

Task ID: 425.028

Task title: Lowering the Environmental Impact of High-k and Metal Gate-Stack Surface Preparation Processes

Deliverable title: Report on the Physico-Chemical Analysis of High-k After Metal Removal

Part 1. *Wet etching of hafnium silicate high-k in different concentrations of HF & Tiron*

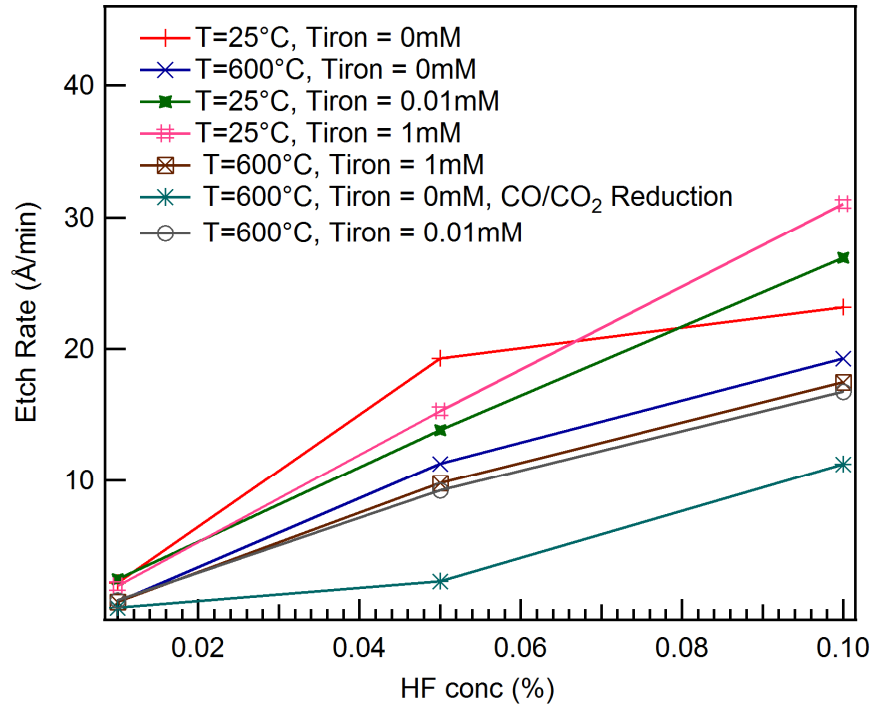
Small pieces of 2 x 1.5 cm were cleaved from the Hafnium Silicate wafer and cleaned by IPA, followed by thorough rinsing with DI water and drying with N₂. The thickness of HfSi_{0.74}O_{3.42} was measured at 5 different locations using a spectroscopic ellipsometer (J.A. Woollam Co.). The oxide was then etched by placing the wafer vertically in different concentration of HF and Tiron solution for different times followed by DI water rinsing and drying with nitrogen. The solution was continuously stirred during etching. The etch rates of HfSi_{0.74}O_{3.42} in Å/min are tabulated in Table.1 and shown in Fig.1.

Table.1 Etch Rate of HfSi_{0.74}O_{3.42} in different concentrations of HF and Tiron solution

	HF Concentration(%)	0.01	0.05	0.1
Tiron conc	0 mM			
Temperature & Time	T=25°C	2.2	19.28	23.16
	T=600°C, 15min	0.73	11.29	19.29
Tiron conc	0.01 mM			
Temperature	T=25°C	2.48	13.85	26.90
	T=600°C, 15min	0.87	9.23	16.74
Tiron conc	1.0 mM			
Temperature	T=25°C	1.96	15.26	31.04
	T=600°C, 15min	0.73	9.81	17.48
Tiron conc	0 mM			
Temperature	T=600°C, 15min/CO/CO2 reduced	0.31	2.31	11.24

The heat treatment reduces the etch rate of HfSi_xO_y as shown in Table.1. Reduction in CO/CO₂ reduces the etch rate of heat treated (600 °C) samples.

Fig:1 Etch Rate of $\text{HfSi}_{0.74}\text{O}_{3.42}$ in different concentrations of HF and Tiron solution



Part 2: *Direct measurement of surface properties during and after the etch and surface cleaning processes*

In this part the Electro-Chemical Residue Sensor (ECRS) with special coating of high-k material has been prepared and ready for tests. In parallel, a set of quartz crystals in Quartz Crystal Micro balance (QCM) system has also been coated with high-k materials (Hf oxide and Hf silicate); experiments are now underway for the measurements of surface properties after etc and cleaning.