# Surface Reaction and Plasma Induced Damage by atomic layer etching process

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As the semiconductor integrated process enters the region below 10 nm, the removal of contaminants on the silicon wafer surface is crucial for high-integration device products and has a great influence on the yield, quality, and reliability of these products. Therefore, a cleaning method with high efficiency and high selectivity is required.

Correspondingly, the NOR (native oxide removal) dry cleaning method, which removes the native oxide films by using indirect plasma with hot $H_2$ or $H_2/NF_3$ gases, has attracted attention as a next-generation cleaning process because it can etch various thin-films with profile control. According to Toshio Hayashi et al. the mechanism for the dry cleaning process using hot $H_2$ gas and down flow $NF_s$ gas, which are not decomposed at the plasma source, is that fluorine, which has high electronegativity, is adsorbed well on the surface of the silicon wafer and reacts with hydrogen gas; it then generates $NH_4$-F-$NH_4$ because of Coulomb interaction. Therefore, $(NH_4)_2SiF_6$ is formed on the silicon substrate and vaporized at above 100 °C.

Dry cleaning can control selectivity of the contaminants and roughness of the wafer surface, depending on gas flow, temperature, pressure, plasma power, and pressure distribution. However, controlling various process parameters is very difficult; It is necessary to understand the mechanism of gas reactions based on the plasma used for controlling etch rate and selective thin-film uniformity.

In this study, we investigated the method of surface planarization as well as removal of contaminants during dry cleaning using down flow $H_2$ and $NH_3$ gas. According to the gas flow, dry cleaning of oxide, nitride, and p-doped wafers was performed. On analyzing the quality of each film, we propose an analysis method for controlling etch rate to selective thin-films and contaminants in a trench region below 10 nm.

In this experiment, the characteristics of each thin-film were analyzed by Raman spectroscopy, which can quantify and provide qualitative analysis of selective parts through beam focusing. When the characteristics of p-doped thin-films are analyzed by selective removal of oxide and nitride films, which are deposited on p-doped silicon in trenches with a width of 10 nm or less, we can use Raman spectroscopy to determine the appropriate etch rate and time.