Overview of SEMI Standards for EUV Masks

Scott Hector

ISMT/Motorola

Chairman of SEMI EUV Mask Task Force

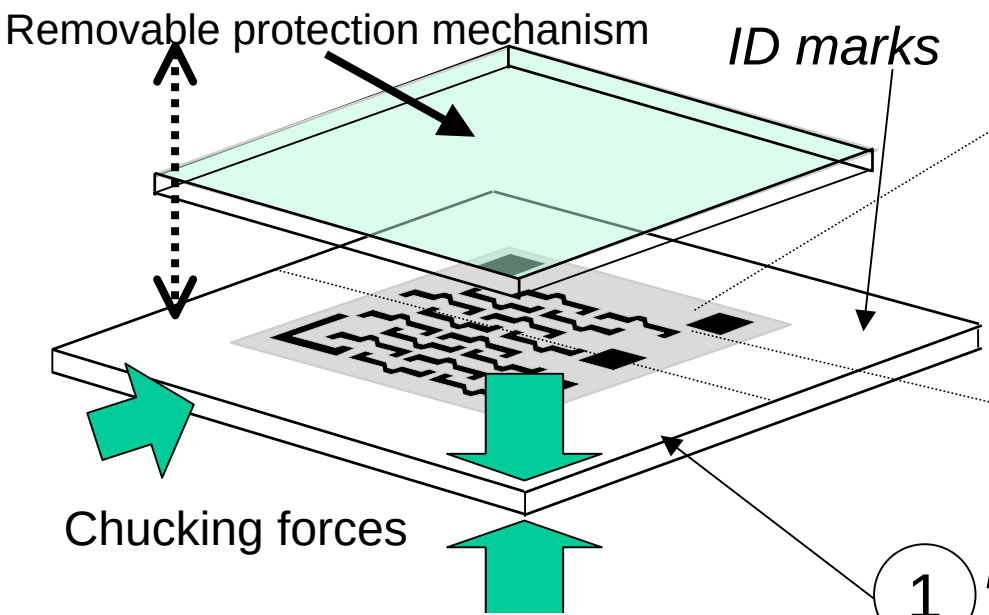
EUVL mask standards

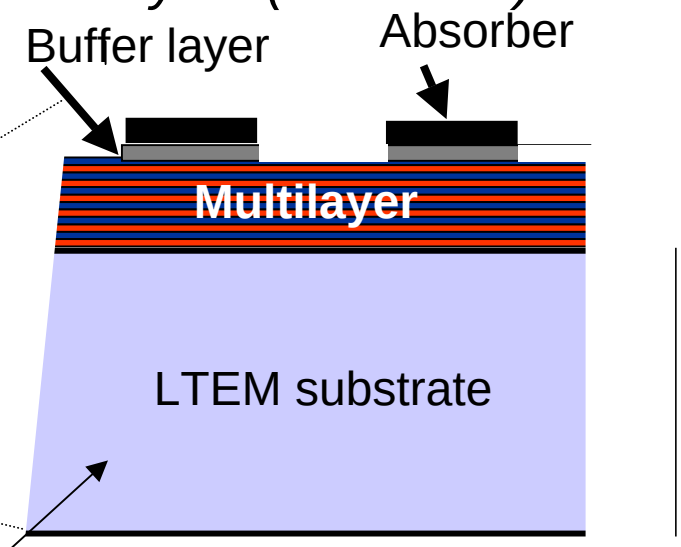
4 *Storage container and attributes of removable protection mechanism (3553)*

Future focus on RSP150 format
New activity approved by Global PIC Committee

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

Revisions approved as P38-1103





Cross-section of EUVL mask

1 *Mask substrate (P37-1102)*

Revisions are proposed, but on hold for release of chucking standard.

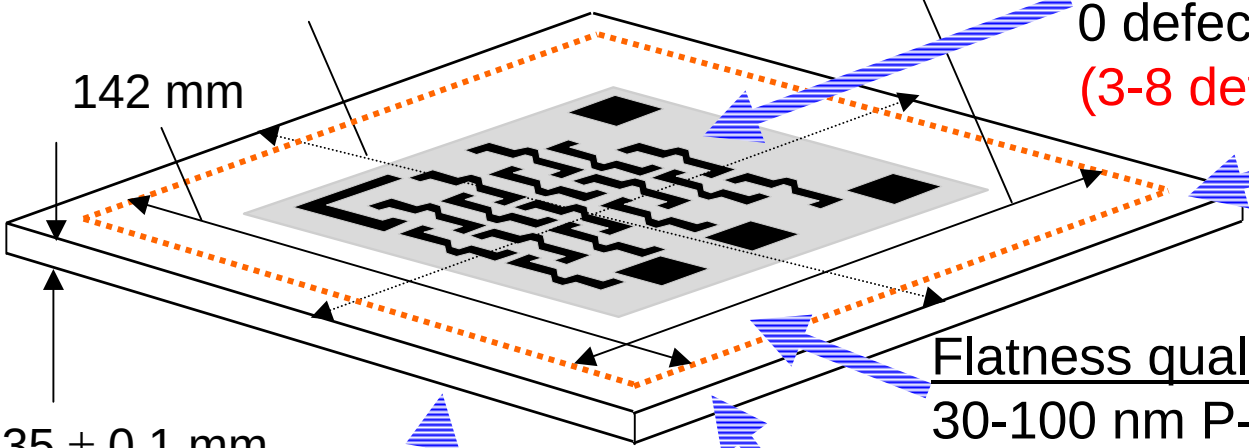
2 *Chucking in processing and exposure tools, location of ID and alignment marks (P40-1103)*

Standard approved as P40-1103

SEMI® International Standards

1

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



Defect quality area:
0 defects >50 nm
(3-8 defects >90 nm best)

Edge region flatness:
<1000 nm P-V

Flatness quality area:
30-100 nm P-V flatness (<100 nm)
50 nm LOTV $\lambda_{spatial}$ > 152 mm
HSFR <0.15 nm rms; (0.20 nm rms)
Local slope < 1mrad; (<3 mrad)
100 mm > $\lambda_{spatial}$ > 400 nm

Backside flatness quality area:
30-100 nm P-V flatness (500 nm)
HSFR <0.50 nm rms; $\lambda_{spatial}$ < 10 μm
0 defects > 1 μm

Substrate material:
CTE < 30 ppb/ ºK a (<20 ppb/ ºK)

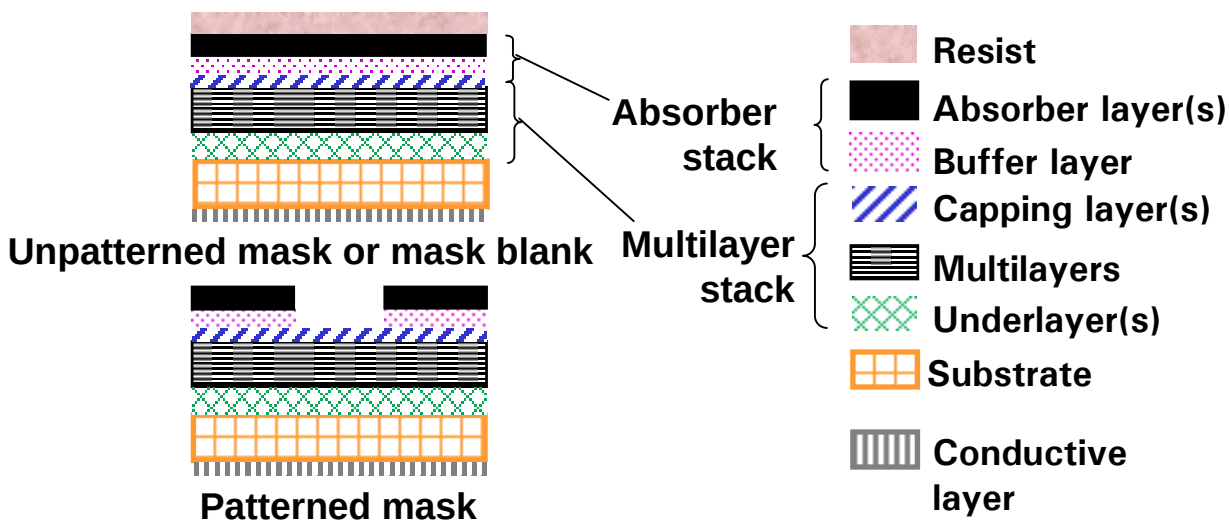
SEMI standard P37-1102

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

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

<u>Supplier (mask blank supplier)</u>
Responsible for verifying that the mask blank meets the requirements listed in the standard to the satisfaction of the user. Responsible for acquiring substrates that meet SEMI P37-1101.

User/supplier negotiation for purposes of this standard

<u>User (mask patterning facility)</u>
Orders mask blanks from the mask blank supplier, Responsible for communicating patterning process and end user needs to the mask blank supplier

(Guided by SEMI P10 for optical masks)

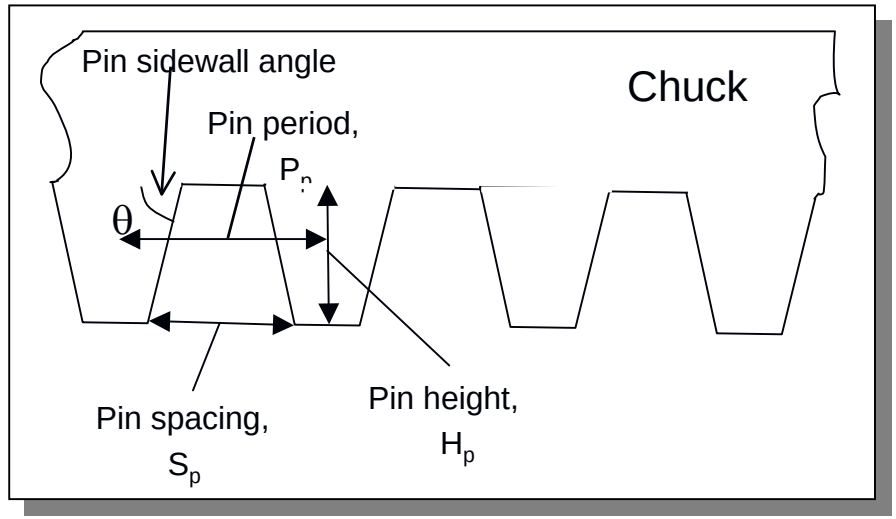
<u>End user (using exposure tool)</u>
Communicates mask performance and durability requirements to mask patterning facility. Some requirements are provided by the exposure tool supplier.

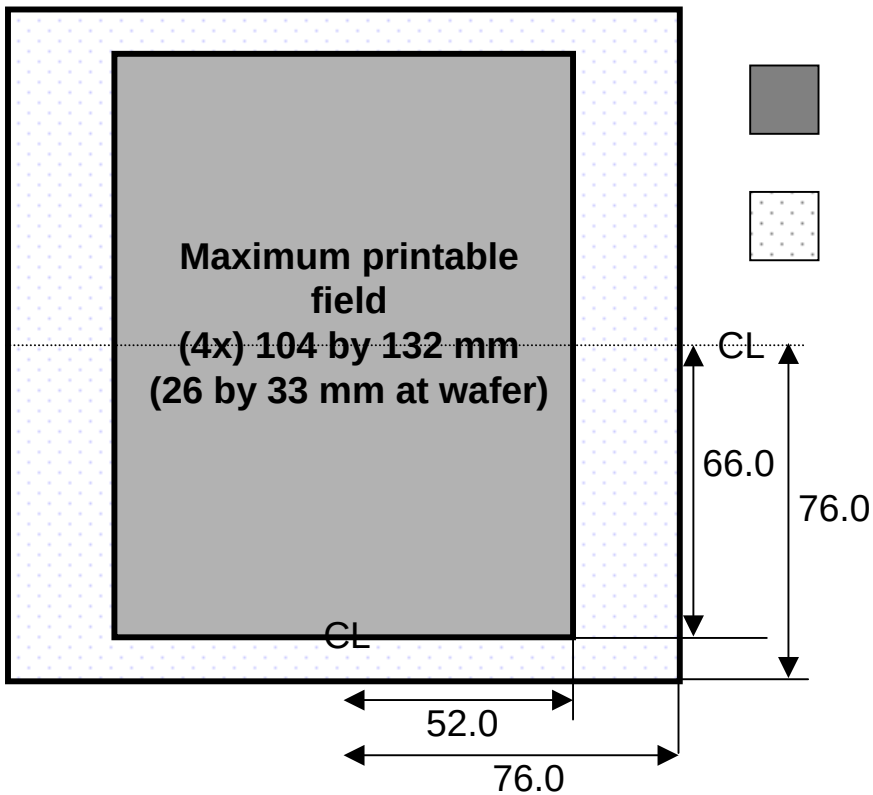
<u>Exposure tool supplier</u>
Defines some aspects of mask performance to end user to meet error budgets for exposure tool performance

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

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.

Discussion of SEMI P40-1103

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

Proposed future technical changes to 3419 (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 3419 (2)

- Pin/pedestal forma 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 3419 (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**

Potential action items for University of Wisconsin

- Investigate the effects of acceleration on clamping requirements. If a higher clamping pressure is required, model the effects of this clamping pressure on flatness.
- Investigate the effects of pin shape to determine whether pin spacing or pin period should be standardized. Determine of pin asymmetry affects this specification.
- Investigate whether the pin locations make a difference in the flatness error.
- Investigate the effects of clamping area, considering the effects of large flatness error near the substrate edge and the possibility of thickness error near the edge of a sputtered conductive coating on the backside.
- Develop a proposal for a substrate flatness specification based on Legendre modes. The specification should include LOTV error tolerances.

Discussion of SEMI P38-1102

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

Proposed future technical changes to 3688 (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
    $4 < f < 10$ 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	
Slope (low)	0.2 mrad rms	$0.001 < f < 0.5$
Slope (high)	0.4 mrad rms	$0.5 < f < 3.5$
HSFR*	0.15 nm	$4 < f < 20$

* Ultimately could be decided between substrate and coating vendors.