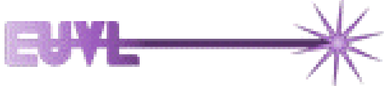
Discussion of SEMI P38-1102 and blue ballot 3688

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



Overview of mask absorber and multilayer standard (SEMI P38-1102)

Mask blank types:

Absorber stack

Multilayer stack

Unpatterned mask or mask blank

Patterned mask

Resist

Absorber layer(s)

Buffer layer

Capping layer(s)

Multilayer

Underlayer(s) (in P37 and 3414)

Substrate (properties defined in P37-1101)

Backside coating

1 2 3

- Lists all parameters of the *mask blank coatings* that user and supplier need to define for mask performance, including patterning requirements
- Consider needs for mask absorbers and multilayers through the 22-nm half pitch ITRS node

Relationship model for ML/absorber standard

Supplier (mask blank supplier)
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

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

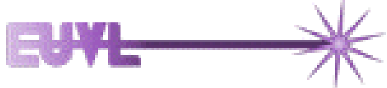
(Guided by SEMI P10 for optical masks)

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

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

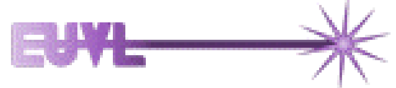
Status and timeline

- Blue ballot issued
  - Voting closed on 2-20-2003
  - Blue ballot responses
    - Five votes to accept, no votes to reject and no abstaining votes
    - Comments from ASML loaded to SEMI website
- Yellow ballot planned in cycle 2
  - Draft of yellow ballot due by 4-24-2003

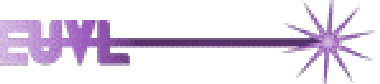


Comments from ASML

- **Draft 3688 Contains multiple errors in the references to the Figures and Tables on Page 1, 2 and 3. These should be corrected.**
  - **This happened to the yellow ballot as well. This was due to a pdf conversion error. These errors will be corrected.**
- **ASML agrees with the changes to Paragraphs 7.2, 7.4 and 12.9.**
- **In the Note following Table 3:**
  - **what was the justification for this proposed change ?**
    - **ASML advises against this change to 125 uJ/cm2/pulse. Our calculations estimate that this limit may be exceeded in high throughput systems. ASML recommends retaining the original spec, or at least 1 mJ/cm2/pulse.**
    - **Propose using >=1 mJ/cm2/pulse. (Is this the possible pulse intensity at the mask?)**
  - **In addition, what was the justification for the change to "2% FWHM" ? Shouldn't it be "2% * Nominal Wavelength ?**
    - **2% FWHM bandwidth was used to be consistent with typical specification of EUV source requirements**

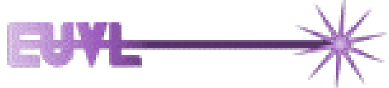


Summary of changes made to P38 in 3688



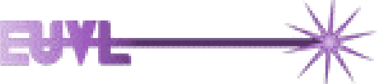
Proposed revisions of SEMI P38-1102

- Require a conducting path between the front and backsides of the mask blank.
  - E-beam lithography requires that the front surface of the mask be grounded.
  - The use of thermophoresis for mask protection from defects requires that the front surface of the mask be grounded.
  - Grounding front to back will require the ML or other conducting layer to extend to edge
  - *Task Force: Add this item into the ordering information but leave it up to the user and supplier to negotiate the details.*
- Possible international standard for multilayer coating median wavelength
  - *Task Force: EAPSMs used today require many different types of mask blank coatings for different users. Since a source choice has not been made and tool designs are in early development, this issue will be addressed in the future if the users and mask blank suppliers raise it as a concern.*



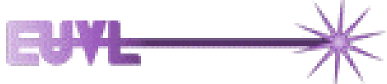
Proposed revisions of SEMI P38-1102 (continued)

- Change the footnote in Table 11 from "** At 30 degrees with respect to normal to the absorber surface" to ""* At normal incidence"
  - Better define what is meant by normal incidence in the text
  - *Normal incidence is the preferred value*.
- Need to add a requirement for uniformity of reflectivity at the inspection wavelength
  - Initial proposal is ±1.5% range
  - *Requirement probably not needed if absorber stack reflectivity <10%*



Proposed revisions of SEMI P38-1102 (continued)

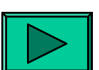
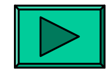
- In Table 10/11: An alternative would be to define the reflectivity values at one specific inspection wavelength, which shall be agreed upon between user and supplier.
  - Some materials might be excluded if they do not fulfill the reflectivity properties over the whole specified range (150 – 257 nm), even if they would be appropriate for the selected inspection wavelength.
  - Text can be added in Sections 7.2 and Sections 7.4 to accommodate this option.
  - Propose that range of inspection wavelengths is reduced to 193 to 257 nm.
- In Table 9, depending on attributes, some properties refer to the absorber stack only (stress,...) and others to the global stack (reflectivity,...) for a better understanding it would be better to indicate this in the table.
  - This might be noted where appropriate using a footnote.

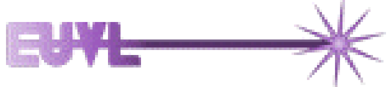


Proposed revisions of SEMI P38-1102 (continued)

- In Table 9, "Stress change" should be specified as an absolute value of this attribute that has to be below the limit
  - This change should be made to allow both an increase or a decrease in stress.
- Reconsider the requirement for 50 MPA stress change after 50 billion pulses.
  - This requirement might be too demanding and too difficult to test.
  - @10 kHz, ~800M pulses per day; 50B = 140 days
- Figure 4 should refer to the EUV reflectivity definition (wavelength and angle) to Section 12.2
  - A reference to Section 12.2 can be added to the caption of Figure 3.

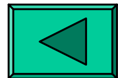
Proposed revisions of SEMI P38-1102 (continued)

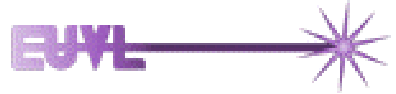
- Secondary electron contrast properties defined in Table 7 apply to the entire stack of materials since the underlying layers may contribute to this property (at least at higher acceleration voltages.
  
  - This might be noted with a footnote.
- Eliminate secondary electron contrast properties from Table 7 to not drive absorber stack material choice with this parameter
  
- Add 1% absolute to all reflectivity values in Table 5
  - Allows for 1% reflectivity loss due to the patterning process while still meeting the ITRS requirements for the 32-nm node



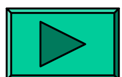
Proposed revisions of SEMI P38-1102 (continued)

- Add another Type 4 to Table 1 without a backside coating.
  - This would allow the option of applying the coating after mask processing.
  - The coating might be required for pattern generation lithography if the draft 3419 chucking standard is adopted.
  - There could be three combinations of this proposal if it is made an option for any of the three mask blank types in the standard. Should we add three more types? Maybe we could make the backside coating layer optional if permitted by draft 3419.
- Add class E (test) for >90 nm defect size into Table 13





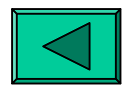
Proposed revisions of SEMI P38-1102 (continued)

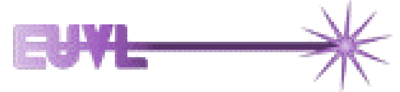
- Add an additional row to Table 12 

  Areas of conductive coating Agreed upon between user and supplier.

  - This option would allow for an introduction of a backside exclusion zone, which might become necessary if contact with the backside layer creates unacceptably high particle levels during handling.

- In Table 15, specify which type of labeling should be used. Should the information be etched in to a blank layer or the edge, or should it be printed on the box?
  - The present standard allows either option.



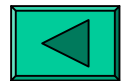


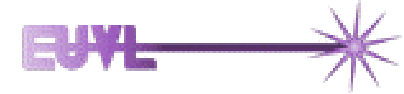
Proposed revisions of SEMI P38-1102 (continued)

- Include a requirement on the thickness of the backside layer so that its resistivity divided by its thickness is greater than 2 Ohms to prevent significant eddy currents in the e-beam writer
- Change Section 4.2 to read:

  "Resist system – Layer of radiation-sensitive material with an optional hardmask layer between the radiation-sensitive material and the absorber material. The radiation-sensitive material is patterned in the lithography process for fabrication the mask.“

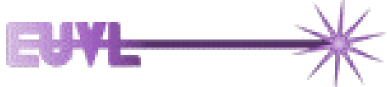
  – P38-1102 allows a hardmask because in Section 4.3, one or more layers are permitted for the absorber layers.





Discussion of SEMI P37-1102 from 10-14-2002

SPECIFICATION FOR EXTREME ULTRAVIOLET LITHOGRAPHY MASK SUBSTRATES



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

152.0 ± 0.1 mm

142 mm

142 mm

6.35 ± 0.1 mm

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 (300 nm)
50 nm LOTV $\lambda_{spatial}$ > 152 mm
HSFR <0.15 nm rms; (0.25 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 (<20 ppb/ ºK)

SEMI standard P37-1102
*5 suppliers have delivered a total of 133 mask substrates to the EUV LLC.**

* Supported by ISMT LITH 111

Possible revisions of SEMI P37-1102

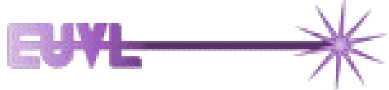
- Change order of classes for flatness

  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.
  - Consider relaxing backside flatness requirement if permitted by chucking approach.
  - *Status: awaiting chucking standard. Free form flatness specification proposals are under review.*



Possible revisions of SEMI P37-1102 (cont.)

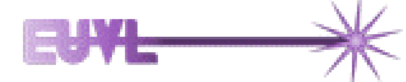
- Relax dimensional tolerances somewhat
  - Increase tolerance on edge length to 0.2 mm from 0.1 mm
  - Increase squareness from 0.01/25.4 to 0.04/25.4
  - Relax tolerances on rounded edge or camfer dimensions by ~2X
  - Change the locations where the notch is dimensioned
  - *Status: awaiting proposed 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.)

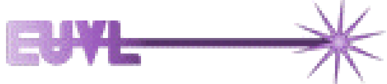
- Modify standard to allow for low order Legendre modes in flatness error
- Change CTE specification to use ASTM E228-95 standard definition of mean CTE (see Corning presentation)
  - Check whether slope of CTE with temperature needs to specified
  - Specify maximum temperature of substrate during fabrication of mask or its use
- Modify specification on local slope and HSFR as follows:
  - 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.



Appendix



Proposed mask layout (Figure 1)

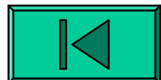
- Provided by SVG in 2000 and might need updating.

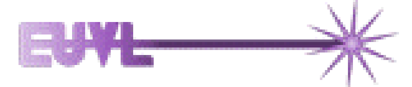
P38-1102 Table 5

Table 5 Peak EUV reflectivity of multilayer stack

Class	*Mean peak reflectivity*
A	>67%
B	65 - 67%
C	63 – 65%
D	60 – 63%

Note: Mean is determined from measurements made at different spatial locations on the mask blank surface. Sample size and measurement locations for determining mean are to be agreed upon between user and supplier.

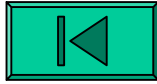


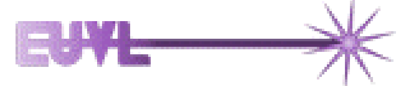


P38-1102 Table 7

Tabl(7 Properties of buffer layer

Buffer layer properties	*Requirement*
Buffer layer etch selectivity to multilayer	Agreed upon between user and supplier
Buffer layer material composition	Agreed upon between user and supplier
Focused ion beam etch selectivity between buffer layer and absorber	Agreed upon between user and supplier
Focused ion beam etch selectivity between buffer layer and multilayer	Agreed upon between user and supplier
Secondary electron contrast of the buffer layer with respect to the absorber layer(s) for between 0.5 and 2 kV primary electrons	Agreed upon between user and supplier
Secondary electron contrast of the buffer layer with respect to the capping layer(s) for between 0.5 and 2 kV primary electrons	Agreed upon between user and supplier
Buffer etch selectivity to absorber stack	Agreed upon between user and supplier
Buffer layer thickness	Agreed upon between user and supplier





P38-1102 Table 9

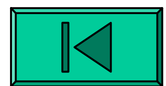
Tabl(9 Properties of absorber stack

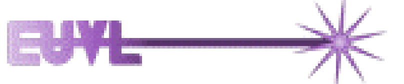
Attribute	*Requirement*
Stress	-200 to 200 MPa
Mean reflectivity at EUV wavelength***	<0.5%
Uniformity of EUV reflectivity	<0.1% TIR
Thickness uniformity	Agreed upon between user and supplier
Etch rate in cleaning solutions ****	Agreed upon between user and supplier
Thickness change after 50 billion pulses in EUV exposure tool*****	< 1 nm
Stress change after 50 billion pulses in EUV exposure tool*****	< 50 MPa
Absorber stack outgassing during EUV radiation*****	Agreed upon between user and supplier

Note: Mean is determined from measurements made at different spatial locations on the mask blank surface. Sample size and measurement locations for determining range are to be agreed upon between user and supplier.*** Reflectivity at 6 degrees angle of incidence with respect to the normal to the absorber surface at the mean median reflected wavelength specified in Table 4 and integrated over the bandwidth equal to the FWHM of the reflectivity versus EUV wavelength

**** Cleaning solutions to be agreed upon between user and supplier

***** 3 to 15 mJ/cm2/pulse in FWHM bandwidth of EUV spectrum





P38-1102 Tables 10-12

Tabl 10 ptical properties of buffer layer and multilayer stack

Minimum multilayer stack reflectivity at $150<\lambda<257$ nm*	55%
Buffer layer reflectivity at $150<\lambda<257$ nm *	Agreed upon between user and supplier

λ is the inspection wavelength
Reflectivity is specified for <1% fractional bandwidth
* At normal incidence

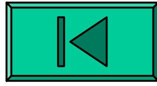
Tabl 11 ptical properties of absorber stack surface

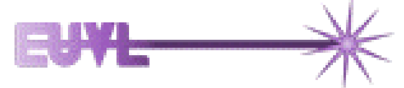
Class	*Absorber reflectivity at $150<\lambda<257$ nm***
A	5%
B	10%
C	15%
D	20%

λ is the inspection wavelength
Reflectivity is specified for <1% fractional bandwidth
** At 30 degrees with respect to normal to the absorber surface

Tab 12 roperties of the conductive layer on the back side of the mask substrate

Conductive layer properties	*Requirement*
Thickness	Agreed upon between user and supplier
Stress	Agreed upon between user and supplier
Mechanical durability	Agreed upon between user and supplier





P38-1102 Tables 13

Tabl 13 efect requirements for multilayer stack

Class	*PSL equivalent size range (nm)**	*Maximum defect count*
A	> 25	0
B	> 30	0
C	> 40	0
D (Test)	> 60	Agreed upon between user and supplier

*PSL equivalent size means the detected defect appears to be the same size as a polystyrene latex sphere examined under the same inspection conditions. Defect count for defects with size smaller than that shown is not specified.