Abs. 899, 206th Meeting, © 2004 The Electrochemical Society, Inc.

Advanced Dielectric Etch Using 200/300-mm Low Residence Time GroovyICP™ Etcher

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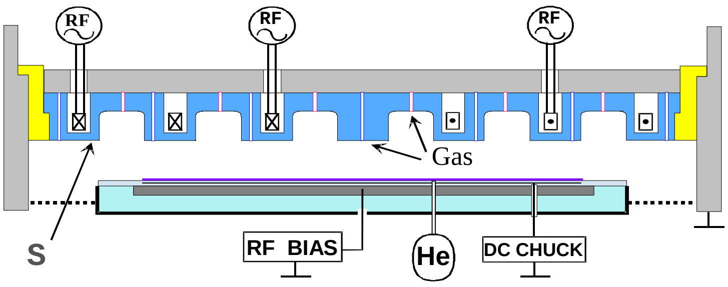

Figure

There is presently only one type of 200/300-mm plasma processing chambers for highly selective SiO_2 etch, especially for high aspect ratio contact holes (HARC): parallel-plate capacitive discharges. Known inductively coupled plasma (ICP) sources, realized in flat compact configurations, do not provide radial process uniformity. An increase of the discharge gap does improve the uniformity but decreases selectivity to photoresist at the same time.

We present here process results obtained with our 300-mm etchers showing principal advantages and exclusive controllability of the new manufacturing equipment over traditional capacitive etchers. Such results are yet unachievable for other inductive etchers.

300-mm GroovyICP™ plasma source incorporates three geometrically separate and independently adjustable ring-shape inductive plasma sources designed as annular grooves in a flat roof made of crystalline silicon, ceramics, or fused silica (Figure) depending on the etching applications. Every coil has its own RF power control. The coils and RF matching system are specially designed in order to avoid power interference between annular discharges in the grooves thus achieving full controllability over the radial sputtering and etch profiles. Coils are not sensitive to each other for a wide range of RF power and operate as independent ICP sources in the integrated flat plasma source. The plasma source shows discharge stability in a pressure range from 3 millitorr up to 100 Torr: about five orders of magnitude.

Every groove generating an independent plasma ring has its own gas supply for independent adjustment of chemistry in the radial direction.

Consequently, GroovyICP™ has two powerful and substantially independent means for profile/uniformity adjustment: rate of physical sputtering and density of chemically active components. Thus, the new plasma source allows independent distributions of physical and chemical plasma parameters without compromising damage issues caused by usual attempts to compensate one non-uniform parameter by another.

Stable process operation range for oxide and low-k etch is within about 5-60 mTorr gas pressure range. The integrated plasma source is also capable of oxygen discharges up to 2 Torr gas pressure, which is useful for a free-radical dry chamber cleaning and in-situ ash.

Etching processes are well characterized on a number of bare and patterned production wafers with different materials: photoresists (KrF, ArF), silicon oxide, organic and inorganic low-k materials like SiLK, SiOC, polyimidazole derived, fluorinated polymers, and silicon.

One of the features of the GroovyICP™ is its ability for low power ignition because of quasi-immersed nature of the induction coils. Low-power ignition prevents production wafers from specific plasma damages typical for capacitive etchers.

Plasma density is constant within the level of experimental errors over 300-mm wafer surface. There are no bumps or valleys at the grooves or between them. Since oxide etchers operate under the highest RF bias power among all etchers, the uniformity of sputter rate distribution over the wafer surface is vitally important for advanced processing. The sputter rate uniformity of GroovyICP™ is better than 5%. There is no problem with the edge non-uniformity typical for capacitive tools.

The controllability of radial sputter profile is an essential feature of GroovyICP™. Indeed, the process window of usual etchers is essentially limited with only a few external discharge parameters. No one of them is adjustable over the wafer radius. There is a narrow parameter range producing a flat etch profile: step up or step down changes the etch ratio center/edge. GroovyICP™ overcomes this principal limitation by independent adjustment of the edge/center etch profile thus essentially expanding the process window.

Etch rate on bare wafers for different materials is uniform. Oxide etch non-uniformity at 5 mTorr is within ±1.4% (range). Typical etch non-uniformity for organic (SiLK) or inorganic low-k materials at the discharge pressure of about 30 mTorr are within about ±2%. Even at 60 mTorr, the uniformity level is better than ±5%. Process conditions can be varied from “clean” etch mode to polymer deposition mode, which is preferable for highly selective etch in respect to the polymer resist.

In order to characterize an oxide etcher, we etched HARC holes: 80-nm-diameter with aspect ratio 20. Oxide to photoresist etch selectivity of about 119 (bulk) and about 7.1 (facet) was easily achieved.

GroovyICP™ operates in a wide range of RF bias conditions: from extremely high, typical for oxide etchers, down to extremely low, typical for pure inductive discharges. This unique combination of so many different, and incompatible in usually capacitive etchers, properties in one process chamber sets a new industrial standard for a Low-k etcher. It allows excellent multi step multi processing of newly developed structures with organic/inor-ganic low-k insulators and SiO_2, SiC, or SiOC hard masks, spacers, and stoppers in one chamber. Obviously, such processing brings about essential improvement in overall quality, throughput, and reduces cost of ownership for end users.

Organic Low-k pattern (SiLK) with SiO_2/SiC or SiOC hard masks processed in GroovyICP™ has no micro trenching in the low-k layer in a half-etched pattern, while the taper angle in the completed sample is 89 degree.