Accelerating the next technology revolution

Reticle Handling / Shipping / Storage - From Blank Suppliers, Mask Makers, to Wafer Fabs

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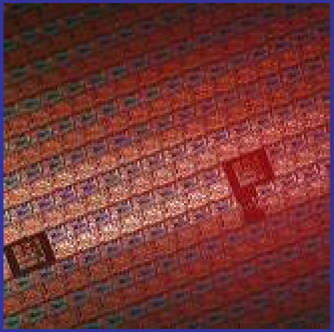

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goals

1. **Propose implementation strategies**
    - Blank shop, mask shop, wafer fab
2. **Identify major gaps**
    - Storage capability and fundamental understanding
    - Mask lifetime

      By minimizing needs for clean in wafer fabs
    - (most people anticipate no major ESD issue)
3. **Clarify common, key logistic questions**

Outline

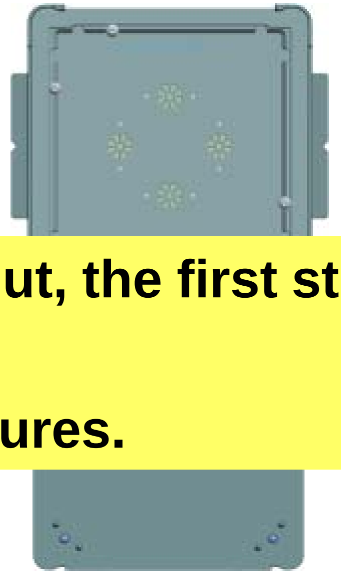
- Introduction
- Carrier: E152 EUV-pod
- Blank / Mask Shop Implementation strategies
- Shipping
- Reticle flow in wafer fabs
- Reticle lifetime
- In-fab storage
- In-fab particle protection
- Summary

Introduction

- **EUV mask is expected to show up in wafer fabs *clean, free of particular contamination.***
- **Realistically, wafer fabs should be prepared for *occasional* particle contamination.**

  (Either from shipping or use in wafer fabs)
  - In-fab detection and recovery capabilities are needed.
  - In-fab molecular contamination must also be addressed, in parallel.
- **The focus here is to address the key question: How to minimize mask contamination and maximize mask lifetime.**
  - EUV carrier implementation
  - Contamination reductions

SEMI E152 Allows Carrier Dedication



Inner pod cover

- **Goal is to work towards a single copy of carrier. But, the first step is to show a carrier that works for all!**
- **It's manageable, with the help of identification features.**

types of inner pod, major differences are on the baseplate

Inner pod Type-A for scanners

Type-B for other than scanners, like storage

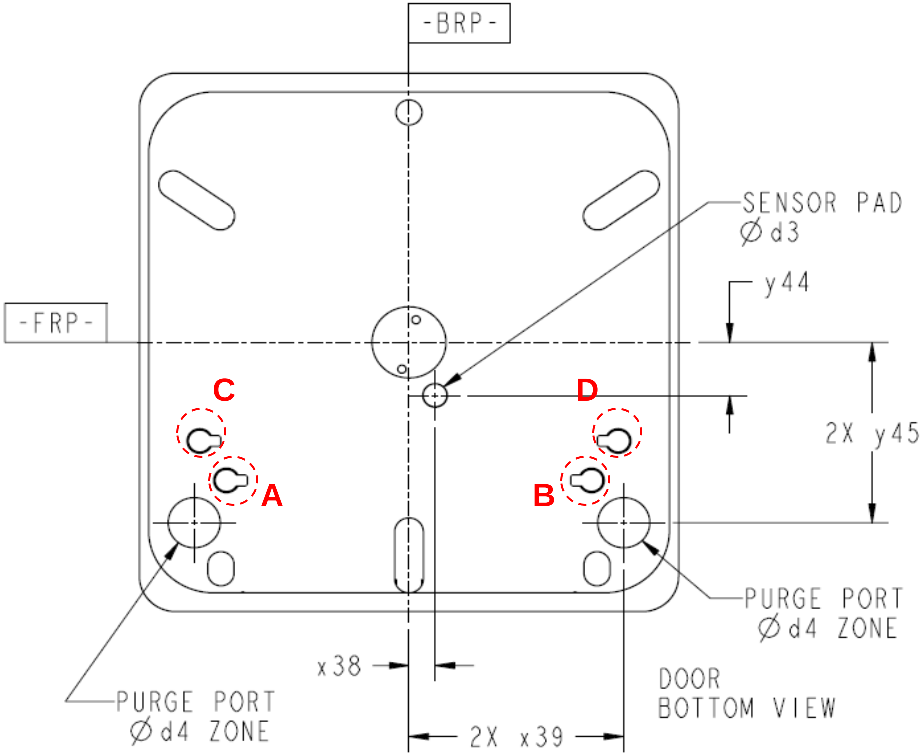
- E152 specifies 1 outer pod type, 2 inner pod types namely Type-A or B.
- Additional features built to Type-A for positive identification by scanners
- Even Type-A is allowed to be supplier-specific.
- **All tools other than scanners required to be *"type-blind,"***
  - Only use identical interfaces available on all EUV pod carriers

	Type B	Type A		
		Suppl 1	Suppl 2	Suppl 3
Scanr. suppl. 1	✗	✓	✗	?
Scanr. suppl. 2	✗	✗	✓	?
Scanr. suppl. 3	✗	?	?	✓
Other mask tools	✓	✓	✓	✓

A likely inner pod dedication scheme

EUV Pod Identification

- **E152 standard allows two types of inner pods, practically there could be more (to be discussed later).**
- **E152-compliant carriers can be managed by one of the two identification features or both.**
  - **Info pad:** to be specified in E152 revision, allowing 16 possible combinations.
  - **RFID:** already in E152

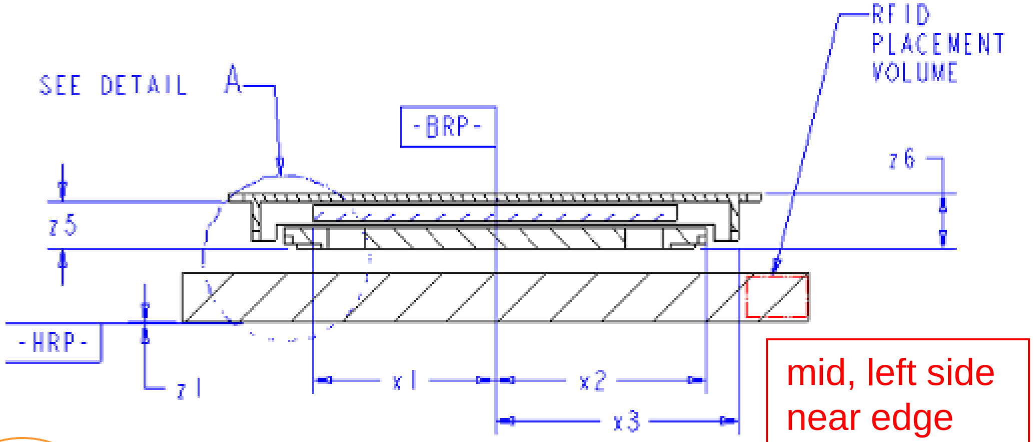


Identification by info Pad: EUV pod can be configured and identified by properly plug the 4 holes, or info pads at the bottom of outer pod: A, B, C, and D

EUV Pod Can Also be Identified by RFID

- **E152 standard specifies RFID location which is embedded in the outer pod door.**
- **RFID itself can not be specified. Fortunately, everyone uses identical part.**
- ***RFID-traceable to outer pod!***

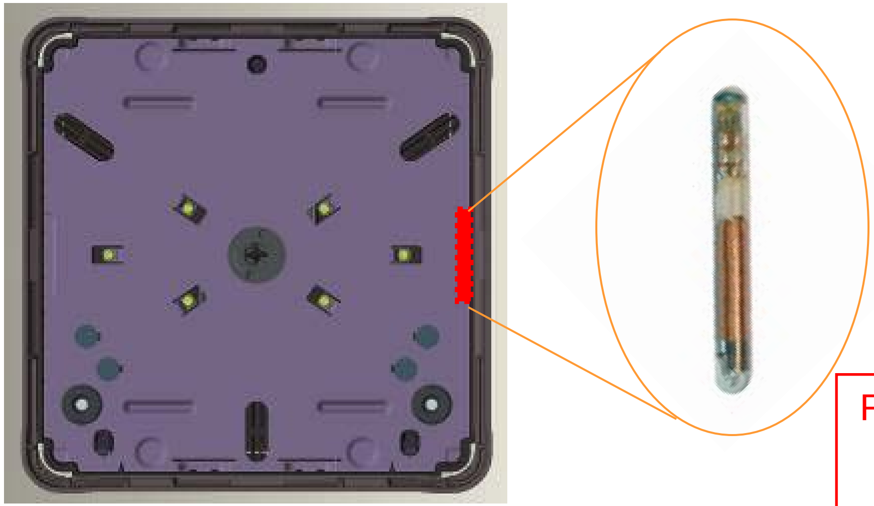
  (manual inner pod type control)



mid, left side near edge

Figure 6
Inner Pod – Internal Front View

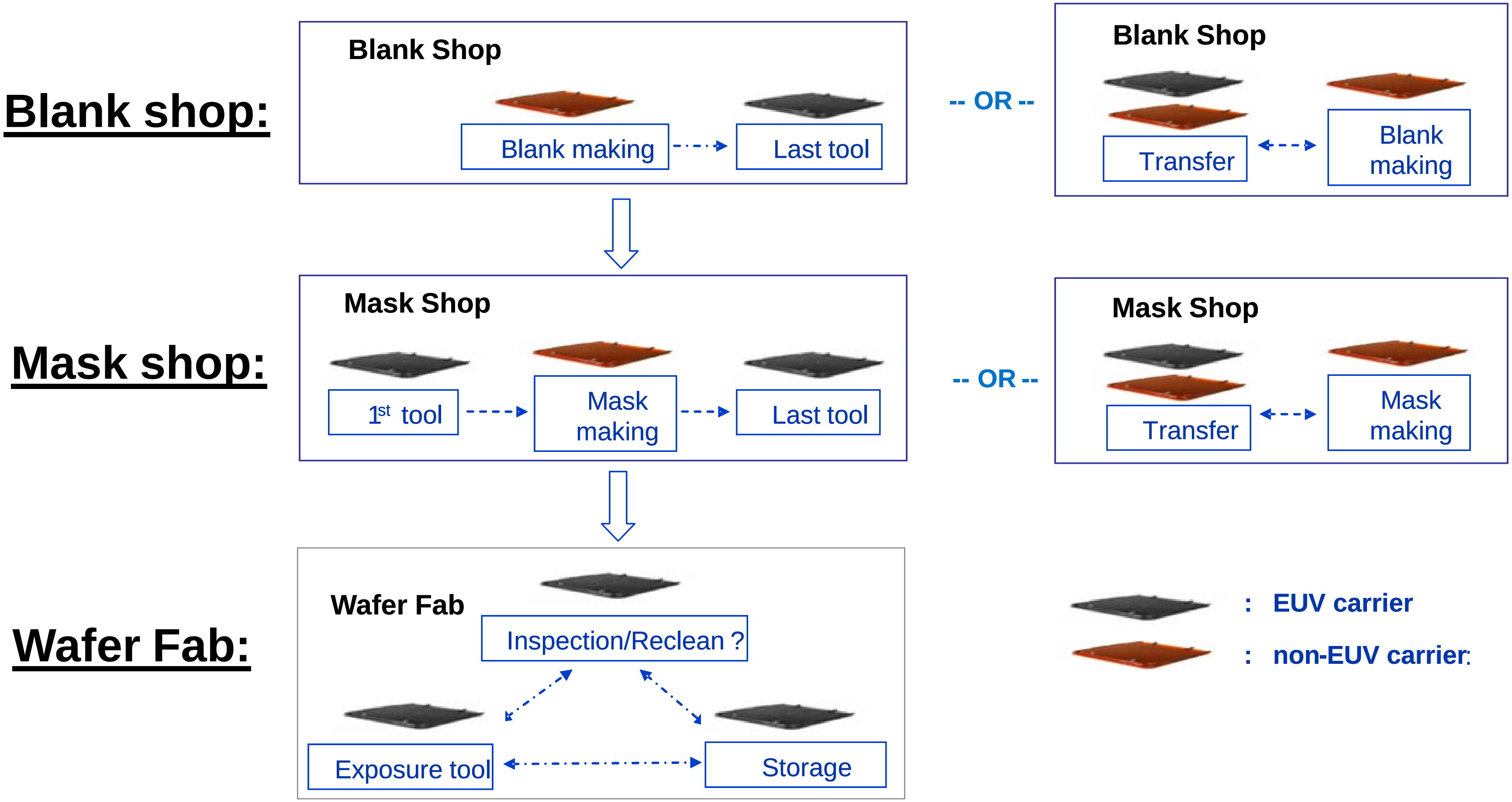
E152 specifies RFID location to mid left side near edge in outer pod door



RFID location
in a bottom view of an E152
compliant outer pod door

RFID: Texas Instruments RF device (P/N RI-TRP-DR2B) mounted inside the door in the area as marked in red.

Early Discussion of EUV Carrier Implementation



Blank shop:

Blank Shop

Blank making → Last tool

-- OR --

Blank Shop

Transfer ↔ Blank making

Mask shop:

Mask Shop

1st tool → Mask making → Last tool

-- OR --

Mask Shop

Transfer ↔ Mask making

Wafer Fab:

Wafer Fab

Inspection/Reclean ?

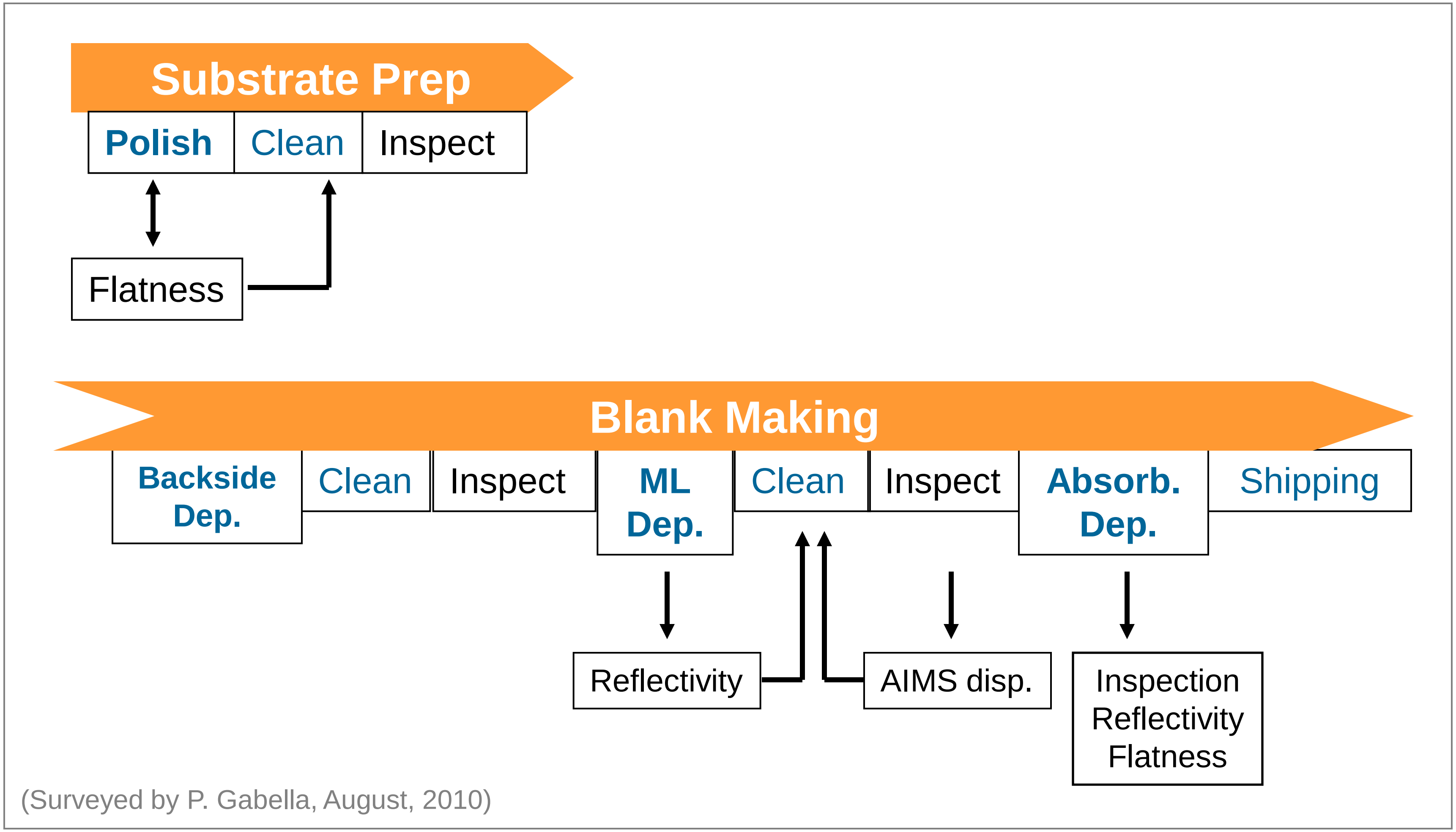
Exposure tool ↔ Storage

: **EUV carrier**

: **non-EUV carrier**

Now it's time to discuss in depth, as pre-production tools are coming to wafer fabs.

EUV Blank Manufacture Flow



Substrate Prep

Polish | Clean | Inspect

Flatness

Blank Making

Backside Dep. | Clean | Inspect | ML Dep. | Clean | Inspect | Absorb. Dep. | Shipping

Reflectivity

AIMS disp.

Inspection
Reflectivity
Flatness

(Surveyed by P. Gabella, August, 2010)

- **What are the most particle-vulnerable steps in blank making?**
- **How likely for blank making to be handling-particle-free, using optical mask carrier?**

Key Questions to Determine if Blank Shops Need EUV Pod

Blank making:

- **Could handling related particles be fully eliminated in ML and absorber film stacks?**

Blank shipping:

- **Will blanks be shipped with resist on?**
  - If yes, use EUV pod.
  - If no,
- **What's the expectation at mask shops when blanks arrive?**
  - Must be particle free or some particles are acceptable?
  - All added particles are cleanable without much negative impact?
  - Always clean in mask shops before resist coating?

E152 EUV-Pod Implementation Strategy in Mask Shops

Option 1. ***x-board conversion: high risk and cost-prohibitive***

- **Convert all mask tools to handle EUV pods.**
  - Unacceptable interruption to optical mask production
  - Unnecessary since defect-free patterning is routine for optical masks.

Option 2. ***Last tool conversion: cost-effective***

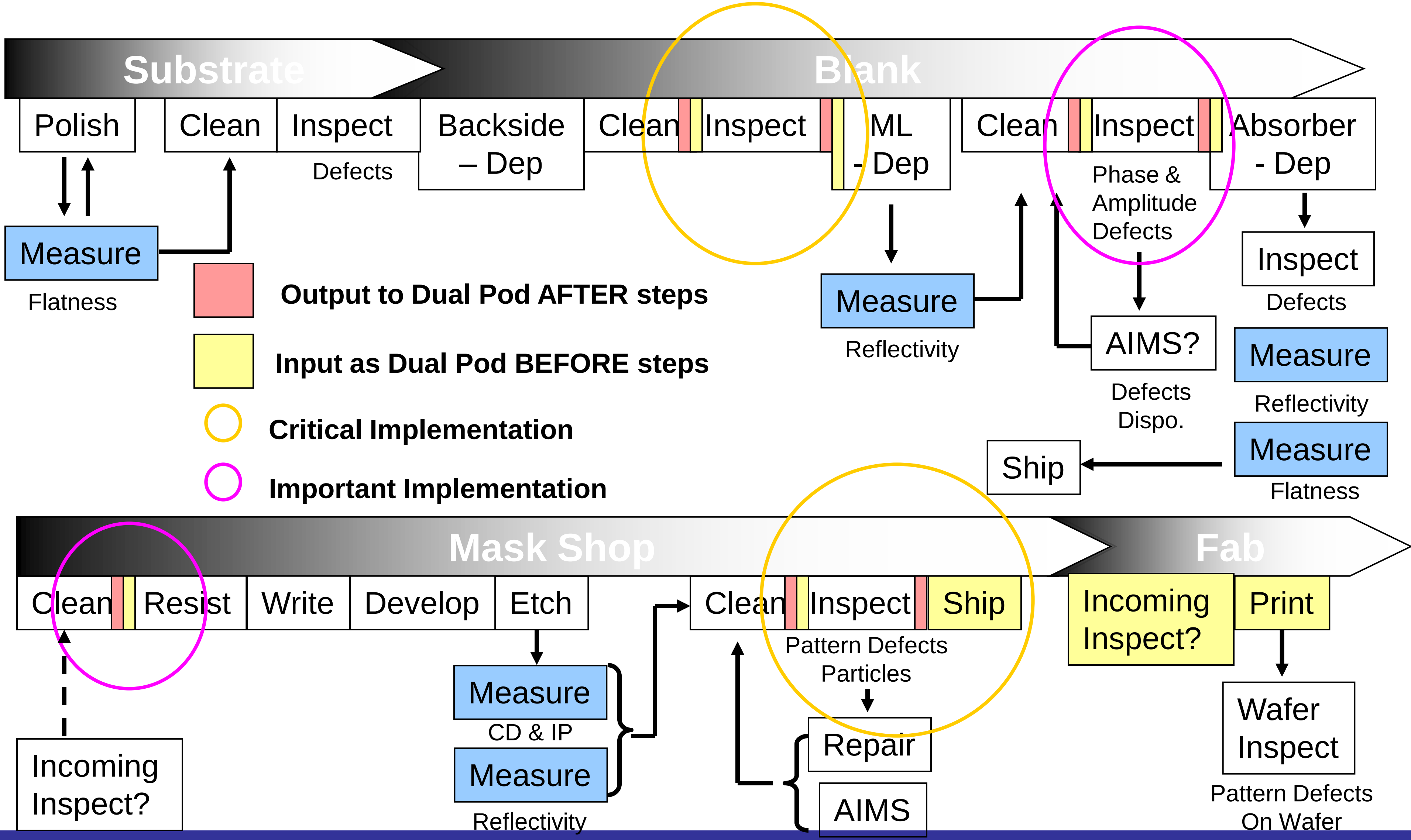
- **Implement capability on the *last mask-making tool,* either the final clean or inspection**
  - Dual capabilities required for tool sharing, to interface with both EUV and optical mask carriers.

Option 3. ***Stand-alone transfer: clear-cut***

- **Implement capability with a stand-alone transfer tool**
  - It adds an additional transfer step, which is not preferred.

Tools in mask shops must be blind to any difference that differentiates pod types.

Likely dual pod usages within mask flow for substrate to users in pilot line and HVM



Substrate

Blank

Polish

Measure

Flatness

Clean

Inspect

Defects

Backside – Dep

Clean

Inspect

ML - Dep

Measure

Reflectivity

Clean

Inspect

Phase & Amplitude Defects

AIMS?

Defects Dispo.

Absorber - Dep

Inspect

Defects

Measure

Reflectivity

Measure

Flatness

Ship

🟥 **Output to Dual Pod AFTER steps**

🟨 **Input as Dual Pod BEFORE steps**

○ **Critical Implementation**

○ **Important Implementation**

Mask Shop

Fab

Clean

Resist

Write

Develop

Etch

Incoming Inspect?

Measure

CD & IP

Measure

Reflectivity

Clean

Inspect

Ship

Pattern Defects

Particles

Repair

AIMS

Incoming Inspect?

Print

Wafer Inspect

Pattern Defects On Wafer

Implement EUV Pod on the Last Tool (Option 2)

- **Obvious candidates for the *last-tool*: final clean and final inspection.**
- **The last tool should fully comply with both EUV-pod standard (SEMI E152) and optical pod standard (E100).**
  - Blind to differences among EUV-pod Types and any supplier-specific features, and accepting all EUV pods.
  - Such capabilities are already commercially available.
- **Capability to unload mask to the same or a second EUV pod**

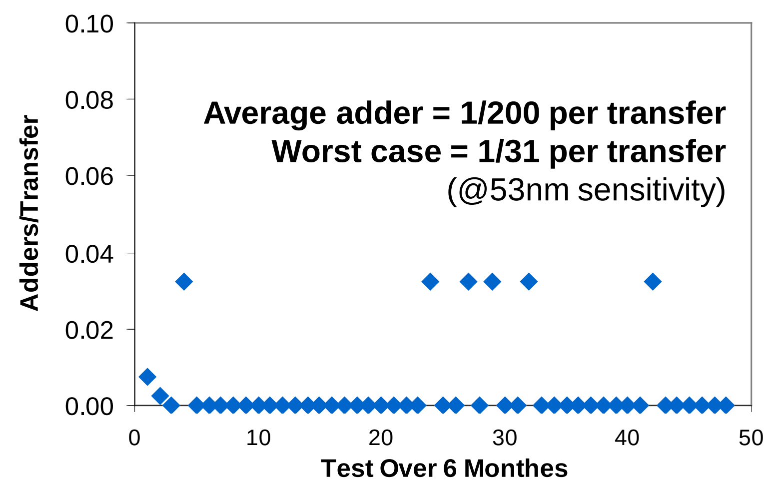
Last-tool Operation

EUV or optical pod

EUV or optical pod (optical for tool sharing)

Implement with Stand-alone Transfer Tool (Option 3)

- **Minimal requirement:**
  - Fully compliant with E152 (EUV Pod) and E100 (RSP200) standards
  - Blind to all difference among EUV-pod types and all supplier-specific features.



Loadport A:
EUV Pod
RSP200

Loadport A:
EUV Pod
RSP200

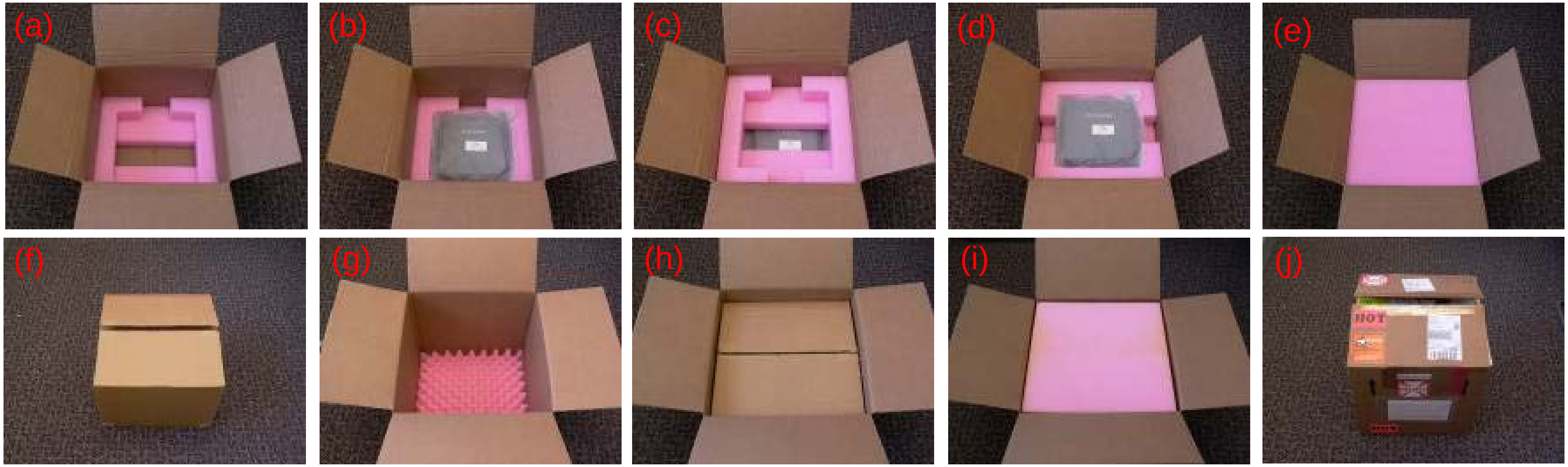
Stand-alone tool is commercially available. Capabilities demonstrated at SEMATECH in 2007 (far above)

Capability to handling both carriers on the same load-port is a must-have.

For Shipping, Good Packaging is Key

- **As robust as EUV pod is, packaging is key for shipping.**

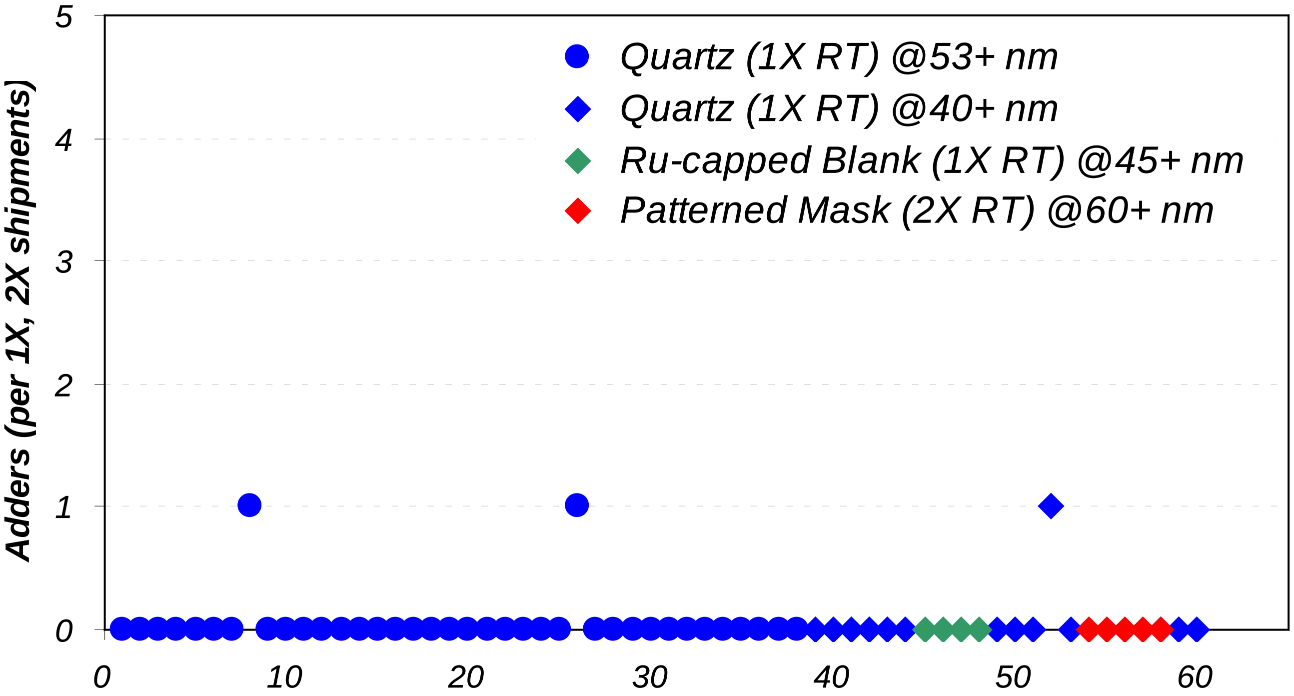
An example of packaging known works:



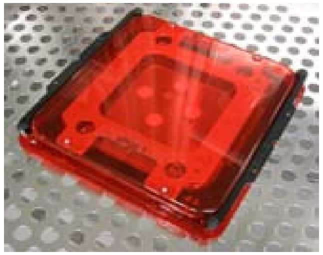
Box-in-box construction of EUV reticle shipping package. Inner box packaging from (a) to (f): with 1st fitting on bottom; place 1st pod in; with 2nd fitting in; place 2nd pod in; place top foam on; and close. Outer box packaging from (g) to (j): with bottom foam in; place inner box in; place top foam on; and close.

Shipping Data Summary

- **Nearly particle-free, but be prepared for occasional particles at mask arrival!**
  - At <<5% odds, there will be a 50nm particle or larger landed on mask patterns at arrival.
  - Prepare for more at EUVL nodes (< 20nm).
  - On implementation, every detail matters!



EUV-pod (sPod)



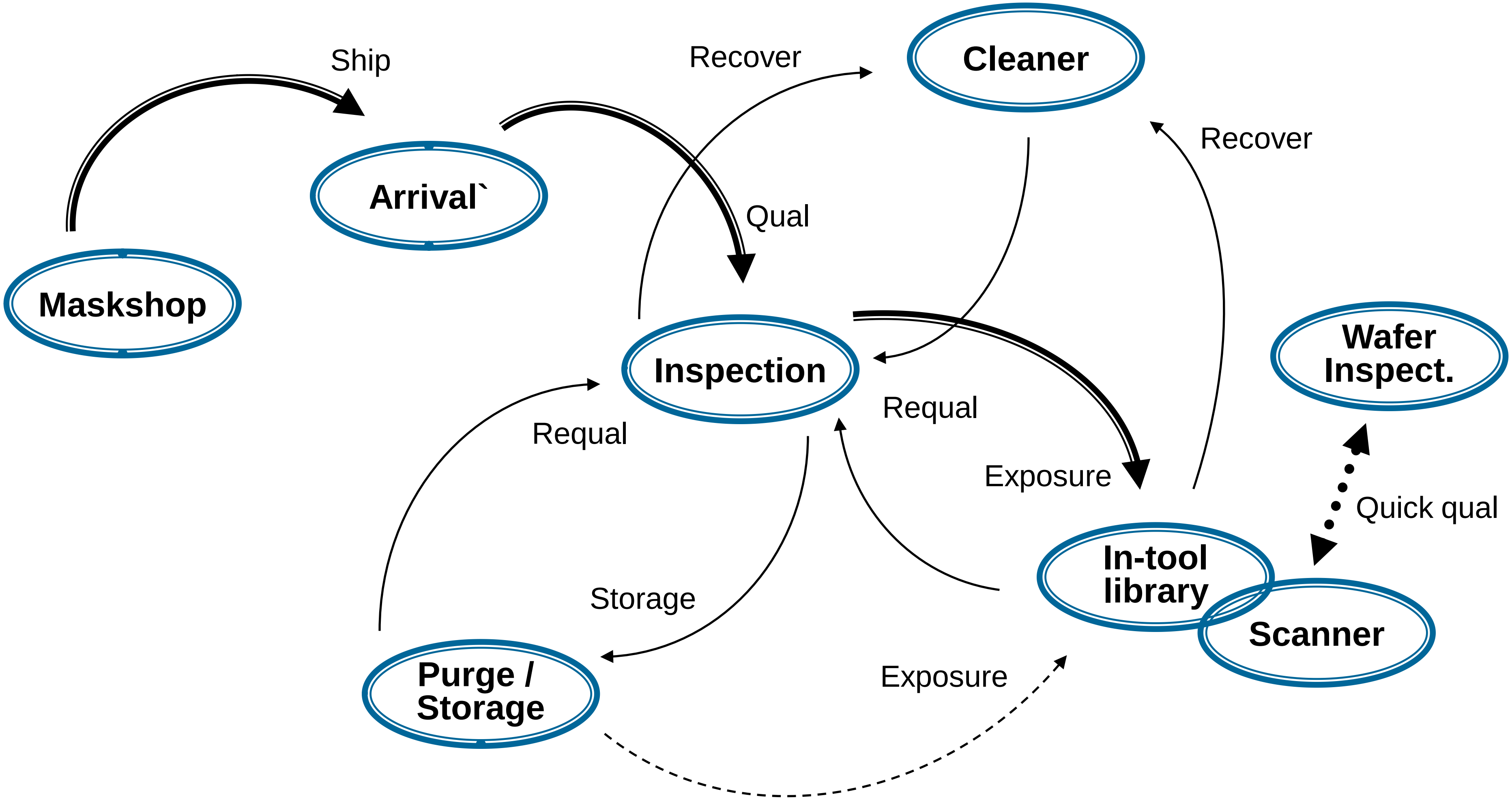
Prototype EUV-pod (sPod)

(Shipped commercially, either across country or between continents)

Reticle Acceptance and Recovery in Wafer Fabs

- **Acceptance inspection**
  - Particle inspection is sufficient.
- **Recovery**
  - Re-clean in wafer fab.
    - It may not be cost-efficient to send masks back to mask shop for frequent cleans.

Reticle Flow in Wafer Fabs



Maximizing Reticle Life Key to EUVL Cost Benefit

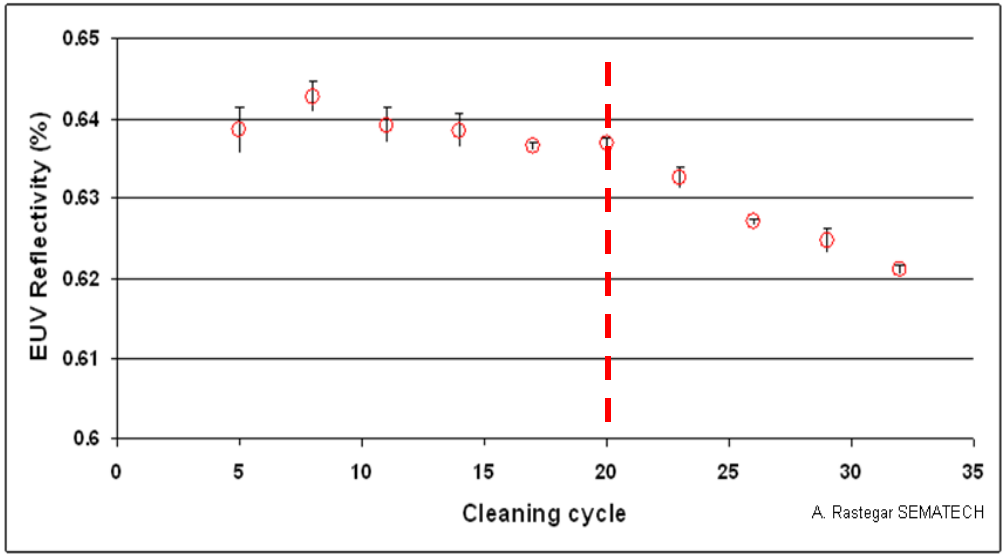
- **Mask cost is key to overall EUVL cost:**
  - Blank cost/yield
  - Patterning cost/yield
  - Useable mask lifetime
- **Robust contamination protection minimizes mask cost.**
  - Robust particular and molecular contamination protection minimizes the costs associated with frequent mask inspection and recovery.
  - Minimizes the wear and tear associated with mask clean.

Wafer Prints Between Cleans Determine Life Expectancy

- **A mask can not be cleaned forever.**
  - Currently 20 times
- **For a mask life of 25K wafers, we must keep it clean for an average of 1,250 wafer prints.**
  - Are we there yet?

If 20 Cleans	If 30 Cleans	Wafers/Mask
1,250	*830*	*25K*
2,500	*1,650*	*50K*

Average wafer output between 2 cleans required for expected mask life



Blank reflectivity change vs. number of cleans showing an EUV mask may be cleaned for 20 times. (Courtesy of Abbas Rastegar)

Need Reticle Storage Capability

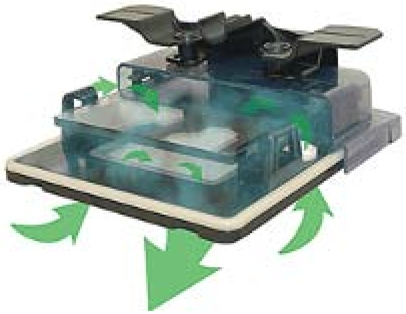
- **193nm**
  - Confirmed molecular contamination (or haze) leads to PID
  - Developed ultra clean dry air purging for mitigation
- **EUVL**
  - EUVL does not have enough volume yet for one to observe PID. But, similar problem should be anticipated.
  - Will need to develop purge capability.
  - Contamination is also partially addressed by carrier material selections, as 193nm did.
- **Unlike 193 which tolerates particles up to >>10um, EUV reticle storage/purge must be particle-free down to sizes comparable to the technology nodes (<20nm).**
  - Robust particle filtering capability required!

Technical Approaches

- **Vacuum storage**
  - In-tool/vacuum library
    - Good: minimized air-bone molecular contamination
    - Bad: limited vacuum space
- **Atmospheric storage**
  - Purging: ultra high purity N2 or air
    - Good: virtually no space constrains
    - Bad: need transfer before uses
  - Minimal requirement: no particles added
- **Where is a balance?**
  - Sufficient vacuum storage space for heavily used masks
    - How big is sufficient?
  - Atmospheric storage for the rests
- **May need to investigate if require additional molecular contamination protection during reticle shipment.**
  - Ru surface is active and may be contaminated in a few hours.

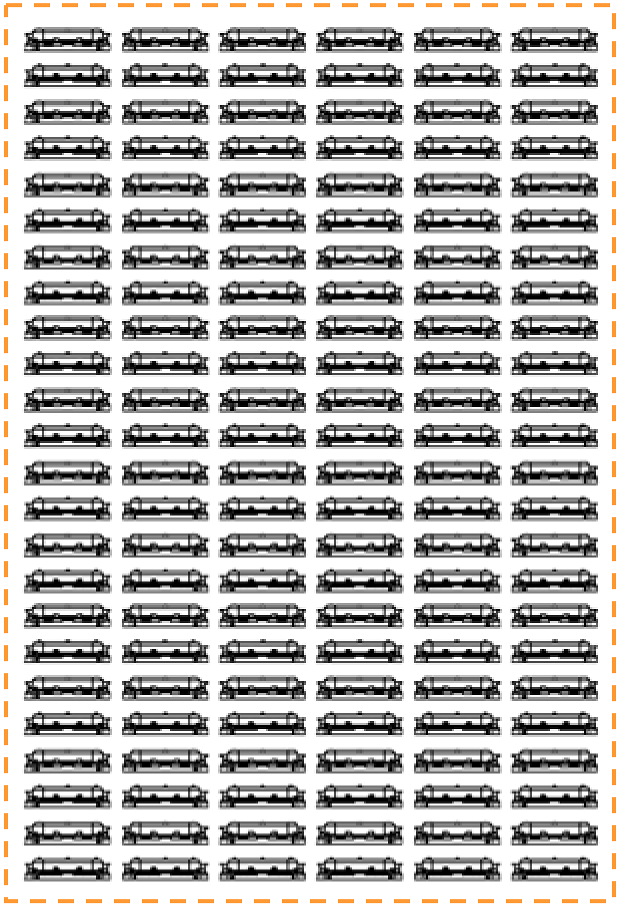
Atmospheric Storage

- **Need capability to keep masks *sufficiently clean* for 6 months.**
- **Capability has NOT been demonstrated.**



Reticle purging concept: constantly replace air around masks with clean gas (RSP150 in illustration)

Section of an engineering purge rack with EUV pods mounted



Concept of large storage/capacity *with purge capability*

During storage, masks remain in (complete) EUV-pod carrier which is quick-connected to the purging gas.

What Data Needed for Atmospheric Storage

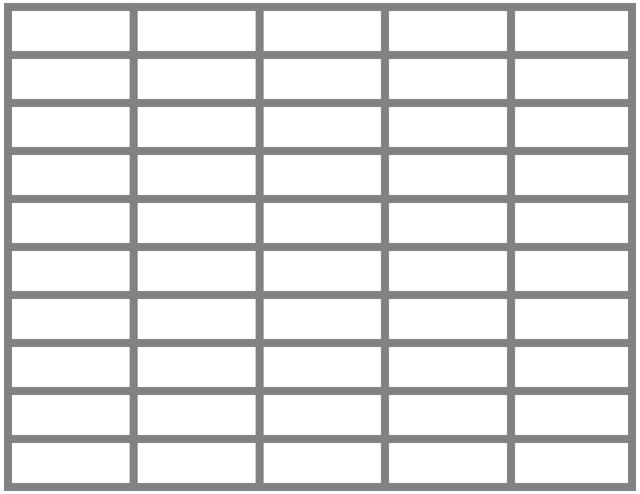
- **Surface contamination analyses, such as by TOFSIMS, IC, ICPMS, AES, etc...**
  - Surface contamination is always there. How much is too much?
  - Goal should be for the “lowest” detectable contaminations, since no data available to show where to draw a line.
- **Ultimately, the final tests will be wafer printing.**
  - Success criterion is no Photon Induced Defects (PID) can be detected.

Basic Requirements for Atmospheric Storage for HVM

Area	Requirement	Description	Must-have
Stocker	Standalone Stocker	Enclosed environment: ISO Class 1 or better	Yes
	Library type	Individual EUV pod	Yes
	Purging ports	E152-compliant (new revision at works)	Yes
	Purge capability	Flow gas through individual outer pod up to 5LPM	Yes
	Gas purity	Acceptable	Yes
	Gas exhaust	Depending on gas type	Yes
Purging	***Gas / flow rate***	***Develop purging processes***	
	Particle protection	No particle transported to mask	Yes
Automation	SECS/GEM	Automation standard compliance	Yes
	E152-compliant	Meet mechanical interface and weight standard	Yes
	Automated handling	Robot to store and retrieve EUV pod to / from stocker library	Yes
	Mask tracking	Indentify mask by RFID	Yes

Vacuum Storage

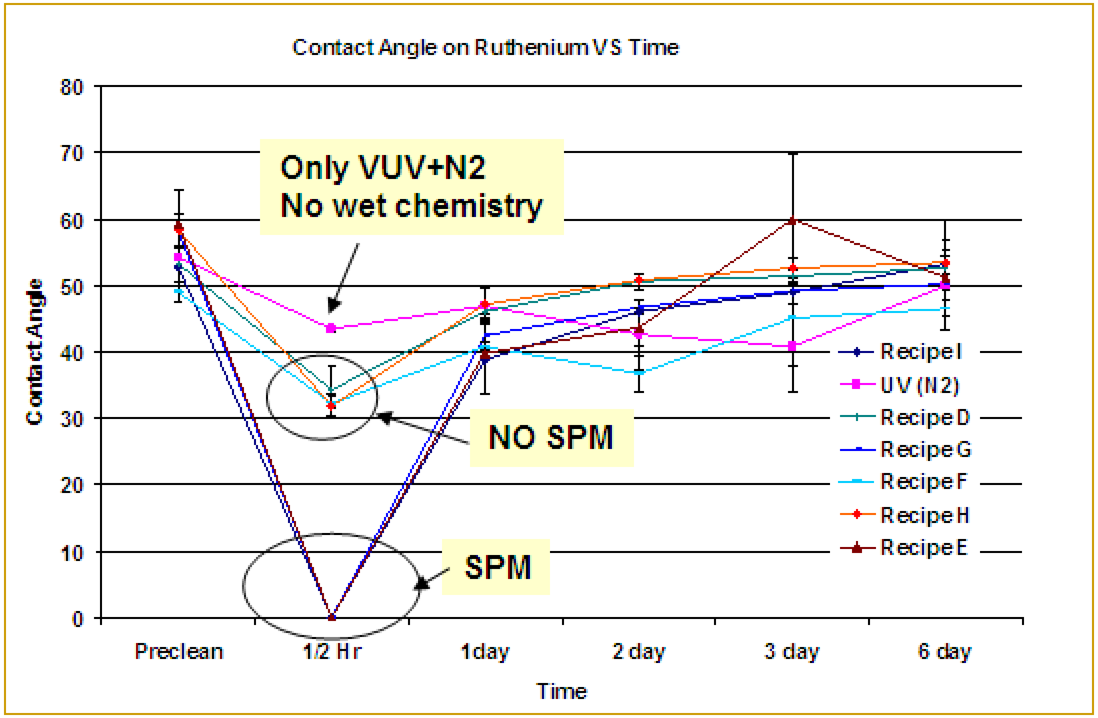
- **In-tool reticle library**
  - Reticle remains in inner pod when stored.
  - Each slot only holds one mask / inner pod.
- **How big should be the library capacity?**
  - Key question to ask is what's the primary function, storage or reticle que.
- **Stand alone vacuum storage system may have limited benefit.**
  - There is risk associated with additional reticle transfer out of vacuum.



Schematics of reticle library in vacuum. Each slot holds one inner pod (one mask).

Molecular Contamination During Shipping

- **Contact angle measurements indicate freshly cleaned Ru surfaces can be contaminated in <3 hrs when not protected.**
- **One obvious approach is to reduce the humidity of carrier ambient during shipping.**
- **Do we really need it?**



Only VUV+N2
No wet chemistry

NO SPM

SPM

Contact angle vs. time.
Note SPM (H2SO4/H2O2) is the most suitable chemistry for final clean
(Courtesy of Abbas Rastegar)
.

Survey on Storage

- **Do we need standalone vacuum storage?**
- **What purging gases do you think are more suitable for EUV mask?**

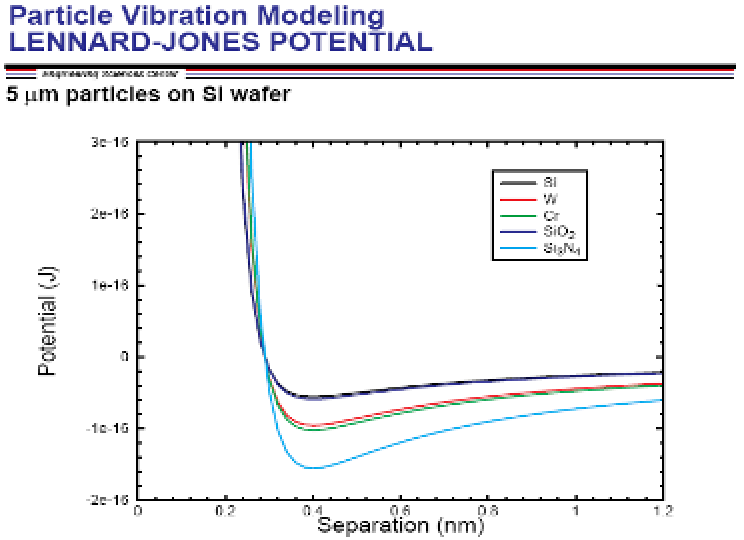
  For factors like protection efficiency, cost, safety, etc...
- **How long do you think storage capability should be targeted for, 1, 3 or 6 months?**
- **Do we need SECS/GEM capability for standalone stokers?**

In-situ E-chuck Cleaning

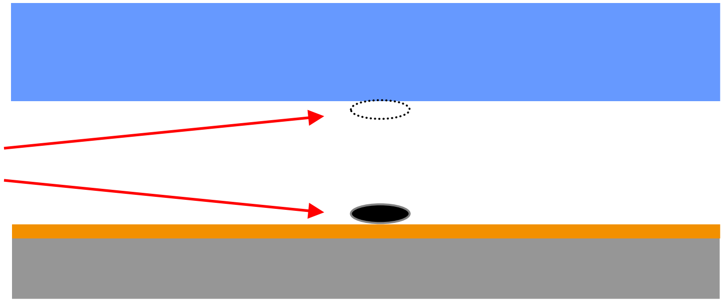
- **Exposure tool e-chucks will generate particles both on the backside of mask and themselves.**
  - No data available to show there is no particle generation.
  - Assume it's a matter of how soon there will be too many particles and must be cleaned.
- **How to clean it?**
  - Clean by breaking vacuum may take days. Can we afford it in HVM?
  - In-situ clean may be much quicker and cost effective. But how?

Concept for *in-situ* e-Chuck Clean

- **Concept:**
  - Contact, stick, and remove particle
- **Material requirements:**
  - “Stickier” to particle than e-chuck surface
  - Leave no residuals behead
  - Meet vacuum outgassing spec



To remove a particle, the bonding force between cleaning film and the particle must overcome bonding potentials



e-Chuck facing down

Particle removed

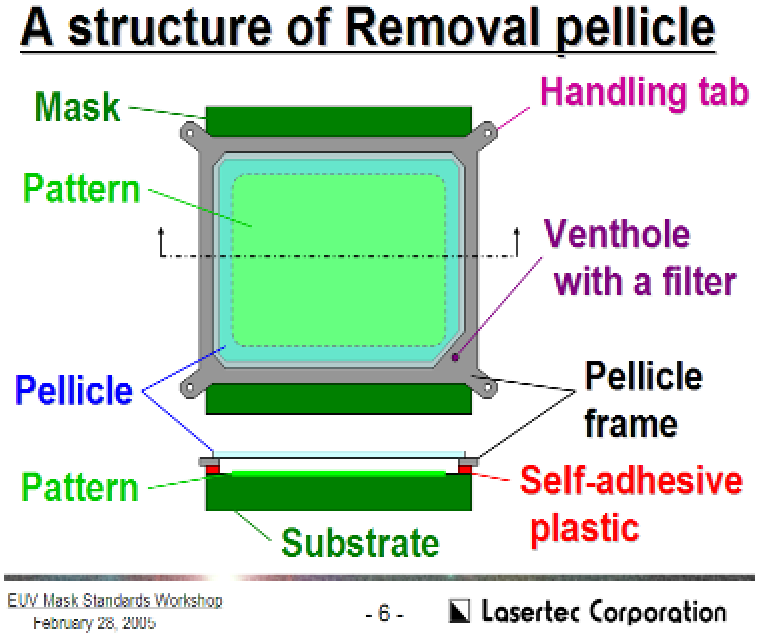
Cleaning film

Mask substrate

Concept to remove a particle from chuck surface by mechanically contacting the chuck/particle

Material Holds the Key

- **Material development needs broad collaboration.**
- **Possible materials:**
  - Performance elastomer families, such as DuPont’s Kalrez
  - Undisclosed material that Lasertec once studied for removable pellicle
  - Variations of them


A structure of Removal pellicle

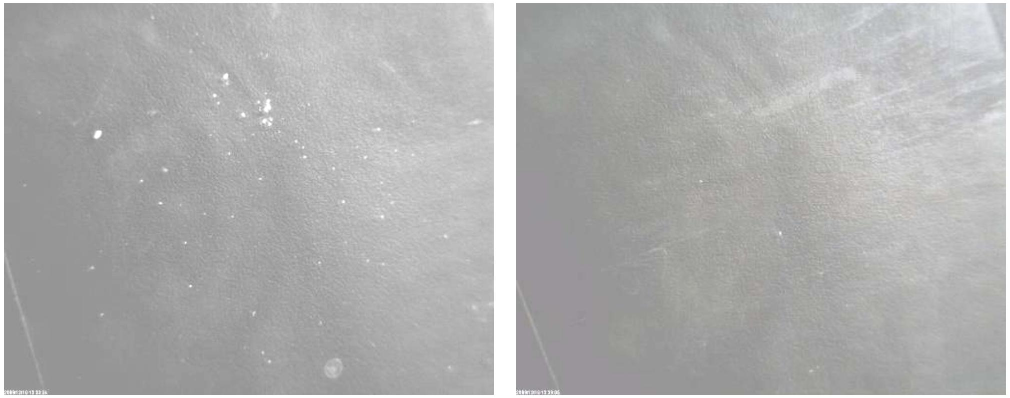
EUV Mask Standards Workshop
February 28, 2005
- 6 -
Lasertec Corporation

Lasertec studied a un-disclosed adhesive film for removable hard pellicle. It could be a material option for chuck clean.

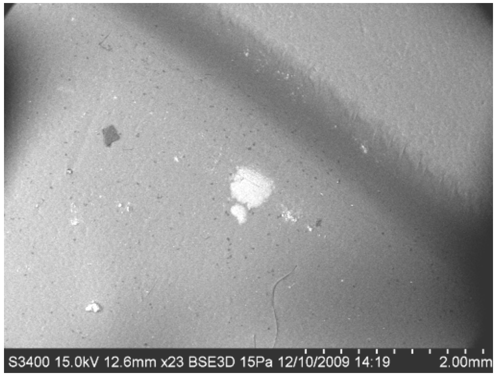
Kalrez® perfluoroelastomer parts
A Product of DuPont Dow Elastomers

Chemical Resistance and Fluid Compatibility, Including All Chemicals Under the Clean Air Act

Feasibility Demo: Alumina Particle Removal from Glass by Contacting



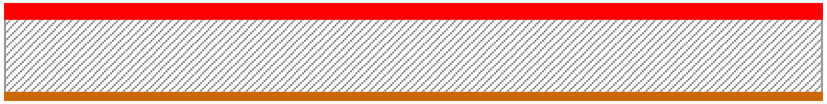
Microscopic pictures of glass with micron size alumina particles (right), and after one contact with an elastomer (far right)



SEM picture of the elastomer surface showing alumina particles from glass surface. Compositions were verified with EDX.

How to Turn Feasibility to *in-situ* e-chuck Clean

- **Challenges:**
  - Develop a suitable elastomer
    - Stickier" than e-chuck surface
    - Leave no residuals behead
    - Meet vacuum outgassing spec
  - Develop bonding technology to attach elastomer to substrate
    - Low outgassing
- **Other requirements**
  - Comply with P37 standard:
    - Size: 152.0 ± 0.1 mm
    - Thickness: 6.35 ± 0.10 mm
  - Backside coating identical to mask
  - Overall surface P/V variation is in the order of a few microns.
  - Plate can be re-cleaned.
  - Plate can be handled with EUV-pod exactly the same way as a mask.



Chuck cleaning plate. From bottom to top are backside coating, mask substrate, and a topping elastomer.

Survey on *in-situ* Clean

- **Is there conclusive data to show mask backside contamination is not an issue?**
- **What are the main sources for mask backside contamination?**
  - Through physical contact with gripper, pod, chuck?
  - Environmental: particles generated somewhere, but transported to mask?
- **Should chuck contribute to backside contamination, what are the options to mitigate risk?**
- **What could be better alternatives than in-situ chuck clean?**

Survey on ESD

- **Do you think there will be significant ESD issues?**
- **Do you think reticle purging will increase the odds for electrostatic discharge (ESD)?**
  - Any indication on 193 masks?
- **If yes, what are the mitigation options do you think we should investigate?**

In Summary: Top Three Focuses

1.
2.
3.