TECHCET's Review of Sematech's Surface Preparation & Cleaning Conference
Saratoga Springs, NY, May 12-14, 2015
Part 1 of 2

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

The 17th annual SPCC was held at the Hilton in Saratoga Springs, NY with a great turn out of around 70-80 people. There was lots of positive attitudes and interest from all parties, both suppliers and end users alike. In general, the meeting was a complete success and it paved the way for next year's even bigger event.

INTEL – III-V Material Etch/Clean, S. Gardner
One of the highlights of the conference was a presentation given by Sanaz Gardner from the Intel Components Research that outlined their desire to fully explore the III-V compound materials for their advanced roadmap and associated cleaning challenges. . They believe that for beyond 7nm, they will have to move away from the conventional Si material in the 4 grouping to the ever intriguing III-V materials.

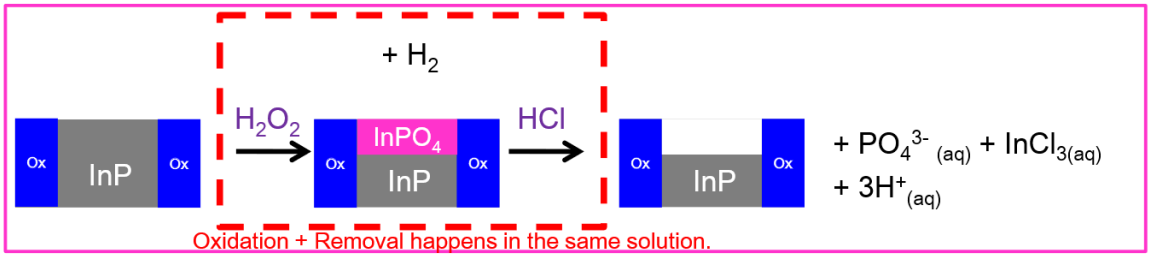
In particular, they were investigating InP, InGaAs, and GaN and looking at the various ways to clean these materials given the other new materials and challenges that surround them. Interesting enough, Intel was able to achieve most of the cleaning and desired selectivity with conventional and well know materials such as hydrogen peroxide, citric acid, and hydrochloric acid. In short, modified SC-2 style environments. This was surprising and at the same time, disappointing, to the chemistry suppliers there who were looking to leap on a new materials and technology opportunity for cleaning challenges.

However, Intel did have one struggle: GaN material that could not easily be oxidized by the peroxide based solutions and removed. This mechanism works for other materials but not GaN. They ended up using a plasma source to create a high energy oxidizing environment to oxide the GaN to Ga2O3 which then could be easily removed by a conventional KOH solution.

One conference attendee suggested that a peroxydisulfuric acid solution be evaluated to see if its aggressive oxidizing power would affect the GaN material. Another equipment supplier, Dan Alverez from Rasirc, suggested the use of their innovative hydrogen peroxide system that could deliver wet and dry oxidizing power at levels beyond what the normal chemistry could achieve.

Intel's Garner also presented their work on the SiGe/Ge materials, where better selectivity etch chemistries are required to preferentially etch the III-V materials and as well as chemistries to preferentially etch the surrounding dielectric.

Figure 1: Alternative Wet Etch Method - Uniform (Smooth) InP Recess



INTEL – Wet Chemistry Cleaning Challenges, J. Hemphill

Jeff Hemphill, another Intel presenter, focused his talk on the challenges with wet chemistry quality. He mentioned that the wet chemical consumption is increasing due to mutli-step complex process flow, increased defect reduction, and single wafer processing. Although not specifically detailed, it was estimated that the clean volume/wafer would be more than 10x for 10nm than what was required for the 65nm node.

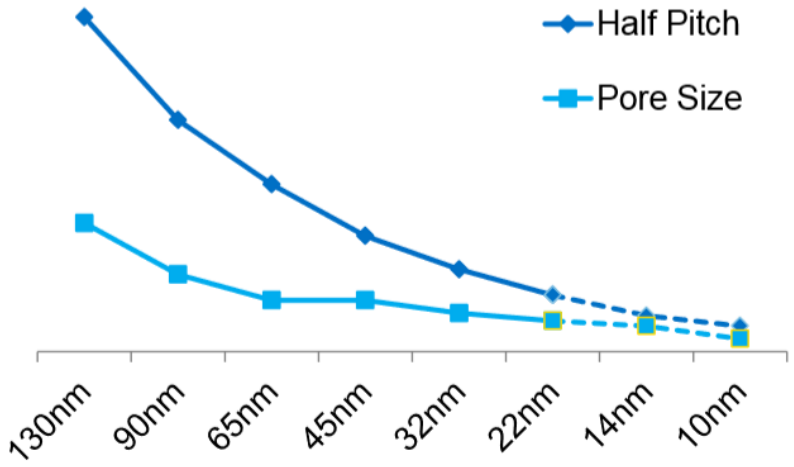
This was consistent with the other talk from Brian Raley from the Global Foundries team indicated that single wafer tools were using more chemistry than expected and not only driving up consumption costs, but causing additional waste disposal costs. Specifically, they indicated that the target for UPW consumption estimated by the ITRS 2015 was 6.5L/cm2. This was severely underestimated, as revealed by a typical fab UPW usage for the just single wet cleaning tools, estimated to be~ 6.0 L/cm2 !

He specifically singled out sulfuric acid volumes and noted that the waste alone for this was 76.0 g/cm2 compared to the ITRS 2015 target of 8g/cm2 for ALL waste streams combined. An estimate of $7/gallon of sulfuric used was presented as the cost to treat, transport and dispose of the acid. It is of interest to the readers that the time may be right to implement the sulfuric acid reprocessing system that originally ventured into the industry back in the early late 1980s.

In addition to revealing concerns about growing usage of UPW and wet chemistries, Hemphill was focused on needing "pure enough" materials to address the new process technologies. That is, the traditional Semi Grade may no longer be sufficient. This means that the chemical suppliers need to be in direct control of their raw materials, the purification, and complete supply chain. As a natural follow on to these concerns, is the supporting metrology to detect or prove that the material is indeed "clean enough". IC devices are becoming more sensitive to trace impurities whether they be organic or trace metal in nature.

Chemical filtration is also becoming a challenge as feature sizes are being reduced at a faster rate than the filtration roadmap for most filtration companies. The real the challenge is to ensure that killer particle sizes do not make it to the wafer.

Figure 1: Feature Sizes Reducing at a Faster Rate than Filtration Roadmap



Reference: Jeff Hemphill, Intel, SPCC 2015

AVANTOR, Peroxide Based Cleaning vs. Selective Cleaning Chemistry, C. Sherman

Chien-Pin Sherman, from Avantor (chemical supplier), presented new metal nitride selective etch chemistry that had tungsten compatibility for the 10nm and beyond nodes. (This was refreshing to see in amongst the fabs' desires to use known chemistries.) As one engineer from IBM indicated "we will use what we have and only switch to a new cleaning technology if forced to when everything else fails".

Nitradtion of the metal film is used in the semiconductor industry to increase their hardness and thus make great barriers or etch stops such as TiN, TaN, WN, However, this property also causes them to be more resistant to the common cleaning chemicals. As expected, the selectivity demands for the <10nm nodes are drastically increasing to the point that even slight other material loss that was once accepted is now completely process limiting.

Sherman presented a table showing etching of TiN, TaN, WN, W and TEOS oxide using the standard peroxide based cleaning solution, and DHF (dilute HF) as their line of novel selective cleaning chemistries. Avantor's product appeared to have superior selectivity, potentially making it useful for advanced node process development.

NOTE on Green Chemistries

It is of note that few, if any, comments were made towards green style chemistries. Although it is openly believed that everyone would like to have more green and environmentally friendly materials and chemistries in their facility, there is little desire to do this if the cost or performance is not acceptable or aligned with best known methods.

For Techcet's Part 2, of Sematech's Surface Preparation & Cleaning Conference, check back on a few days – Part 2, will be posted on Jun 1. For more information on materials technology trends and supply chains, please contact Techcet at info@techcet.com

Part 2 of 2
TECHCET's Review of Sematech's Surface P Cleaning Conference
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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 sub 7nm technology nodes. In addition to the aggressive feature sizes which are now below 20nm and many with 3 dimensional features. 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 (can't damage the adjacent materials anymore!)

Although viewed as "new disruptive technology" for silicon devices, compound semiconductor processing III-V devices are very familiar with this type of etching. It is based on a type of inverse ALD using thermal desorption.

The four basic steps were detailed as follows:

1. Surface Layer reaction
2. Purge excess reactant
3. Reaction mechanism release
4. Byproduct purge

In keeping with the wet chemistry theme of the conference, Eric presented some atomic layer etching by anisotropic wet etch processes. Again, it is on interest to note that the materials used were HCL, hydrogen peroxide, KOH, TMAH, EDP, and IPA. Once again, the industry is looking to use what is available. He also outlined the dry etch capabilities using CxFyHz style gases to show the various selectivity between SiO_2, SI_3N_4.

In this case, he was exploring some new dry etch gases that may provide more beneficial than others depending on the application.

In short, the nitride etch rate could be favorably controlled by fluorocarbon reaction layer thickness. In addition to the impact of chemistry, there is a strong need for high precision ion energy control.

The table below shows a quick look at various materials to etch, selectivity requirements, and any structural considerations.

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

Again, to emphasis what is also becoming a theme at the conference, is selectivity is becoming more and more important as there is no room for damaging adjacent materials as there was in the past.

In keeping with this theme, Steven George from University of Colorado stressed that ALE 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 is not possible since it is exothermic in nature, so a sequential self-limiting type of thermal reaction 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. In order to do the process, he relied on fluorination and ligand exchange, so HF was once again a popular go-to chemistry.

Akshey Sehgal from Global Foundries presented a very interesting discussion on a process improvement for 20nm HKMG formation. In a standard HKMG formation process flow, the following steps are typically executed:

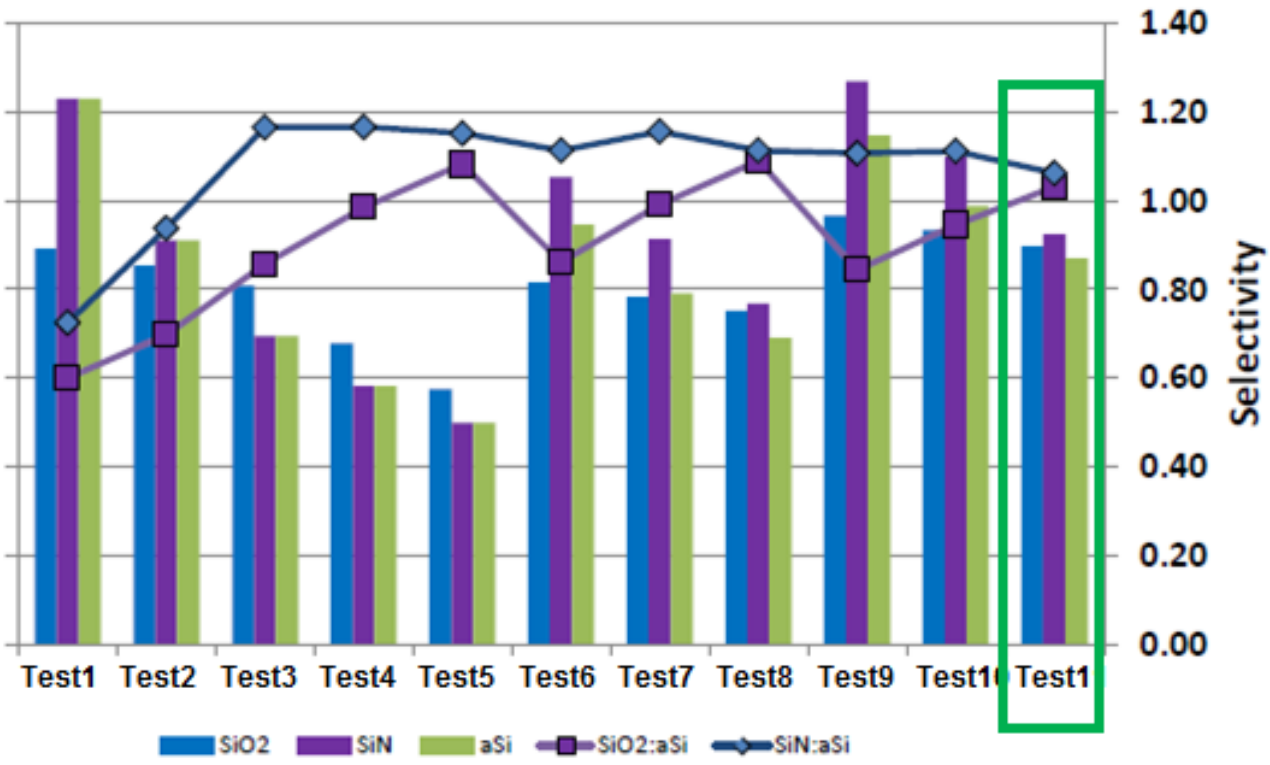
- ILD deposition

- Poly open CMP
- Poly etch removal
- Metals positions
- Metal Gate CMP

The challenge like in the large WIW non-uniformity in the CMP planarization step (poly open CMMP step). This carries through to the non-uniformity in the metal gate CMP process which has a negative affect on device performance,

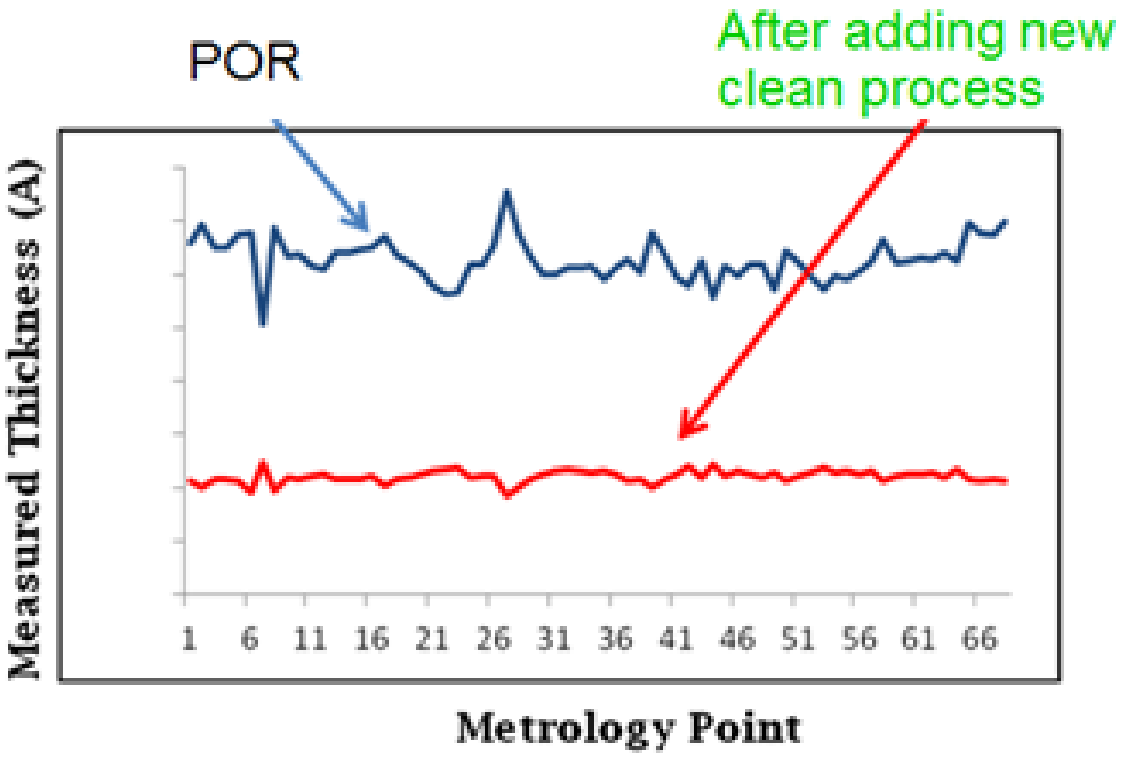
A solution that they came up with was to inset a new cleaning step or process after the poly open CMP step to minimize or remove the non-uniformity situation. This new clean is referred to as "Gas Cluster Ion Beams" or GCIB and is a new technology for modifying surfaces. It can smoothen a wide variety 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 and encouraging news for the process engineer.

Notice the improvement of GCIB after Poly Open



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.