Process Gas Ar Flow Usage Reduction in Aerosol Cleaning

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April 20, 2016

SPCC 2016
Surface Preparation and Cleaning Conference

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Outline

Background

Particle Removal in Cryogenic Aerosol Cleaning

- Effect of process gas on particles

Methods

Throughput Improvements on Ar Aerosol Cleans

- Tuning recipe parameters
- Ar flow usage reduction, process time & throughput

Results

Throughput Improvements on Aerosol clean @ GLOBALFOUNDRIES

- UPH gain and saving (14 nm)

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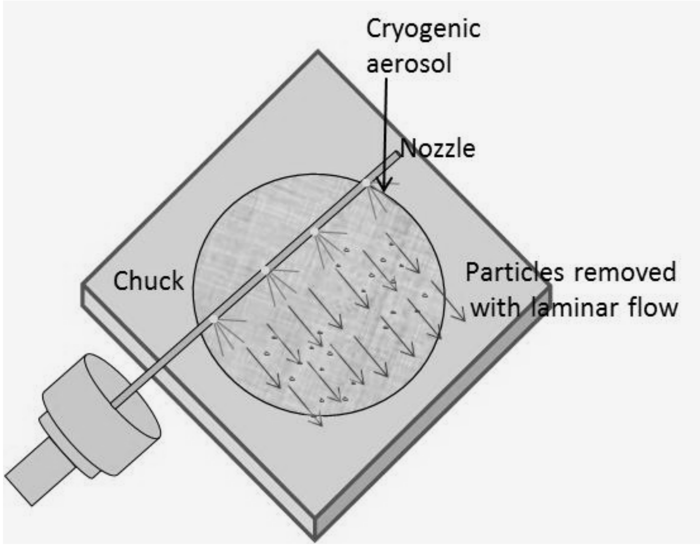
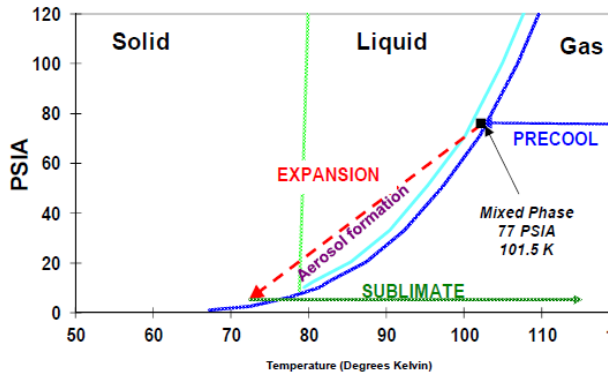
Particle Removal: Cryogenic Aerosol Clean



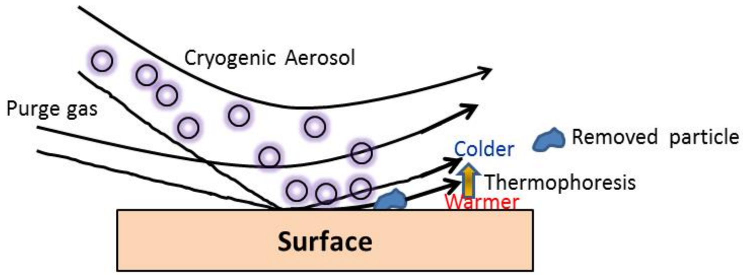
Schematic Cryogenic Aerosol Clean



[1,2]*Pressure-temperature diagram Ar:*N_2 *system*

Process parameters

- **Process Gas**
- process gas pressure
- chamber pressure
- **Chuck speed/indexing**
- chuck temperature
- Dewar back pressure

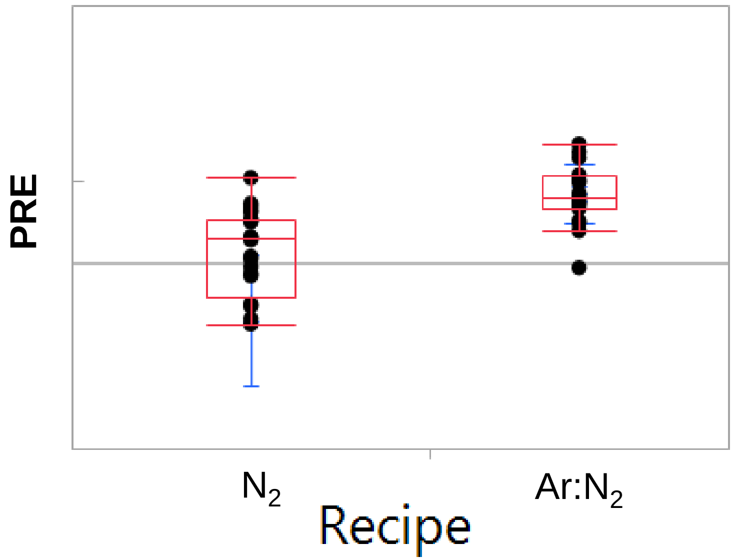


Schematic (redrawn from [1]*)*

[1]Particle Adhesion and Removal, p 460, Wiley & Sons
[2]*ANTARES® System, TEL*

Effect of Process Gas

Particle removal efficiency (@ 32 nm)



PRE (Particle removal efficiency)
(calculated from pre-post/pre)

Aerosol Cleaning Force[3]:

Momentum, $mv = F.\Delta t$

Collision force, $F = V\rho.\frac{v}{\Delta t}$

where, V is volume and ρ is density of cryogenic aerosol

Atomic mass Ar = 39.948 amu
Molecular weight N_2 = 28.0134 amu

- Ar:N_2 mixture will have greater momentum transfer than N_2 only

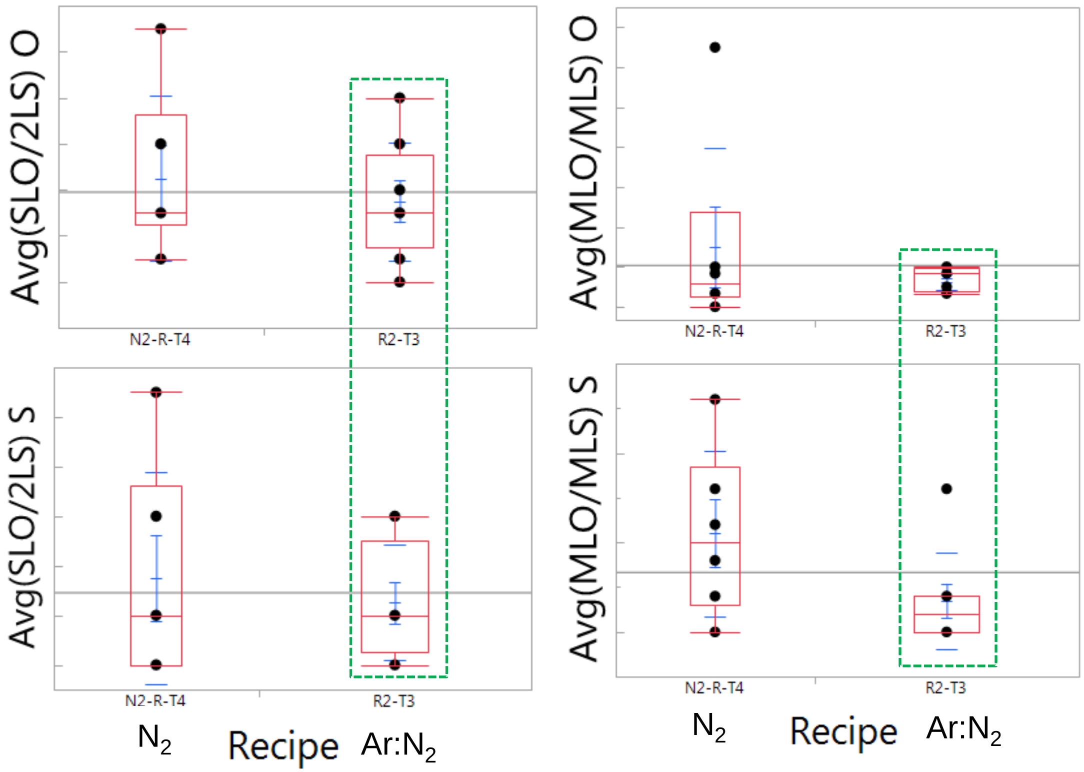
Summary:

- **Particle removal efficiency higher for Ar:N_2 mixture**
- **Ar:N_2 aerosol - greater momentum transfer than N_2**

3: IEEE TRANSACTIONS ON SEMICONDUCTOR MANUFACTURING, VOL. 20, NO. 2, MAY 2007

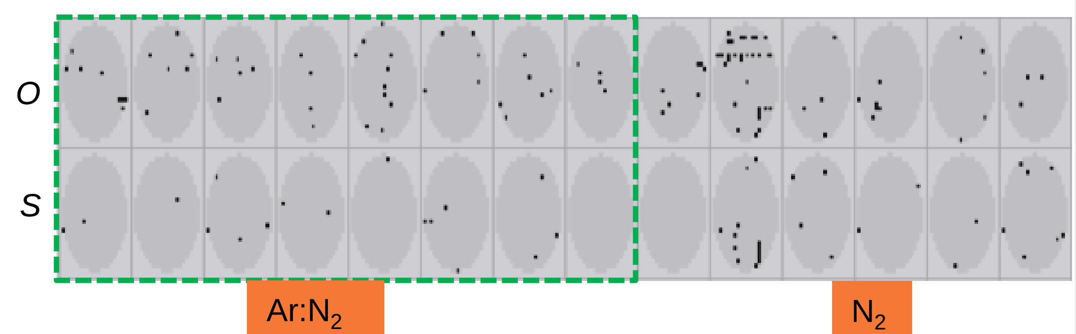
Effect of Process Gas on Performance

28 nm: Open and shorted via chains



D_0 Reduction (%) by Ar addition			
SLO/2LS		MLO/MLS	
O	*S*	*O*	*S*
15	28	52	68

Ar ($Ar:N_2$) aerosol cleaning shows better opens and shorts performance than N_2 aerosol cleaning



Summary:

- **$Ar:N_2$ aerosol cleaning shows reduced D_0 than N_2**

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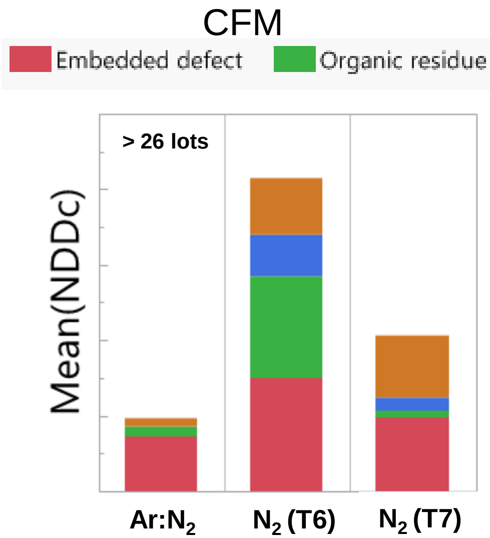
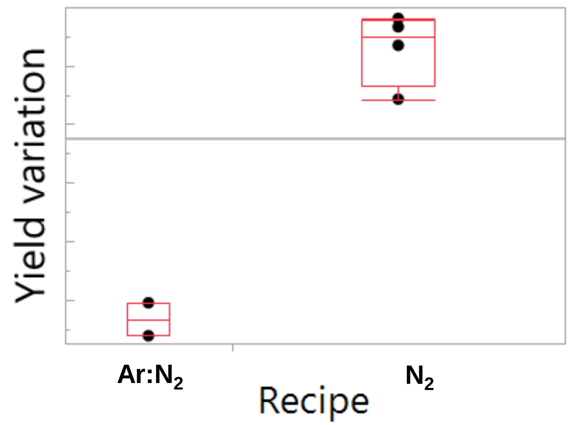
Effect of Process Gas on Performance

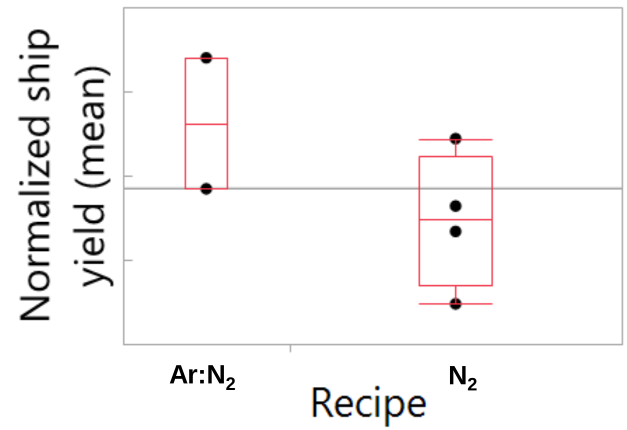
28 nm CFM Defectivity, and Yield



Defect overlay map - 4 random wfrs



Yield variation ⇩ 74%



0.7 % ⇧ in HVM Yield

NDDc / normalized defect density counts ⇩ > 55 %

Summary:

$Ar:N_2$ aerosol cleaning show improved inline performance

- **NDDc reduction > 55%**
- **Yield improvement by ~ 0.7%**
- **Yield variation reduced by ~74%**

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- **Recipe parameters tuning**
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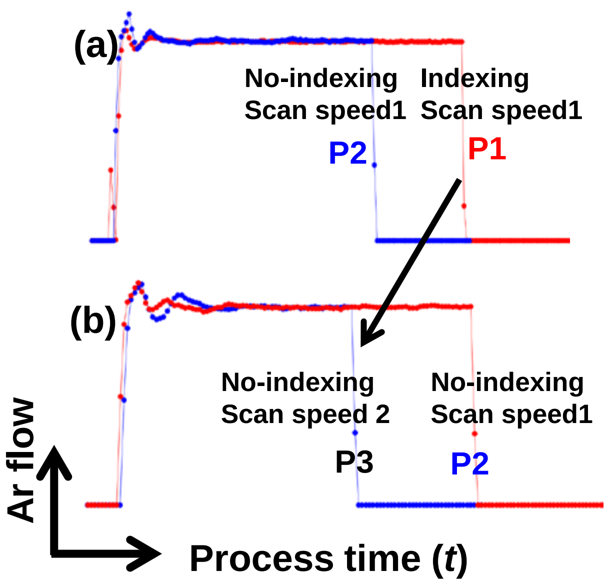
Throughput Improvements on Aerosol Cleans:

Recipe parameters tuning

Engineering Process Parameters



Process	Recipe parameters	T
P1	Indexing, scan speed ***S1***	*t1*
P2	No-indexing, scan speed ***S1***	*t2*
P3	No-indexing, scan speed ***S2***	*t3*

t1 > t2 > t3
Scan speed S2 > Scan speed S1

P1 ➡ P2 (~32% process time reduction)

P2 ➡ P3 (~28% process time reduction)

Tuning parameters

- Process time
- Particle removal efficiency
- Throughput

Summary:

- **P1** ➡ **P3, process time reduction by ~ 60%**
- **Throughput gain**
- **Cost of ownership**
- **Ar flow usage reduction**

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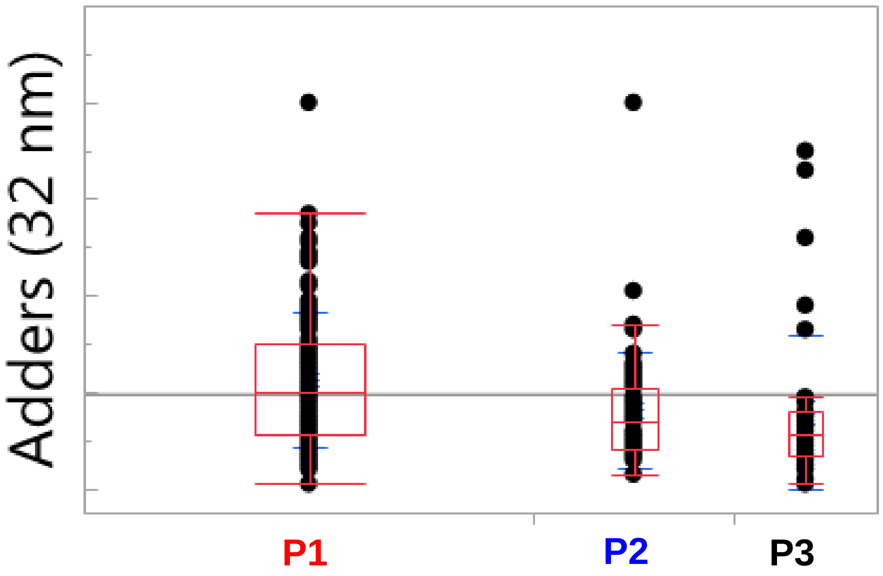
Throughput Improvements on Aerosol Cleans:

P1, P2, P3: Comparison of True Adders

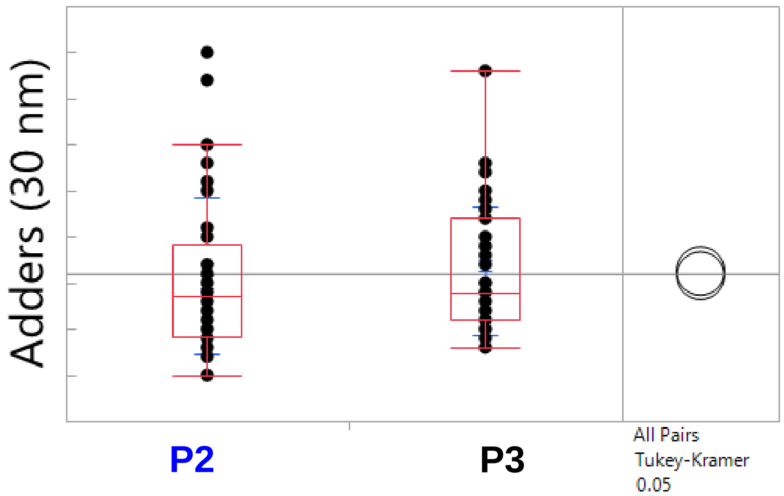


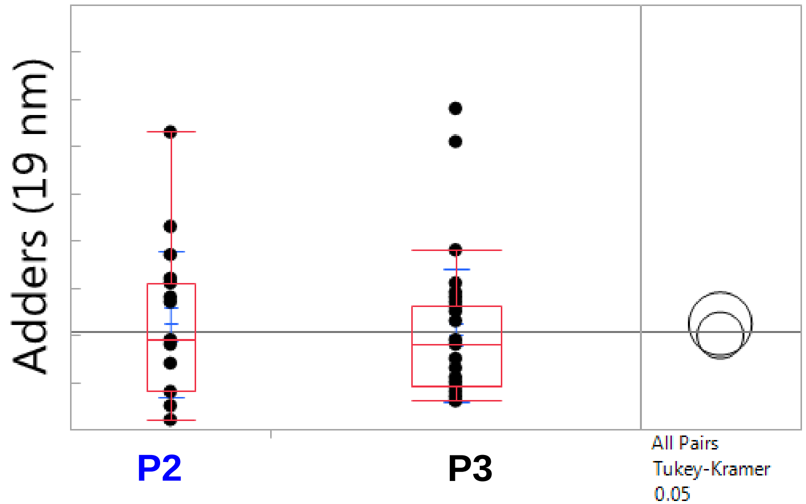
Summary:

- **True adders in, P1 to P2 to P3, are comparable**

Throughput Improvements on Aerosol Cleans

Adders (@ 19 nm) for 14 nm HVM



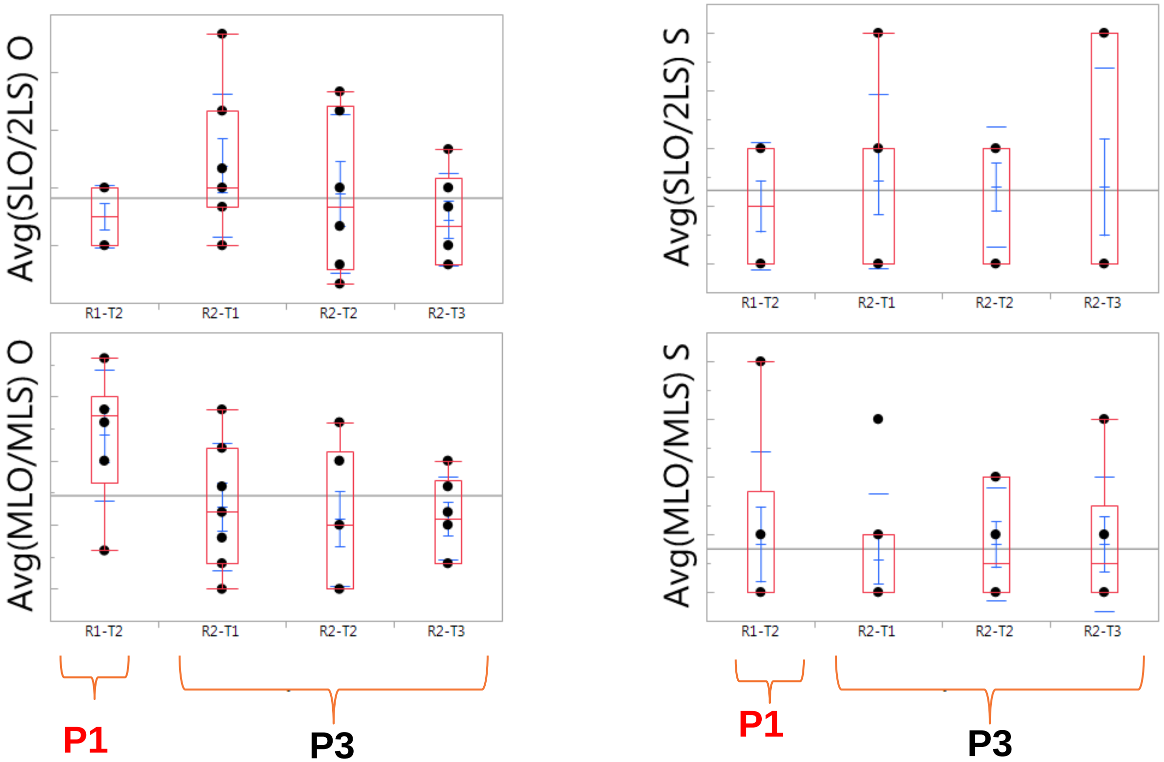


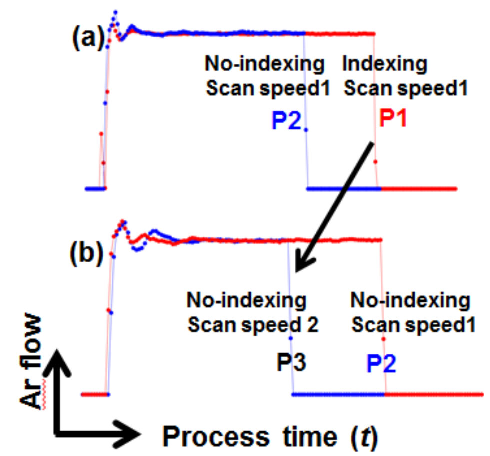
Summary:

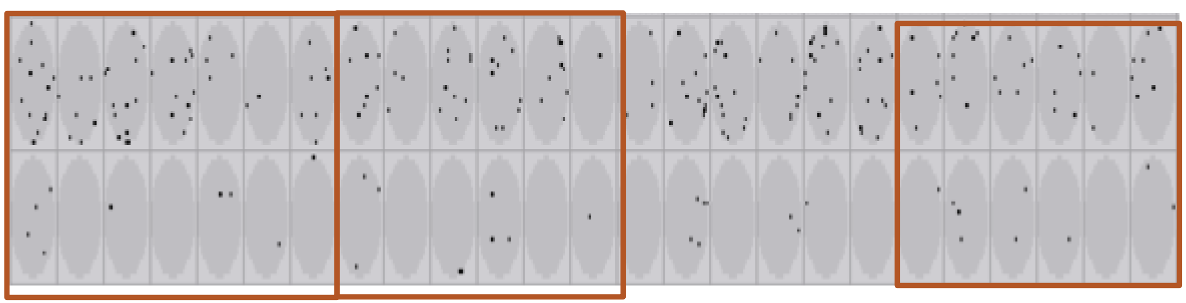
- Comparable adders performance @ 19 nm

Throughput Improvements on Aerosol Cleans:

28 nm product: Via Opens and Shorts







P3/T1 **P3/**T2 **P1**/T2 **P3**/T3

Summary:

P1 and P3 show comparable D_0 (opens and shorts) performance of 28 nm HVM

Outline

Background

Particle Removal in Cryogenic Aerosol Cleaning

Effect of process gas on particles (Sub 28 nm node)

Methods

Throughput Improvements on Ar Aerosol Cleans

- **Recipe parameters tuning**
  - Process time, throughput, Ar flow usage reduction

Results

Throughput Improvements on Aerosol clean @ GLOBALFOUNDRIES UPH gain and saving (14 nm)

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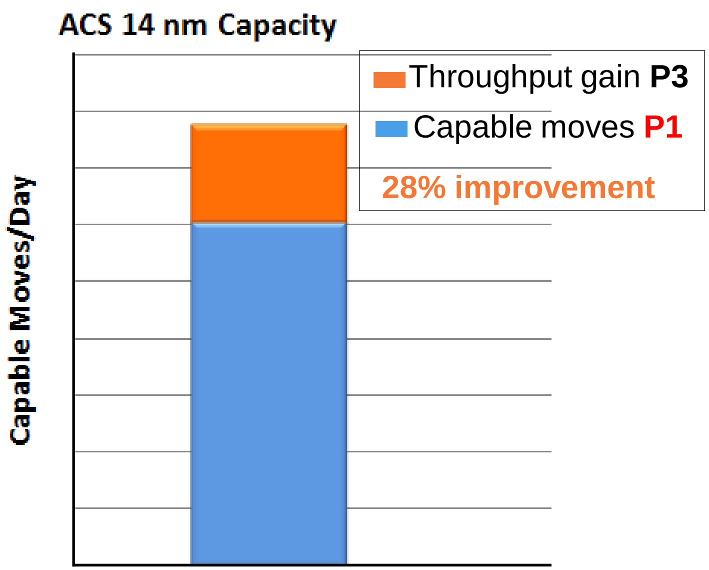
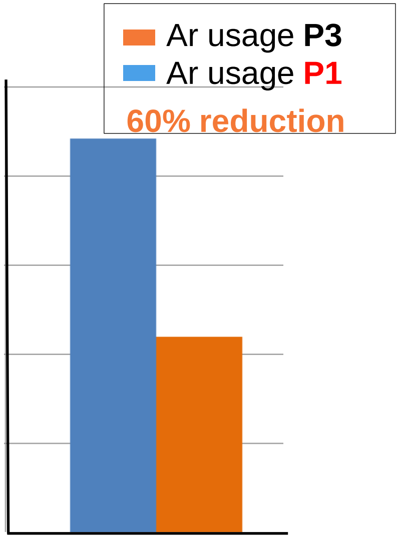
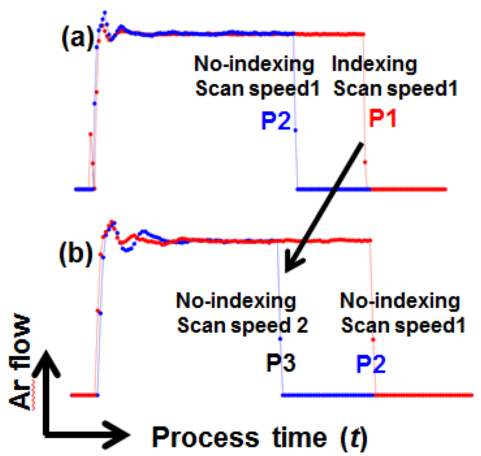
Throughput Improvements Aerosol Cleans:
UPH Gain and Cost Saving

Engineering Process Parameters







Summary:

P3 implementation at GLOBALFOUNDRIES

- faster throughput
- capable moves
- lowering CoO
- saving on Ar

CapEx saving to date (%)	CoO saving on Ar usage
28%	60%

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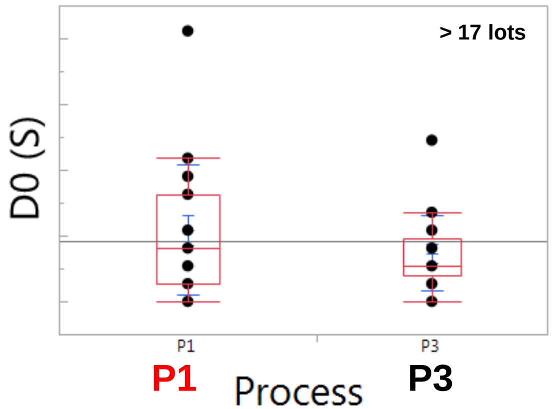
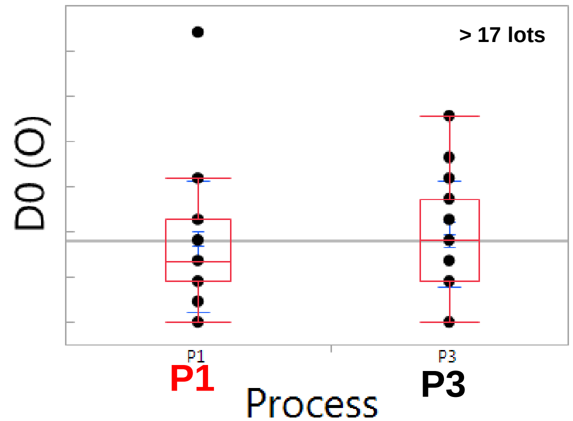
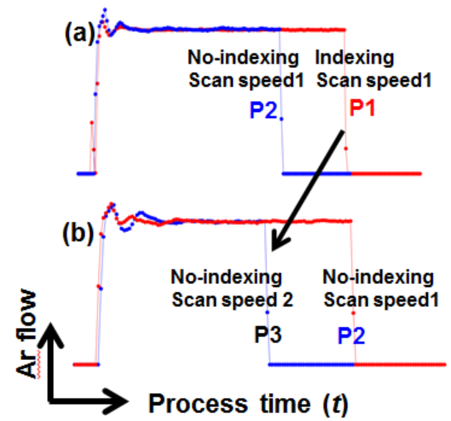
Throughput Improvements Aerosol Cleans

14 nm product: Via Opens and Shorts

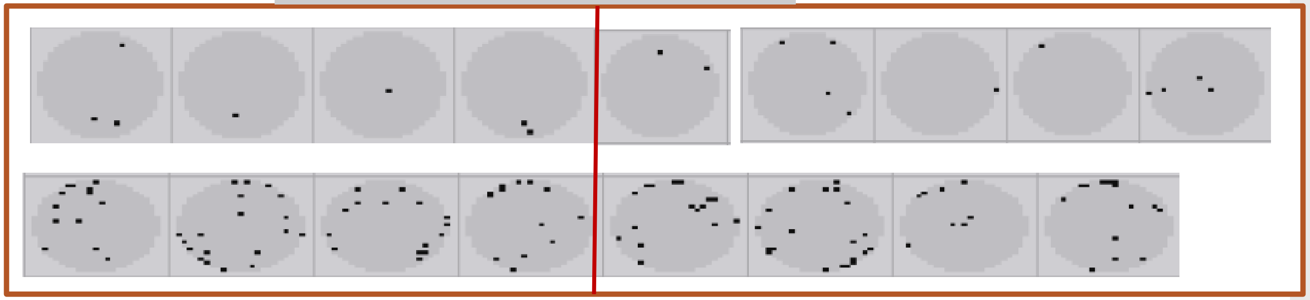






D_0 via opens and shorts are comparable for P1 and P2 process

D_0-Opens/shorts wafer maps



P1 P3

Summary:

- **P1 and P3 show** comparable D_0(opens and shorts) performance on product
- Faster throughput recipe cleaning performance could be maintained at BEOL cleaning process steps

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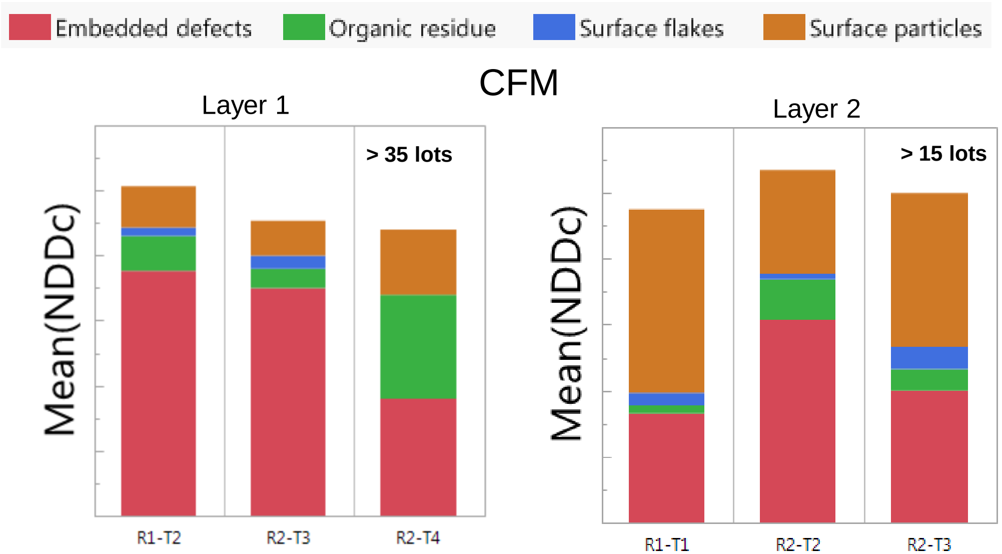
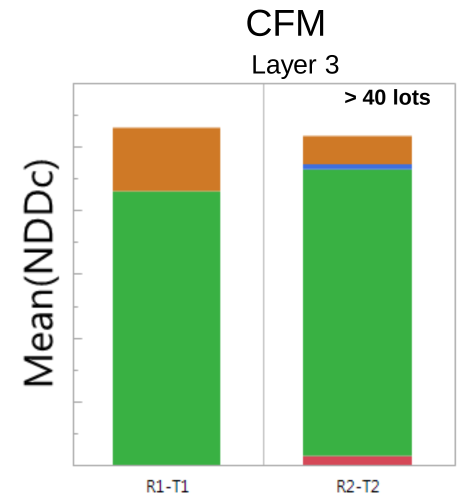
Throughput Improvements Aerosol Cleans

Impact 14 nm CFM Defectivity

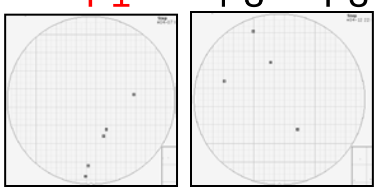


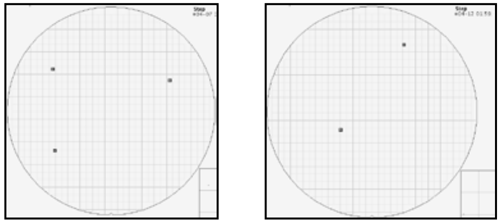


P1 P3 P3

P1 P3 P3

P1 P3





Defect overlay map - 4 random wfrs

NDDc (defects) comparable

Summary:

P1 and P3 show comparable inline CFM performance on 14 nm HVM

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Summary and Conclusions

Ar (Ar:N_2) aerosol

- – Shows reduced D_0 than N_2
- – NDDc improvement > 55%
- – HVM Yield improvement by ~ 0.7%

Throughput improvement, P3 implementation at GLOBALFOUNDRIES

- – Faster recipe on 14 nm HVM
- ✓ Comparable D_0 (opens and shorts)
- ✓ Comparable inline CFM performance
- – Increased capacity with same number of tools
- – CoO ⇩ by ~ 28%
- – Ar gas consumption ⇩ ~ 60%

Acknowledgements

Grateful thanks to:

- Wet Cleans Colleagues in GLOBALFOUNDRIES

- Process Integration Colleagues in GLOBALFOUNDRIES

Questions?