AXIC APPLICATION REPORT

PHOTORESIST STRIPPING

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THERE ARE MANY APPLICATIONS OF PLASMA PROCESSES to organic materials. These include surface property modifications to improve wetting, dyeing, printing, and adhesion properties of polymeric materials, as well as, plasma ashing to remove ***"organic smear"*** that results from mechanical drilling of printed circuit boards [1]. The original and still most widely applied use of plasma processing to the electronics industry is photoresist stripping, which is the removal of polymeric photoresists following lithography, etching and deposition processes in semiconductor manufacturing. A competing photoresist stripping technology is wet stripping, which is the removal of photoresists with chemical solutions. However, there are many advantages to dry, plasma stripping over wet chemical stripping as outlined in Table 1.

A generalized diagram of thin film patterning is shown in Fig. 1. As can be seen, plasma treatments are used at several steps - cleaning and activation of the surface prior to thin-film deposition, dry development, plasma descumming, and resist stripping. This application note deals with the last two processes - plasma descumming and plasma stripping. Photoresists are photosensitive organic polymers used for device patterning during IC fabrication. The photoresist is exposed to light though a mask and subsequently developed, which results in a pattern of areas free of photoresist. The exposed areas are etched or coated with another layer, while the unexposed, resist protected areas are not affected. Following the process step, the photoresist has to be removed (stripped) to prepare the wafer for the next fabrication step.

Plasma activated oxygen atoms react vigorously at room temperature with photoresists (low temperature ashing). The oxidation products, CO, CO_2, and water vapor are evacuated from the chamber with unreacted feed gas (see Fig. 2).

The objective in plasma stripping is the rapid removal of resists, without etching or otherwise damaging the substrate or underlying thin-film structure. Stripping rates can vary from 100 nm/min. up to several microns/min. Strip rates primarily depend on the oxygen content of the feed gas, which is controlled by flow rate of oxygen gas into the reactor chamber and chamber pressure.

The addition of ***"impurity gases"*** to molecular oxygen will enhance the production of oxygen atoms in plasma. For example, small additions of CF_4 or SF_6 can increase stripping rates as the result of increased oxygen radicals and increased initiation rate via indiscriminate abstraction of hydrogen from the photoresist by highly reactive fluorine atoms in the plasma. Hence, etch rates can be enhanced further by optimizing CF_4/O_2 ratios of the feed gas mixture. In some cases, hydrogen gas is added to the feed gas mix to improve anisotropy. However, this will slow the etch rate.

TABLE 1
Comparison of wet and dry resist stripping.

Disadvantages of wet resist stripping	Advantages of dry (or plasma) stripping
• handling and disposal of large volumes of either hydrocarbon solvents or strongly oxidizing acids • safety and technical requirements to handle toxic and corrosive liquids • handling and disposal of large volumes of deionized water • can leave traces of photoresist on the wafer • environmental contamination • waste disposal	• using a gas medium - usually oxygen • non-toxic, non-corrosive • low-temperature processing • control of process • low price for medium • less environmental impact • simple handling and manipulation • more cost/materials/energy/work effective

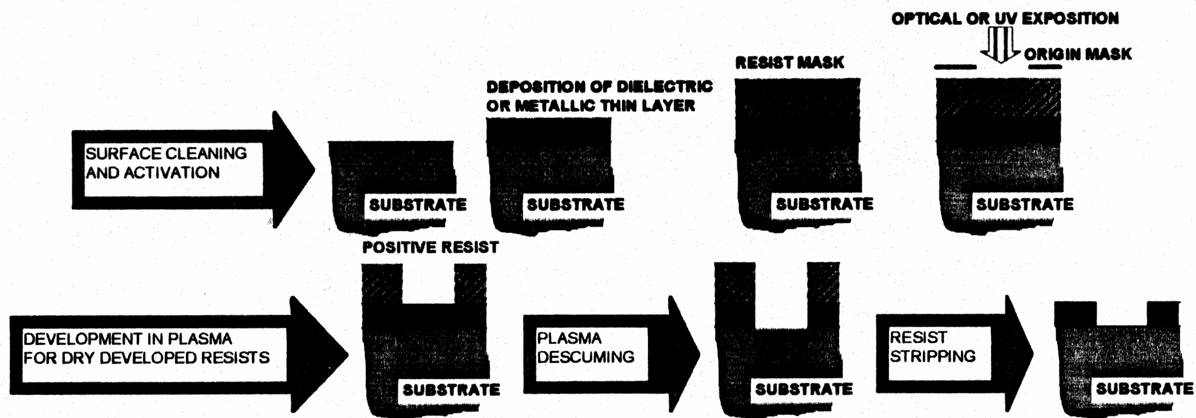


FIG. 1
Simplified process scheme for typical patterning of a thin layer using a lithographic procedure with positive resist. Plasma treatment steps are indicated.

Another variable effecting plasma stripping rates is temperature. Strip rates increase exponentially relative to temperature. Surface bombardment by photons, electrons, and ions may result in surface heating of the photoresist resulting in surface temperatures of approximately 100 degrees Celsius. At temperatures above 150 degrees Celsius many photoresists will begin to decompose. Thus, the application of external sources of heat can greatly increase plasma stripping rates [2,3].

In addition to contributing to heat production, ion bombardment can physically break surface bonds generating radical species at the resist surface and product desorption.

Of course, resist type will also contribute the determination of the strip rate. Some are more difficult to remove than others.

Plasma reactor configurations are selected based on process needs. A variety of configurations have been applied to plasma stripping (see Table 2). A reactor with parallel plate electrodes (Fig. 2) provides good removal uniformity as the result of good thermal contact between the wafer and the electrode. A 13.56 MHz RF generator is typically used in plasma stripping and with

placement of the wafer on the grounded parallel electrode, ion bombardment is reduced. Plasma generation at lower frequencies (40 - 400 kHz) will result in higher surface temperature from increased ion generation and bombardment, but should not be used in processes that are sensitive to ion bombardment.

TABLE 2
Typical process parameters in resist stripping.

FREQUENCY AND REACTOR TYPE	PRESSURE (mtorr)	TEMPERATURE (°C)	ETCH RATE (nm/min)	RESIST MATERIAL
rf, barrel	500-1000	100-150	100-500	KFTR
rf, barrel	800	100	300	AZ 1350
rf, parallel plate (diode)	500-1000	100-150	100-500	KODAK 747
rf, RIE	10-150	40	100-500	AZ 2450
rf, RIE	75	40	150	AZ 1350
microwave, downstream	1000-5000	130-160	300-1000	AZ 1370

Ion bombardment can be completely eliminated in reactors configured with a cage electrode in combination with a Faraday cup (perforated cylinder, Fig. 3), or a downstream (afterglow) reactor. Downstream reactors utilize microwave excitation (2.45 GHz). In some special instances Reactive Ion Etch (RIE) processes have been enhanced with magnetic fields. For example, polyimide has been etched at 2.5 microns/min. in an RIE reactor with a 50 mtorr oxygen plasma enhanced by a magnetic field [5].

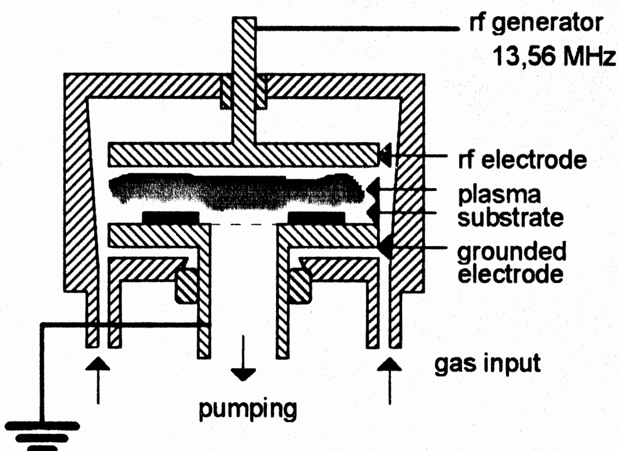


FIG. 2
Schematic of parallel plate plasmochemical reactor.

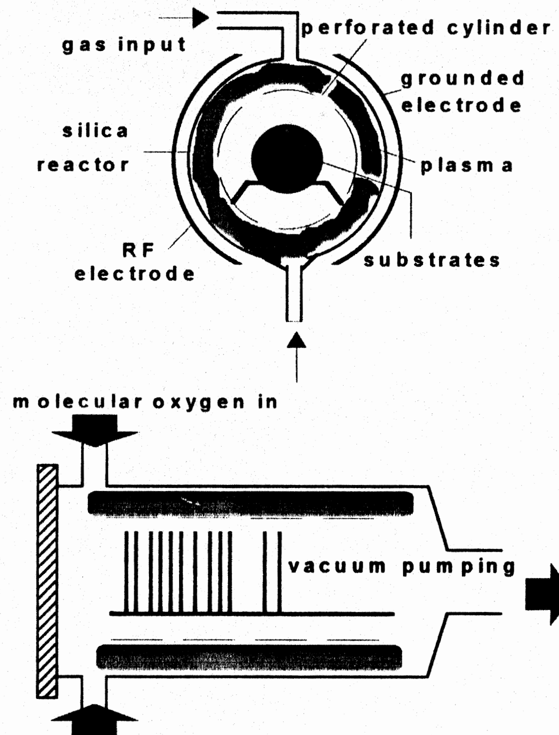


FIG. 3
Typical cylindrical configuration of capacitively excited plasma reactor.

Generally, end point determination is not critical to plasma stripping processes because of the high selectivity of the plasma process. However, when end point detection is critical, there are several

means by which this can be achieved. Sensing of CO plasma emissions or even simple observation of plasma discharge color and pressure changes are frequently used.

AXIC offers all the plasma electrode and reactor configurations discussed for plasma stripping [7]. A very simple, but versatile system for these applications is our MultiMode product line (Fig. 4). The MultiMode system can be configured with parallel plate electrodes, cylindrical cage electrode, or tray electrode system (Figure 5).

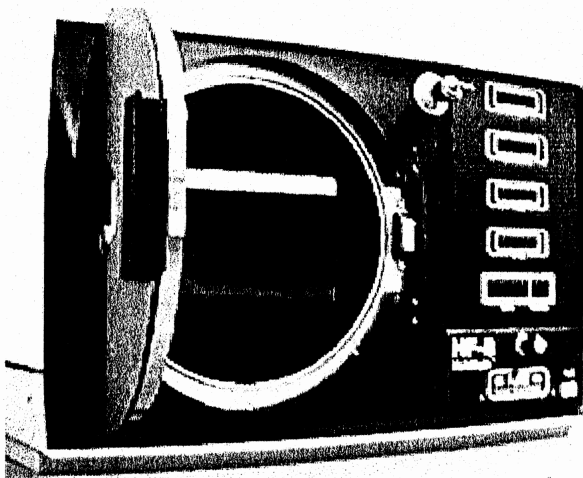
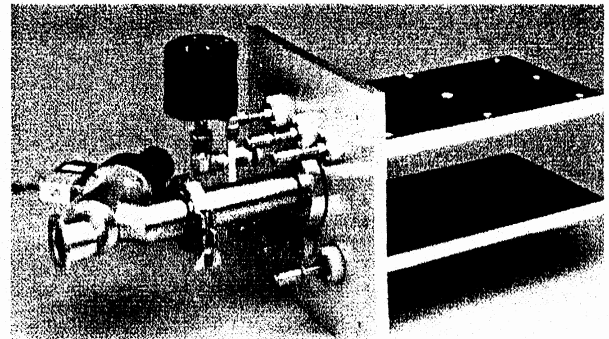


FIG. 4
Plasma reactor for resist stripping MultiMode HF-8 by Axic.

Another related application of plasma to thin-film patterning is oxygen plasma ***"descumming"*** (Figure 5). Following photoresist development, a thin film of the resist may be left in developed areas. This remaining film, or scum may prevent the initiation of uniform wet or dry etching, or reduce the adhesion properties in the lift-off technique. Short processing times in an oxygen plasma can descum these areas and resolve these problems. When used in anisotropic processes (RIE), plasma descum steps will improve the wall profile of the masking resist (Fig. 6). This improves the masking behavior of the resist for subsequent anisotropic etching of the thin layer.



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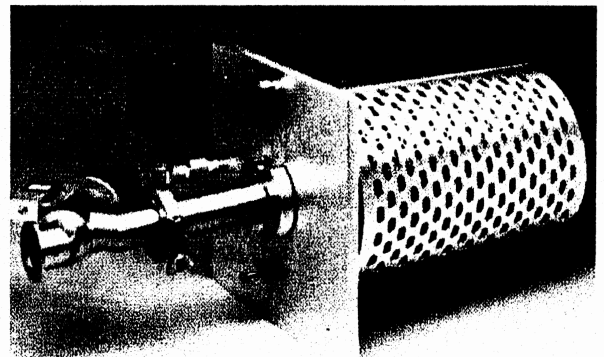

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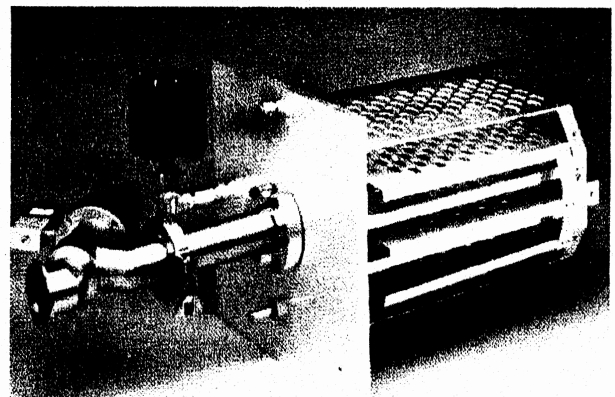

c)

FIG. 5
Modular electrode system for plasma reactor MultiMode HF8: (a) - parallel plate configuration, (b) - cage and (c) - tray electrode setup.

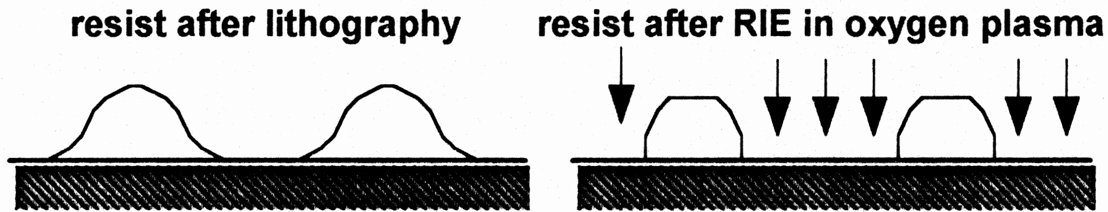

FIG. 6
Plasma descumming: Oxygen easily removes polymerized layers and also provides vertical walls for masks.

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