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Gas Purge or Wet Cleaning: Decontamination Solutions to Control AMCs in FOUPs

Surface Preparation and Cleaning Conference

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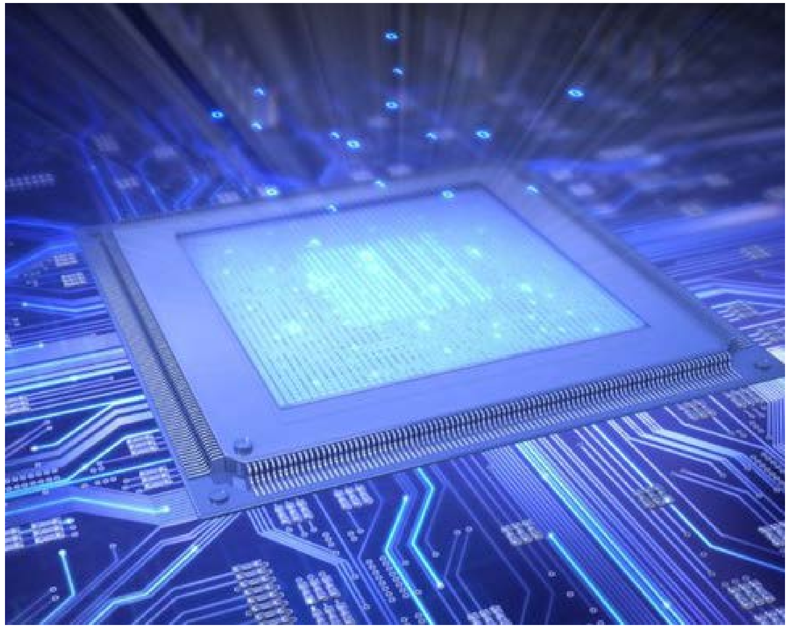
OUTLINE

- Introduction
- Goals
- Gas purge
- Wet clean
- Numerical simulation
- Summary

45 nm 32/28 nm 22/20 nm 16/14 nm 10 nm

Manufacturing/Development → Research



INTRODUCTION: AMC

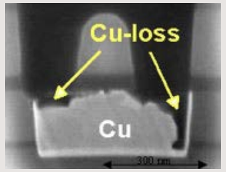
- Airborne molecular contamination (AMC) may be responsible for severe yield losses
- Among AMCs, HF is identified as root cause of defectivity, where moisture and time play a critical role:

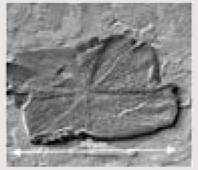
Cu loss, Crystal Growth & Corrosion

$Cu + O_2 + H_2O \xrightarrow{F^- \text{ as catalyst}}$ Oxidized Cu $\longrightarrow$ Removed by following wet cleaning (Cu-loss)

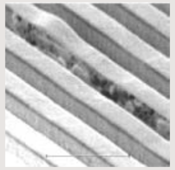
- F_2 and Cl_2 are common gases used for etching
- Residual F_2 and Cl_2 will react with H_2O and form HF and HCl

$Cl_2 \xrightarrow{H_2O} HCl$ $\quad$ $\boxed{F_2 \xrightarrow{H_2O} HF}$

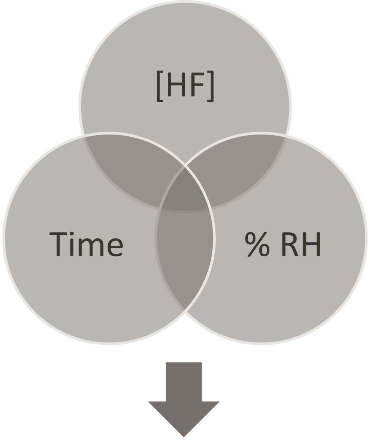




Crystal growth on TiN



Al corrosion



Wafer defectivity

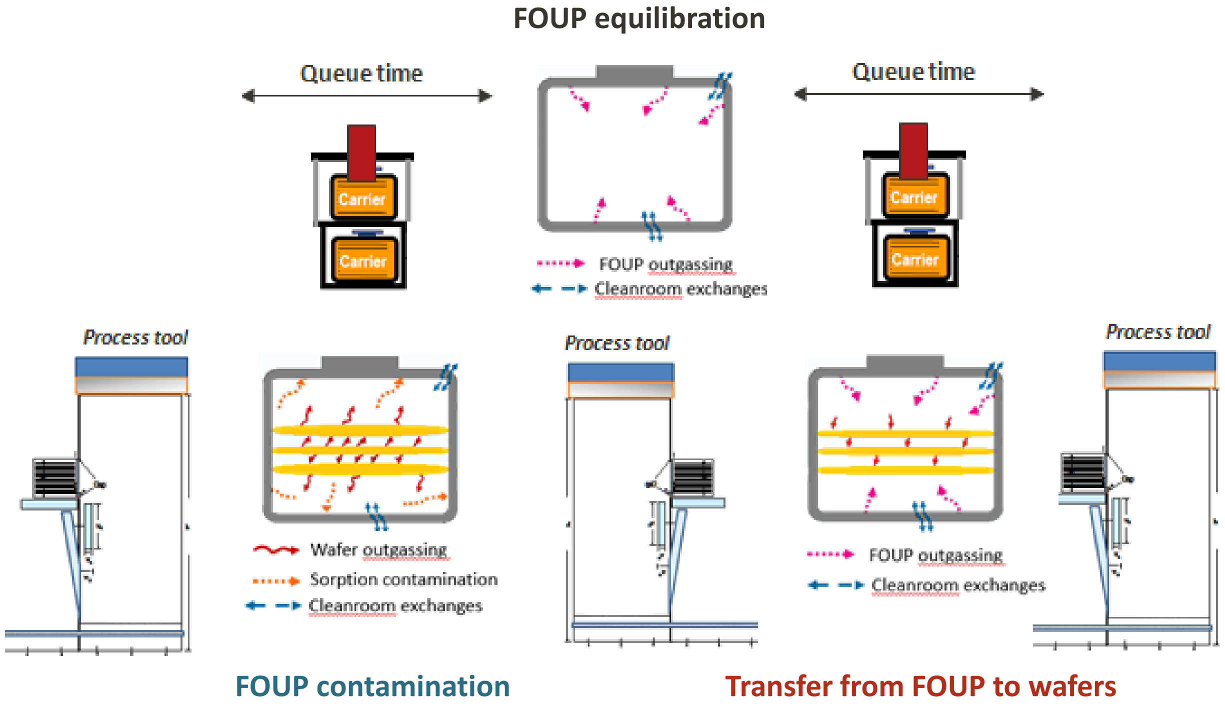
Jun B., Bai H., Lin K.I., Lui S.S., AL-Cu Pattern wafer study on metal corrosin due to chloride ion contaminants. IEEE Transactions on Semiconductor Manufacturing., Vol 23 (2010), 553-558

Luo V., Ding J., Zhan W., Peng L., Wang A., Liu B., Song Y., Yin D., Method to redice crystal defects in AlCu bond pad. ECS Transactions. 27 (2010), 321-325

T. Kamoshima, Fujii Y., Noguchi T., Saeki T., Takata Y., Ochi H., Koiwa A., “Controlling ambient gas in slot-to-slot space inside FOUP to suppress Cu-loss after dual damascene patterning,” IEEE Trans. Semicon. Manufact., vol. 21. (2008), 573-577

INTRODUCTION: FOUP TO WAFER CROSS CONTAMINATION

Demonstration of a cross-contamination chain between FOUP and wafers

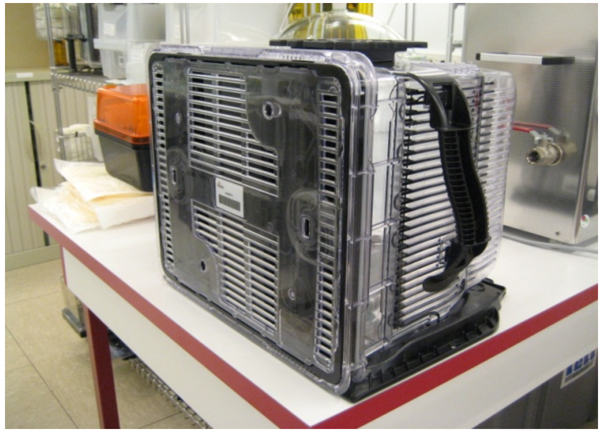


- Solution-diffusion model (polymer membranes): molecular transfer governed by gas **solubility** and **diffusion** in polymers
- New generation FOUPs must minimize the impact of the AMCs (not only particles) onto the wafers
- Air FOUP control or FOUP decontamination must be implemented to limit AMC contamination
  - Gas Purge
  - Wet Clean

GOALS

- Evaluate gas purge & wet clean efficiency for critical HF contamination in terms of contaminant transfer to wafer
  - Quantitative assessment of cross-contamination phenomena depending on decontamination solution → direct relevant data at the FOUP scale
  - Comparison of different FOUP materials in terms of contamination reduction

☑ SPECTRA PC

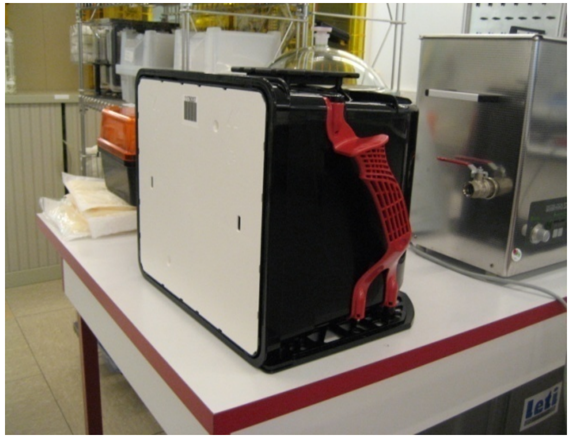


Polycarbonate

☑ SPECTRA PC/CP

Polycarbonate/C-powder

☑A300 EBM/CNT



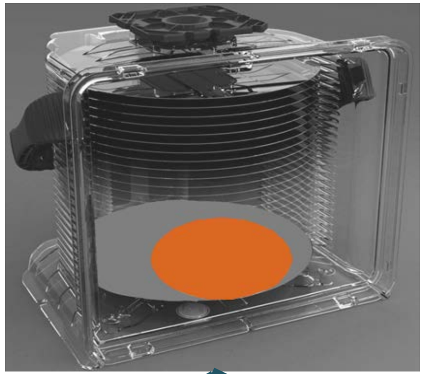
EBM/C-nanotubes

GAS PURGE TEST: EXPERIMENTAL

FOUP Conditioning
Clean room equilibration (21°C 40% RH)
7 days

Intentional Gaseous HF Contamination
10 µl- Droplet of HF 2%
(9.2 ppmv after total evap.) 2 hours

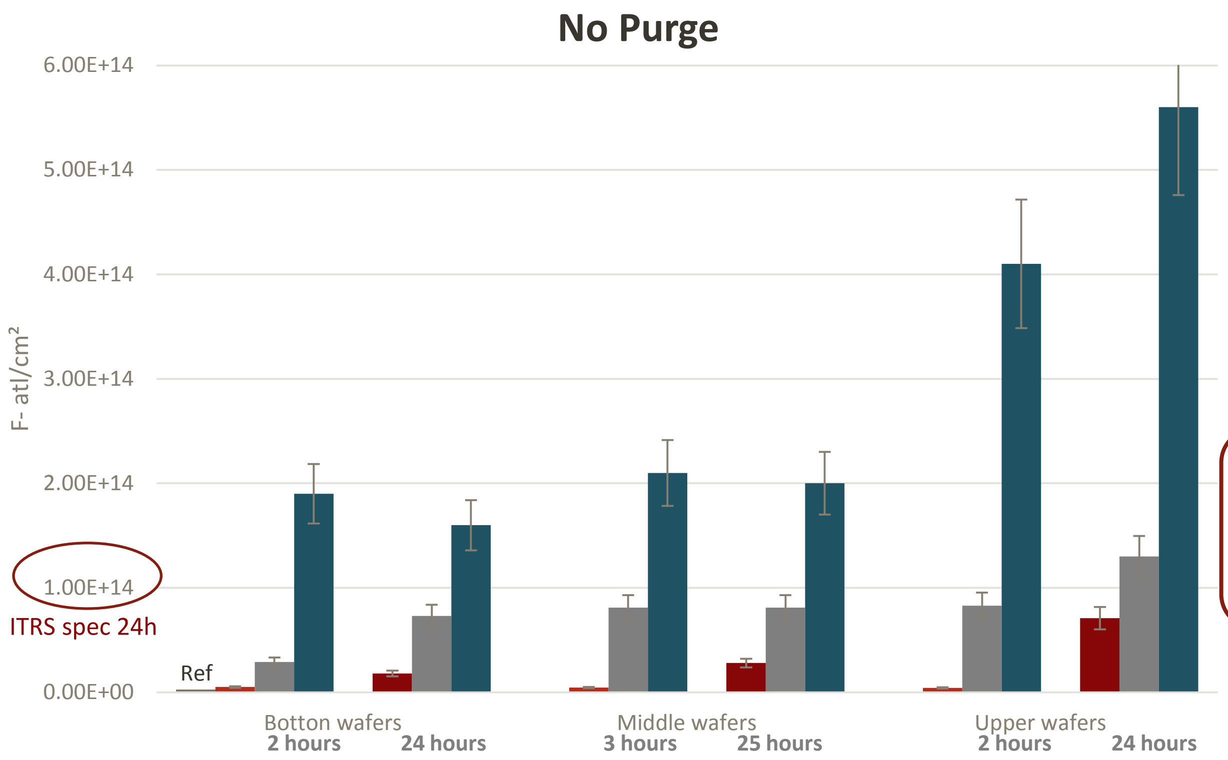
25 300mm Si wafers
6 200 mm Cu Wafer Storage
LPE-IC 2 hours, 25 hours

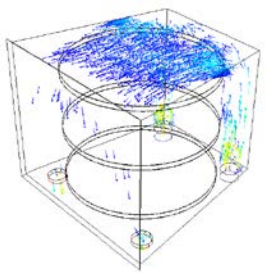


Standard Purge 5L/min
door closed 24 hours

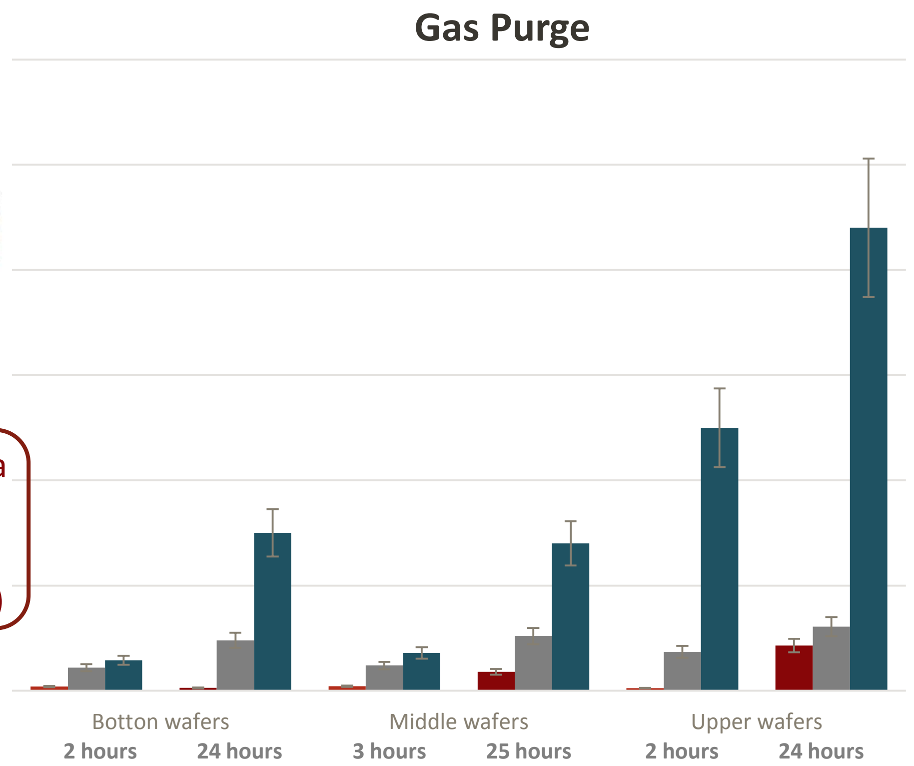
No Purge
door closed 24 hours

GAS PURGE TEST: RESULTS OF THE HF TRANSFER ON STORED CU-WAFERS





5 L/min purge is a very low flow (Fab flows are around 50 L/min)



- HF transfer: EBMCNT < PCCP < PC
- Remarkable 25 slot effect
- Main transfer during first hours of exposition
- EBMCNT respect ITRS limits

- HF transfer: EBMCNT < PCCP < PC
- 25 slot effect
- Significant HF transfer reduction (40-80% short time and 20-40% long time)
- EBMCNT & PCCP respect ITRS limits

WET CLEAN TEST: EXPERIMENTAL

Intentional Gaseous HF Contamination
(9.2 ppmv after total evap) 2 hours

0h

4h

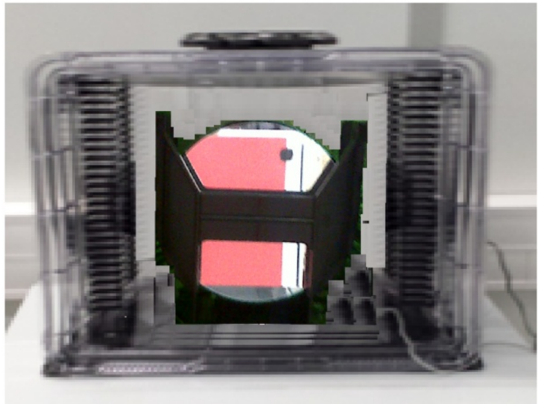
22h

With or w/o
Wet cleaning

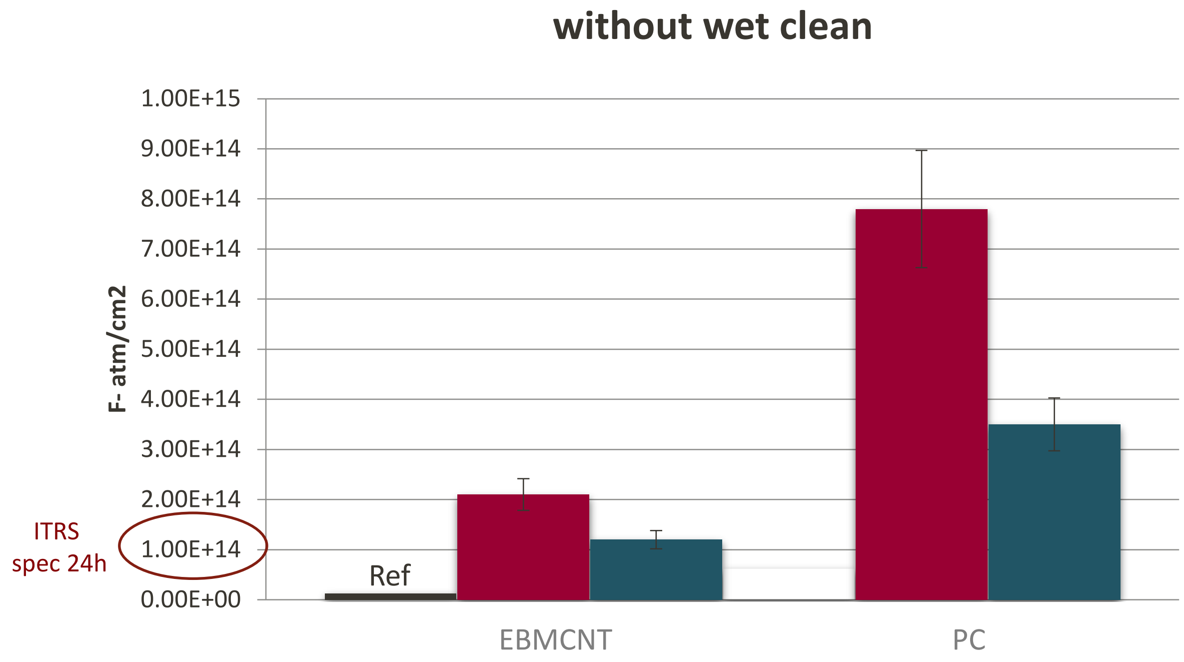
DMS M300, Spray surfactant 1 min,
total rinse 3 min, total dry (70°C) 29 min

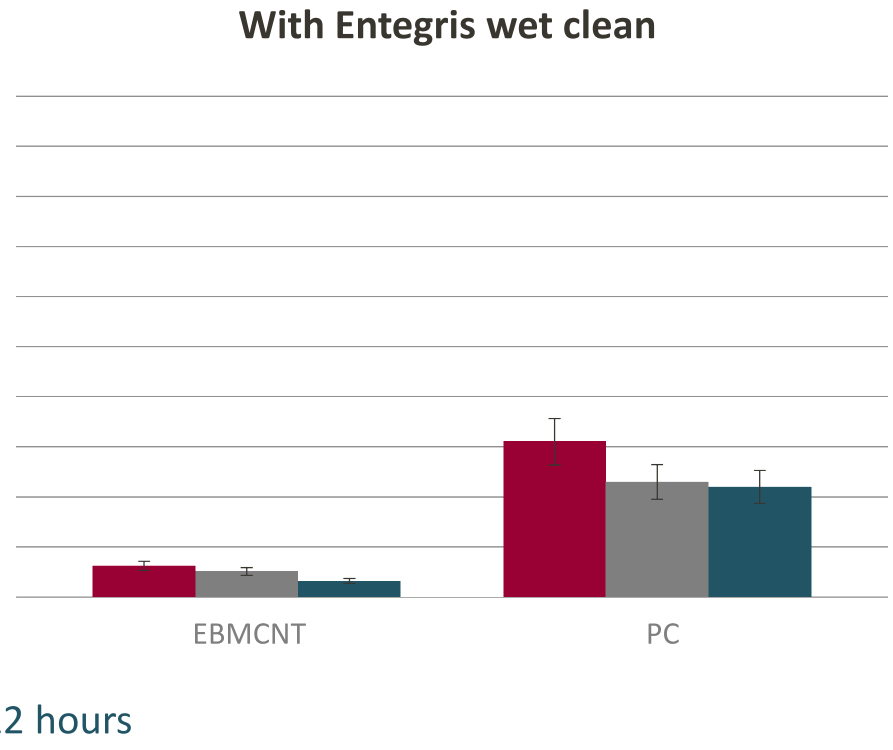
3 hours

Cu Wafer storage
66 hours - LPE



WET CLEAN TEST: RESULTS OF THE HF TRANSFER ON STORED CU-WAFERS

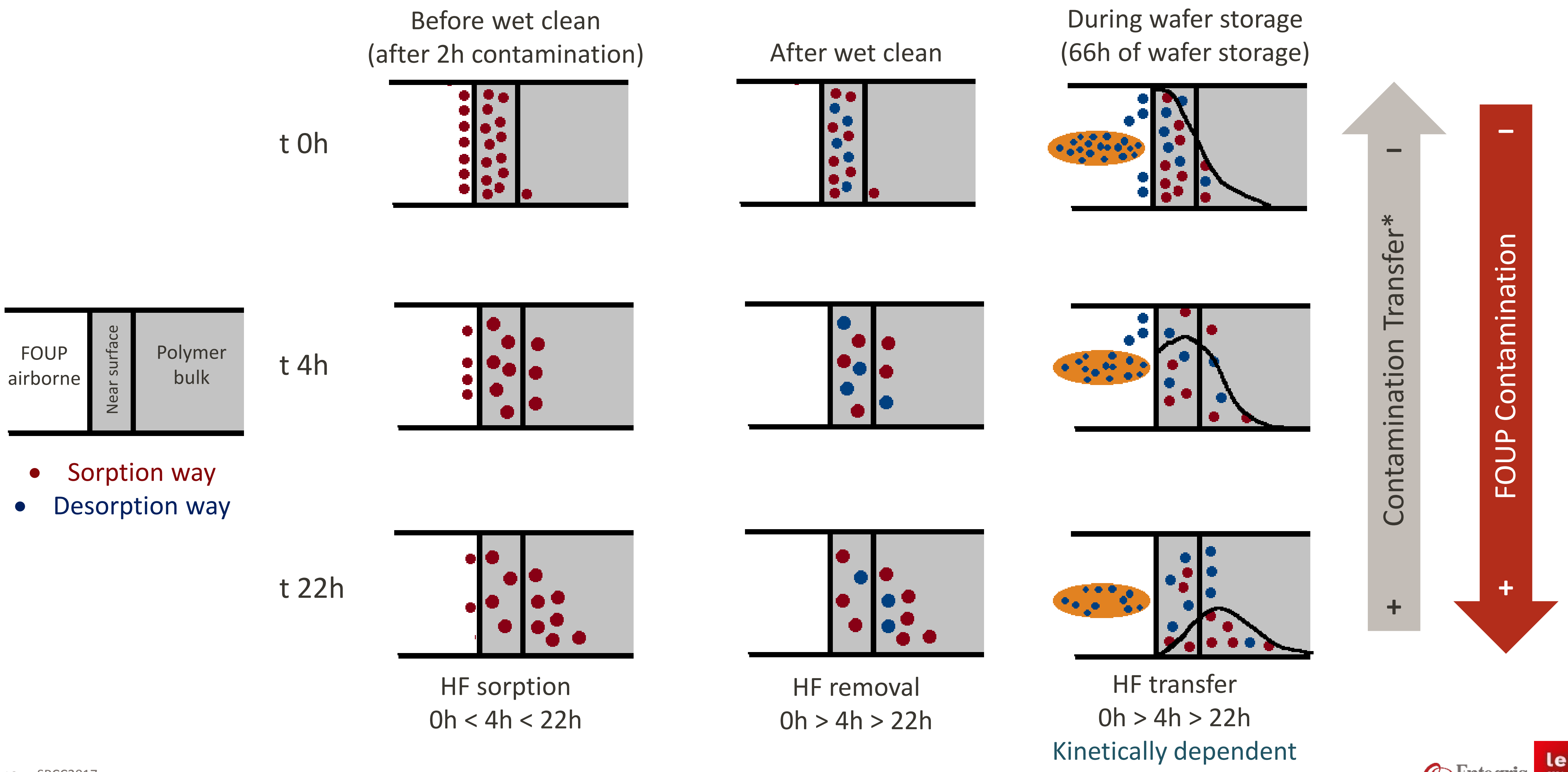




- HF cross contamination: EBMCNT < PC
- Contamination transfer decreases with the time: HF diffusion in bulk

- Wet clean decreases HF transfer between 40 & 60% (depending on time) in PC and around 70% in EBMCNT
- EBMCNT respect ITRS limits after clean

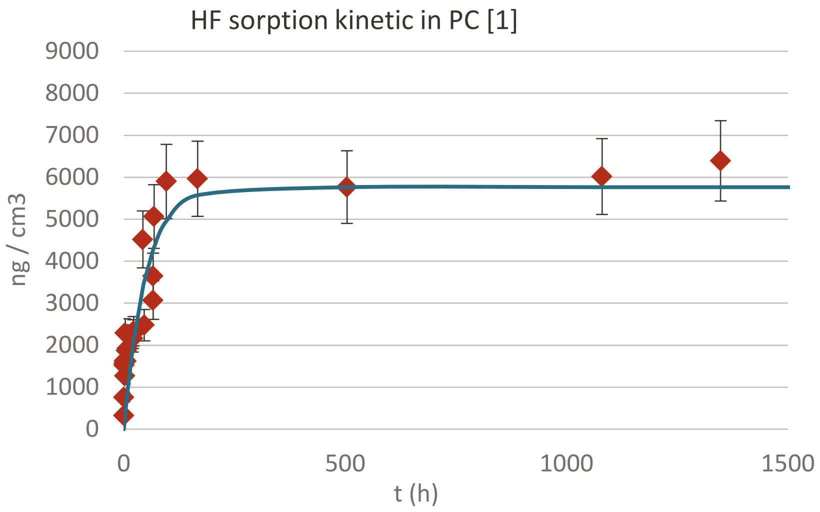
WET CLEAN TEST: HF TRANSFER VS WAITING TIME



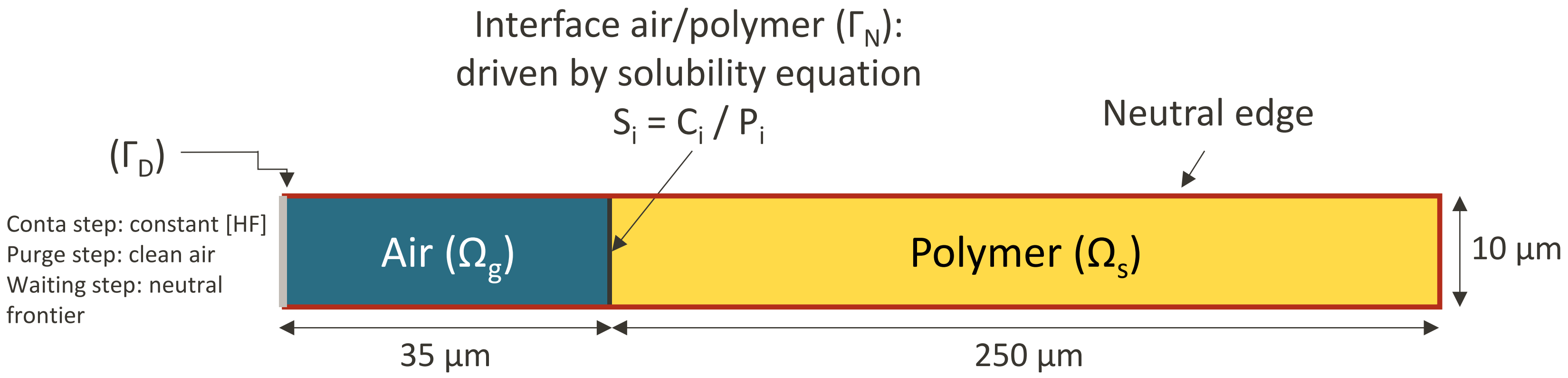
NUMERICAL SIMULATION: MODEL IMPLEMENTED

Knowledge of basic HF transport properties [1]

Polymer	PC		EBM
D (m^2/s) 10^{15}	1.70 ± 54%	>	0.37 ± 50%
S ($m^3(STP)/m^3pol$ Pa)	0,344 ± 21%	≈	0.386 ± 19%



Simple membrane model using Comsol multiphysics tool [2]



- Only diffusion phenomenon is considered in Ω_g and Ω_s
- Mesh element size: max 1.10^{-2} µm (422 400 elements)

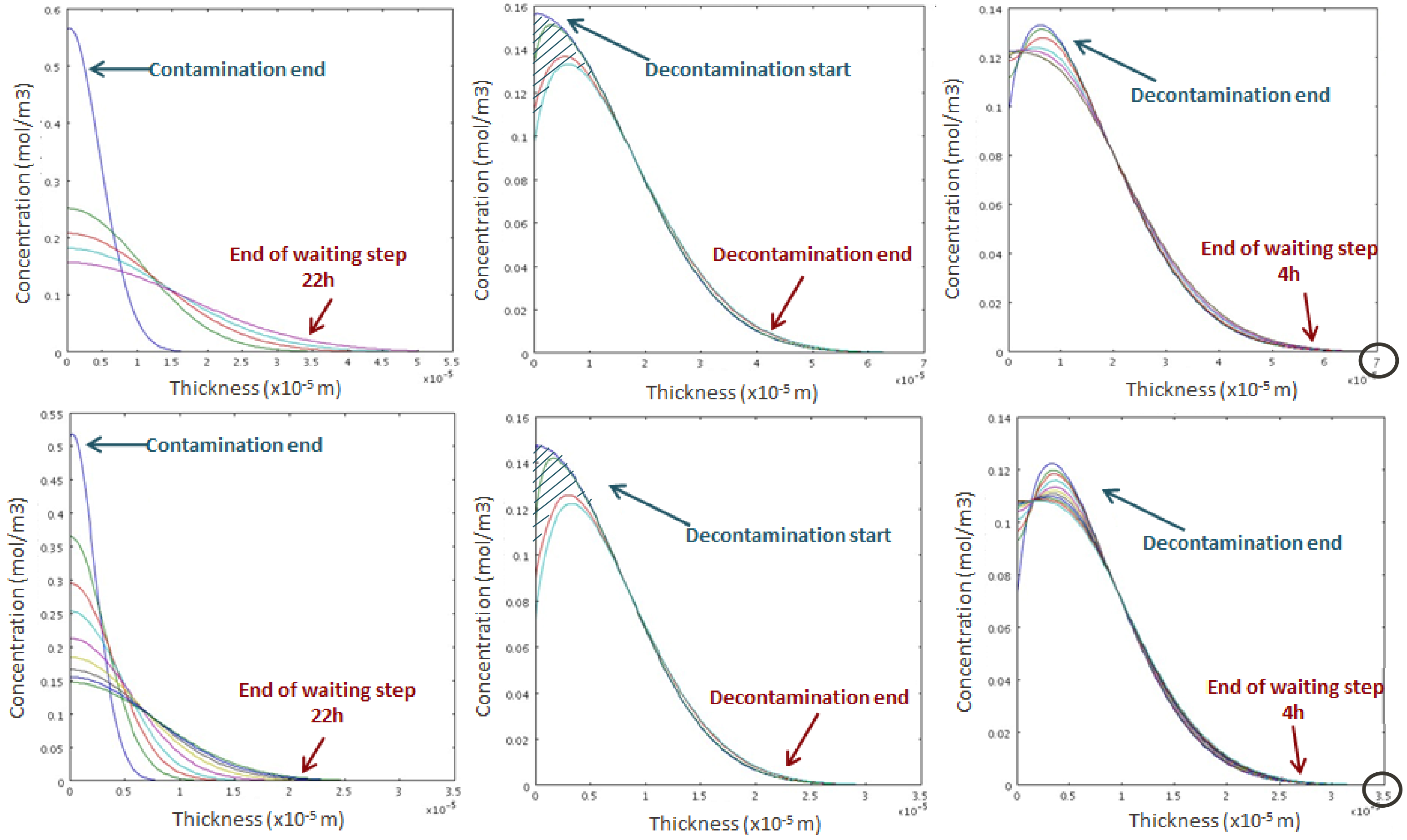
[1]: HF transport coefficients in polymers used for microelectronic applications.
Gonzalez-Aguirre P., Fontaine H.; Beitia C.; Pastorello R.; Ohlsen J.; Lundgren J. Defect and Diffusion Forum, Vol 367 (2016), 68-76
[2]: Mathematical Modeling of the AMCs Cross-Contamination Removal in the FOUPs: Finite Element Formulation and Application in FOUP's Decontamination.
N. Santatriniaina, J. Deseure, T. Q. Nguyen, H. Fontaine, C. Beitia, L. Rakotomanana. International Journal of Mathematical, Computational Science and Engineering, Vol 8, No 4, (2014), 30-35

NUMERICAL SIMULATION: EVOLUTION OF [HF] PROFILES IN POLYMER (WET CLEAN SCENARIO)

Waiting step (post conta) | Wet clean (34 min) | Post clean (over 4h)

PC

EBM



Contamination reduction: -5%

Contaminant diffusion depth : 60 µm

Contamination reduction: -7%

Contaminant diffusion depth: 27 µm

EBM: slow kinetic → lower [HF] in bulk

NUMERICAL SIMULATION VS. EXPERIMENTAL RESULTS

Intentional Gaseous HF Contamination

0h

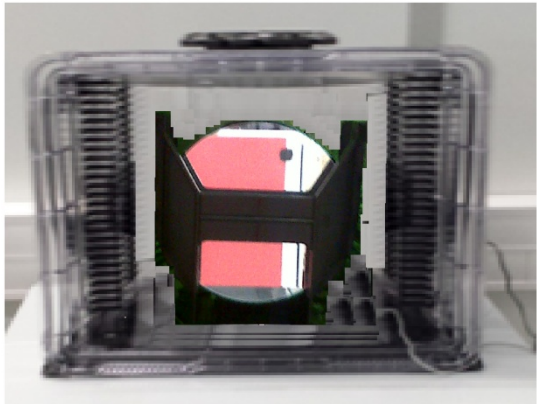
4h

22h

Wet cleaning

3 hours

Cu Wafer storage



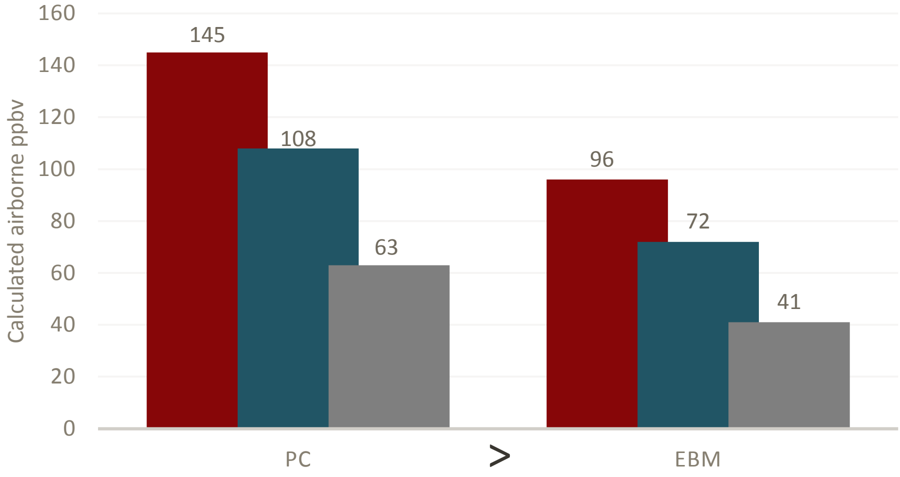
HF cross contamination

EBMCNT < PC

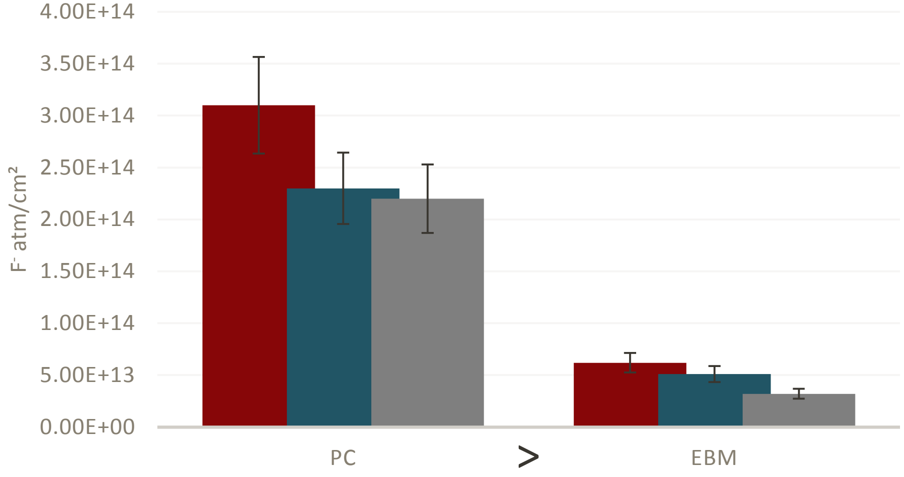
Waiting time effect

0h > 4h > 22h

Simulated airborne HF concentration



Experimental HF contamination transfer



SUMMARY

- HF transfer from FOUP to Cu-wafers:
  - In purge solution: PC > PC/CP > EBM/CNT
  - In wet clean solution: PC > EBM/CNT

  Mainly diffusivity-dependent
- Gas purge
  - Limits (control) HF cross contamination by airborne removal during wafers storage
- Wet clean
  - Removes (partially) HF contamination in near polymer surface
  - More efficient closer to the contaminant event/process
- Use of obtained D,S coefficients allow HF behavior estimations as a contaminant into the polymer by simulation based on a membrane model
- Numerical estimations presents the same trend as experimental results

Among the tested FOUPs, EBM/CNT is the most efficient to limit HF contamination transfer to wafers → reduced wafer defectiveness is expected

ADVANCED WAFER HANDLING: SOLUTIONS FOR CONTAMINATION CONTROL

Cross contamination is a synergic phenomena, decontamination solution as well

- No single solution can avoid cross contamination

Barrier FOUP

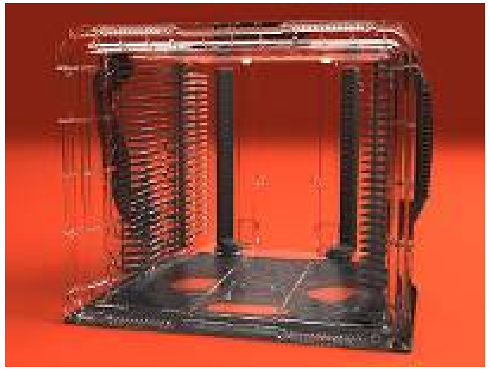
Moisture, HF
content remains low longer

Barrier material
and/or coatings

+

Advanced FOUP Purge

Moisture content decreases faster



Flow distribution diffusers to improve purge
near to wafer critical position (edge/top)

+

Wet clean

Very efficient for particles
removal

Wet clean by ECP

FOUP material, purge and wet cleaning are a set of variables that have great impact on yield, until now better strategy to improve yield and minimize the wafer loss is to combine these three

50 YEARS OF PURE ADVANTAGE