to control cleanliness in gas
Ashing of organic materials	• it can destroy the physical structure • interfere with analysis of trace elements	• volatile products
Handling of cleaning media	• handling and disposal of large volumes of either hydrocarbon solvents or strongly oxidizing acids • safety and technical requirements to handle with toxic and corrosive liquids	• using of gas medium - usually oxygen • non-toxic, non-corrosive • simple handling and manipulation with cylinders • low-temperature processing • control of process
Environmental impact	• handling and disposal of large volumes of DI water • environmental contamination waste disposal	• low price for medium • less environmental impact • more cost/materials/energy/work effective

A special category of plasma cleaning is low temperature sterilization and disinfection for medical purposes.Currently, a number of plasma-based techniques for sterilizing and disinfecting heat-sensitive medical equipment have been developed [7].

Plasma equipment is comparable in size to existing medical autoclaves and offers the potential for very rapid sterilization. Typical plasma parameters for low temperature medical sterilization include the use of non toxic gas mixtures ($Ar+N_2+O_2$), 400-700 mtorr pressure, and moderate RF or microwave power levels (~200 W). In some cases plasma afterglow is used. Low temperature plasma sterilization has the potential of becoming the practical choice for a wide range of medical sterilization needs.

The preceding presents a brief overview of plasma cleaning and ashing applications and techniques.

AXIC (Santa Clara, California) manufactures a range of plasma products that address most of these applications [8]. Our MultiMode HF-8 system offers the versatility of multiple electrode configurations (parallel plate, cage, and tray) in an affordable package - Figure 3.

The cleaning and pre-treatment in an oxygen plasma had influenced chemical and physical properties of the material surface [9]. Generally, the samples pretreated in an oxygen plasma are exhibiting higher wettability in deionized water and chemical solutions (Fig, 4).

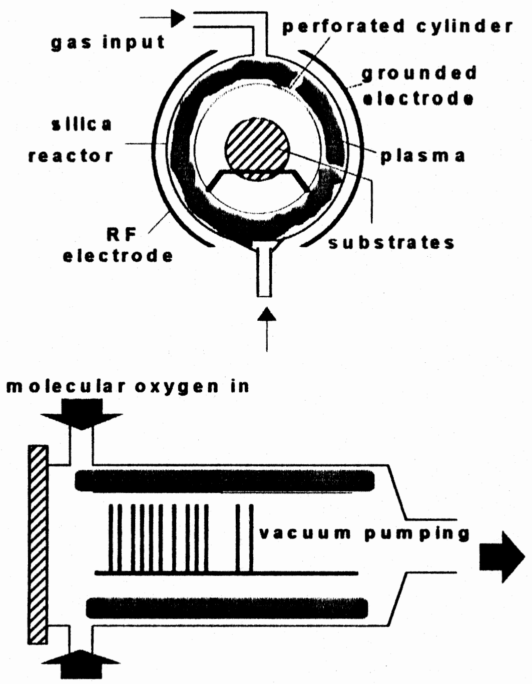

FIG. 1
Typical cylindrical configuration of capacitively excited plasma reactor.

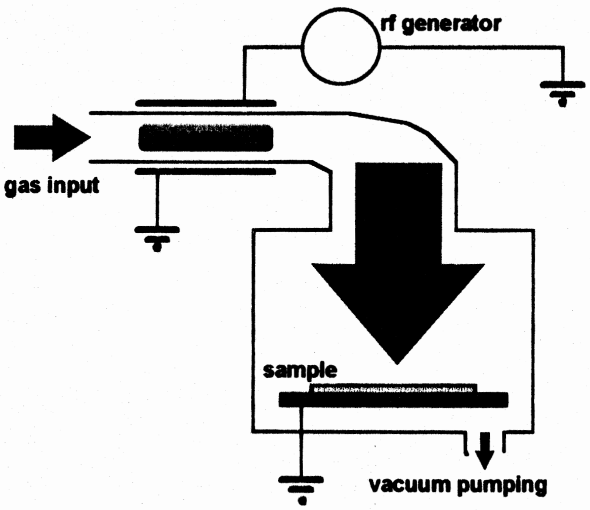

FIG. 2
Typical downstream (remote) plasma reactor.

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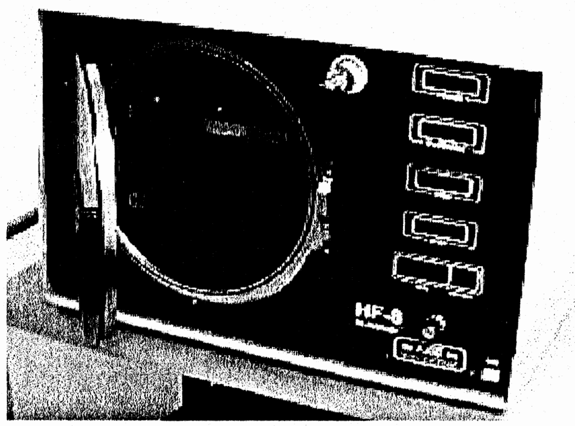

FIG. 3
Plasma reactor MultiMode HF-8 by Axic, Santa Clara, California.

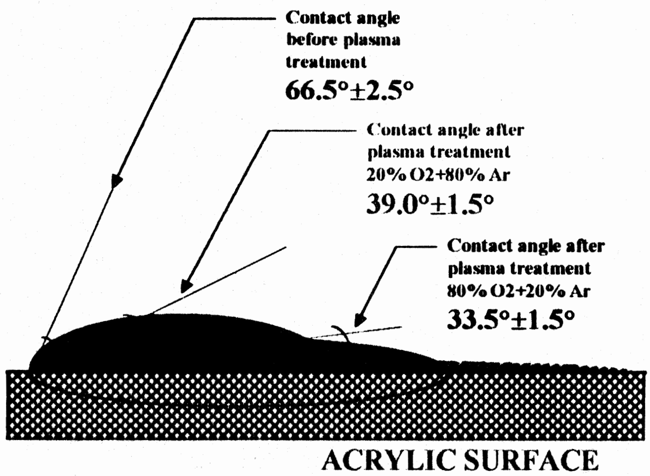

FIG. 4
The illustration of a contact angle of water on acrylic surface dependence on the plasma processing parameters (intraocular lenses application [9]).

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TABLE 2
Cleaning procedures.

MATERIAL / SURFACE	PLASMA PARAMETERS
Cleaning silicon surfaces prior to the deposition of epitaxial silicon films by LP CVD [2]	• inert gas (usually Ar) with addition of H_2 • zero bias to exclude substrate damage by ions
Removal of metallic contaminants on the silicon wafer [3]	• conversion of metallic species at temperature below 200 °C into complexes that trap the metal (plasma in halogens, for example chlorine produces compounds with almost all the metals of interest) • reduction of pressure and increase of temperature allows the volatilization of the compounds
Special procedure of silicon cleaning and preparation for VLSI fabrication [4]	• resist strip (1 μm) in oxygen at 1 torr, 200 °C, 650 nm/min, 2 min. • residual oxide etch (1.4 nm) in mixture of NF_3, H_2, and Ar (1:2:97) at 1 torr, 200 °C, 40 s • organic removal, oxide regrowth (1.3 nm) in O_2 at 1 torr, 200 °C, 30 sec. • metal complexing in HCl+Ar (1:9) at 1 torr, 200 °C, 30 sec. • residual oxide etch, partial voltilization of metal compounds in mixture of NF_3, H_2, and Ar (1:2:97) at 1 torr, 200 °C, 2.5 nm/min, 40 sec. • final volatilization - temperature ramp in vacuum at 20 mtorr, 750 °C, 2 min. • protective oxide regrowth (2 nm) in O_2 at 1 torr, 750 °C, 25 sec.
Cleaning of Si surface for GaAs growth by MO CVD [5]	• prior to film deposition substrate cleaning in hydrogen and arsine plasma (53+2 sccm) at 450 °C
Cleaning of polymeric surfaces [6]	polyimide or photoresist surfaces - oxygen plasma, low energetic ions (<50 eV) 500mtorr - 1.5 torr, 100 - 250 W, oxygen/argon mixtures [9]
Ashing	• resist ashing in oxygen plasma at 0.5-1 torr, 100-150 °C, 300-800 nm/min.
Medical sterilization	• hydrogen peroxide (or peracetic acid) plasma, below 60 °C, rf power 100-200 W, 60-90 min
Wettability improvement	• plasma in oxygen/argon mixtures, 800mtorr - 1.5 torr, 150 - 200 W, several minutes [9]

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