Optimization of the removal of wafer backside defects arising from electrostatic clamping during ion implantation by scrubber processing with acidic chemical

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Agenda

- **Motivation**
  - Backside particle/defect removal requirement
  - About electrostatic clamp (ESC)
- **Experimental and Result**
  - Chemical screening for ESC defects
  - ESC defects removal by scrubber processing with acidic chemical
- **Summary**

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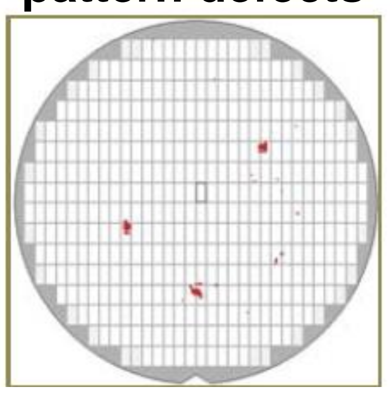
- **Summary**

♦ Impact of backside particles on frontside patterning

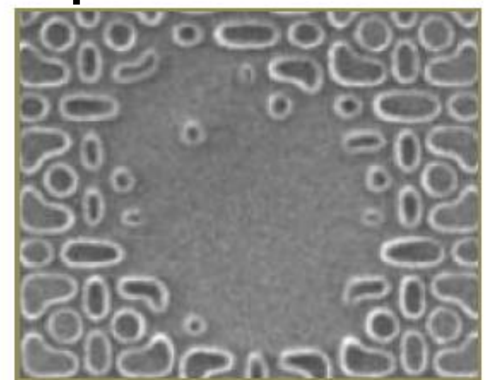
– Focus-spot failures in lithography become more critical in advanced logic nodes and 3D stacked memory devices.

Wafer map of pattern defects



Optical image of pattern defect

SEM image of pattern failures



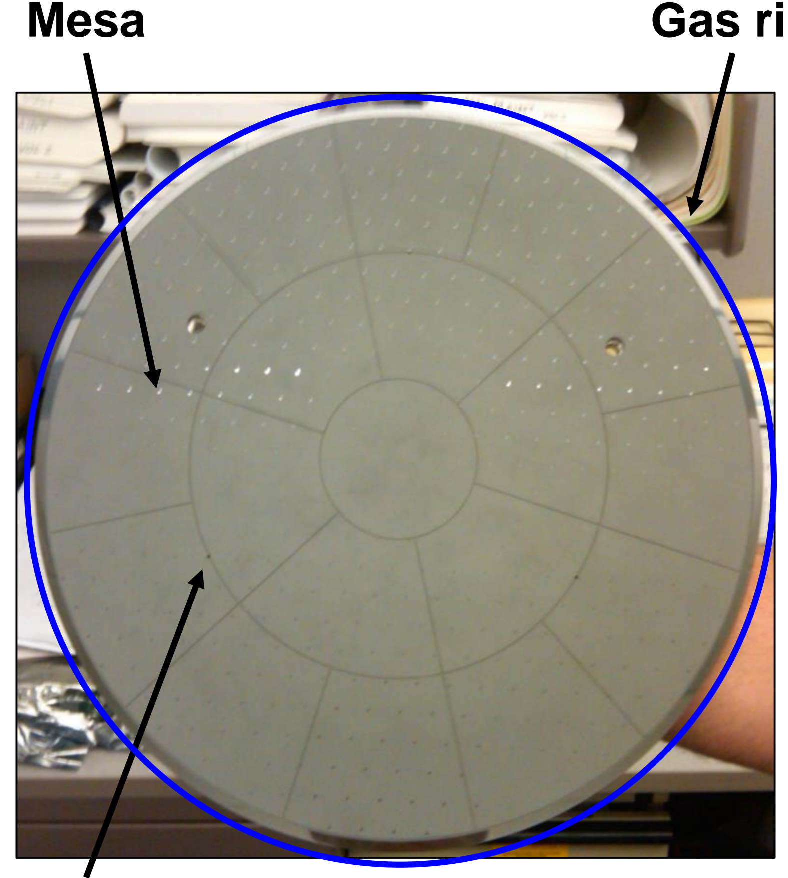
H.-S. Sohn, ECS transactions, 11 (2) 95-100 (2007)

Year of production	2011	2013	2015	2017
DRAM ½ pitch (nm)	40	32	24	20
Critical particle size (nm)	20	16	12	10
Backside Defect Size (nm)	200	160	125	100

Backside defect size requirements according to the ITRS 2011, 2013

About electrostatic clamp (ESC)

♦ ESC electrode picture



- Most ion implanter use electrostatic clamp (ESC) to hold wafer during processing
- Ion implantation requires ESC to be mechanically scanned during processing, and also to cool the wafer
- Mesa contact with wafer during processing. Material is AIN.
- Backside gas is channeled and then retained with Gas ring which is located outside of ESC electrode.
- Backside gas is purged from BSG inlet and dissipates heat from the incident ion beam.

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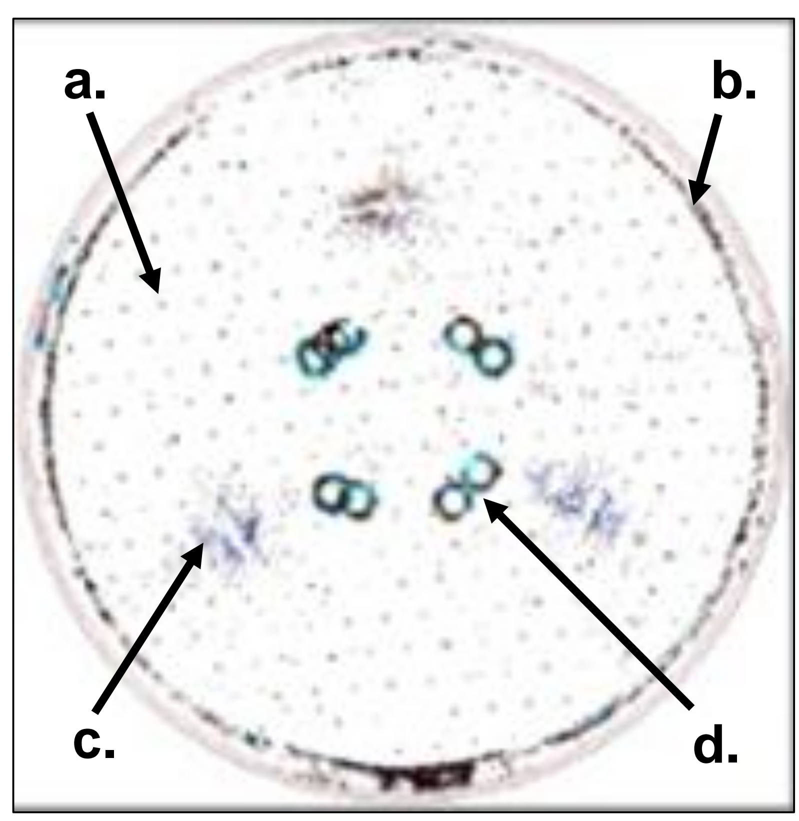
Typical backside defects generated by implanter

♦ Particle MAP after implanter



Typical Defects

Generate by ESC

a. Mesa

b. Gas ring

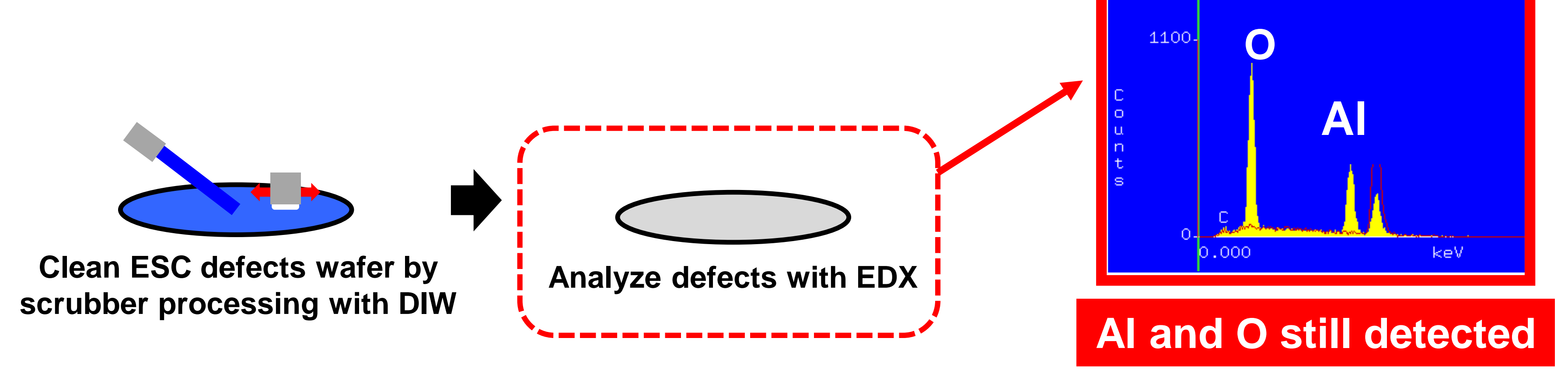
c. BSG inlet

Generate by transfer robot

d. In air end effector

Identification of ESC defects

	Mesa		Gas ring	BSG inlet	In air end effector
SEM	scratch				
EDX		2100, Si, Al, N, C, O, 0, 0.000, keV, Counts	2200, Si, Al, N, O, 0, 0.000, keV, Counts	2200, O, Si, C, P, 0, 0.000, keV, Counts	2200, Si, O, C, P, 0, 0.000, keV, Counts



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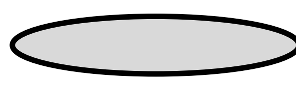
♦ Experimental

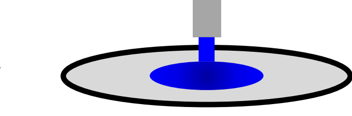
– Cleaning for SiO defects

- Particle removal efficiency $= \frac{\textit{(pre particle count)} - \textit{(post particle count)}}{\textit{(pre particle count)}} * 100\ [\%]$

  – Test chemicals; NH_4OH, $HCl+O_3$, NH_4OH+O_3 and $HF+O_3$(FOM)

- Si roughness

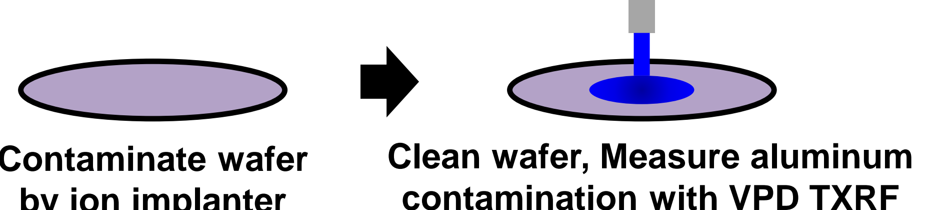




– Cleaning for AlN defects

- Metal removal efficiency

  – Test chemicals; SC-1, HF, SPM, SC-2 and $HF+O_3$(FOM)



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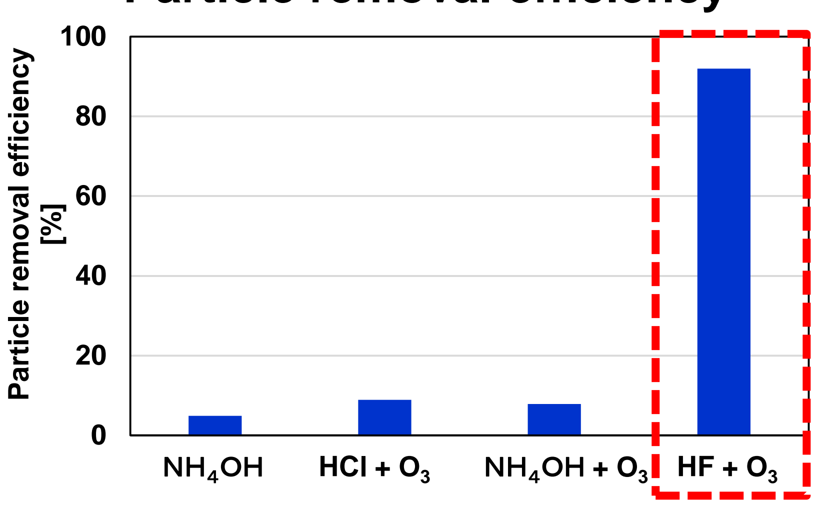
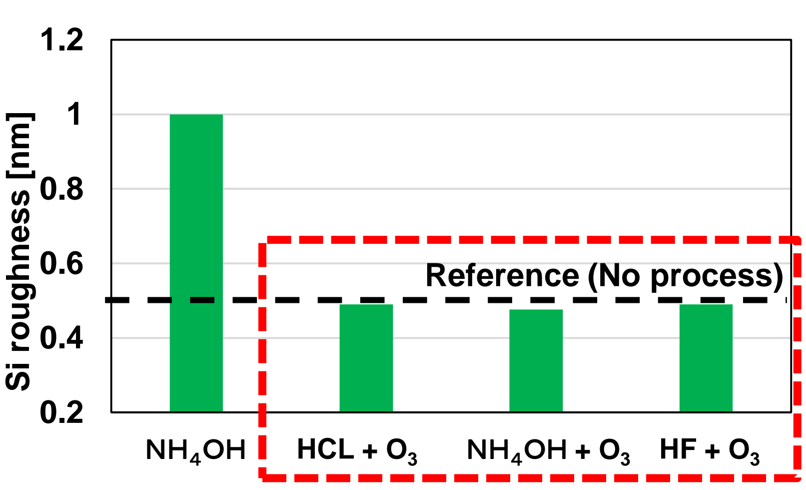
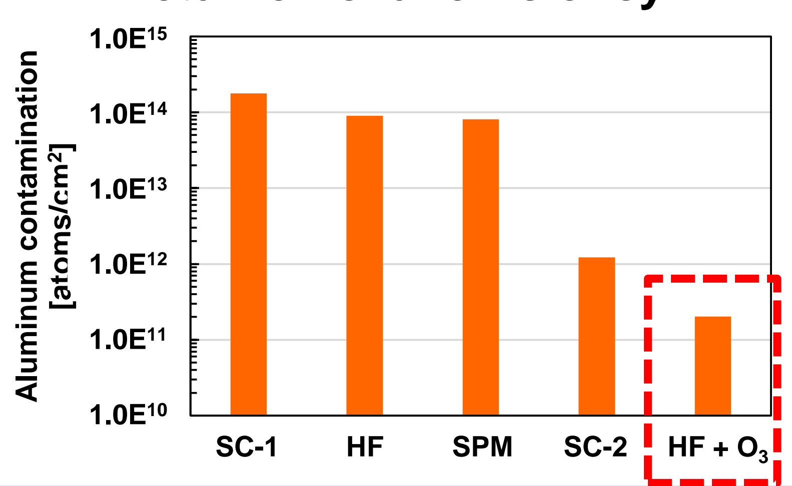
Result of chemical screening for ESC defects

♦ Cleaning for SiO defects





♦ Cleaning for AIN defects



$HF + O_3$ (FOM) is the most effective to remove SiO and AIN defects.

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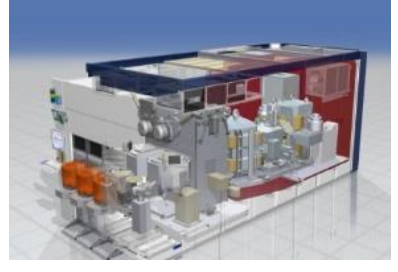
♦ Experimental

- Implant process can generate backside particles due to electrostatic clamping. SCREEN cleans the wafers and confirms defects removal efficiency with 1.0 µm particle size, SEM inspection and EDX analysis.

Implant wafer



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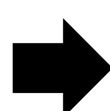

Clean ESC defects wafer

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Test sample		Axcelis			SCREEN	
		Transfer	ESC clamp	Ion implantation	Scrubber processing with FOM	Scrubber processing with DIW
1	Beamless implant	V	V		V	V
2	ESC clamp only	V	V		V	V
3	Low Energy High Dose P+	V	V	V	V	V
4	Mid Energy High Dose As+	V	V	V	V	V

Result of ESC defect removal by scrubber processing with acidic chemical

♦ ESC defect removal efficiency

Particle removal efficiency [%]

100
80
60
40
20
0

■ Scruber processing with FOM ■ Scruber processing with DIW

Beamless implant | ESC clamp only | Low Energy High Dose P+ | Mid Energy High Dose As+

Scrubber processing with FOM could improve 10 - 40% of ESC defect removal efficiency from scrubber processing with DIW at each test condition.

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Result of ESC defect removal by scrubber processing with acidic chemical

♦ SEM inspection and EDX analysis

		Mesa		Gas ring	BSG inlet	In air end effector
SEM	Pre	scratch	Al, N	Al, N	Si, O	Si, O
	Post	scratch	scratch Al, N	scratch		
EDX			N, Al	Si	Si	Si

AlN and SiO defects on wafer could be removed, but there are embedded AlN defect in scratch. Need to reduce the scratches caused by Mesa.

Hardware approach for ESC defects and verification by scrubber processing

♦ Next experimental

– New type ESC to reduce scratches at mesa

	Current type	New type
Mesa Material	AlN	Carbon based polymer
Mesa contact area	4% (No change contact area)	

– Test condition
  - ESC defects removal efficiency with 1.0 μm size particle
  - SEM inspection and EDX analysis

Test sample		Axcelis			SCREEN
		Transfer	ESC clamp	Ion implantation	Scrubber processing with FOM
1	Low Energy High Dose P+	V	V	V	V
2	Mid Energy High Dose As+	V	V	V	V

ESC defects comparison after implantation

♦ SEM inspection and EDX analysis (Post implant)

	Current type ESC		New type ESC	
	SEM image	EDX	SEM image	EDX
Mesa	scratch		scratch	
		N, Al		C
Gas ring		N, Al		C

Scratches seem to be shallower and AlN were not detected with new type ESC, however carbon defects were observed.

Result of ESC defects removal by scrubber processing with acidic chemical

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♦ SEM inspection and EDX analysis (Post backside cleaning)

		Mesa		Gas ring
SEM	Pre		C	C
	Post			C
EDX		Si	Si	C Si

Carbon defects could be almost removed, but there is small defects remain at Gas ring defect.

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Result of ESC defects removal by scrubber processing with acidic chemical

♦ ESC defects removal efficiency

Current type ESC　New type ESC

Defects removal efficiency [%]

100
80
60
40
20
0

P implantation　As implantation

ESC defects removal efficiency is further improved by new type ESC.

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- New scrubber processing has been developed to enable efficient removability for SiO and AIN defects, 10 - 40% improvement compared to conventional process.

- New type of ESC has demonstrated backside defect reduction and confirmed effectiveness against scratches related to Mesa contacts.

- Combination of new type ESC with new scrubber processing achieved 90% of ESC defects removal efficiency.

Thank you for your attention

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