CHAPTER FOUR : WAFER SURFACE ETCHING RATE

4.1 Objective and Experimental

This Chapter studied the (100) and (111) wafer's etching rate at different etchant lifetime in order to gain more understanding on preferential etchant used for OISF delineation. Two tests were conducted; the first test was to determine etching rate at different etchant lifetime. This is to avoid using decomposed etchant to etch wafers.

For this purpose, preferential etchant was prepared (*Refer Table 3.1*), and seasoned using dummy wafers. Both-surfaces-etched wafers with different crystal orientation were preferentially etched together using the same this etchant at different etchant lifetime. Wafers etching rates were determined. This test was conducted on the same etchant for etchant lifetime ranged from one day to eight days.

When etchant activity at different etchant lifetime was studied, another test was conducted to confirm if there is any difference in preferential etching rate between etched wafer and polished wafer. If there is no significant difference found in etching rate between etched and polished wafers having the same crystal orientation then etched wafer could be used to monitor polished wafer's etching rate in subsequent tests. Etched wafers are preferred because they are much cheaper than polished wafers. The same etchant preparation and etching rate determination procedures were employed.

Properties of polished wafers used in etching rate study are given in Table 4.1. These polished wafers were also used in the studies of OISF dimension and OISF density as a function of surface removal and blasting pressure in Chapter 5 and Chapter 6.

Table 4.1 : Properties of Wafer Used for OISF Density and OISF Dimension Studies.

No	Wafer Characteristics
1	Czochralski grown 5" diameter wafer, p-type (Boron), 4.0 – 6.0Ωcm, (100) surface orientation, both surface polished
2	Czochralski grown 5" diameter wafer, p-type (Boron), 5.0 – 7.0Ωcm, (111) surface orientation, both surface polished

4.2 Results

4.2.1 Impact of Etchant Lifetime to Etching Rate

Etching rate of etched (100) and (111) wafers were determined from the gradient of the graph which etching removal was plotted against etching time as in Figure 4.1 and Figure 4.2. For the same etchant prepared, etching rate reduces drastically as etchant lifetime increases. When etchant lifetime increases, more etchant decomposes therefore its activity decreases leading to the reduction of its etching rate.

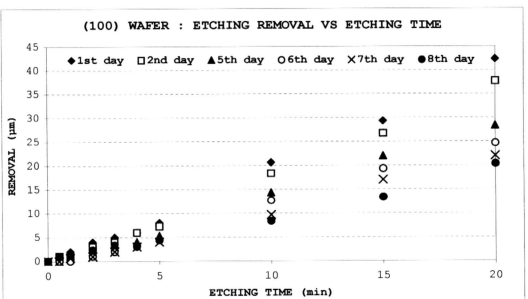


Figure 4.1 : Etching removal vs etching time for (100) wafer at different etchant lifetime.

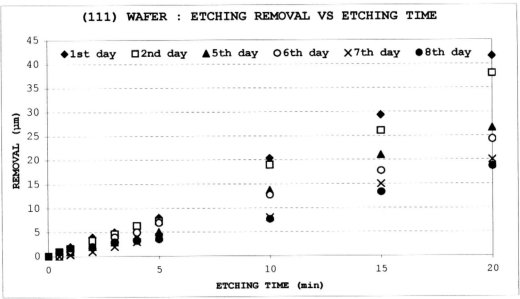


Figure 4.2 : Etching removal vs etching time for (111) wafer at different etchant lifetime.

All etching rates determined for (100) and (111) etched wafers were plotted against respective etchant lifetime in Figure 4.3. When etchant lifetime increases from one day to eight days, etching rate reduces linearly from 2μm/min to 0.9μm/min, regardless of wafer crystal orientation.

Etching rate is a linear function of etchant lifetime for both (100) and (111) wafers. Equation given below shows the etching rate of (100) wafer, $R_{(100)}$, and etching rate of (111) wafer $R_{(111)}$, as a function of etchant lifetime, t. For the same etchant lifetime, etching rate difference (difference in gradient) between these two types of crystal orientations is very small.

$$R_{(100)}(\mu m/min) = -0.15t + 2.15$$

$$R_{(111)}(\mu m/min) = -0.16t + 2.16$$

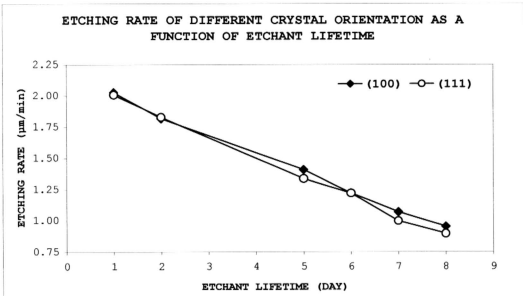


Figure 4.3 : Etching rate of (100) and (111) wafers as a function of etchant lifetime

4.2.2 Impact of Wafer Surface Finishing to Etching Rate

In order to study if there is difference in etching rate for wafers having the same chemical and electrical properties but of different surface finishing, the etching rate of etched (100) wafer was compared with polished (100) wafer while etched (111) wafer was compared to polished (111) wafer. Referring to Figure 4.4 and Figure 4.5 plotted, etching rate for same crystal orientation but different surface finishing does not differ significantly in etching rate. This trend was observed in both (100) and (111) wafers.

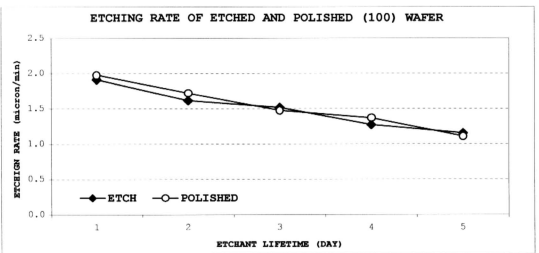


Figure 4.4 : Etching rate comparison between etched and polished (100) wafer.

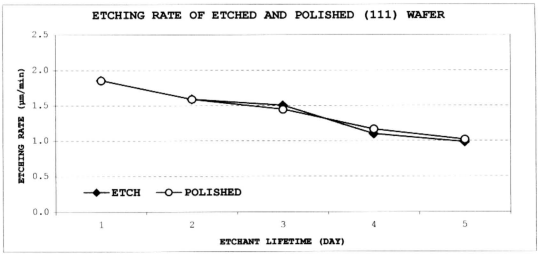


Figure 4.5 : Etching rate comparison between etched and polished (111) wafer.

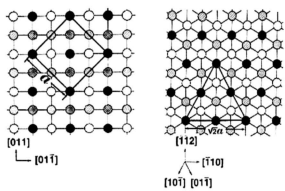
4.3 Discussion

Etching rate was studied for wafers having different surface crystal orientation and surface finishing. Besides, etching rate for the same etchant at different etchant lifetime was determined. For preferential etching process such as this one, the etching rate for silicon material is dependent of crystal orientation. Etching rate for (100) wafer is expected to be higher than etching rate of (111) wafers [2] due to (111) plane packing density is higher than (100) plane's (*Refer to Figure 4.6*).

The plane packing density for (111) wafer is 15 percent higher than the packing density of (100) wafer. Hence, the bonding between silicon atoms on (100) plane would be weaker compared to the bonding of silicon atoms on (111) plane. Nevertheless, no significant difference in etching rate was observed in the results obtained.

Same etching rate for (100) and (111) wafer observed in one of the tests is believed to be cause by the resolution of thickness measurement gauge used. The resolution of digital dial gauge used for thickness measurement is one micron. The amount of surface removal targeted is relatively small. Some of the repeated measurement as repeated etching progressed showed no change in thickness. This complicates the detection of the difference in etching rate between (100) and (111) wafers.

For the same etchant used, its etching rate is affected by etchant lifetime [2] because etchant will decompose over time. The etchant activity also reduces when the amount of wafer etched was increased. Due to these behaviours of etchant, etching rate for all tests was not calculated using equations shown above but they were used to estimate etching time required for targeted surface removal in Chapter 5 and Chapter 6's tests.



Description	(100) Wafer	(111) Wafer
No of atom on the drawn crystal plane enclosed by black thick lines	2	2
Area of the drawn crystal plane	a^2	$0.8660a^2$
Plane Packing Density	2 atoms/a^2	2.31 atoms/a^2

Figure 4.6 : Crystal plane and plane atomic packing density of (100) and (111) wafer

Second test's results shows no significant difference in etching rate between etched and polished wafers therefore etched (100) wafer can be used to monitor etching removal of polished (100) wafer. This is also applicable for polished (111) wafer etching removal monitoring using etched (111) wafer.

In short, etched wafer can be used to monitor polished wafer etching removal in tests stated in Chapter 5 and Chapter 6 whenever test is conducted and etching removal have to be determined separately using etched wafers whenever etching is done because etchant activity changes over time.