SEMATECH Surface Preparation and Cleaning Conference

Comparison of HF and HCl cross-contamination between different Entegris FOUP platforms and Cu-coated wafers

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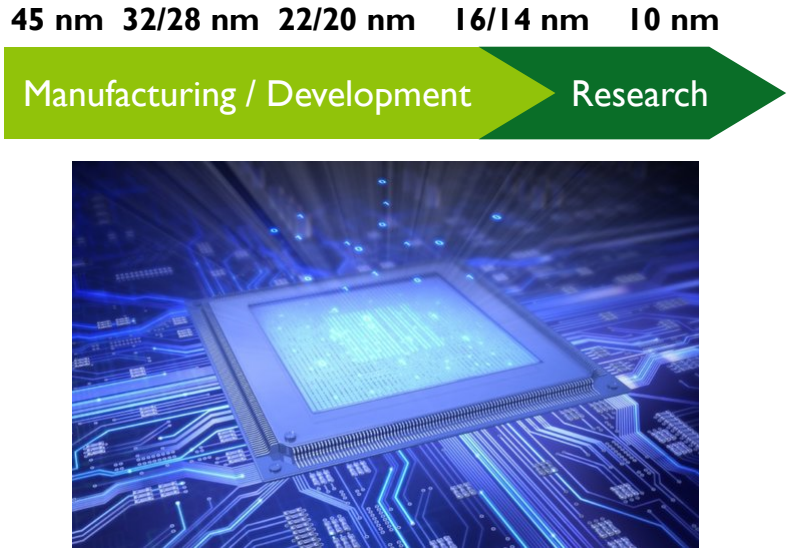
OUTLINE

1. Introduction
2. Issues/objectives
3. Experimental protocol
4. Results
   - HX adsorption by the FOUPs
   - HX outgassing from the FOUPs
   - HX transfer to Cu-coated wafers
5. Conclusions

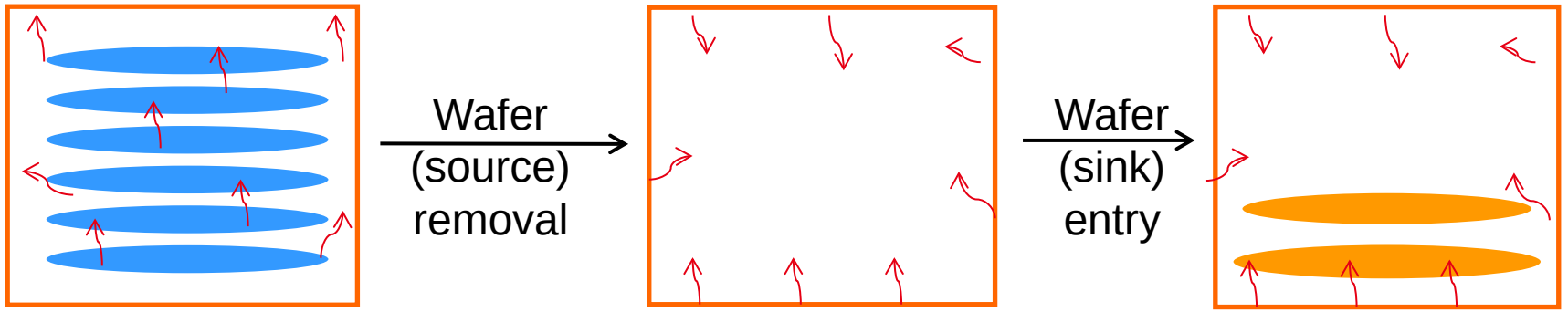


INTRODUCTION

AMC sorption from CR air, released from stored wafers, equipment connection…

Subsequent outgassing, transfer to wafers & potential defectiveness

*Air → FOUP → Wafers



FOUP contamination by wafer outgassing

Contaminant outgassing FOUP → air up to equilibrium

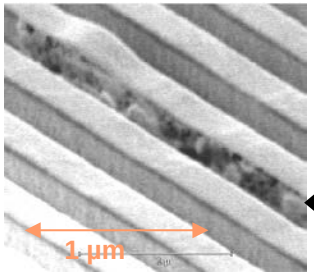
Contamination transfer FOUP → Air → Wafer

- 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

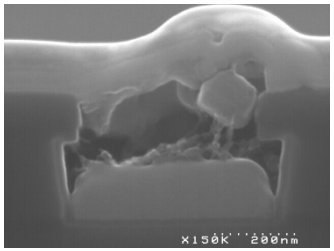
*H. Fontaine et al., Solid State Phenomena, 2008

ISSUES/OBJECTIVES

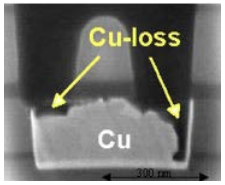
- Among AMCs, **HX** are identified as **root cause of defectiveness** where **moisture** and **time** play a critical role as well:



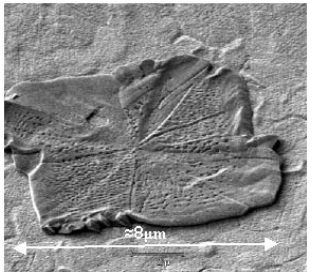
Corrosion of a Cu via →

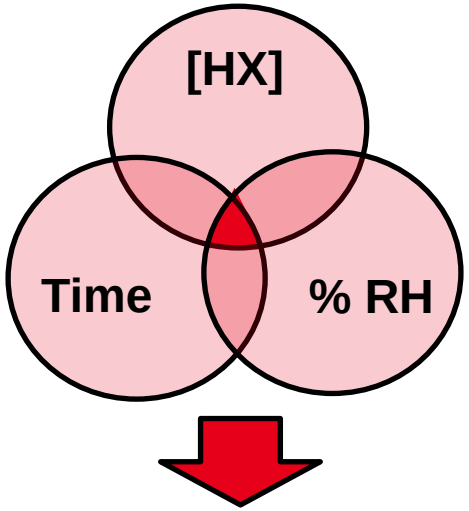


← Al lines corrosion



TiF_x crystal growth on TiN →





Wafer DEFECTIVINESS

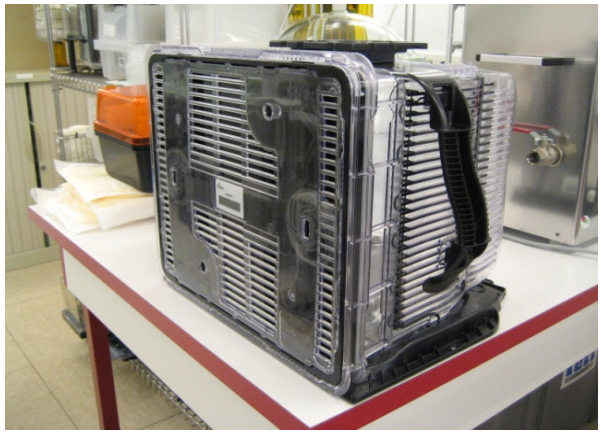
Objectives: to compare two critical molecules (**HF*/HCl**) and **three Entegris FOUP models** in terms of:

- **HX contamination, sorption & subsequent release**
- **HX cross-contamination on stored wafers**

*P. Gonzalez-Aguirre et al., Microelectronic Engineering, 2013

EXPERIMENTAL PROTOCOL

☑ SPECTRA PC

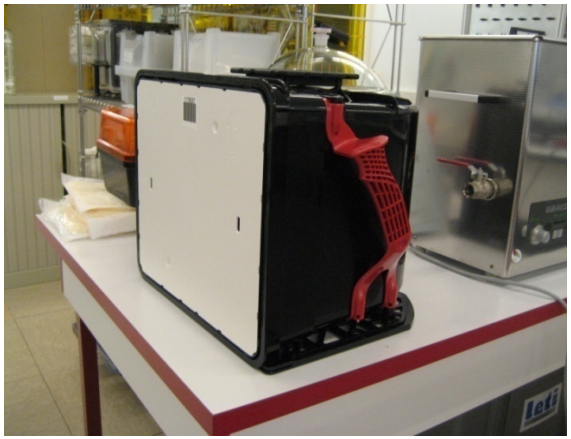


Polycarbonate (ref.)

☑ SPECTRA PC/CP

Polycarbonate/C-powder

☑A300 EBM/CNT



EBM/C-nanotubes

FOUP INTENTIONAL CONTAMINATION

Contamination phase; t = 24h

10 µL droplet, evaporation within FOUP's volume:

- **HF 2% → 9.8 ppmv**
- **HCl 3,7% → 10.3 ppmv**

EXPERIMENTAL PROTOCOL

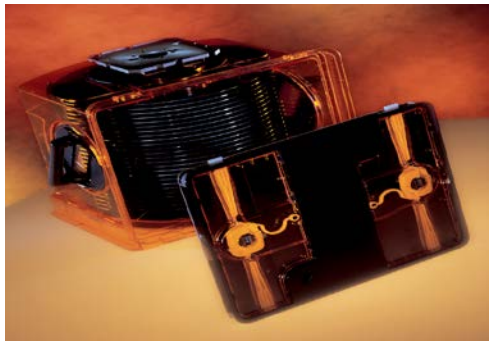
0) FOUP CONDITIONING
Clean room stabilization
(21°C, 40% RH) 7 days

1) INTENTIONAL GASEOUS HX CONTAMINATION
10µL- droplet, 24h

2) PURGE

(N_2 gun) 5 min

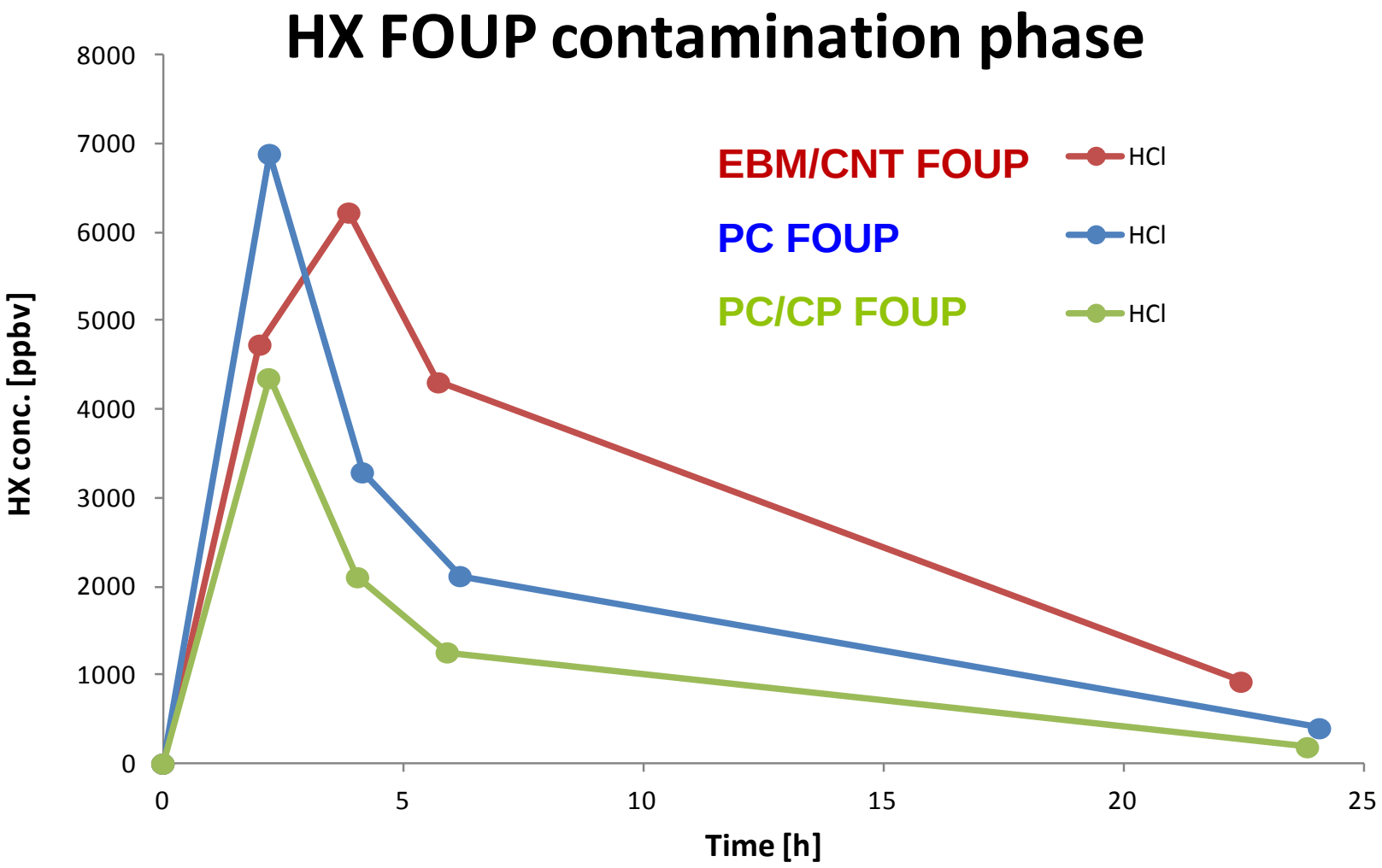
3) OUTGASSING MONITORING, IMPINGER-IC
(once per day) 7 days



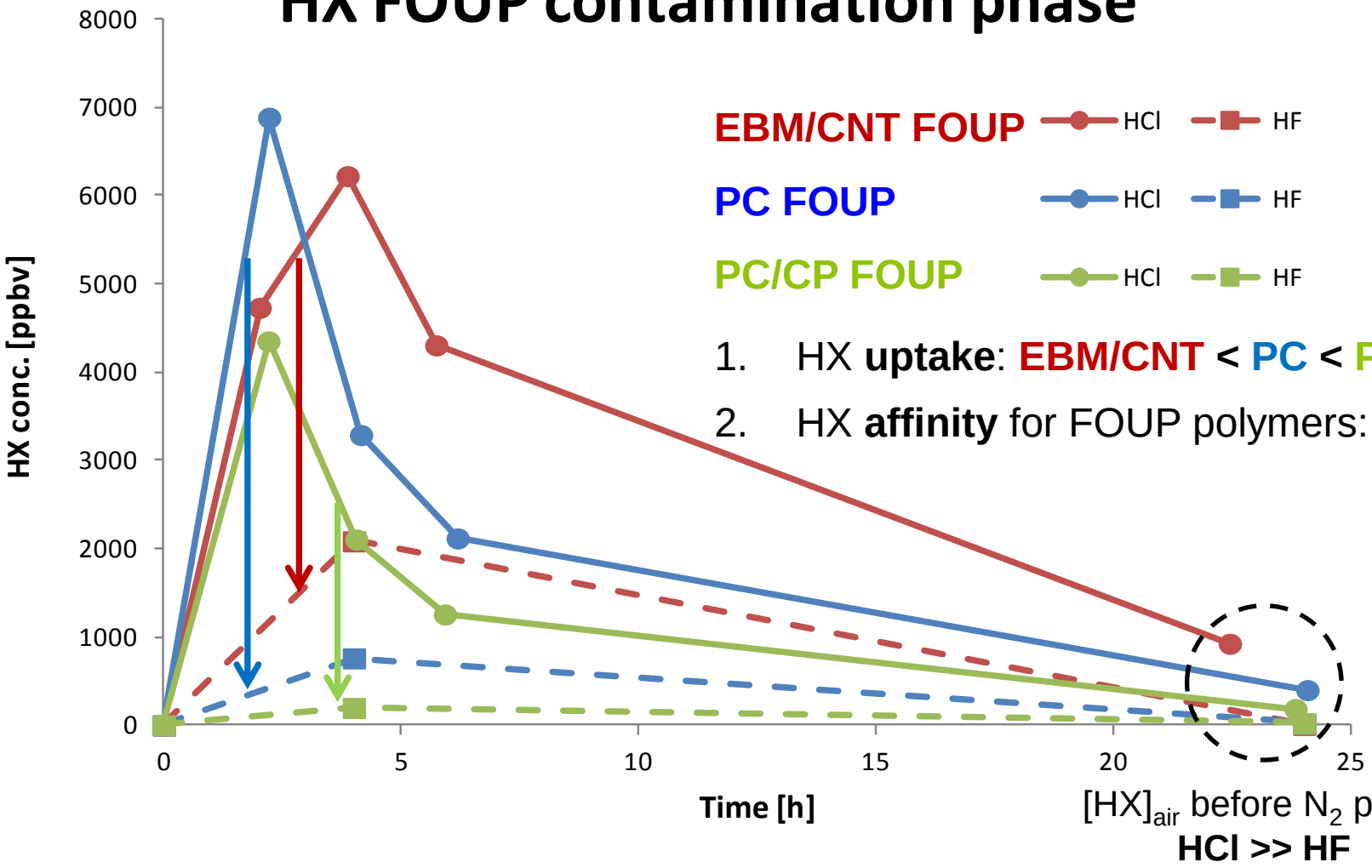
3) STORAGE of Cu-WAFERS, LPE-IC
HF: t < 12 days
HCl: t < 2 days

IC = Ion Chromatography, LPE = Liquid Phase Extraction

HX SORPTION BY FOUPS



HX FOUP contamination phase

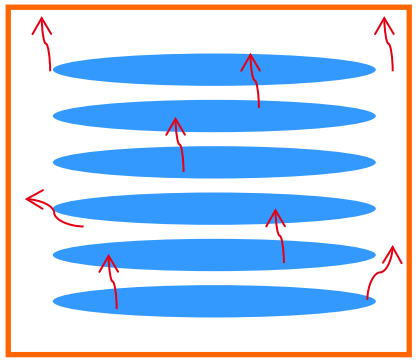


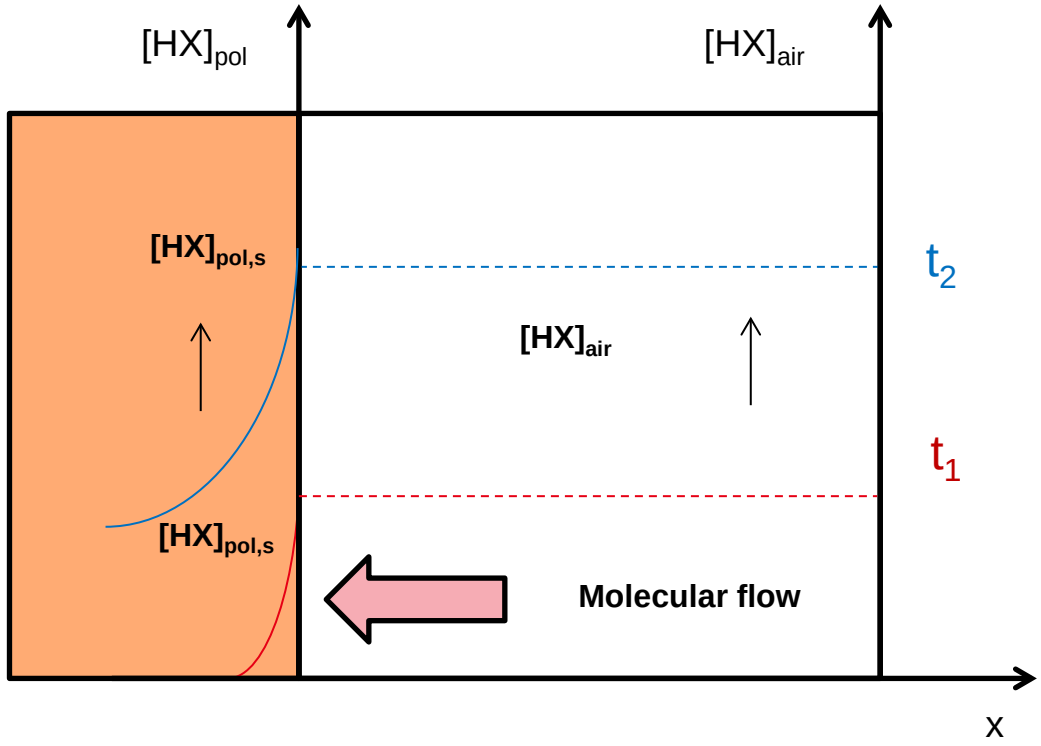
1. HX **uptake**: **EBM/CNT** < **PC** < **PC/CP**
2. HX **affinity** for FOUP polymers: **HF > HCl**

$[HX]_{air}$ before N_2 purge

HCl >> HF

FOUP contamination: wafer outgassing $[HX]_{air}$





1. $[HX]_{air}$ **increases and penetrates the polymer**
2. **FOUP's contamination: f (D, S)**

$$[HX]_{pol,s} = \textbf{Solub.}\ [HX]_{air}$$

$$J_{HX} = -\textbf{Diff.}\ \nabla[HX]_{polymer}$$

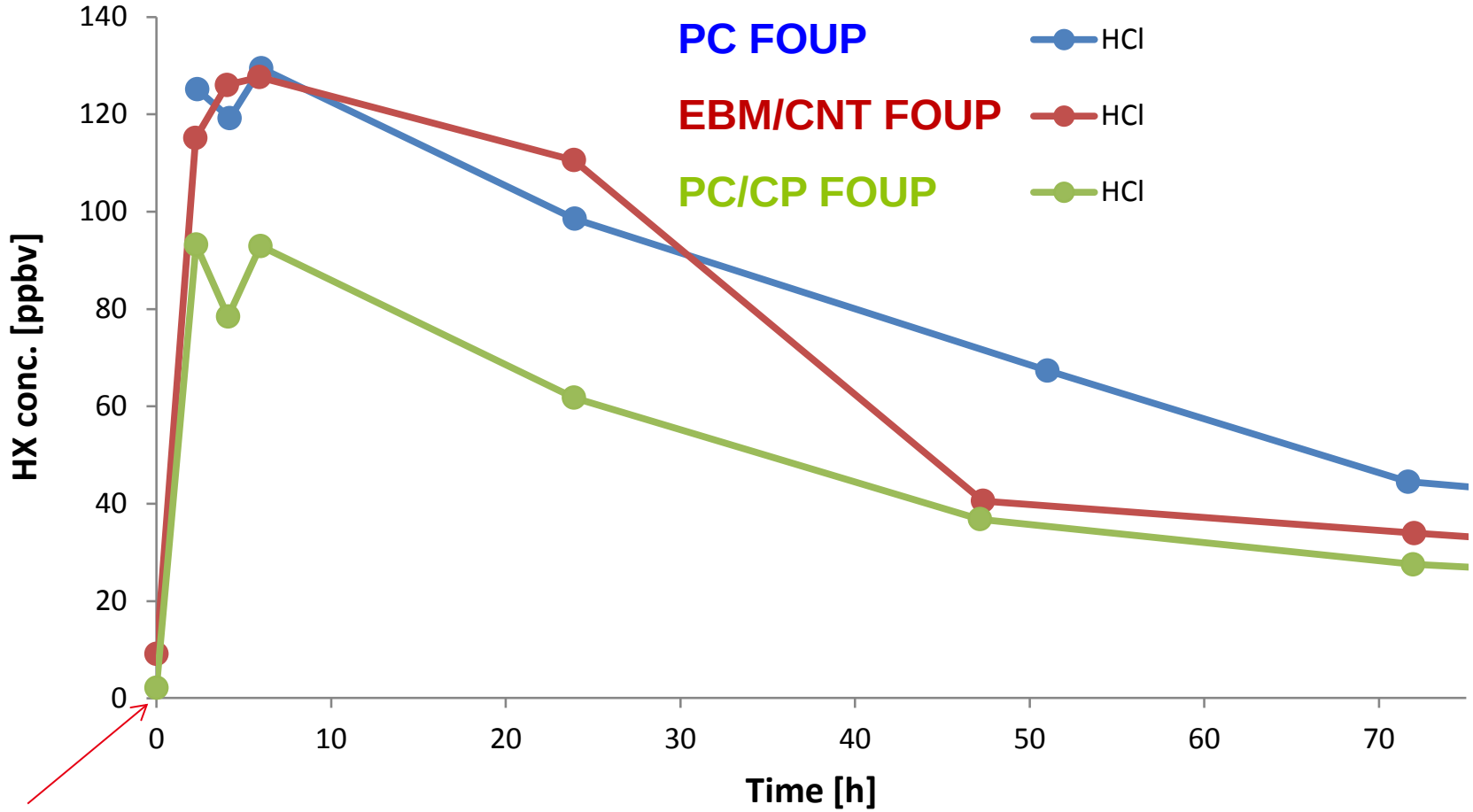
Before purge [ppbv]:

$[HCl]_{EBM/CNT} \approx 1000$

$[HCl]_{PC} \approx 400$

$[HCl]_{PC/CP} \approx 200$

HX-FOUP outgassing phase



5 min purge

HX OUTGASSING BY FOUPS

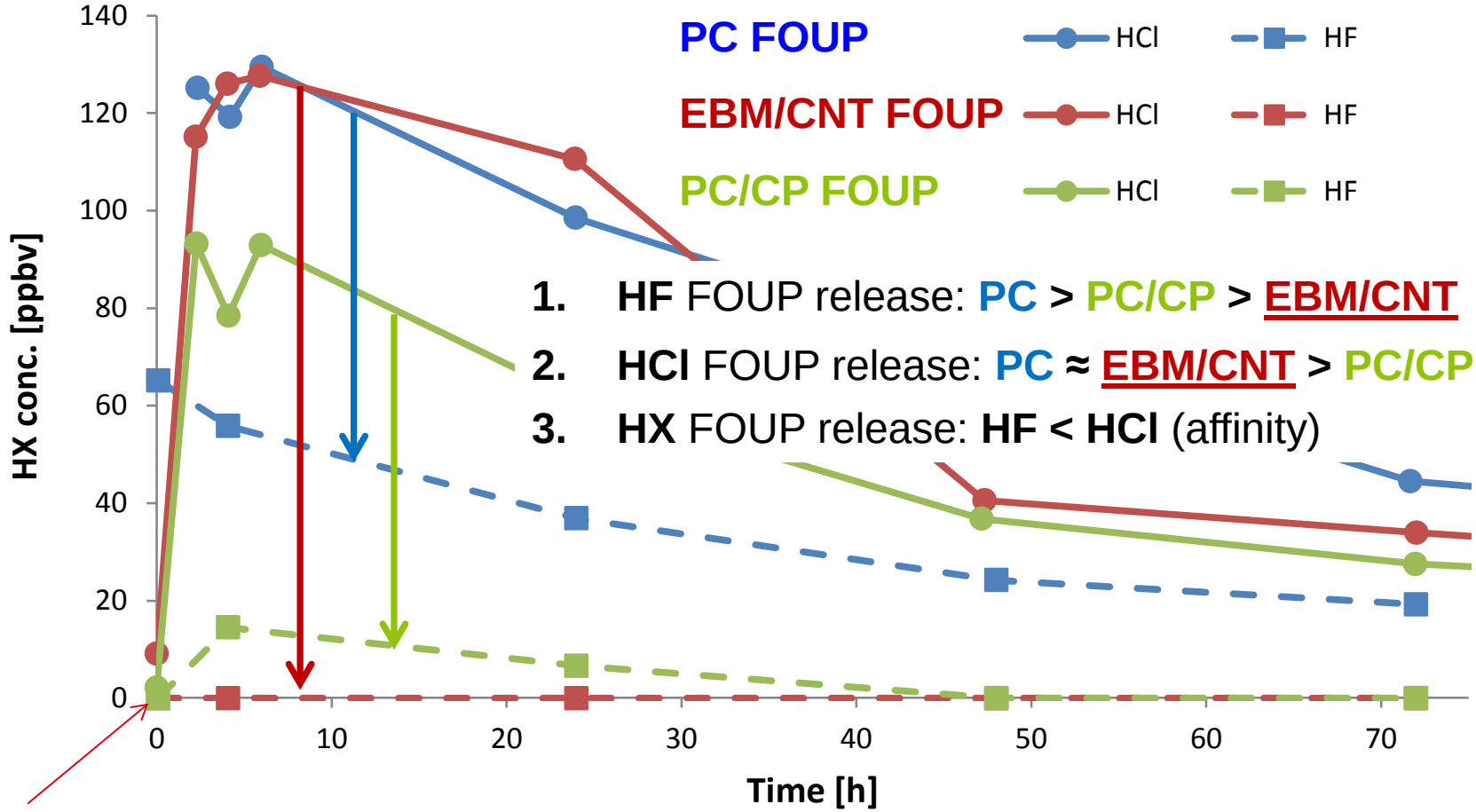
Before purge [ppbv]:

$[HCl]_{EBM/CNT} \approx 1000$

$[HCl]_{PC} \approx 400$

$[HCl]_{PC/CP} \approx 200$

HX-FOUP outgassing phase

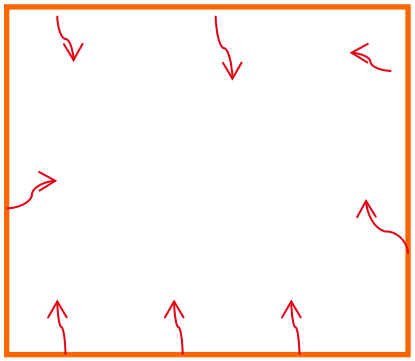


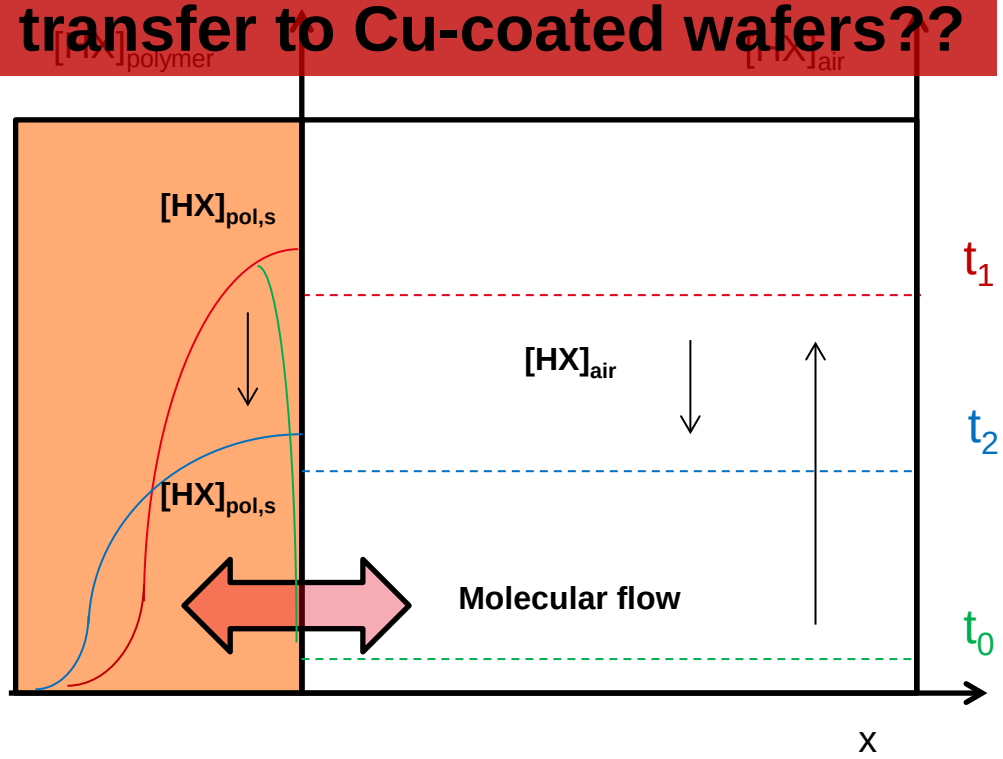
1. **HF** FOUP release: **PC** > **PC/CP** > **EBM/CNT**
2. **HCl** FOUP release: **PC** ≈ **EBM/CNT** > **PC/CP**
3. **HX** FOUP release: **HF** < **HCl** (affinity)

5 min purge

✓ **HX transfer to Cu-coated wafers??**

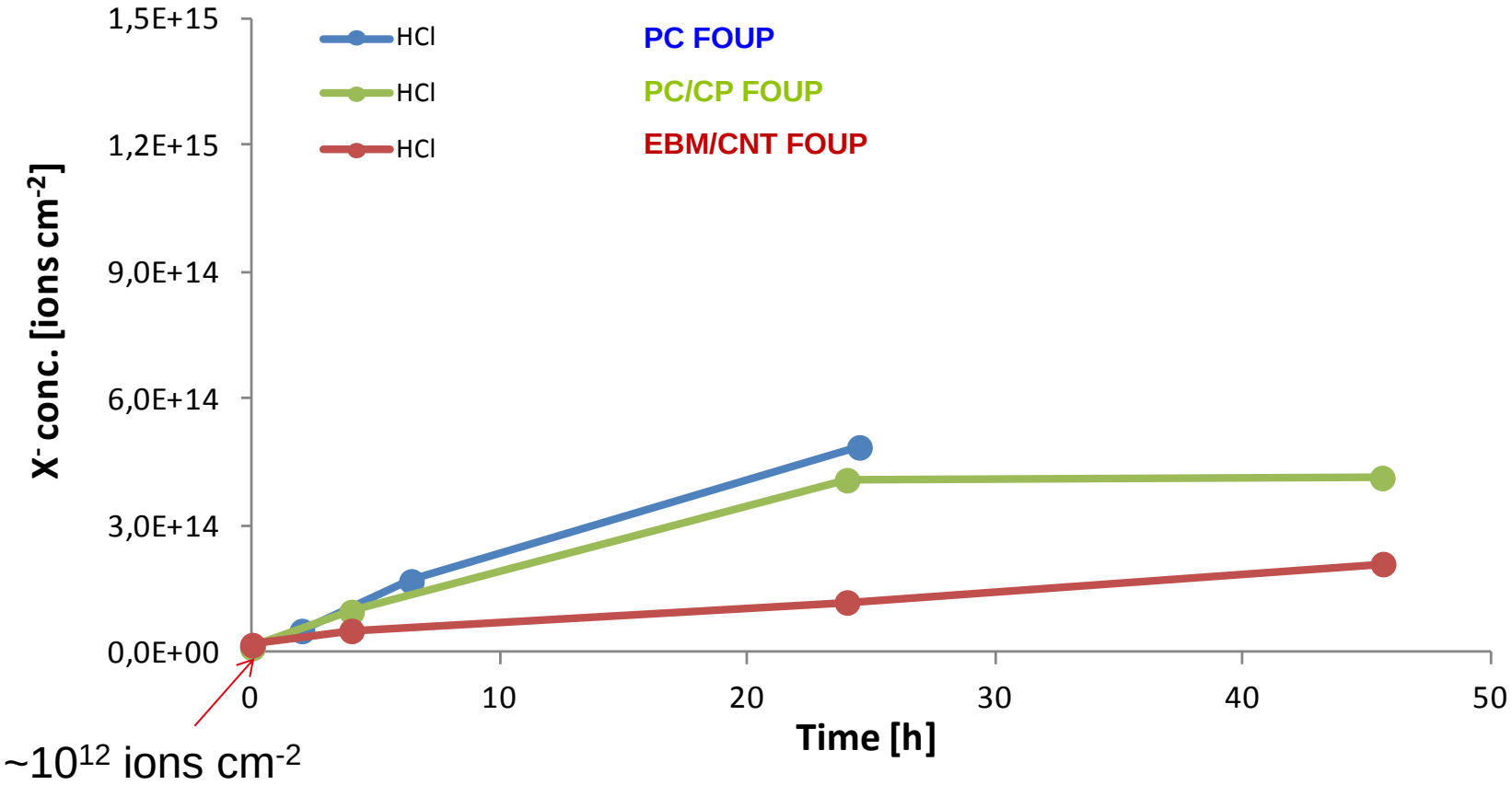
Empty FOUP: outgassing [HX]air





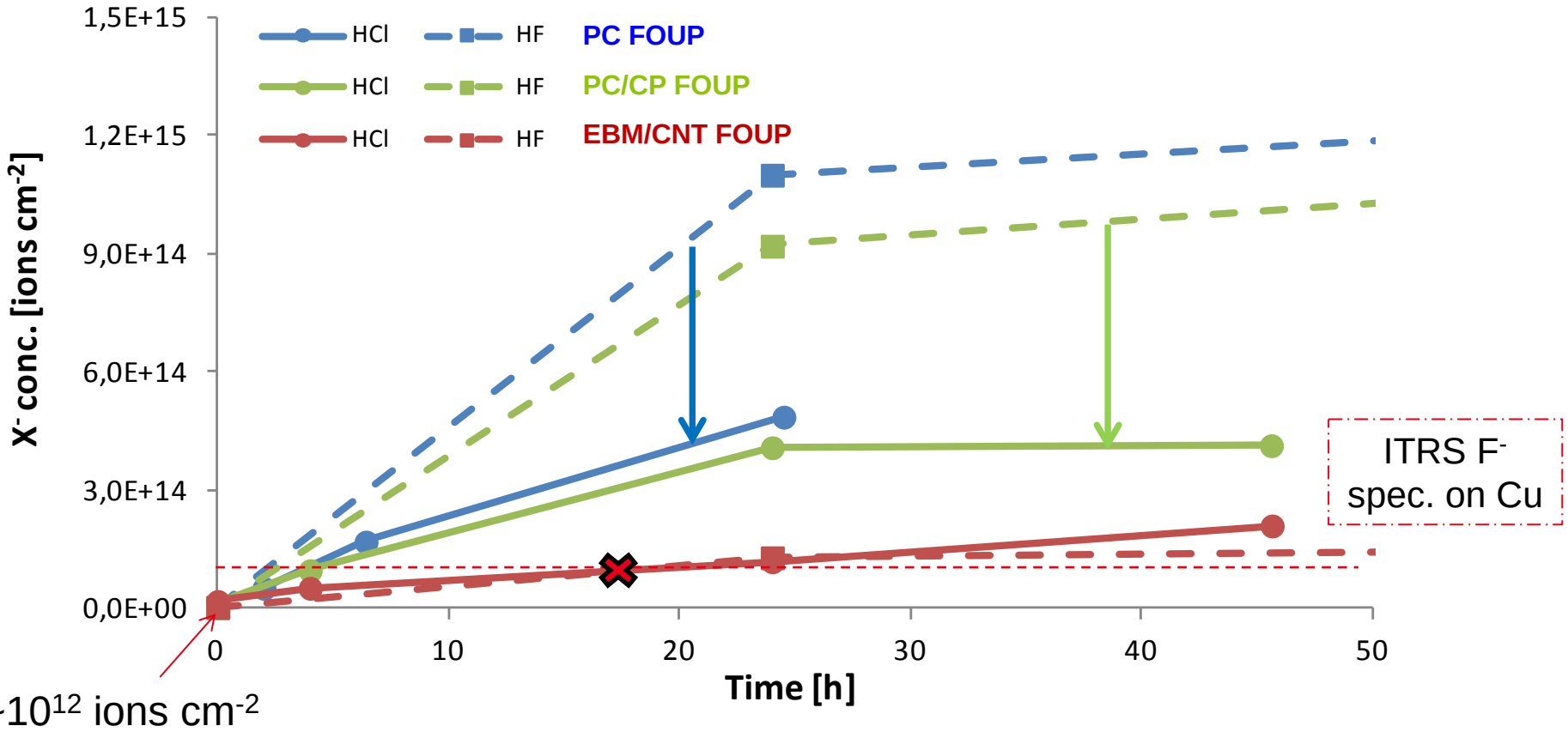
1. $[HX]_{air}$ sharp increase until $[HX]_{pol,s}$ equilibrium → Solub.
2. Outgoing diffusion: $[HX]_{pol,s}$ is reduced → $[HX]_{air}$ pulled down
3. $[HX]_{air}$ is mainly <u>solubility-dependent</u>

Cu-wafer exposure into HX-contaminated FOUPs



1. **HCl** outgassing rate: **PC** ≈ **EBM/CNT** → **though the lowest transfer**

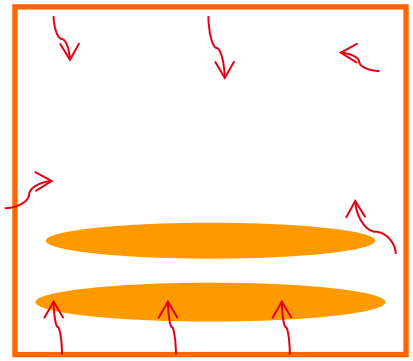
Cu-wafer exposure into HX-contaminated FOUPs

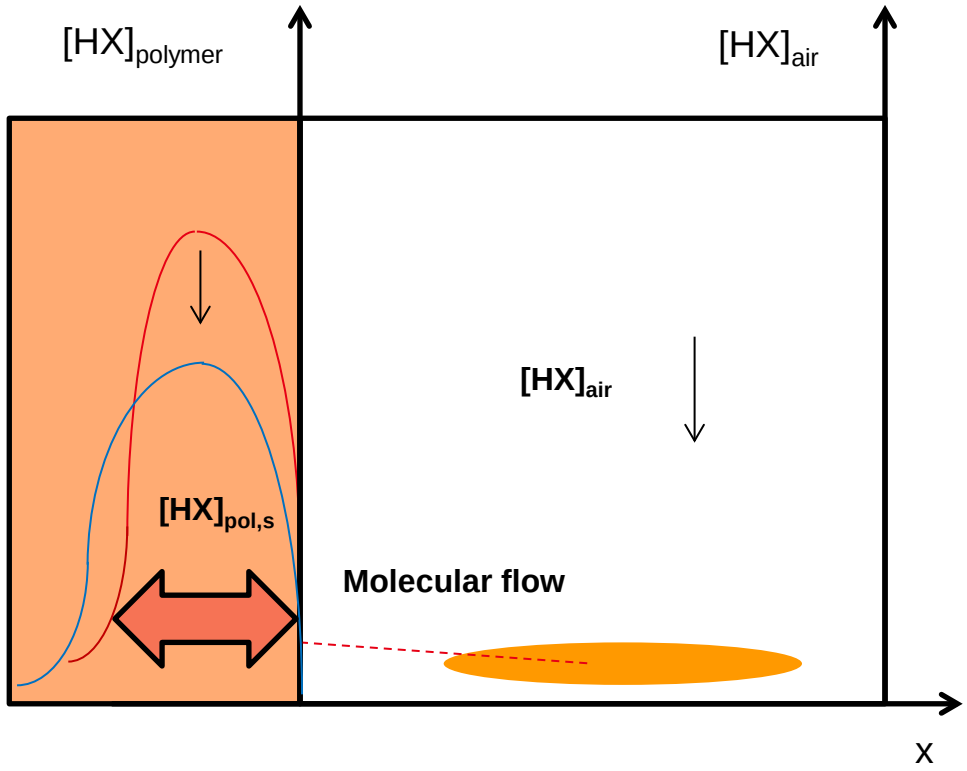


1. **HCl** outgassing rate: **PC** ≈ **EBM/CNT** → **though the lowest transfer**
2. **HX** transfer: **PC** > **PC/CP** > **EBM/CNT**
3. **HF** transfer ≈ **HCl** transfer for **EBM/CNT** only

HX TRANSFER TO CU-WAFERS

Wafers within FOUP:
$[HX]_{air} \rightarrow 0$





1. $[HX]_{air} \rightarrow 0$ (HX affinity Cu) then $[HX]_{pol,s} \rightarrow 0$
2. HX molecular flow: FOUP's inner surface → copper wafer
3. $D_{air} >> D_{polymer}$ → <u>HX transfer</u> to Cu mainly <u>governed by $D_{polymer}$</u>

CONCLUSIONS

To summarize:

→ **HX affinity** by FOUP's polymers: **HF > HCl**

→ **HX outgassing** after int. contamination: HF < HCl, **f (solubility)**

→ **HX transfer** to wafers: HF > HCl, **f (diffusivity)**

→ **EBM/CNT** FOUP: exhibits a strong HCl outgassing rate but low transfer to copper wafers (**low S and D**)

→ **FOUP's performance** in terms of AMC cross-contamination must be assessed by **wafer exposure**

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

Thanks for your attention

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