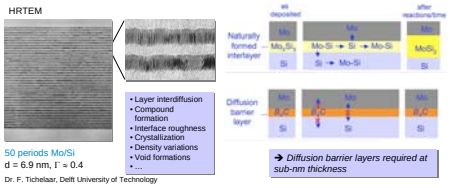
Reflective multilayer coatings, an enabling component of Extreme Ultraviolet Lithography

E. Louis[1], R. van de Kruijs[1], S. Bruijn[1], A. Yakshin[1], J. Bosgra[1], A. van den Boogaard[1], D. Paardekooper[1], V. Medvedev[1], E. Zoethout[1], G. von Blanckenhagen[2], H. Enkisch[2], S. Muellender[2], and F. Bijkerk[1,3]

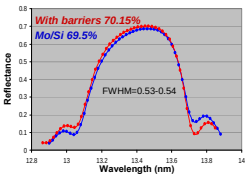
[1] FOM Rijnhuizen, PO Box 1207, 3430 BE Nieuwegein, The Netherlands, www.rijnhuizen.nl
[2] Carl Zeiss SMT AG, Oberkochen, Germany
[3] MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

Interface engineering: Reflectance and Stability



'Interface engineering':
barriers to prevent interlayer formation and diffusion, can also enhance the reflectance

Reflectance enhancement



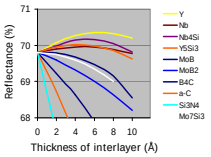
•Single layer diffusion barrier:
→ reflectance enhancement
→ reduced diffusion

Six-layer design to enhance reflectance and reduce diffusion

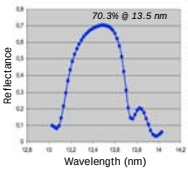
Traditionally one diffusion barrier with both favorable optical and diffusion reduction properties per interface.

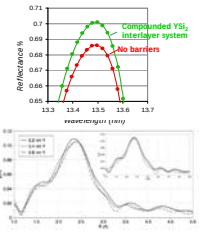
Can this be functionally split in optical - diffusion functionality by applying a ultra thin diffusion barrier and a ultra thin reflectance enhancement layer at each interface?

Calculated reflectance for candidate reflectance enhancement layers



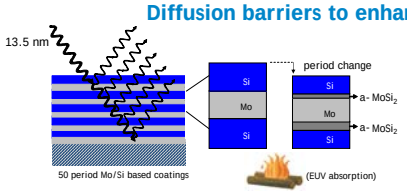
Experimental verification:

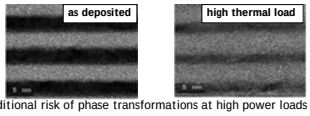




➔ *Sub nm interlayers can improve refractive index distribution*

Diffusion barriers to enhance thermal stability

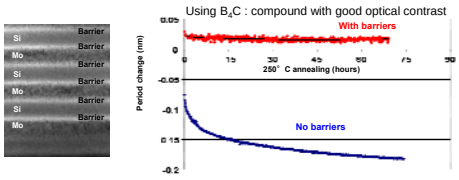




Additional risk of phase transformations at high power loads

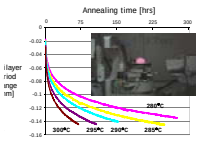
Growth of $MoSi_2$ interfaces and *densification* at high T
Unacceptable **for tool operation!**

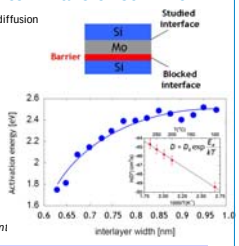
Diffusion barriers for thermal stability



Interdiffusion dynamics in nano-sized films

Selective analysis of interface diffusion by use of diffusion barriers



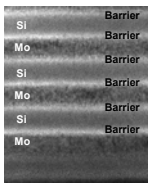


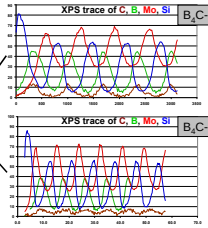
XMO PhD thesis: Bruijn, 2011 University Twente

➔ Diffusion kinetics study reveals interdiffusion layer thickness dependent activation energy (XMO PhD research Bosgra)

What happens with the barriers?

Investigate chemistry: XPS



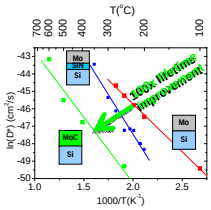


B_4C decomposes on top of Si.

Diffusion scaling laws

Passivated systems and systems with diffusion barriers

Goal: study diffusion at initial stage



Arrhenius plots provide method for scaling of diffusion.

Activation energies provide information about fundamental diffusion processes.

$$D = D_0 \exp\frac{E_a}{kT}$$

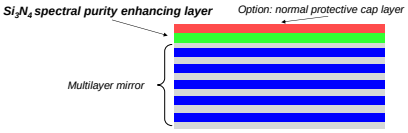
Y-value D_0

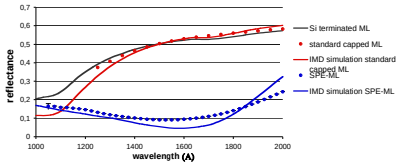
Slope: E_a

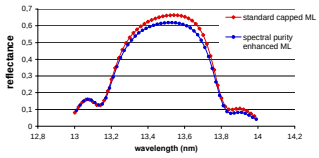
Tsarfati, et al, JAP 105 (2009)
Bruin, et al, ASS, 10-02316R1 (2010)

Spectral purity

(multi)layer based solutions

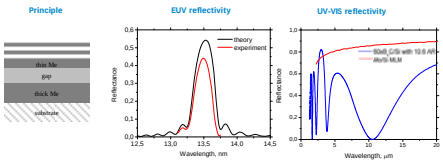




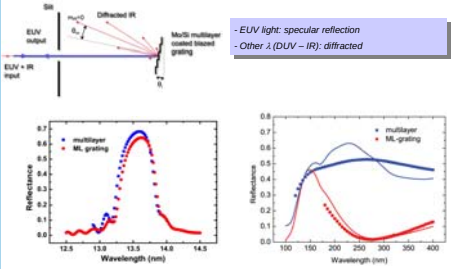


➔ ***Reflectivity loss of SPE-ML at EUV limited to 4.5%***

Integration of EUV mirror with infrared anti-reflecting (AR) coating (see poster V. V. Medvedev, FOM)



Multilayer grating based solutions



1st test: EUV reflectance only 5% reduced ➔ 30 x suppression DUV light

Summary

- Barrier layers can enhance reflectance to > 70%
- Maximum reflectance obtained for six-layer design: 70.3%

- Diffusion barriers can strongly enhance thermal stability

- Various ways to suppress longer wavelength Out of Band radiation
  - DUV suppression layer on high reflectance multilayer
  - EUV reflective multilayer combined with IR AR coating
  - DUV – IR suppression by multilayer gratings

Acknowledgements

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