Challenges and Solutions for 450mm Wet Clean Tool

Bill Yu[1]*, Felix Ku[1*], Charles Taft[1#], Anne-Sophie Larrea[1+], Toyohide Hayashi[2], Akira Morita, Kenichiro Arai[2], Hideji Naohara[2]
[1]G450C, 257 Fuller Road, Albany, NY 12203, USA
[*]TSMC, 8 Li-Hsin Rd. 6, Hsinchu, 30078, Taiwan
[#]IBM, RR 9, Fishkill, NY 12524, USA
[+]CNSE, 257 Fuller Road, Albany, NY 12203, USA
[2]Dainippon Screen, 480-1, Takamiya-cho, Hikone, Shiga 5220292, Japan

Semiconductor manufacturing costs have increased rapidly as technology complexity has accelerated at sub-20nm nodes. Wafer size transition from 300mm to 450mm will be one of the approaches to address this issue[1]. On average, a 30% cost reduction was seen with the implementation of 300mm wafers from the previous 200mm cost basis. Development of 300mm equipment was to simply scale 200mm tools, this won't be adequate to achieve success for 450mm. Innovation in terms of process technology, substrate handling/transport and process flexibility is necessary. For wet clean tools, major challenges are listed below:

- Cleanness for advanced technology nodes
- Pattern collapse & damage
- Wet etching uniformity
- Cost of ownership (CoO) reduction
- Wafer recycling by single wafer tool
- Si_3N_4 selective etching

Cleanness for advanced technology nodes:

Based on International Technology Roadmap for Semiconductor (ITRS), it is certain that the future of semiconductor manufacturing will continue to face significant challenges for surface preparation and critical cleaning steps, e.g. tight specifications for particle and metallic contamination etc. From a hardware standpoint, it can be addressed from three aspects, i.e. chamber atmosphere, quality control of fluids, and parts cleaning and aging. As shown in Table 1, with new design concept on chamber atmosphere control, the particle performance on 450mm alpha tool, Dainippon Screen 450mm cleaning tool(the first workable 450mm wet clean tool in the world), is comparable with or slightly better than 300mm production tool even without consideration of much larger wafer surface area (x2.25).

Table 1 Preliminary particle result on Dainippon Screen 450mm alpha tool compared with mature 300mm production tool

Recipe	300mm tool 45nmUP adder	450mm tool 45nmUP adder
SC1-SC1 NS	8	4
SPM-SC1-SC1 NS	18	9

*NS: Nano-Spray

Pattern Collapse & Damage:

With the dimension and pitch shrinkage, the risk of pattern collapse and damage is increasing during wet clean steps, and use of FinFET for sub-20nm makes it much more vulnerable. Those feasible solutions for 300mm tool, e.g. IPA drying, low surface tension fluids and advanced dispensing method[2], will all be transferred to 450mm tool. Innovative solutions are needed for 450mm wet clean tools, which target application for nodes beyond 14nm.

Wet Etching Uniformity:

For larger wafer, uniformity (within wafer) is a challenge for many processes, including wet etching, dry etching, film deposition and CMP etc. From Fig. 1, it can be found that the uniformity on a 450mm was degraded if using the same 300mm chemical dispenses method. However, with a new method, better uniformity was achieved even compared with 300mm.

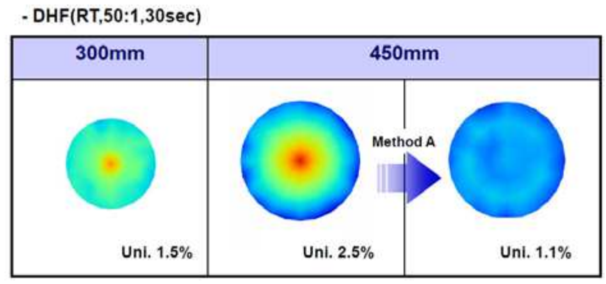


Figure 1: Uniformity for SiO_2 etching by DHF

CoO Reduction:

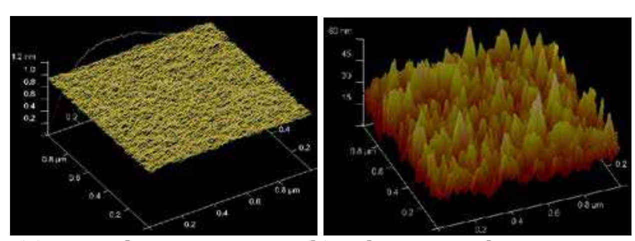
One of the major reasons for 450mm transition is cost reduction. Key areas includes chemical and DIW usage reduction using new dispensing system and circulation, low N2 usage using new pump system, low power consumption using smart idle and new hardware, and smaller footprint by compact chamber etc.

Wafer Recycling by Single Wafer Tool:

There is no wet bench system expected to be developed for 450mm by key wet tool suppliers, which used to be the standard to recycle 200mm and 300mm wafers. For 450mm, the wafer recycling has to be done by single wafer tool. Cost and throughput are major concerns. Good results in terms of short process time and low surface roughness were obtained on SiO_2 and Si_3N_4 recycling wafers, shown in Table 2 and Figure 2. But further study needs to be done for poly-Si wafer recycling due to surface roughness after film strip, e.g. investigation on new chemicals, multi-step recipes etc.

Table 2 Etching rate and roughness after film strip

Film	Chemical	ER (nm/min)	Roughness Ra(nm)
SiO2	49%HF	>5000	0.13
	DHF	378	0.12
	HF/HNO3	208	1.9
	HF/HNO3/CH3COOH	231	1.3
Si3N4	49%HF	513	0.15
	DHF	56	0.12
Poly-Si/SiO2	HF/HNO3	1338	1.7
	HF/HNO3/CH3COOH	1773	1.9



(a) SiO2 by 49%HF (b) poly-Si/SiO2 by HF/HNO3

Figure 2: AFM result for film wafer recycling

Si3N4 Selective Etching:

Currently, there still no solution for SiN selective etching by 450mm wet tools although there were some proposals on how to replace a wet bench by single wafers tool for 300mm[3].

Acknowledgement: Thanks to Katherine Sieg for the AFM measurement.

References:

[1] J. Lin *et al*., "450mm Era: A New Opportunity for the Semiconductor Industry", *Future Fab International*, Issue 45, 12 (2013)
[2] Y. Chang Chien *et al*., "Physical Cleaning Enhancement Using Advanced Spray with Uniform Droplet Control", *Solid State Phenomena vol.* 195, 195 (2013)
[3] B. Yu *et al*., "Novel Wet Etching of Silicon Nitride in a Single Wafer Spin Processor", *Solid State Phenomena vol.* 195, 46 (2013)