

IMPROVEMENT OF ETCH RATE UNIFORMITY USING THE INDEPENDENT MOVEMENT OF ELECTRODE PIECES

FIELD OF THE INVENTION

[0001] The present invention relates to semiconductor fabrication. More particularly, the present invention relates to a plasma etching apparatus.

BACKGROUND OF THE INVENTION

[0002] A typical plasma etching apparatus comprises a reactor in which there is a chamber through which reactive gas or gases flow. Within the chamber, the gases are ionized into a plasma, typically by radio frequency energy. The highly reactive ions of the plasma are able to react with material, such as the dielectric between interconnects or a polymer mask on a surface of a semiconductor wafer during it being processed into Integrated Circuits (IC's). Prior to etching, the wafer is placed in the chamber and held in proper position by a chuck or holder which exposes a top surface of the wafer to the plasma.

[0003] In semiconductor processing, the etch or deposition rate uniformity across the wafer during each process directly affects the device yield. This has become one of the main qualifying requirements for a process reactor and hence is considered a very

important parameter during its design and development. With each increase in the size of wafer diameter, the problem of ensuring uniformity of each batch of integrated circuits becomes more difficult. For instance, with the increase from 200mm to 300mm in wafer size and smaller circuit size per wafer, the edge exclusion shrinks to, for example, 2mm. Thus maintaining a uniform etch rate, profile, and critical dimensions all the way out to 2mm from the edge of the wafer has become very important.

[0004] In a plasma etch reactor, the uniformity of etch parameters' (etch rate, profile, CD, etc.) is affected by several parameters. Maintaining uniform plasma discharge and hence plasma chemistry above the wafer has become very critical to improve the uniformity. Many attempts have been conceived to improve the uniformity of the wafer by manipulating the gas flow injection through a showerhead, modifying the design of the showerhead, and placing edge rings around the wafer.

[0005] One problem in a capacitively-coupled etching reactor is the lack of uniform RF coupling especially around the edge of a wafer. FIG. 1 illustrates a conventional capacitively-coupled plasma processing chamber 100, representing an exemplary plasma processing chamber of the types typically employed to etch a substrate. The plasma reactor 100 comprises a chamber 102, a bottom electrode 104, a top electrode 106. The bottom electrode 104 includes a center bottom electrode 108 and an edge bottom electrode 110. Top electrode 106 includes a center top electrode 112 and an edge top electrode 114. Edge top electrode 114 and edge bottom electrode 110 are in

the shape of a ring respectively encircling center top electrode 112 and center bottom electrode 108 to form a single plane.

[0006] Center bottom electrode 108 is connected to RF power supply 118 while top electrode 106 and edge bottom electrode 110 are grounded for draining charge from plasma 116 produced between top electrode 106 and bottom electrode 104. As illustrated in FIG. 1, the shape of the glow discharge region (plasma 116) is distorted near the edge of center bottom electrode 108 because of grounded edge bottom electrode 110. That distortion causes non-uniform etch rate on a substrate (not shown) placed on center bottom electrode 108.

[0007] During plasma processing, the positive ions accelerate across the equipotential field lines to impinge on the surface of the substrate, thereby providing the desired etch effect, such as improving etch directionality. Due to the geometry of the upper electrode 106 and the bottom electrode 104, the field lines may not be uniform across the wafer surface and may vary significantly at the edge of the wafer 104. Accordingly, grounded ring 110 is typically provided to improve process uniformity across the entire wafer surface.

[0008] Because the parts in top electrode 106 are static, the etch rate cannot be separately controlled at the center and at the edge of the wafer. The non-uniformity during the etching process can lead to different dimensions between the center and the edge lowering the yield of reliable devices per wafer.

[0009] Accordingly, a need exists for a method and apparatus for independently controlling the etch rate at the center and the edge of a wafer. A primary purpose of the present invention is to solve these needs and provide further, related advantages.

BRIEF DESCRIPTION OF THE INVENTION

[0010] A plasma reactor comprises a chamber, a bottom electrode, a top electrode, a bottom grounded extension adjacent to and substantially encircling the bottom electrode. The top grounded extension adjacent to and substantially parallel to the top electrode. The top electrode is also grounded. The top grounded extension is capable of being independently raised or lowered to extend into a region above the bottom grounded extension.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more embodiments of the present invention and, together with the detailed description, serve to explain the principles and implementations of the invention.

[0012] In the drawings:

FIG. 1 is a diagram schematically illustrating a plasma reactor in accordance with a prior art;

FIG. 2 is a diagram schematically illustrating a plasma reactor in accordance with one embodiment.

FIG. 3 is a flow diagram schematically illustrating a method for operating the plasma reactor illustrated in FIG. 2.

DETAILED DESCRIPTION

[0013] Embodiments of the present invention are described herein in the context of plasma reactor. Those of ordinary skill in the art will realize that the following detailed description of the present invention is illustrative only and is not intended to be in any way limiting. Other embodiments of the present invention will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations of the present invention as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following detailed description to refer to the same or like parts.

[0014] In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of engineering for those of ordinary skill in the art having the benefit of this disclosure.

[0015] FIG. 2 illustrates one embodiment of a plasma reactor 200 comprising a chamber 202, a bottom electrode 208, a bottom electrode extension 210, a top electrode

212, and a top electrode extension 214. In accordance with one embodiment, bottom electrode extension 210 includes a grounded ring 210 parallel and adjacent to the bottom electrode 208 and encircling the bottom electrode 208. The top electrode extension 214 includes a adjustable grounded ring 214 parallel and adjacent to the top electrode 212 and encircling top electrode 212.

[0016] Bottom electrode 208 is connected to RF power supply 218 while top electrode 212, top electrode extension 214, and bottom electrode extension 210 are grounded for draining charge from plasma 216 produced between top electrode 212 and bottom electrode 208. By way of example, bottom electrode extension 210 and top electrode extension 212 may be made of a conductive material such as aluminum. As illustrated in FIG. 2, plasma 216 includes two regions 220 and 222 having different plasma densities based on the position (height) of top electrode extension 214.

[0017] Bottom electrode 208 is configured to receive a workpiece and includes an associated bottom electrode area that is adapted to receive the workpiece. Bottom electrode 208 is coupled to at least one power supply 218. Power supply 218 is configured to generate RF power that is communicated to bottom electrode 208. For illustrative purposes only, a dual frequency power supply 218 may be used to generate the high electric potential that is applied to a gas to produce plasma 216. More particularly, the illustrated power supply 218 is a dual power frequency power supply operating at 2 MHz and 27 MHz that is included in etching systems manufactured by

Lam Research. It shall be appreciated by those skilled in the art that other power supplies capable of generating plasma in the processing chamber 202 may also be employed. It shall be appreciated by those skilled in the art that the invention is not limited to RF frequencies of 2 MHz and 27 MHz but may be applicable to a wide range of frequencies. The invention is also not limited to dual frequency power supplies but is also applicable to systems that have three or more RF power sources with a wide variety of frequencies.

[0018] Top electrode 212 is disposed at a predetermined distance above from bottom electrode 208. Top electrode 212, top electrode extension 214, together with ground extension 210 are configured to provide a complete electrical circuit for RF power communicated from bottom electrode 208. Top electrode extension 214 can move up or down independently from top electrode 212 to manipulate plasma density at the edge of bottom electrode 208 – plasma region 222. With the plasma density varied at the edge of bottom electrode 208, the etch rate at that region can be independently controlled (either faster rate or slower rate) from the etch rate in the plasma region 220. Those of ordinary skills in the art will appreciate that there are many ways to lower and raise the top electrode extension 214. For example, a mechanical or motorized knob may be used to raise or lower top electrode extension 214 without having to open and access the interior of chamber 202.

[0019] During plasma processing, the positive ions accelerate across the equipotential field lines to impinge on the surface of the substrate, thereby providing the

desired etch effect, such as improving etch directionality. Due to the geometry of top electrode 212 and bottom electrode 208, the field lines may not be uniform across the wafer surface and may vary significantly at the edge of the wafer. Accordingly, top and bottom electrodes extensions 214 and 210 are provided to improve process uniformity across the entire wafer surface.

[0020] Plasma reactor 200 is configured to receive a gas (not shown) that is converted into plasma 216 by plasma reactor 200. By way of example and not of limitation, the relatively high gas flow rate that is pumped into chamber is 1500sccm. Gas flow rates less than 1500sccm as well as more than 1500sccm may also be applied.

[0021] To generate plasma 216 within chamber 202, power supply 218 is engaged and RF power is communicated between bottom electrode 208 and top electrode 212. Gas is then converted to plasma 216 that is used for processing workpiece or a semiconductor substrate. By way of example and not of limitation, RF power levels of 2W per cm³ of plasma volume may be applied. RF power levels of less than 2W per cm³ of plasma volume may also be applied.

[0022] For illustrative purposes, plasma reactor 200 described in FIG. 2 employs capacitive coupling to generate plasma 216 in processing chamber 202. It shall be appreciated by those skilled in the art, that the present apparatus and method may be adapted to be used with inductively coupled plasma.

[0023] Those of ordinary skill in the art will appreciate that the above configurations shown in FIG. 2 are not intended to be limiting and that other configurations can be used without departing from the inventive concepts herein disclosed. For example, two or more adjacent top electrode extension 214 may be positioned to further control the etch rate at the edge of bottom electrode 208.

[0024] FIG. 3 illustrates a method for using the plasma reactor illustrated in FIG. 2. At 302, the position (raised or lowered) of top electrode extension 214 is selected. Top electrode extension 214 is capable of being raised and lowered to extend into a region above the bottom electrode extension. At 304, plasma reactor 200 processes a wafer supported by bottom electrode 208. At 306, the wafer is examined to determine the etch uniformity throughout the surface of the wafer. At 308, the position of top electrode extension 214 is adjusted based on the analysis at 306 to further improve the etch rate uniformity throughout the surface of the wafer.

[0025] While embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art having the benefit of this disclosure that many more modifications than mentioned above are possible without departing from the inventive concepts herein. The invention, therefore, is not to be restricted except in the spirit of the appended claims.

CLAIMS

What is claimed is:

1. A plasma reactor comprising:
 - a chamber;
 - a bottom electrode and a top electrode enclosed within said chamber;
 - a bottom grounded extension adjacent to and substantially encircling said bottom electrode;
 - a top grounded extension adjacent to and substantially parallel to said top electrode;
 - wherein said top grounded extension is capable of being independently raised and lowered to extend into a region above said bottom grounded extension.
2. The plasma reactor of claim 1 wherein said top grounded extension includes a ring.
3. The plasma reactor of claim 1 wherein said bottom grounded extension includes a ring.
4. The plasma reactor of claim 1 further comprising a power supply coupled to said bottom electrode, said bottom electrode configured to receive a workpiece.

5. The plasma reactor of claim 4 wherein said power supply generates a plurality of frequencies to said bottom electrode.
6. The plasma reactor of claim 5 wherein said top electrode is grounded.
7. A method for using a plasma reactor having a chamber with a top electrode, a bottom electrode, a bottom grounded extension adjacent to and substantially encircling said bottom electrode, a top grounded extension adjacent to and substantially parallel to said top electrode, the method comprising:
adjusting a position of the top grounded extension, the top grounded extension capable of being independently raised and lowered to extend into a region above the bottom grounded extension.
8. The method of claim 7 further comprising supplying power to the bottom electrode, the bottom electrode configured to receive a workpiece.
9. The method of claim 8 further comprising generating a plurality of frequencies to the bottom electrode.
10. The method of claim 7 further comprising grounding the top electrode.