Optimization of Particle and Atmosphere Control in the SPM Process via Nozzle Cover

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Abstract

The sulfuric acid-hydrogen peroxide mixture (SPM), a vital cleaning agent in the semiconductor industry, is widely utilized in key chip manufacturing processes, including photoresist stripping, organic contaminant removal, and metal impurity cleaning. As chip technology advances rapidly toward smaller feature sizes and higher device densities, the high-temperature (>170℃) and even ultra-high-temperature (>190℃) sulfuric acid cleaning process has gradually evolved into a core technology to tackle intractable contamination challenges. This advanced process entails heating concentrated sulfuric acid to temperatures above 170℃, typically within the range of 170~220℃, which markedly enhances the acid's dehydrating and oxidative capabilities, thereby enabling efficient removal of stubborn organic residues that are hard to eliminate through conventional cleaning approaches.

Nevertheless, elevated temperatures also pose notable challenges to material reliability and process control. On one hand, long-term exposure of process chambers, PTFE (Polytetrafluoroethylene) seals, and metal components to high-temperature concentrated sulfuric acid leads to gradual corrosion. This corrosion may further induce particle detachment from component surfaces and heavy metal leaching, which can adversely impact the electrical performance of fabricated chips and the long-term reliability of equipment. On the other hand, high temperatures significantly increase process control difficulty: H_2O_2 decomposes rapidly at high temperatures, generating a large number of oxygen bubbles that disrupt the stability of the liquid film on the wafer surface, trigger liquid splashing and particle suspension, and ultimately result in increased particle density on the wafer surface.

Meanwhile, sulfuric acid volatilization is intensified at high temperatures, producing sulfur trioxide (SO_3) gas. When this gas comes into contact with atmospheric moisture, it condenses to form submicron-scale acid mist particles. Inadequate exhaust gas treatment may cause this acid mist to settle back onto the wafer surface, creating defects and reducing chip yield (Fig.1). To address particle contamination and chamber environment issues caused by high-temperature SPM vapor, this study developed a dedicated nozzle cover assembly consisting of three core components: the nozzle cover body, the cover exhaust module, and the automatic cleaning module. The nozzle cover body effectively blocks acid mist and splashing droplets; the exhaust module absorbs internal acidic gases and efficiently guides them out for centralized treatment (Fig.2); the automatic cleaning module uses deionized water to rinse the inner wall via a tray cup design, ensuring long-term cleanliness of the

assembly (Fig.3).

Experimental results have confirmed that this improved assembly can significantly enhance the on-wafer particle control performance in the H-SPM process (170°C H_2SO_4; H_2SO_4:H_2O_2 = 9:1). As shown in Fig. 1(a), without a nozzle cover, a total of 58 groups of 26 nm particle data were collected, with an average of 23.6 ea @ 26 nm and poor data stability (Fig. 4a). After the SPM nozzle cover is installed as shown in Figure 1(b), a total of 154 groups of 26 nm particle data were collected, with an average of 4.5 ea @ 26 nm and good data stability (Figure 4b). Even after continuous operation for one month without maintenance, no splashing or crystallization was observed in the chamber. The device has achieved stable particle control, which greatly prolongs the service life of the equipment and reduces the overall maintenance cost of the production line. It also exhibits excellent control over small particles: a total of 29 groups of 19 nm particle data were collected, with an average of 9 ea@19 nm (Fig.4c). We are currently collecting data on the performance of the nozzle cover for particles of 15nm and smaller.

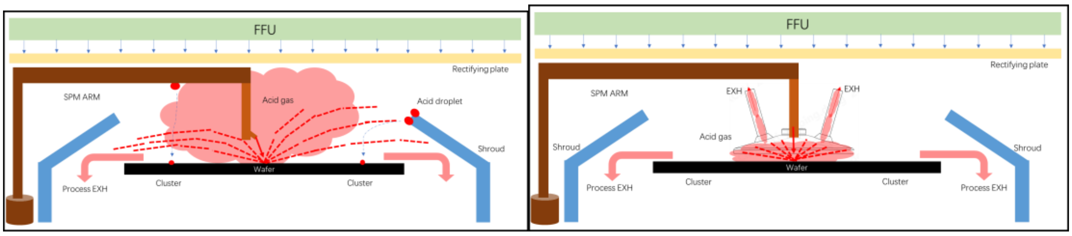

Figure 1. (a) normal SPM process. (b) nozzle cover in SPM process

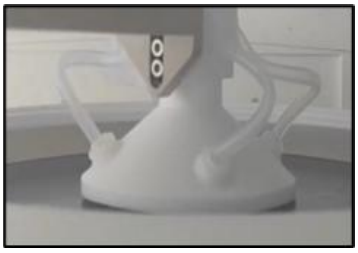

Figure 2. Physical Image of SPM Nozzle cover

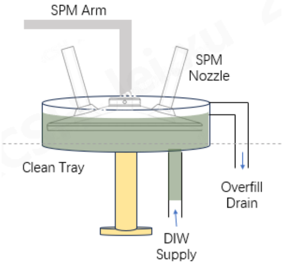

Figure 3. SPM Nozzle Dip and Overfill clean

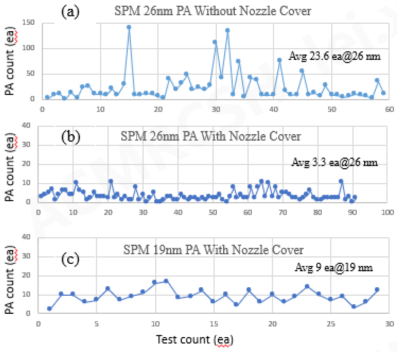

Figure 4. SPM Process PA data: (a) SPM 26 nm PA count without nozzle cover. (b) SPM 26 nm PA count with nozzle cover. (c) SPM 19 nm PA count with nozzle cover.