Optimization of Dummy Poly-silicon removal in high-k metal gate process

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Selected Topic: ADM and SC1 etch on dummy poly-silicon removal and etch uniformity optimization

Abstract

According to Moore's law, semiconductor technology nodes have shrunk to less than 45nm in the last decades. High-K meta gate process is widely used at nodes of 28nm and below, because of low power consumption and lower leakage

In gate first high-k metal gate process, there is a need to remove dummy grid poly-silicon by wet etch and stop on work function metal (WFM) or hafnium oxide (HfO2) after source and drain ion implantation and thermal annealing processes.

The wet etch solutions need to be selected to remove dummy poly-silicon and WFM, but solutions need to be selective, so not to etch grid sidewall silicon oxide. Ammonia etches poly-silicon faster than etching of silicon oxide or titanium nitride (TiN). Some WFM such as titanium nitride can be etched by solutions containing hydrogen peroxide, but HfO2 cannot be etched.

During dummy poly-silicon removal process in a single cleaning tool, the use of high temperature and concentrated etch solutions can cause a problem. When a high temperature solution sprays onto the center of a wafer, there is a high temperature variation which will create a disparity in the etching rate from center to the edge of wafer, this temperature variation will create an etch difference from center to edge. Optimizing the etch uniformity is very important to the dummy poly-silicon removal process.

In this paper, we confirm that a diluted ammonia mixture (ADM) and SC1 etch capability on poly-silicon, thermal oxide and titanium nitride. Based on film etching experiment results, we carried out a high-k loop film etching experiment. Figure.1 shows TEM result of original waferwithout any processing, ADM treated wafer and ADM+SC1 treated wafer. Original wafer is deposited HfO2, WFM, poly-silicon films. ADM etch stop on WFM and ADM+SC1 etch stop on HfO2. So we can effectively control the dummy poly silicon removal process by combining ADM and SC1 etching solutions.

Figure.2 and Figure.3 shows that etch rate and uniformity of ADM on poly-silicon are increased by solution temperature and concentration. When solution temperature and concentration are at a high level, etch uniformity of central spray will exceed 25%. It means that the etch amount of edge is only half of center. When the center etching is complete, there is still a large amount of poly silicon left at the edge of wafer.

Figure.4 shows etch rate distribution in diameter of different process mode. As the result shown in table.1, when the nozzle is fixed in the center of wafer, the etch uniformity exceeds 30% and etch amount of the center has exceeds 2 times of the edge. This is unacceptable in semiconductor process. When the nozzle moves at a uniform speed on wafer surface, etch rate distribution in diameter changed from inverted V-shape to M-shape. Uniform speed increases the etch rate of edge and decreases the etch rate of center at the same time. When the nozzle moves at a variable speed on the wafer surface, and every speed change is controllable uniformly, the range of etch rate distribution is smaller than uniform speed. The etch uniformity can be improved to less than 4% by optimizing the velocity and acceleration of the center, middle and edge position. In this paper, we confirm ADM and SC1 etch ability on different films. We have also shown how to effectively control dummy poly silicon removal in gate first high-k metal gate process by combining of ADM and SC1 solution. We also showed how to improve the etch uniformity of poly silicon by optimizing the chemical scan profile on the wafer from 36% to less than 4% under condition of 70°C and mix ratio 1:5.

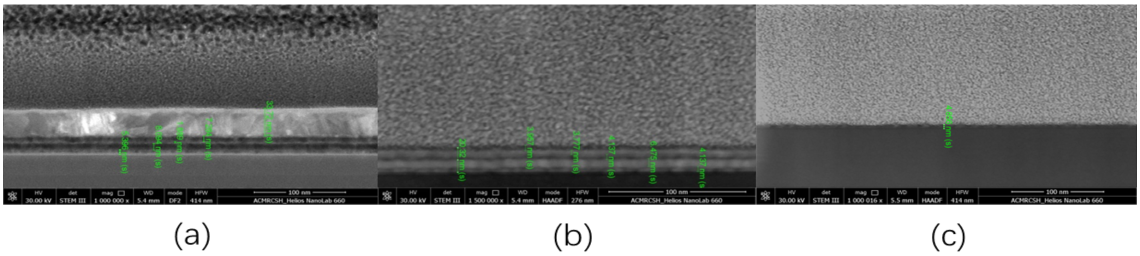

Figure.1 TEM image of wafer: (a) original wafer; (b) ADM treatment; (c) ADM+SC1 treatment

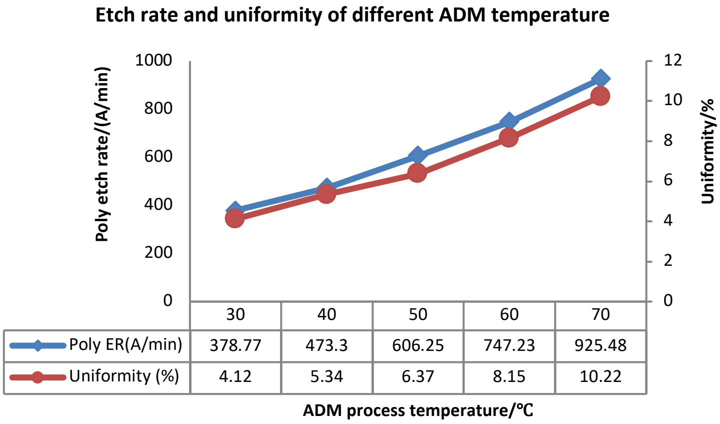

Figure.2 Relationship between etch rate and uniformity and solution temperature

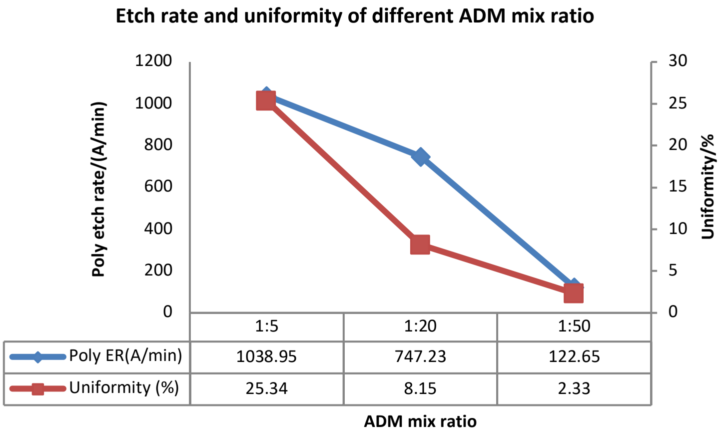

Figure.3 Relationship between etch rate and uniformity and solution temperature

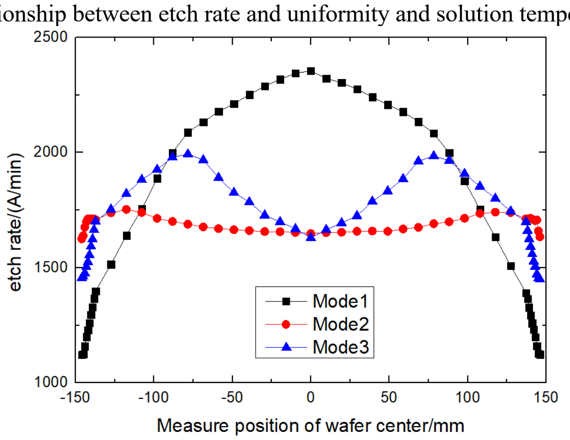

Figure.4 Distribution of different process mode

Process mode	Mode1	Mode2	Mode3
Scan profile	NA(fix in center)	Uniform speed	Variable speed and uniform acceleration
Uniformity (%)	36.02	15.86	3.78

Table.1 Comparison of etch uniformity on three different scan mode