Part 2 of 2: TECHCET's Review of Sematech's Surface Preparation & Cleaning Conference, Saratoga Springs, NY, May 12-14, 2015

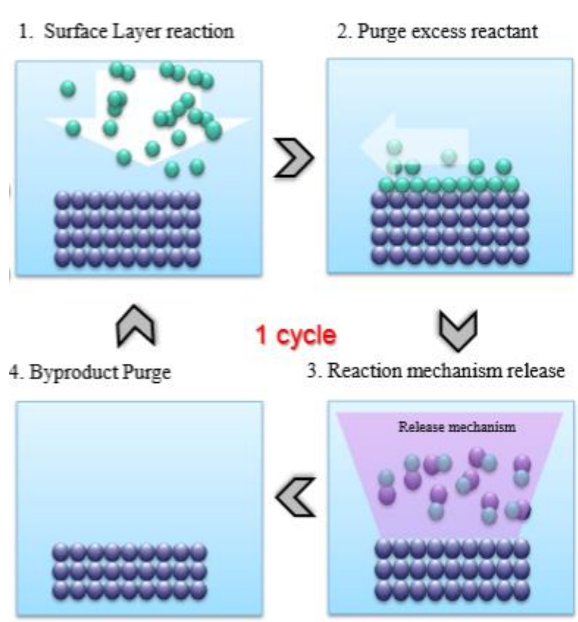
Presentations from SPCC related to the latest Wet Cleaning / Etching / Surface Preparation developments are provided here as a service to our readers.

IBM and University of Maryland, Eric Joseph and Gottlieb S. Oehrlein,– ***Selective Etching Chemistries and Mechanisms***

The IBM team was well represented with members from both Yorktown heights and CSNE. Eric Joseph from the Yorktown facility provided an excellent presentation on several applications for Atomic Layer Etching. He pointed out that there is an increasing need for atomic scale precision in every new and future device. This is especially important for technology nodes below 20nm that incorporate 3D features (3D NAND, FINFETs), and especially important for sub 7nm node devices. These challenging geometries drive the need for selective etching and cleaning of atomically thin films. Trigate, SiNanowire devices, III-V material devices and Piezo devices require atomic layer precision in order to achieve sufficient yields and performance. Two key attributes to enable atomic layer etching are Conformality and High Selectivity. (Those adjacent materials can no longer tolerate residual damage from etch or cleaning steps anymore!)

Although viewed as "new disruptive technology" for silicon devices, compound semiconductor processing III-V devices are very familiar with this type of atomic layer etching. It is based on a process that is best described as 'an inverse ALD' process using thermal desorption. The four basic steps were detailed as follows:

Figure 1: Atomic Layer Etching



Reference: Eric Joseph, IBM, and SPCC 2015

In keeping with the wet chemistry theme of the conference, Joseph presented some atomic layer etching by anisotropic wet etch processes. Again, one should note no novel chemistries where employed, i.e. materials used were HCL, hydrogen peroxide, KOH, TMAH, EDP, and IPA. He also outlined the dry etch capabilities using $C_xF_yH_z$ style gases to show the various selectivity between SiO_2, SI_3N_4. New dry etch gases were tested that may provide more beneficial than others depending on the application.

In short, the nitride etch rate could be favorably controlled by the fluorocarbon reaction layer thickness. In addition, there is a strong need for high precision ion energy control. The table below shows a quick look at various materials, requirements and considerations:

Table 1: The ALE Method Will be Chosen Based on Selectivity Requirements and Structural Considerations

ALE Method
Thermal ALE
Wet Chemistry ALE
Energy Controlled PE-ALE
Flux Controlled PE-ALE

Material to Etch	Selectivity Requirements	Structural Considerations
High-K (HfO2)	2D / Carbon	Binary Alloy Selectivity to 2D
Silicon / SiGe	SiO2 / High-K / Metal / III-V	Binary Alloy
Silicon Dioxide	SiN / Si / Carbon	Binary Alloy
Ultra Low-K	SiN / Si / Carbon	Complex Porosity
Silicon Nitride / Low-K Spacer	SiO2 / Si / III-V / 2D / Carbon	Complex / Binary Alloy / Selectivity to 2D
Metal (TiN/Cu)	Carbon / SiO2	Grain Structure
III-V	High-K / 2D / Carbon	Complex Alloy
2D / Carbon	Si / Metal / SiGe	ML Precision

Reference: Eric Joseph, IBM, SPCC 2015

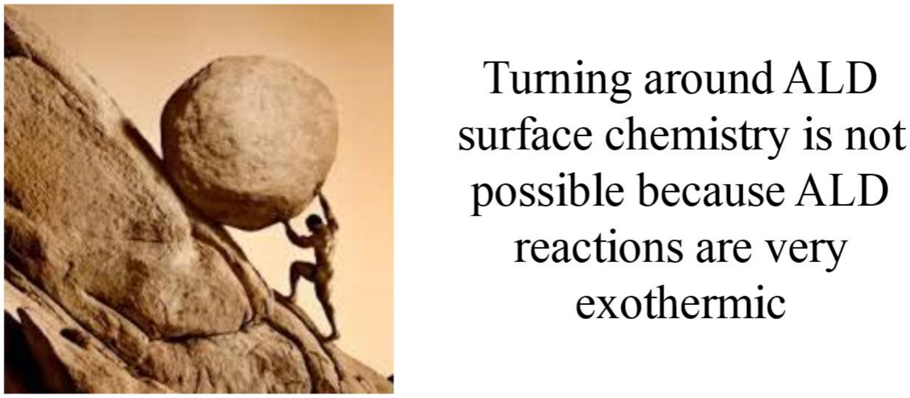
Selectivity is becoming more and more important as there is no room for damaging adjacent materials as there was in the past.

University of Colorado, Boulder, Steven George –
Atomic Layer Etching (ALE) Using Thermal Reactions

In keeping with this theme, Steven George from University of Colorado stressed that ALE (atomic level etching) is needed for atomic level processing. He pointed out that surface preparation and cleaning is critical in order to ensure the surface is ready for the etching step. Then, it must be controlled and be highly selective as pointed out previously by the IBM team.

His point that reversing the ALD (as a means to etch) is not possible since it is exothermic in nature. Hence, a sequential self-limiting type of thermal reaction

Figure 2: Reversing ALD a Difficult Task



Source: Stephen George, SPCC 2015

must be employed. He showed how this could be applicable for both Al_2O_3 and HfO_2 and suggested that is should be possible for many different material types. The process involves fluorination and ligand exchange. Consequently, HF was once again a popular go-to chemistry.

GLOBALFOUNDRIES - Liqiao Qin, Akshey Sehgal, Dinesh Koli, Venugopal Govindarajulu and Ashish Kumar Jha – *Process Improvement for 20 nm HKMG Formation*
Akshey Sehgal from GLOBALFOUNDRIES presented a very interesting discussion on a process improvement for 20nm HKMG (high K metal gate) formation. In a standard HKMG formation process flow, the following steps are typically executed:

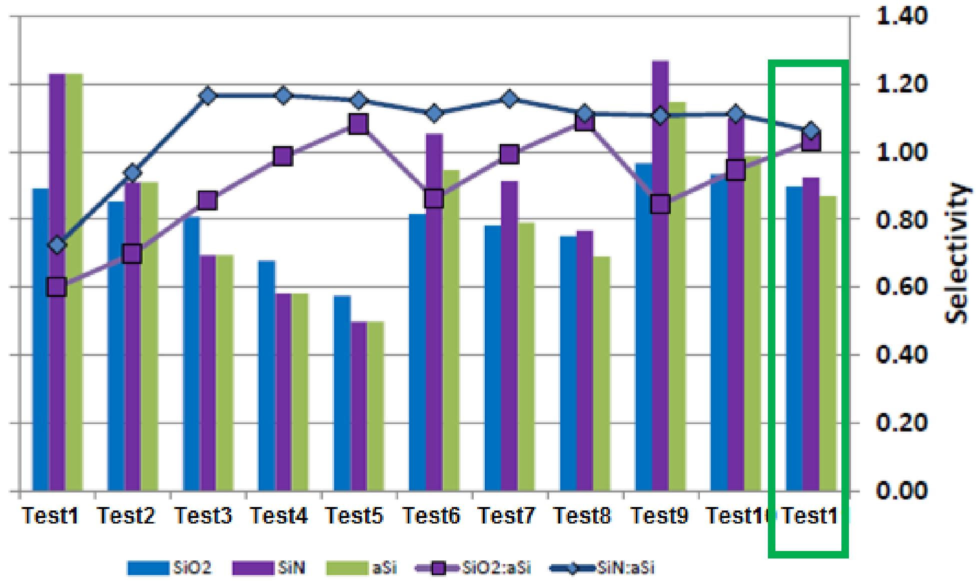
ILD deposition
Poly open CMP
Poly etch reveal
Metals deposition
Metal Gate CMP

The problems start with large WIW non-uniformity generated in the CMP planarization step (poly open CMP step). This carries through to the non-uniformity in the metal gate CMP process which has a negative effect on device performance,

A solution that they came up with was to insert a new cleaning step or process after the poly open CMP step to minimize WIW non-uniformities. This new clean is referred to as "Gas Cluster Ion Beams" or GCIB and is a new technology for modifying surfaces. It can smoothen a wide variety of surface material types without subsurface damage.

The selectivity DOE showed that the etch rates and selectivities for three materials, SiO_2, PolySi, and SiN can be adjusted or tuned based on process conditions. This is good news for the process engineer.

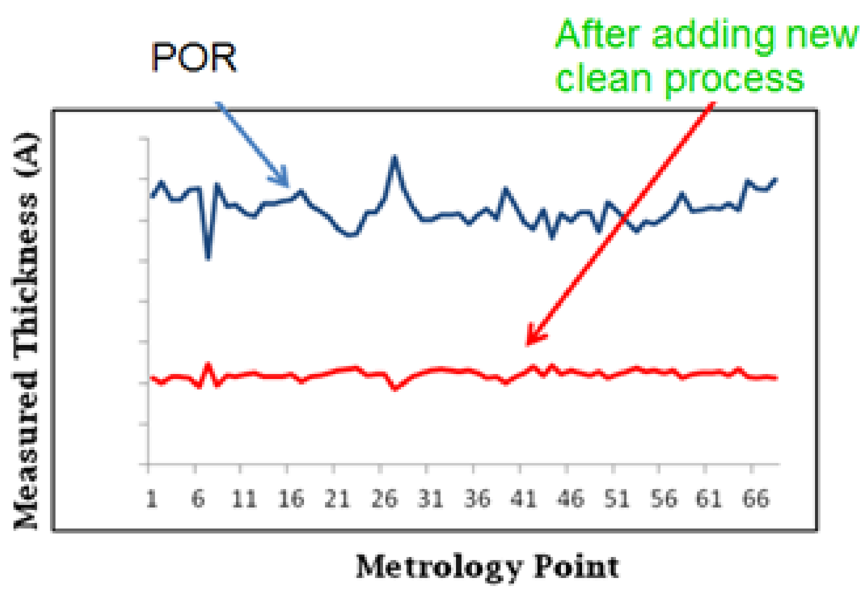
Figure 3: Dry Etch Rates and Selectivities using GCIB (A Highly Tunable Process)



Reference: Liqiao Qin, et al., GLOBALFOUNDRIES, SPCC 2015

Notice the improvement of GCIB after Poly Open

Figure 4: Within Wafer (WIW) Non-Uniformity



Reference: Liqiao Qin, et al., GLOBALFOUNDRIES, SPCC 2015

There is one challenge since GCIB is a micro-etching process, there is some surface roughing after the GCIB process. This is being addressed and removed in the next downstream step, poly open wet clean. A very interesting technique that is sure to bring value to the process. They did not disclose anything new about the wet clean, so it was believed that the standard suite of chemistries were being utilized.