Overview of SEMI Standards for EUV Masks

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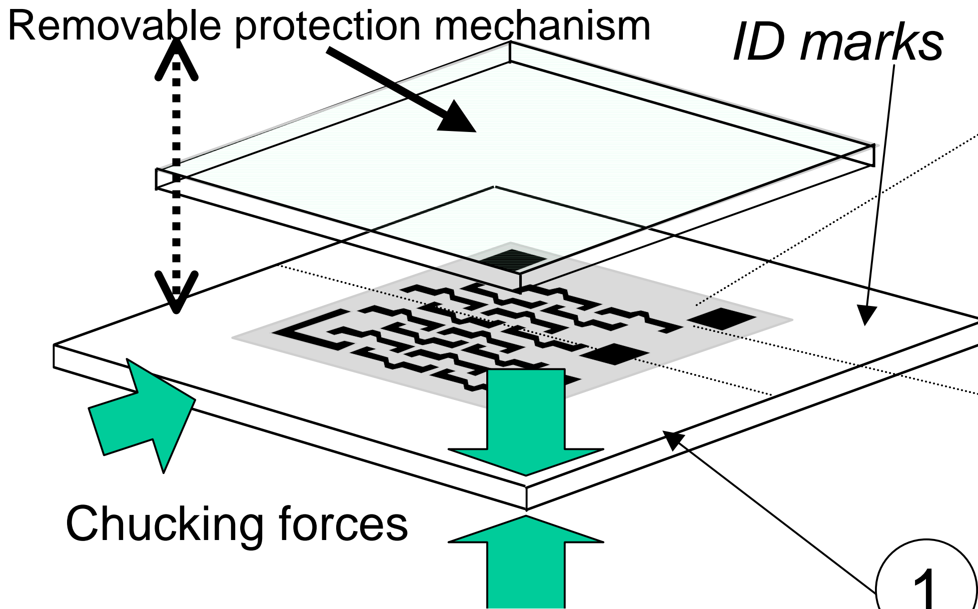
EUVL mask standards

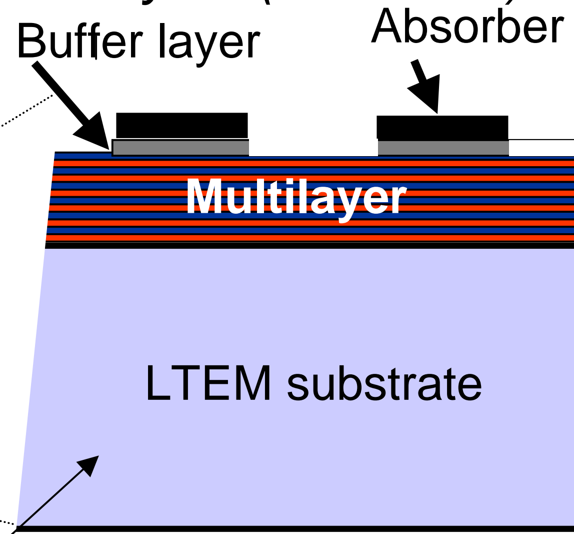
4 *Storage container and attributes of removable protection mechanism (3553)*

Future focus on RSP150 format
White paper being prepared for Global PIC Committee

3 1st revision published as P38-1103

Multilayer coating material, absorber and buffer layers (P38-1103)





Cross-section of EUVL mask

1 *Mask substrate (P37-1102)*

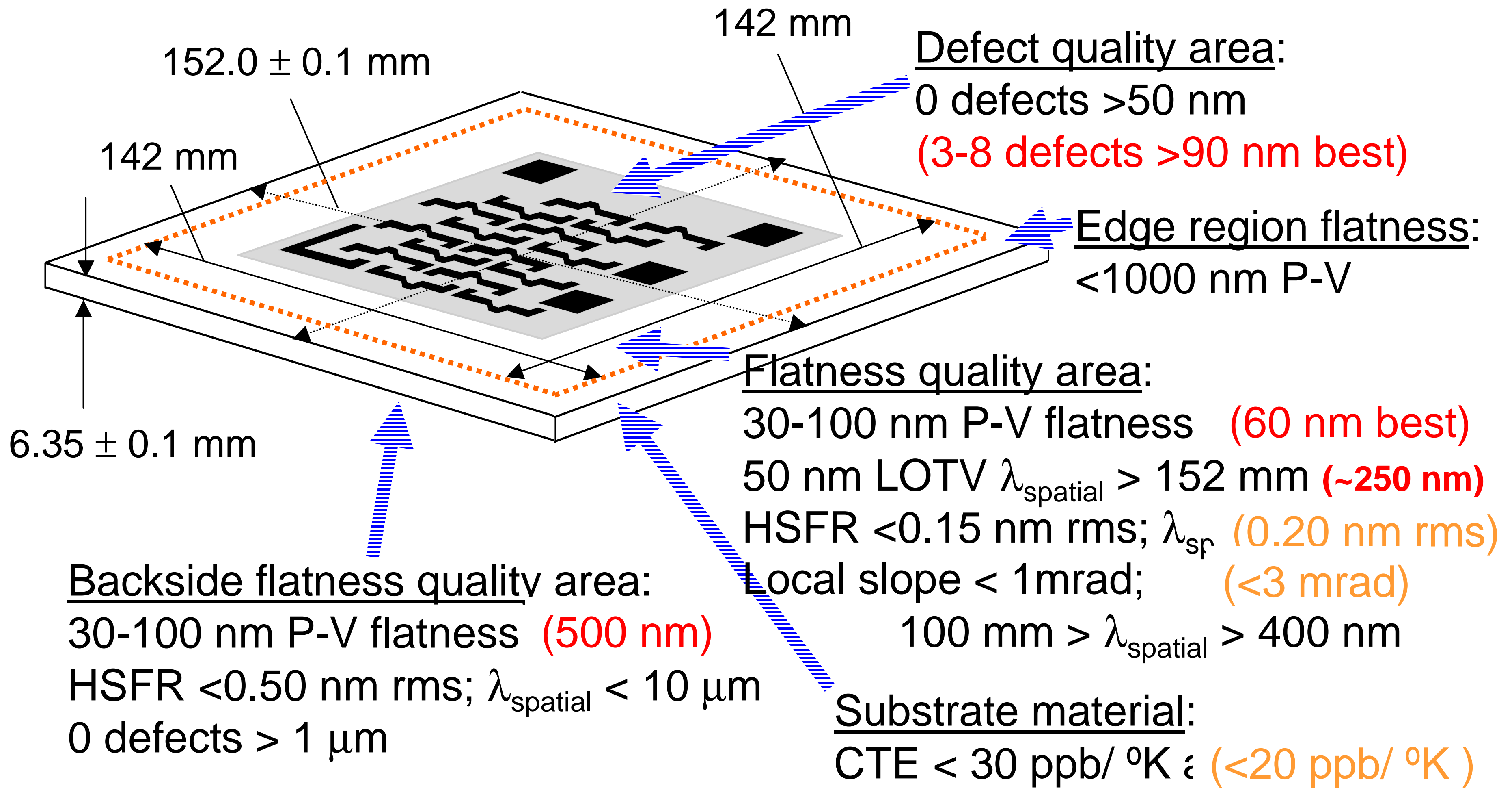
Revisions are proposed for balloting in mid-2004

2 *Chucking in processing and exposure tools, location of ID and alignment marks (P40-1103)*

Standard published as P40-1103

5 *Automated mask order entry for EUV masks (P10)*

Photomask as EUVL mask form factor takes advantage of existing mask infrastructure

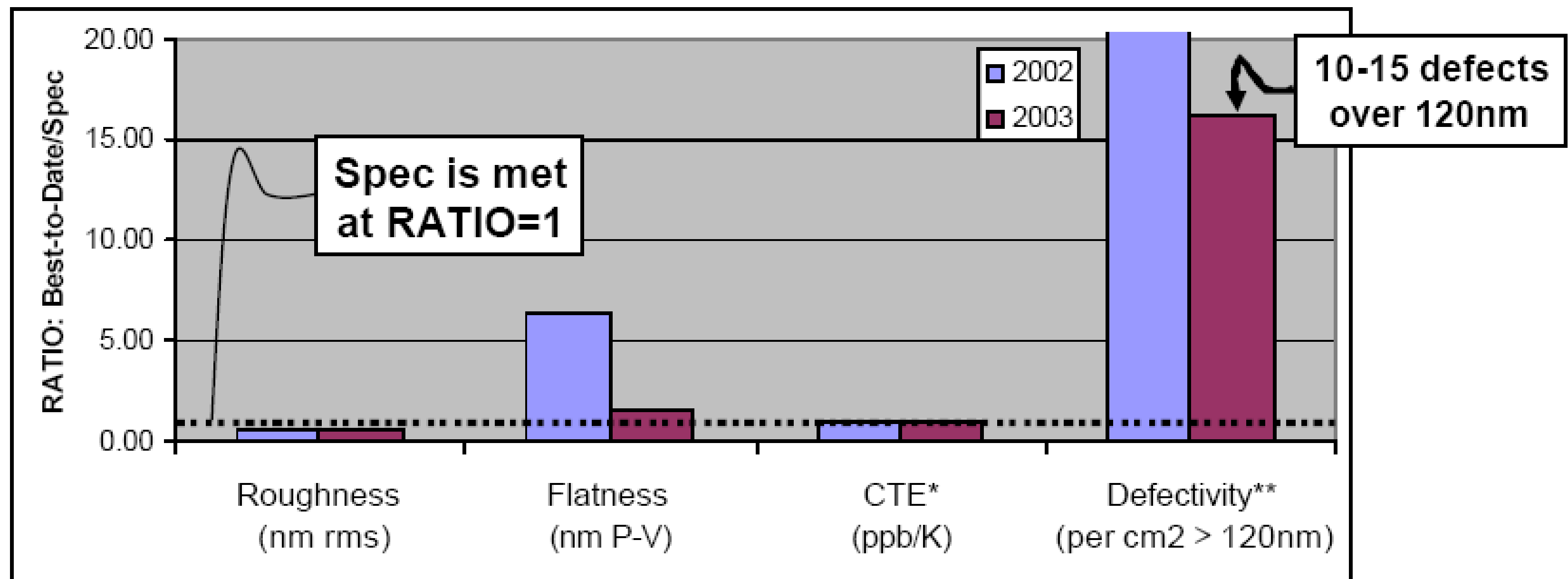


SEMI standard P37-1102

Note: Items in parentheses are approximate capability demonstrated to date, but they are not necessarily obtained on the same mask substrate

Summary: Supplier best data is within 1.5x of target - except defectivity

Comparison of supplier "best to date" capability to specs (P-37 and P-38):



Summary

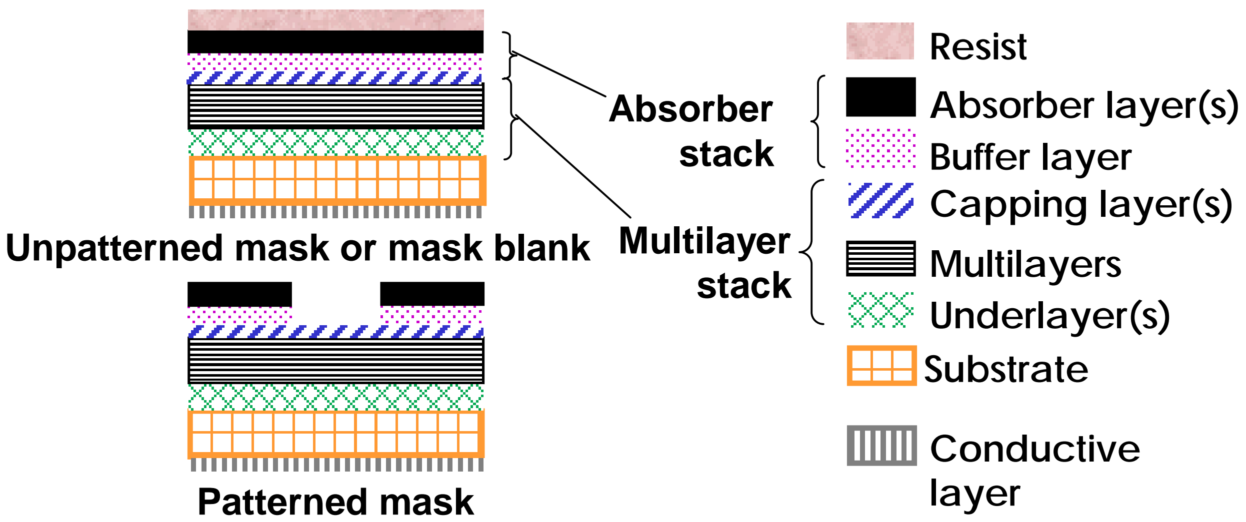
- Roughness, flatness and CTE capability have been demonstrated separately within 1.5X of specification
- Roughness, flatness, and defectivity not yet available simultaneously.

(Results are best-to-date over all suppliers, from different substrates for all categories)
(*CTE for ULE measured indirectly, through strong correlation to refractive index: Hrdina KE, *Proc. SPIE*, vol.5037, 2003, pp.227-35.)
(**Specification is for >25-60nm size; inspection capability is >120nm)
(**Specification is zero defects; unofficially 1/blank =0.008cm² usually tolerable)

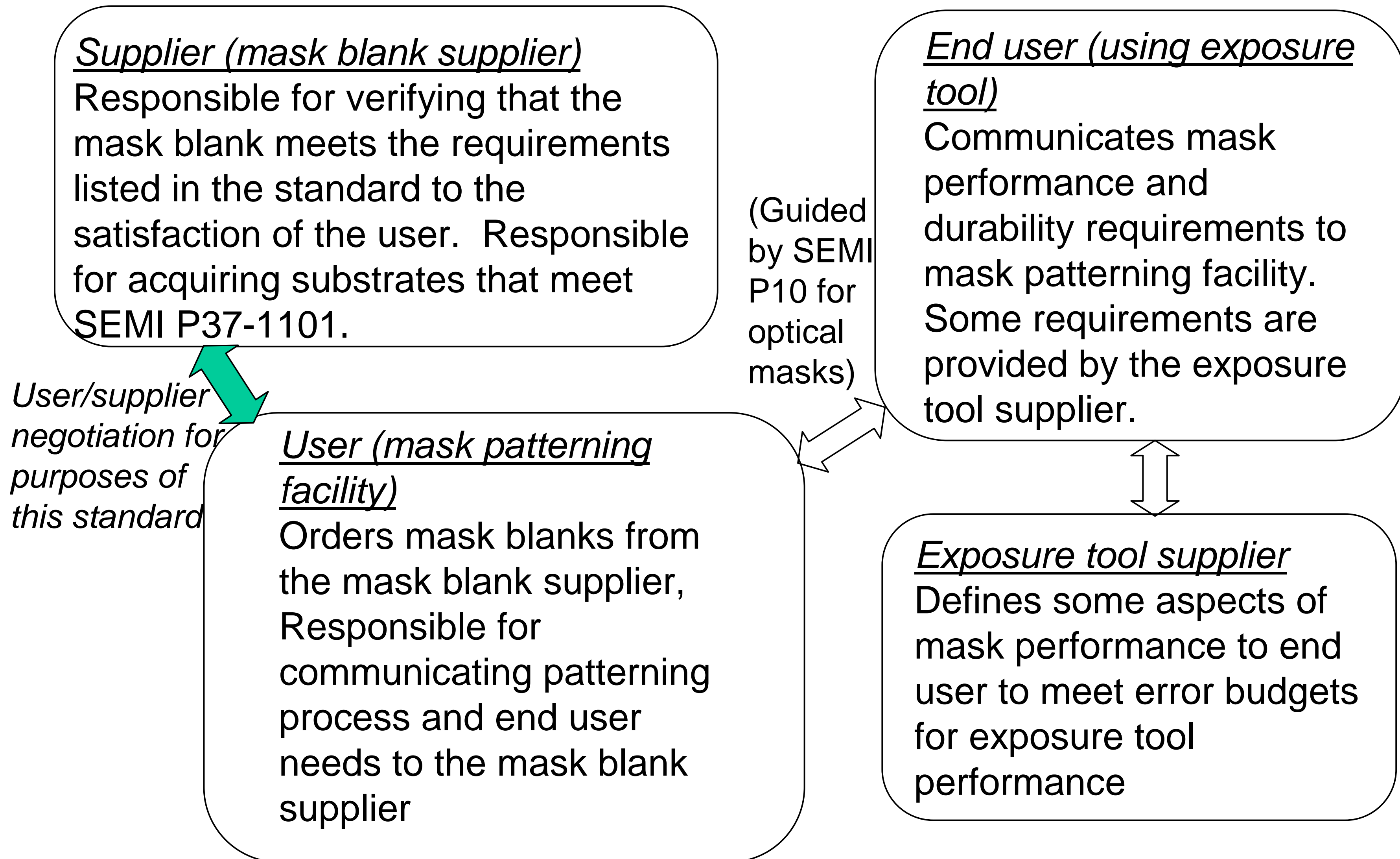
2

P38-1103: Mask absorber and multilayer standard

- Lists all parameters of the *mask blank coatings* that user and supplier need to define for mask performance, including patterning requirements
  – Standard allows for many parameters to be negotiated between user and supplier, thus allowing for innovation in material choice.
  - Allows for capping layers, conductive films, absorber layers, etc.
- Standard lists requirements for mask absorbers and multilayers through the 22-nm half pitch ITRS node



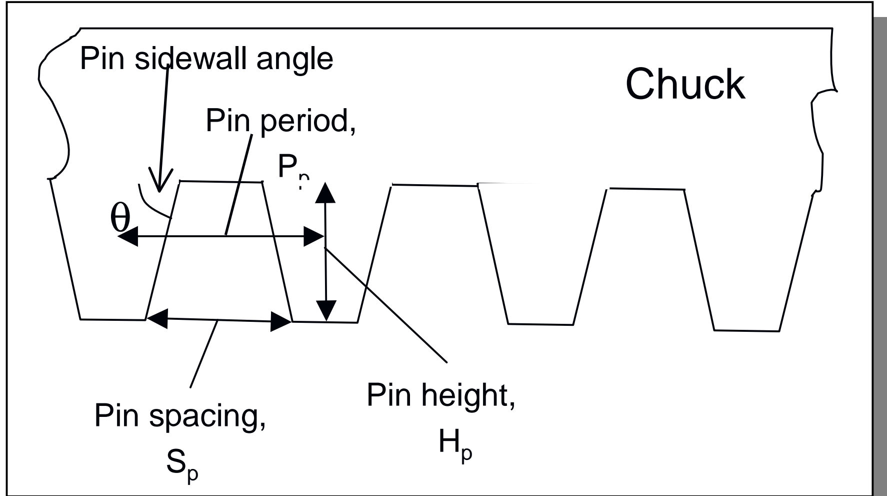
Relationship model for SEMI P-38

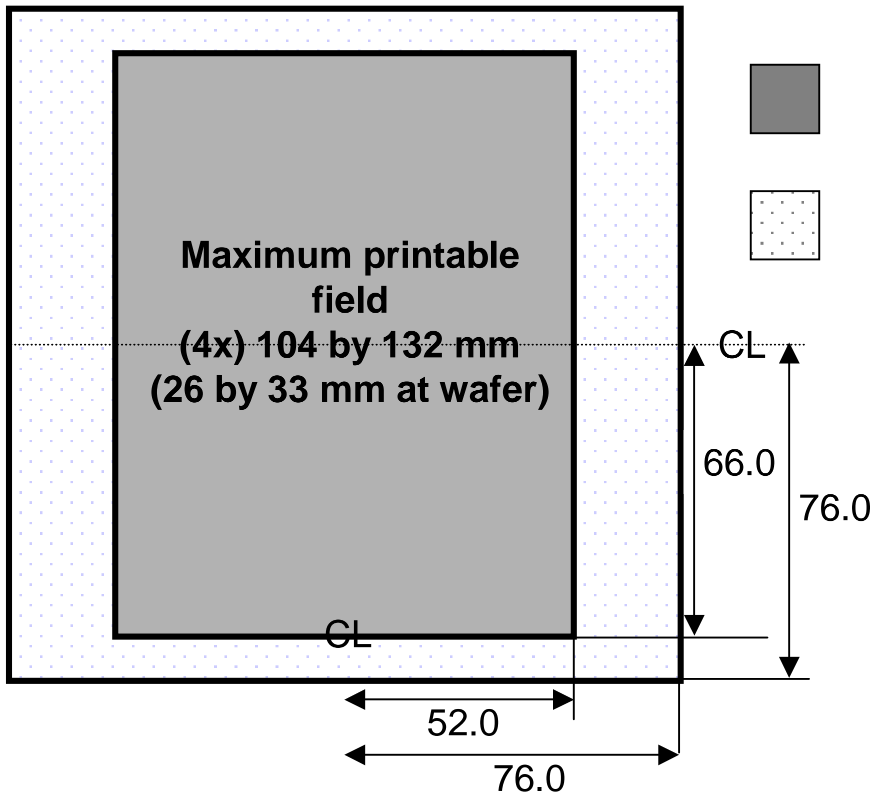


③

P40-1103: Mounting (Chucking) Standard

- **Three rules adopted for mounting**
  - **Chuck flatness (~50 nm P-V)**
  - **Clamping pressure (15±1.5 KPa)**
  - **Chuck stiffness (>30,000 N-m)**
- **Minimum pin spacing >10mm**
- **Initial layout specified**





Area for patterns printed on wafer

Area reserved for alignment marks, ID marks, and handling (The position of these items are to be negotiated between user and supplier.)

Rationale for chucking standard

- Standard for chucking in:
  - Pattern generator (e-beam or optical)
  - Pattern placement metrology tool
  - Exposure tool
- Without compensation, large pattern placement errors relative to ≤45-nm node requirements will occur
- Compensation for these errors will be difficult.
  - Residual error from calculated compensations remains due to errors in measurement of deformation
  - Compensation methods would need to measure the shape of both sides of the mask and predict the position of front surface points after clamping on a flat chuck
- Provides for further reduction of overlay error terms:
  - Reduces placement error term due to stress in absorber stack and due to stress relaxation of multilayer stack
  - Reduces impact of backside flatness errors on pattern placement
    - LOTV requirement remains but errors could be compensated by height mapping on standard mount

4

Document 3553: Storage box standardization

- Components to be considered for 3553
  - Outgassing requirements
  - Holding in box
  - Particle protection
- SEMI EUV Mask Task Force decided at SEMICON/West to pursue amending an existing standard (E111) to include EUV requirements
  - Allows focus on performance requirements rather than form factor.
  - Global PIC Committee agreed to serve as review committee for 3553
  - White paper being prepared

5

SEMI P-10 for EUV Masks

- What is SEMI P-10?
  - “Specification Of Data Structures For Photomask Orders”
  - A precisely defined syntax for transferring mask data between mask customer and mask suppliers
- Mask order structure <EUV Mask Blank Type> included in SEMI Cycle 1 ballot 3863 (voting closes 2/25/2004)

EUV_BLANK_TYPE (1, 2, or 3)
EUV FLATNESS FRONT
EUV FLATNESS BACK
INSPECTION_AREA (x1,y1,x2,y2)
EUV MULTILAYER COMPOSITION
EUV CAPPING COMPOSITION
EUV MMR WAVELENGTH
EUV MEAN PEAK REFLECTIVITY
EUV PEAK REFLECTIVITY UNIFORMITY
EUV ABSORBER COMPOSITION
EUV ABSORBER OPTICAL PROPERTIES
EUV BLANK RESISTANCE
EUV EXPANSION COEFF

Proposed updates to SEMI P-37

- Change order of classes for flatness
- Review and modify spatial frequency requirements on flatness
- Relax dimensional tolerances somewhat
  - *Status: awaiting proposed mask storage and handling standard which might be affected by dimensional tolerances*
- Review datum locations and use
  - Films added to substrate might affect the use of the datum surfaces
  - Datum approach intended to avoid the use of physical marks
- Include fiducial marks on the front of the substrate to aid in defect location registration
  - Data matrix marks might be used

Possible revisions of SEMI P37-1102 (cont.)

- Change CTE specification to use ASTM E228-95 standard definition of mean CTE (proposed by Corning)
  - Check whether slope of CTE with temperature needs to specified
  - Specify maximum temperature of substrate during fabrication of mask or its use
- Modify specification on local slope and HSFR as follows:
  (see proposal made by Eric Gullikson at 2003 EUV Sympsoium)
  - Reduce the frequency range on the HSFR specification to:
    $4 < f < 20$ mm^{-1} (no smoothing) or
    $4 < f < 10$ mm^{-1} (typical for ion beam deposition).*
  - Adopt an RMS slope specification for frequencies < 3.5 mm^{-1}.

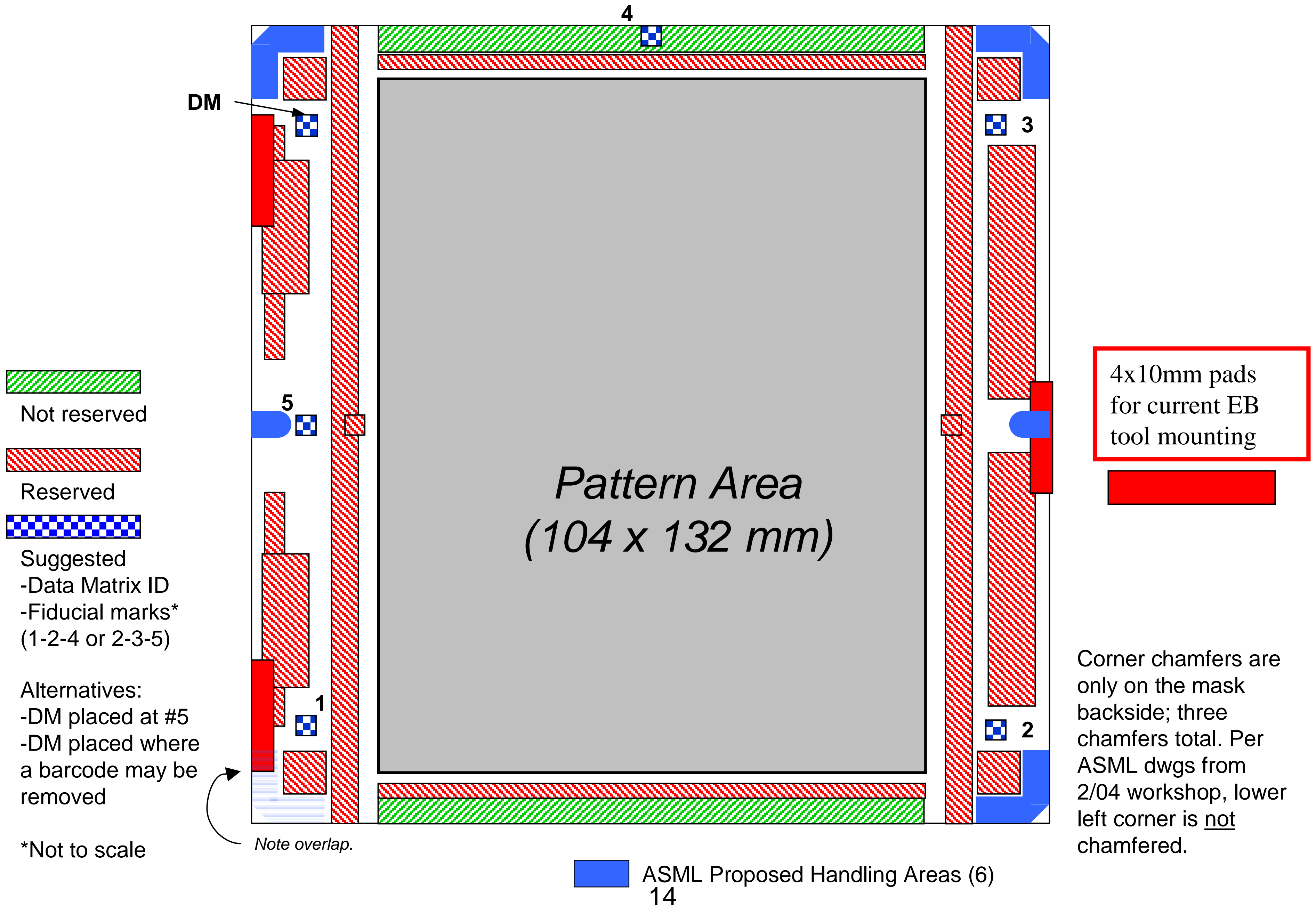
Mask Error	Tolerance	Frequency Range (μm^{-1})
Flatness	50 nm P-V	Legendre mode spec. TBD
Slope (low)	0.5 mrad rms	$0.001 < f < 0.4$
Slope (high)	0.4 mrad rms	$0.4 < f < 4$
HSFR*	0.15 nm	$4 < f < 20$

* Ultimately could be decided between substrate and coating vendors.

Proposed updates to SEMI P-40

- Increase detail in required layout to include areas for handling
  - Need to reach consensus on regions for handling
- Increase clamping pressure requirement to 30 kPa
  - A higher clamping pressure be considered, but the ability to implement an appropriate chuck needs to be determined.
- Pin/pedestal form factor and layout may be specified in more detail
- Improve Figure 5 chuck drawing and labeling
- Add flatness metrology tool to list of tools where standard applies
- Consider removing scope Section 2.1.1 since it is redundant with section 6.5

EUV Mask Layout (area reservations for exposure tools, some writers) (work in progress)



EUV Mask Backside Layout

- - - Quality Area
(142 x 142 mm)

Backup

Discussion of SEMI P40-1103

SPECIFICATION FOR MOUNTING REQUIREMENTS AND ALIGNMENT REFERENCE LOCATIONS FOR EXTREME ULTRAVIOLET LITHOGRAPHY MASKS

Proposed future technical changes to P-40 (1)

- **Increase clamping pressure requirement**
  - **Table 2**
    “The mean clamping pressure, 151.5, seems to be decided based on a throughput 80WPH. If target throughput is 100WPH or 120WPH, the acceleration of reticle stage increases in proportion to (Throughput)^2. Therefore, the clamping pressure requirement should be increased, e.g. 303.0. However, the spatial frequency response of mask bending will become higher, and this will amplify IPD.”
    - **A higher clamping pressure be considered, but the ability to implement an appropriate chuck needs to be determined.**

Proposed future technical changes to P-40 (2)

- Pin/pedestal form factor and layout may be specified in more detail
  - *section 4.2.2 -- should there be mention that pins or pedestals are assumed to be radially or axially symmetric? I can't see that anyone would want to make a pin where the point isn't aligned with the center of the pin base, but it's a possibility.*
  - *section 7.4 -- is there need for a pin layout style parameter? There's nothing that says the pins/pedestals must be laid out in a basic Cartesian matrix, or a hexagonal, or whatever; nor should this be specified within the standard. But including it as something to be specified between supplier & user may be helpful.*
- Improvements to chuck drawing and labeling
  - *Figure 5 -- would this benefit from having a note as to how this cross-section is cut? Along a closest-pin axis, to minimize pin spacing Sp? Also the arrow indicating Hp should have a dotted plane reference at the top.*

Proposed future technical changes to P-40 (3)

- **Add flatness metrology tool to list of tools where standard applies**
  - **Sections 2.1.1 and 6.5 – The flatness metrology tool is one of key the tools to provide a flatness result. The mounting requirements should apply to it as well beside exposure tool, pattern generator and pattern placement metrology tool.**
    - ***Suggestion:* Add the flatness metrology tool along with other 3 tools in the sections.**
- **Clarification**
  - **Consider removing scope Section 2.1.1 since it is redundant with section 6.5 and the information in section 2.1.1 only applies to Section 6.**
- **Increase detail in required layout to include areas for handling**
  - **Need to reach consensus on regions for handling**

Discussion of SEMI P38-1102

SPECIFICATION FOR ABSORBING FILM STACKS and MULTILAYERS ON EXTREME ULTRAVIOLET LITHOGRAPHY MASK BLANKS

Proposed future technical changes to P-38 (2)

“Table 12: Editorial; usability of standard would be better if sheet resistance defined in Section 7.5 would be included in Table 12.”

- **The sheet resistance was removed from Table 12 to allow for the possibility of a conductive substrate material.**
- **Propose that the conductive layer is made optional in the text of Section of 7.5 and that sheet resistance is included in the text as stated and also in Table 12.**

- ***section 14.1 -- if this is an international document, should "state laws" be revised, either to "regional" or the more cumbersome "state, province, district, prefecture, <insert geopolitical unit here>" ? Not every nation uses states.***
- **section 6.2 – delete the reference to section 9.1 of SEMI P37-1101.**
- **Specify the tolerance for the angle of measurement in Section 12.2.2.**
- **“Table 5: Ambiguity for Mean Peak Reflectivity equal to 63% and 65%**
  - **The values in the table represent a range of values. Should this be clarified?**
  - **Propose that the ambiguity be clarified by giving exact value to higher class**
- **section 12.2 -- change "exceptions" to "restrictions".**

Comments that didn't result in proposed editorial changes

- **"The quality area being agreed to between supplier and user should have a not to exceed size specified for example 132mm by 132mm."**
  - **The layer quality area may need to be varied depending on the deposition conditions for the layers and or multilayers.**
  - **The region outside of 132 by 132 mm may need to have specified properties for alignment marks and ID marks.**
  - **Propose that no change is made until a layout (Figure 1 of draft 3419 on chucking) is accepted in a future ballot**

Discussion of SEMI P37-1102

SPECIFICATION FOR EXTREME ULTRAVIOLET LITHOGRAPHY MASK SUBSTRATES

Possible revisions of SEMI P37-1102

- Change order of classes for flatness

  D 30 nm, C 50 nm, B 75 nm, A 100 nm

  In standard P37-1102 in reverse order to allow more aggressive values if needed

  Other class values are not in reverse order. Make class order consistent.

- Review and modify spatial frequency requirements on flatness
  - Consider allowing for free form flatness errors of mask substrate in addition to wedge and thickness variation.
    - Free form flatness error = (front + back – wedge) / 2
    - A proposal to use a basis set such as Legendre polynomials to characterize free form flatness errors will be considered.

Possible revisions of SEMI P37-1102 (cont.)

- Relax dimensional tolerances somewhat
  - Increase tolerance on edge length to 0.2 mm from 0.1 mm
  - Increase squareness from 0.01/25.4 to 0.04/25.4
  - Relax tolerances on rounded edge or camfer dimensions by ~2X
  - Change the locations where the notch is dimensioned
  - *Status: awaiting proposed mask storage and handling standard which might be affected by dimensional tolerances*
- Review datum locations and use
  - Films added to substrate might affect the use of the datum surfaces
  - Datum approach intended to avoid the use of physical marks
- Include fiducial marks on the front of the substrate to aid in defect location registration
  - Proposed location is near the edge with ~0.5 micron depth
  - Laser marks might cause chipping or serve as a location for defects to cluster
  - *Status: need experimental data on defects caused by marks (if any)*
See presentation by Jim Folta. So far, no convincing data is available that adding etched ID marks increases defect levels, but no data is yet available for etching marks into a glass EUV mask substrate.
  - *Incorporate learning from draft 3133 in the SEMI Traceability Committee*

Possible revisions of SEMI P37-1102 (cont.)

- Change CTE specification to use ASTM E228-95 standard definition of mean CTE (see Corning presentation)
  - Check whether slope of CTE with temperature needs to specified
  - Specify maximum temperature of substrate during fabrication of mask or its use
- Modify specification on local slope and HSFR as follows: *(to be updated by Eric Gullikson)*
  - Reduce the frequency range on the HSFR specification to:
    $4 < f < 20$ mm^{-1} (no smoothing) or
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HSFR*	0.15 nm	$4 < f < 20$

* Ultimately could be decided between substrate and coating vendors.

Summary of SEMI EUV Mask Task Force on July 14, 2003

- 24 attendees representing 15 companies or organizations signed in.
- Proposed changes to SEMI P37-1102 for EUV mask substrates were reviewed.
  - Significant changes to CTE definition, flatness requirements, and roughness requirements are anticipated. Defect registration fiducial marks may be added.
  - Targeting a ballot to further revise P37 after 3419 is accepted, so that flatness modes can be added to P37.
- Ballot results on SEMI draft 3688 (revision of P38-1102) for EUV mask blanks were reviewed.
  - One negative may be withdrawn,
  - Many editorial suggestions should be implemented if the standard is updated.
- Ballot results on SEMI draft 3419 (mask mounting) for EUV masks were reviewed.
  - The ballot was clean, but many editorial suggestions should be adopted.
  - Future updates might include pin location, pin shape, increasing clamping pressure requirements, and a revised layout with exclusion zones for handling.
- The blue ballot results for 3553 on mask carriers were reviewed.
  - The committee participants voted to focus on the RSP-150 format rather than the RSP-200 format for the carrier.
  - A poll of the PIC and Microlithography voting members will be taken to verify this choice.
  - A revision to E-111 will be pursued to accommodate EUV carrier requirements, and balloting will be undertaken by the PIC committee.

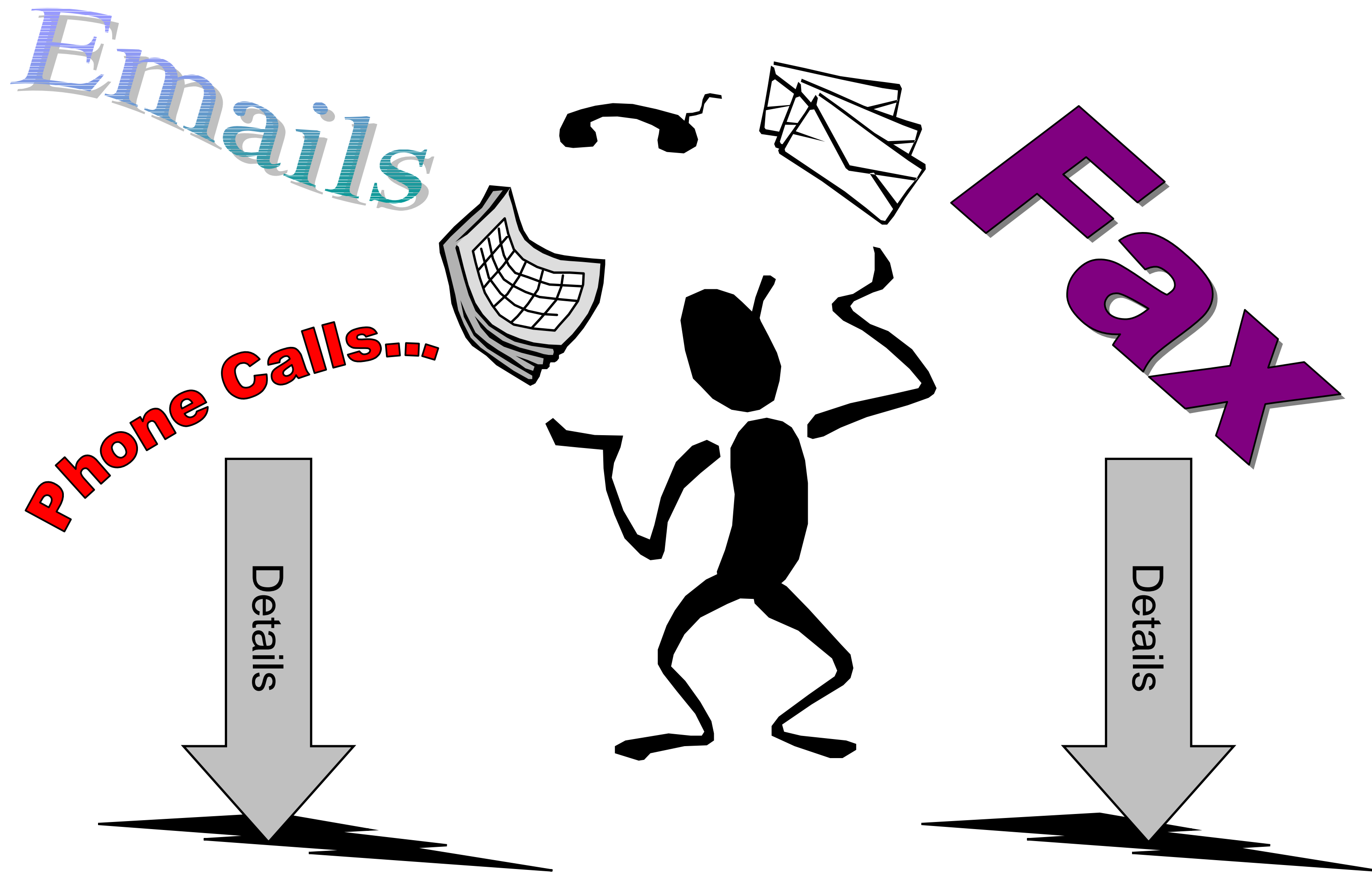
Proposed Modifications to SEMI P-10 for EUV Masks

Scott Hector

ISMT/Motorola

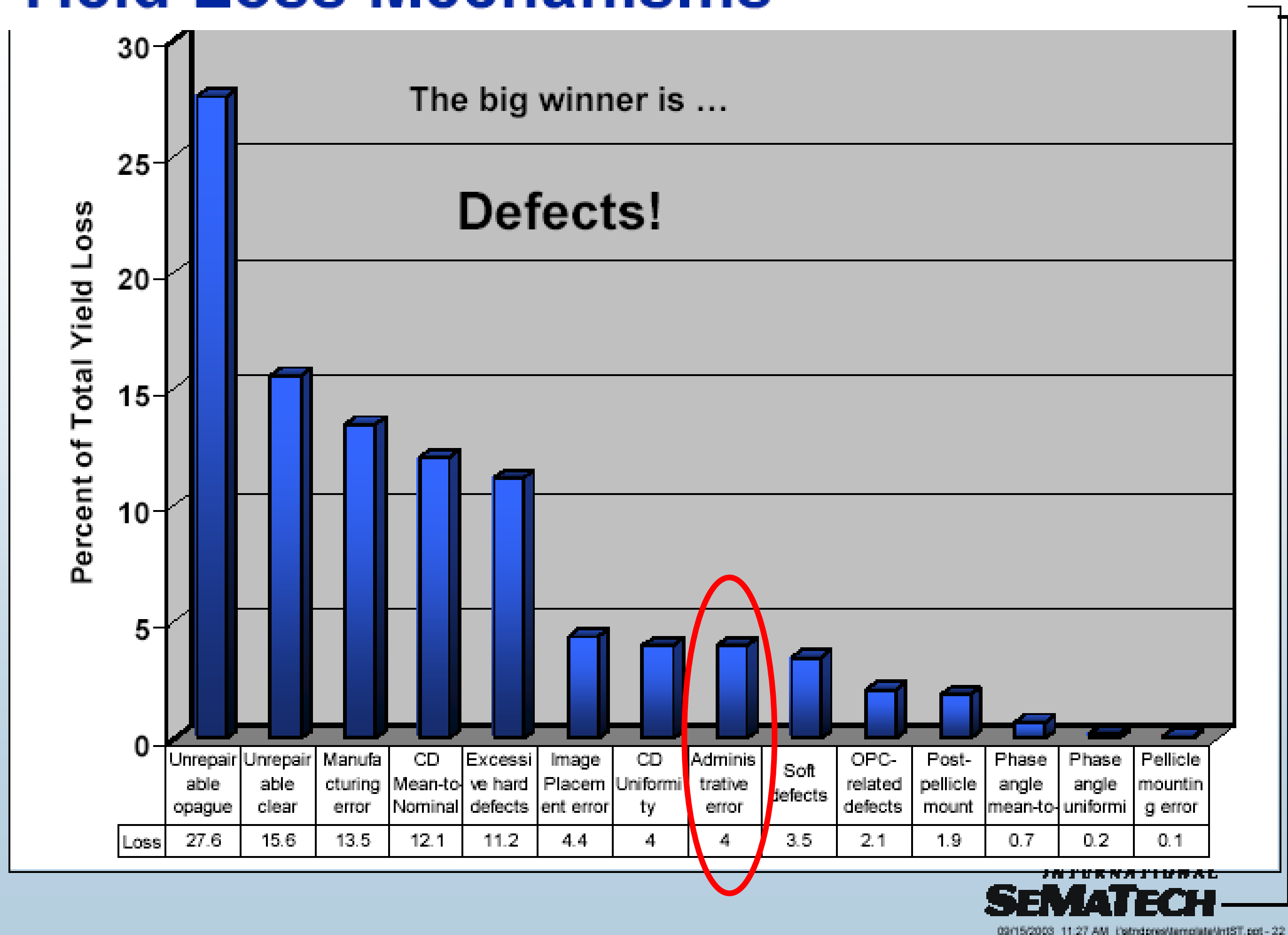
Chairman of SEMI EUV Mask Task Force

Current Ordering Methods



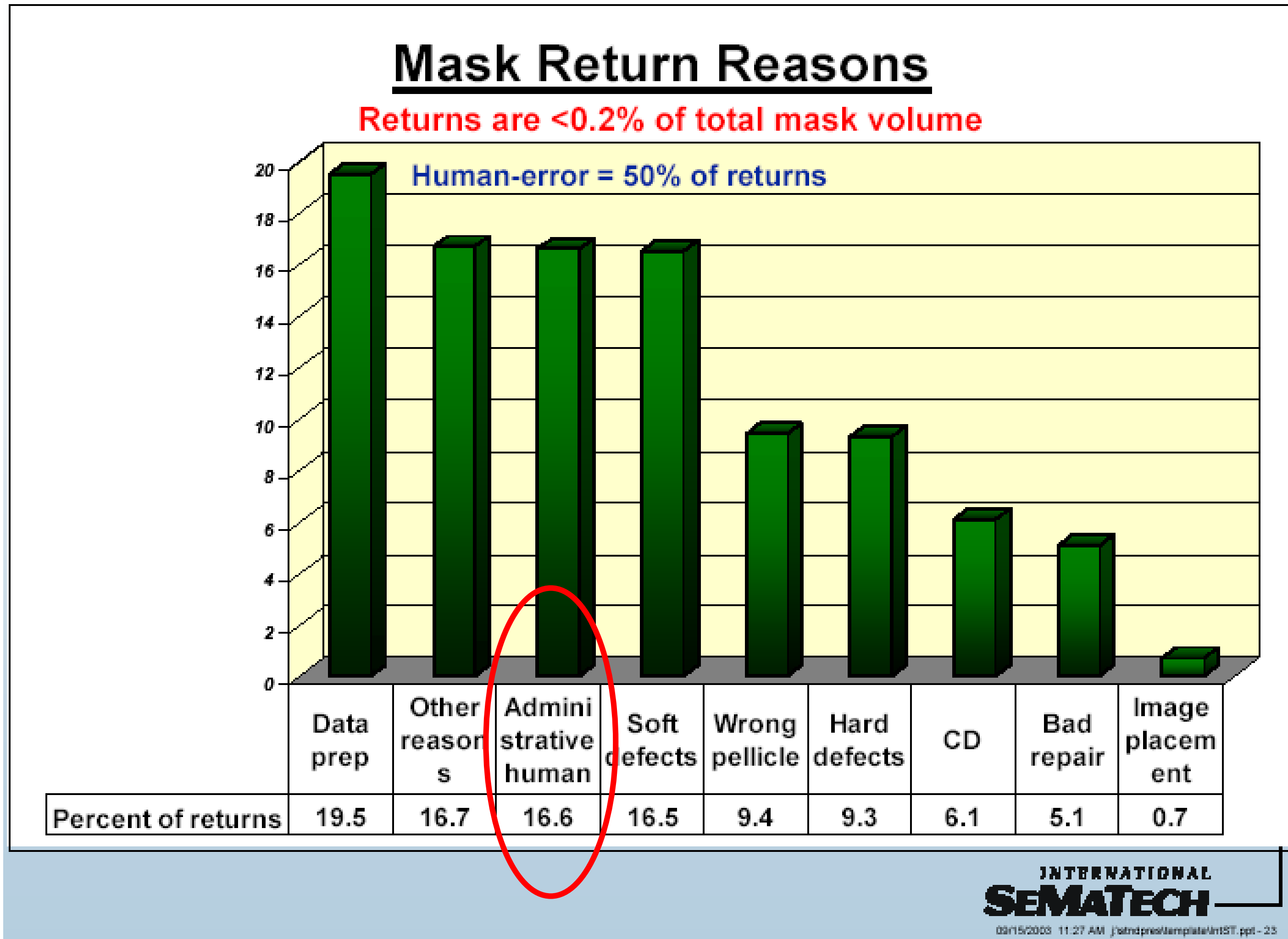
Courtesy of Wes Erck and Harold Patterson, July 2003

Administrative errors account for 4% of mask yield loss



From: Kurt Kimmel, "Mask Industry Assessment 2003," SPIE Symposium on Photomask Technology, BACUS 2003

Reason For Returns



From: Kurt Kimmel, “Mask Industry Assessment 2003,” SPIE Symposium on Photomask Technology, BACUS 2003

What is SEMI P10?

- “Specification Of Data Structures For Photomask Orders”
- A precisely defined syntax for transferring mask data between mask customer and mask suppliers
  - Two structures
    - Mask orders (customer to supplier)
    - Mask results (status and measurements from supplier to customer)
  - Specific limitations and conventions
  - Specifically defined terminology
    - Currently 613 distinct keywords
  - Examples of P10 order files

Typical Reticle Order System

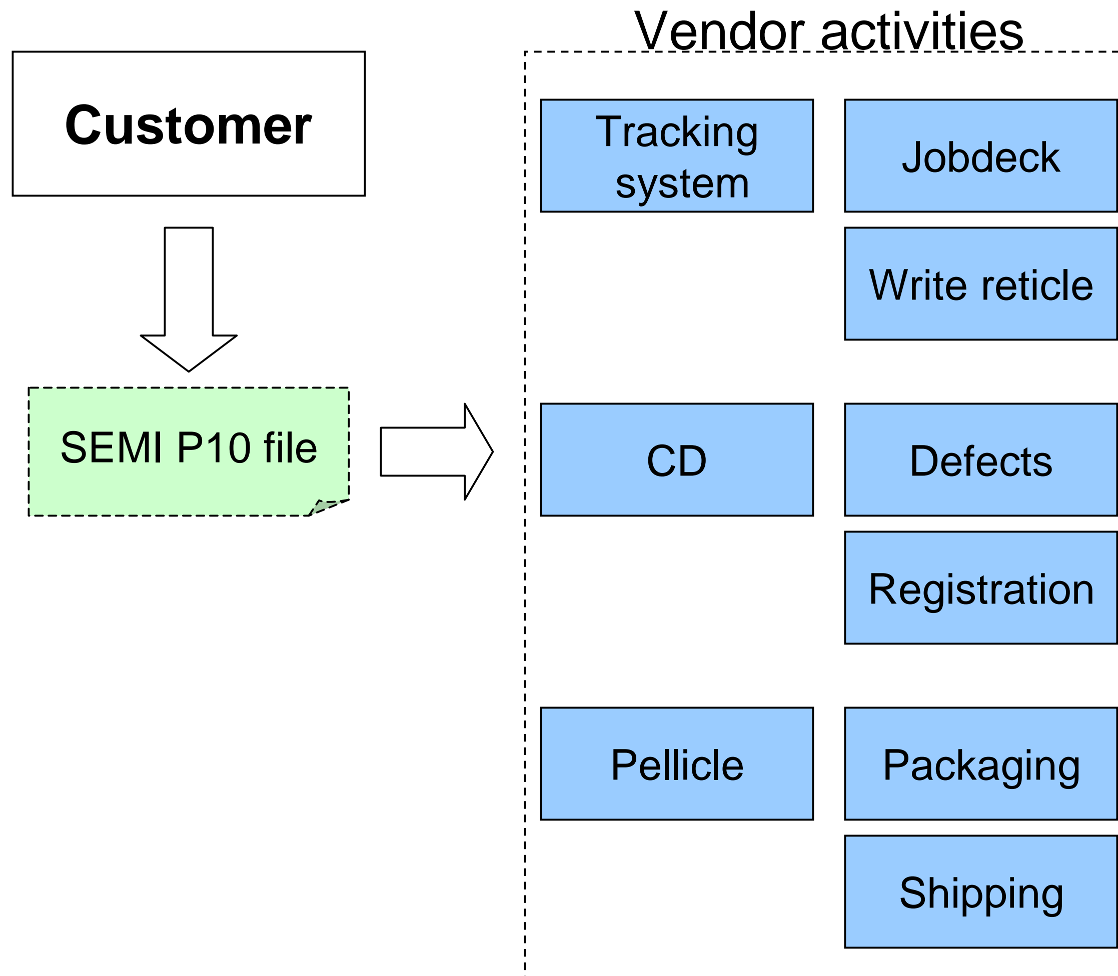
Vendor activities

Inputs (left)	Vendor activities		Inputs (right)
Basic order info →	Tracking system	Jobdeck	← Customer jobdeck or Placement info
		Write reticle	
Device specific insp. info, Quality specs →	CD	Defects	
		Registration	
Device specific order info →	Pellicle	Packaging	← Packaging specs
		Shipping	

CenterLink

Courtesy of Wes Erck, Jim McCracken and Harold Patterson, July 2003

Order System with SEMI P10



Courtesy of Wes Erck, Jim McCracken and Harold Patterson, July 2003

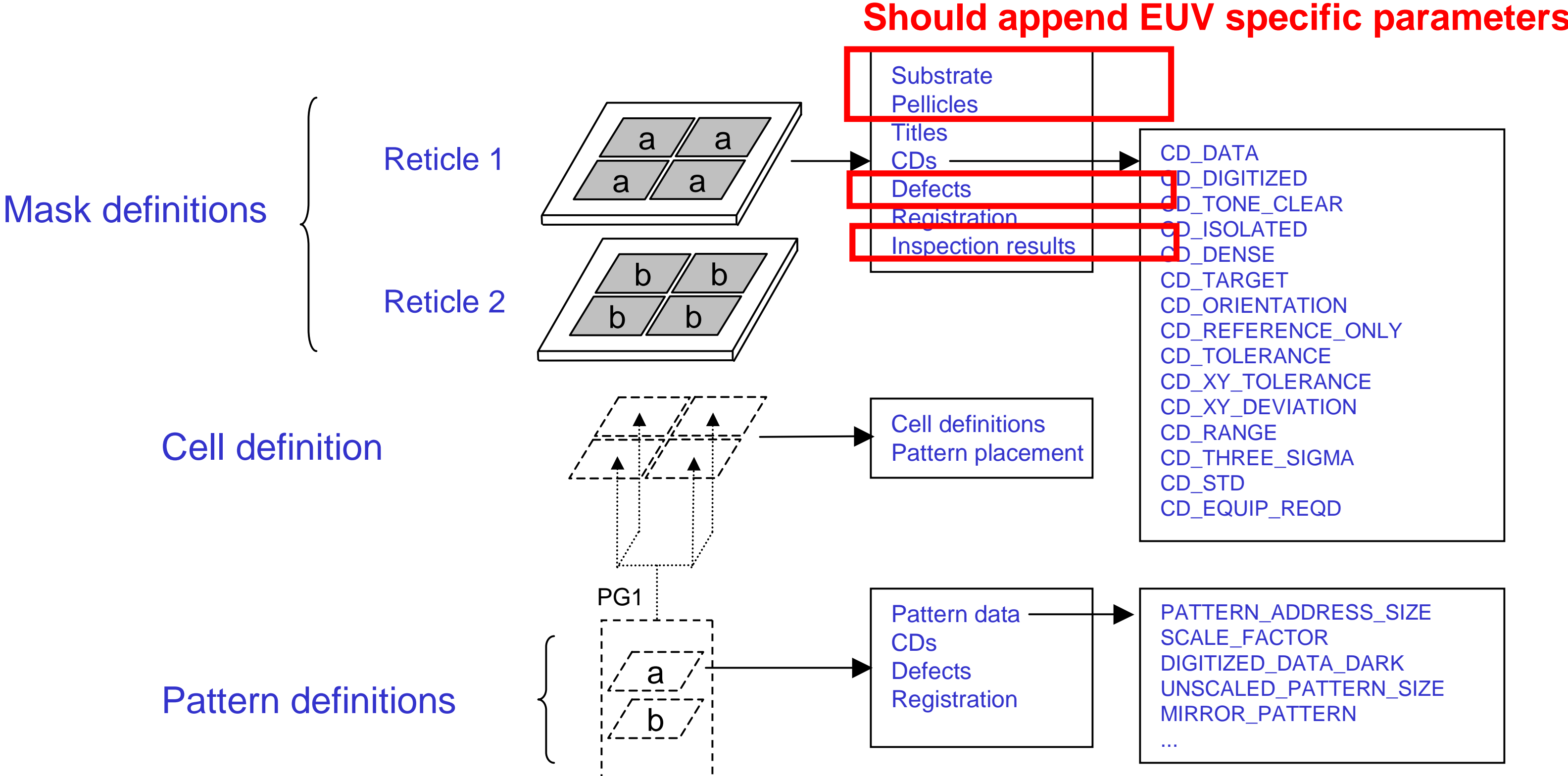
SEMI P10 Structure

- The data model is influenced by concepts from GDSII and MEBES jobdeck format
- Hierarchy is used to organize data and manage complexity
- Key elements

Should append EUV specific parameters

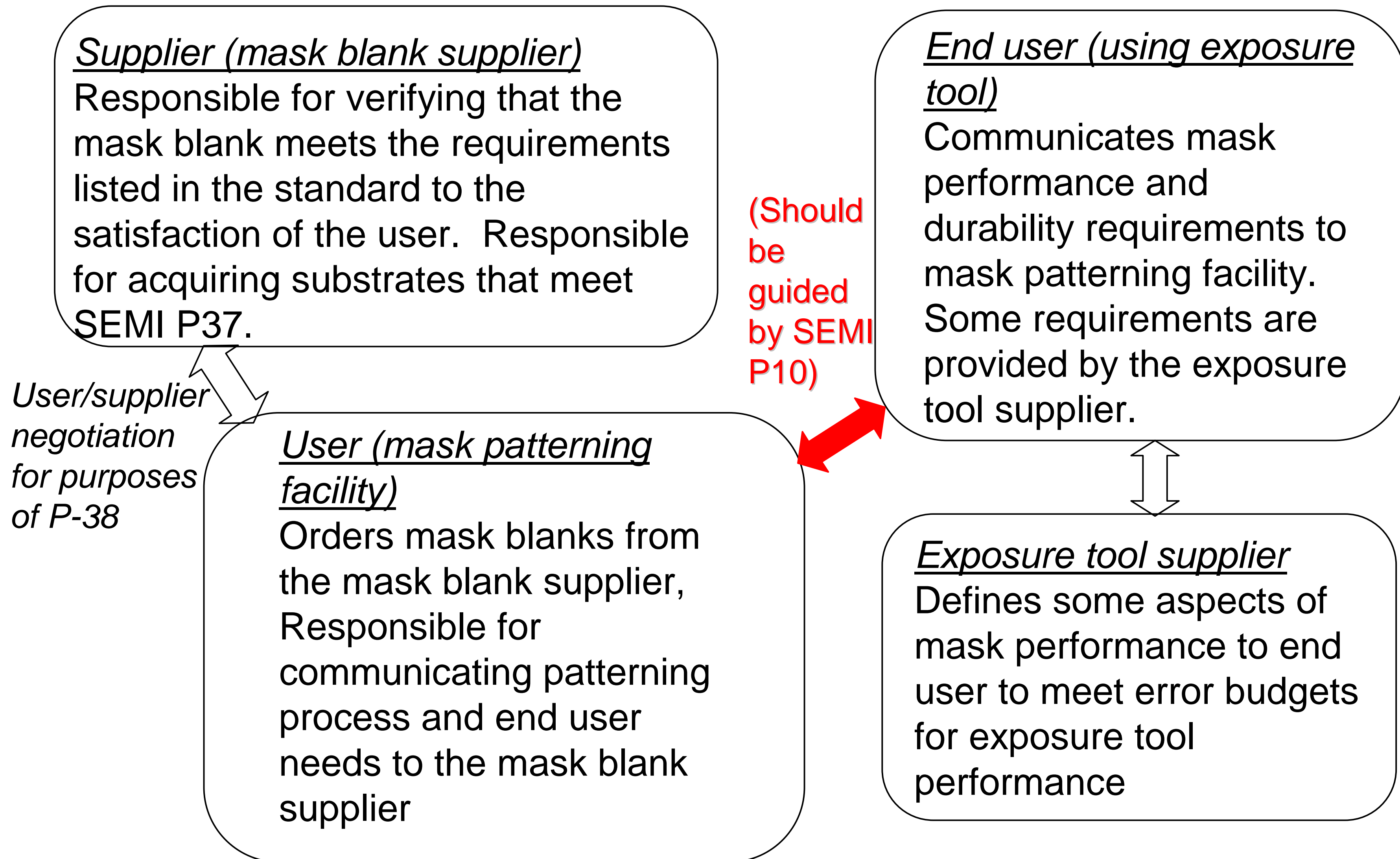
  - *Mask definition* **- usually one for each physical substrate**
  - *Pattern definition* **- individual pattern file details**
  - *Pattern group* **- collection of pattern definitions, the basic unit of pattern placement**
  - *Cell definition* **- contains *Pattern group* placements and/or placements of other *Cell definition*s**
  - *Mask group* **- collection of reticles with common pattern layout**
  - **Multiple** *mask groups* **used for mix and match**

P10 Keyword Level



Courtesy of Wes Erck, Jim McCracken and Harold Patterson, July 2003

Relationship model for EUV mask requirements



Proposed SEMI P-10 elements for EUV masks

Proposed priority

- Substrate
  - (1) – Mask blank attributes need to be specified by party ordering patterned mask
    - Selected items from Table 2 in SEMI P38
- Pellicles
  - (2) – Requirements for mask protection from defects might be appropriate
- CDs
  - (2) – May be sidewall slope requirement
- Defects
  - (2) – May be EUV-specific requirements regarding printability or location (buffer vs. absorber)

Proposed items to be included in substrate parameter list in SEMI P-10 for EUV masks

- Defect quality area
- Flatness
- Material composition of multilayers
- Composition of capping layers on the multilayer stack
- Multilayer stack mean median reflected wavelength
- Multilayer stack mean peak reflectivity
- Multilayer stack peak reflectivity uniformity
- Absorber stack material composition
- Optical properties of absorber stack
- Electrical resistance measured between the surface of the absorber stack and the backside of the mask blank

Contacts for SEMI P-10 questions

- Wes Erck, wes.erck@sbcglobal.net
- Article in MICRO Magazine, June 2002, ”Streamlining the front-end reticle fabrication process by improving mask ordering” by Edward Suttile, Charles Croke, and James Morrison, Photronics, at http://www.micromagazine.com/archive/02/06/suttile.html.