A New Absorbing Stack for EUV Masks: Simulation and Deposition Studies

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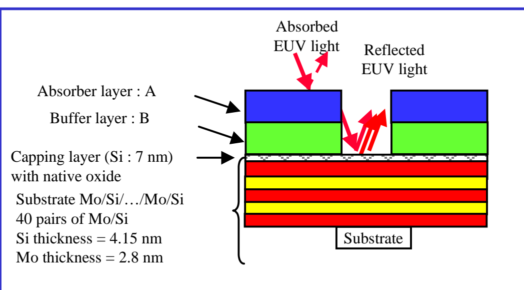
Extreme Ultraviolet (EUV) masks are composed of EUV-reflective regions (multilayer) and of EUV-absorbing regions (patterned areas). The choice of materials for the absorbing stack (i.e. the buffer layer and the absorber layer) is crucial for providing good optical performances.
A new absorbing stack A/B is proposed: this stack completely fulfils optical specifications and its total thickness is much lower than those found in the literature, with absorbing materials like TiN, Cr or TaN for instance. This thin thickness enables to reduce shadowing effects, which is particularly interesting for very advanced nodes.
Deposition studies were then carried out on A and B-materials.

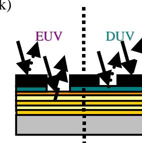
Structure of the mask



Criteria for choosing materials of the absorbing stack

- Optical aspects :
  - EUV reflectivity of the whole absorbing stack lower than 1%
  - DUV performances: good contrast between the whole structure (multilayer + the absorbing stack) and the stack composed by the multilayer and the buffer layer (after the etching of the absorbing layer). In accordance with SEMI standard norms, the DUV reflectivity of the absorbing stack should be lower than 20 % (D-class) or lower than 5 % (A-class)
  - low thickness to minimize shadowing effects (due to the small incidence angle of the EUV radiation on the mask)
- Repair ⇒ Thickness of the buffer layer ð 20 nm
- Technological feasibilities
- Ageing and utilization aspects (stability, cleaning capability)

In a first approach, we mainly focused on criteria 1 and 2.



Simulation Studies

Conditions:

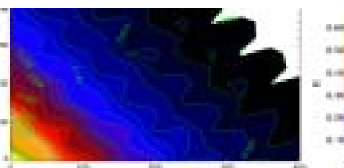
Software: xop [1]
Material Indices: see cxro library [2]

EUV Wavelength = 13.5 nm
DUV Wavelength = 248 nm

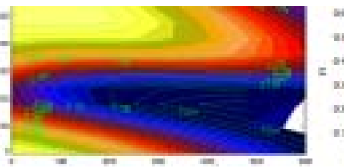
Incident angle of EUV radiation: 6 ° to the normal of the mask
Incident angle of DUV radiation: perpendicular to the mask

A new configuration is proposed:

It is called A/B: A is the new absorbing layer and B the new buffer layer



Reflectivity of the absorbing stack A/B at 13.5 nm



Reflectivity of the absorbing stack A/B at 248 nm

It is possible to find a couple of thicknesses which enable to get a EUV reflectivity lower than 1% and a DUV reflectivity lower than 5% (A-class)

An optimized configuration is a 60 nm-thick absorbing stack composed of a 20 nm-thick buffer layer (B) and of a 40 nm-thick absorber layer (A)

EUV and DUV performances of the new absorbing stack A/B compared to other bi-layer stacks:

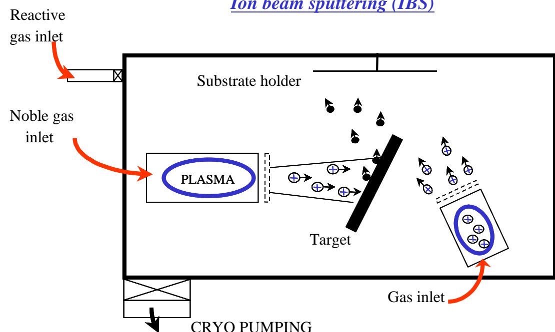
Absorbing Stack (Absorber/Buffer)	Reflectivity at 13.5 nm	Reflectivity at 248 nm Stack: ML + Buffer Layer	Reflectivity at 248 nm Stack: ML + Buffer Layer + Absorber layer	Total Thickness of the absorbing stack (nm)
TiN/SiO_2	R < 1 %	70 %	30 %	155 nm (< D-class)
Cr/SiO_2	R < 1 %	43 %	54 %	95 nm (< D-class)
B/SiO_2	R < 1 %	67 %	35 %	101 nm (< D-class)
TaN/Cr	R < 1 %	59 %	4 %	100 nm (A-class)
A/SiO_2	R < 1 %	50 %	1.4 %	80 nm (A-class)
TaN/SiO_2	R < 1 %	46 %	0.01 %	75 nm (A-class)
A/B	R < 1 %	23.2 %	2 %	60 nm (A-class)

- The new configuration fulfils all the optical criteria and enables to reach A-class
- Its total thickness is only 60 nm, which is much lower than those of all the configurations presented in the chart

⇒ It enables to decrease shadowing effects, which is particularly interesting for very-advanced nodes

Deposition Studies

Low-temperature deposition of A-material: Ion beam sputtering (IBS)

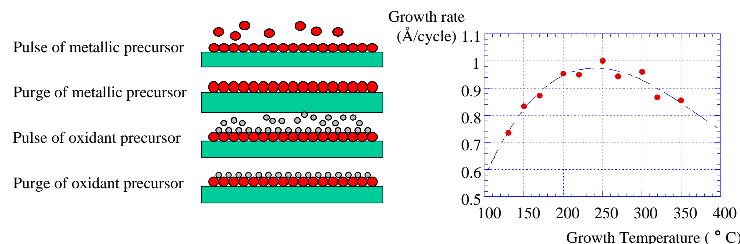


A-material was successfully deposited at a temperature lower than 100 °C.

- Low temperature deposition (i.e < 100 ° C)
- Highly energetic process: dense and stable coatings
- Homogeneity better than 2 % (3σ) on a 8" wafer
- Contamination free (as compared to MOCVD)
- Stress remains high
- Stoichiometric materials

Low-temperature deposition of B-material: Atomic Layer Deposition (ALD)

20 nm-thick layers were grown by Atomic Layer Deposition (ALD) on Si substrates in a Pulsar™ 2000 reactor from ASM Microchemistry Ltd.



B-material layers were deposited at a temperature of 120 ° C. At this temperature, the growth rate is very low (less than 0.07 nm/cycle) due to a precursor adsorption limitation. Moreover, the condensation reaction is not complete and a lot of –OH groups remain in the bulk.

B-material was successfully deposited at 120 °C.

Conclusions

- A new absorbing stack A/B was proposed. This new structure entirely fulfils EUV and DUV optical criteria. Moreover, its thickness is only 60 nm, which is much lower than that of other configurations like TaN/Cr or TaN/SiO_2. This very thin thickness enables to reduce the shadowing effect due to the small angle of incidence of the radiation of the mask, which is crucial for very advanced nodes.
- For the carrying out of the mask, we mainly focused on deposition studies of A and B-materials. We showed that A-absorber material could be deposited by Ion Beam Sputtering at a temperature lower than 100 ° C and that B-buffer layer can be deposited by Atomic Layer Deposition at 120 ° C. The other technological aspects are still been studied and need to be optimized in order to prove the complete carrying out of our new structure A/B.

Acknowledgments

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References

[1] http://www-.esrf.fr/computing/scientific/xop
[2] http://www-cxro.lbl.gov/optical_constants/getdb2.html