# Thermal stability and lifetime scaling of multilayer EUVL optics

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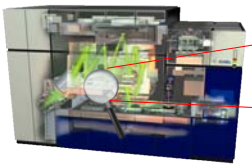
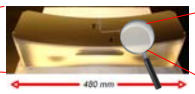
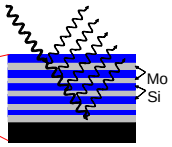
## Multilayer EUV reflective optics





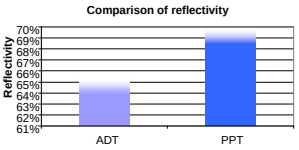

Example of multilayer coated (illumination) optics.

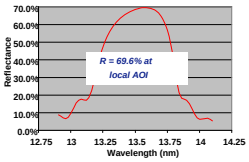



50 bilayer Mo/Si based multilayer

- Mo/Si multilayered structure usually have a period of ~7 nm

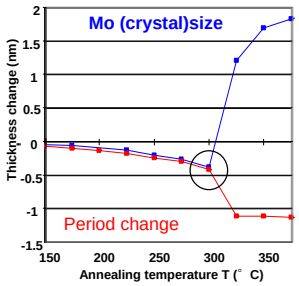
## Pre production tool coatings

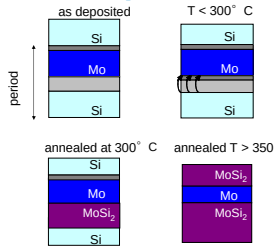



- Reflection improved by 4% from Advanced Development Tool (ADT) to Pre-Production Tool (PPT)
- Enabling ~50% gain in throughput

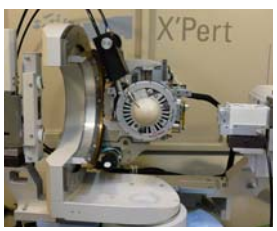
## Interdiffusion at elevated temperature [1]



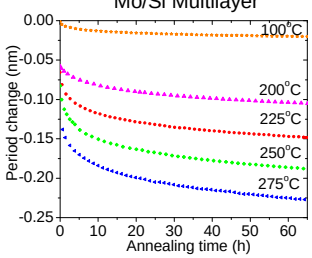




- Due to diffusion, $MoSi_2$ is formed at the interfaces between Mo and Si
- Reduction in period and reflection
- At 325°C the $MoSi_2$ layer crystallizes, followed by complete intermixing

## Diffusion monitoring with picometer accuracy [2]

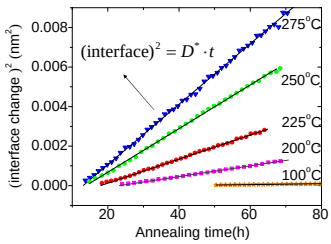


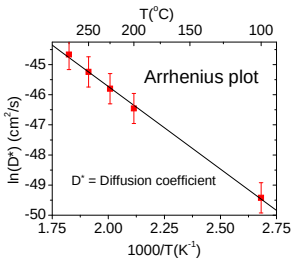

Mo/Si Multilayer




- The period change can be determined during annealing with an *in situ* x-ray diffraction system
- Picometer precision for accurate determination of lifetime is obtained
- Mo/Si multilayered structures are studied as a model system

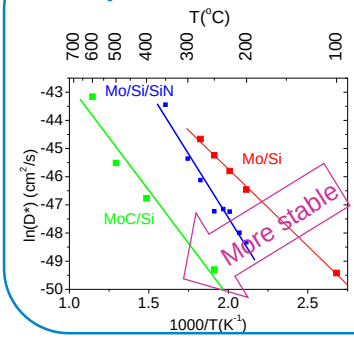
## Model to predict lifetime in Mo/Si




- After an initial phase (first hours) the diffusion follows the quadratic interface growth law
- The diffusion coefficients scale with temperature according to Arrhenius law
- Correcting for the initial phase, the model predicts optics thermal lifetime for different temperatures

## Examples of more thermally stable structures

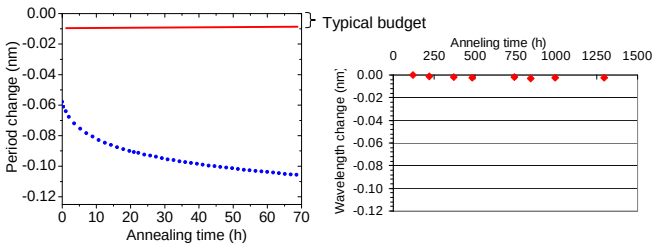



- Examples of modified compositions
- Model is generally applicable to multilayered structures with a barrier layer or replacement of one of the layers by a thermally more stable compound

## Application: illuminator coatings

Mo/Si multilayer

Thermally improved multilayer for PPT




- Standard Mo/Si multilayer coating does not meet multilayer period budget
- Thermally improved systems shows no changes in wavelength within 1300h
- Extrapolation of these data: thermally improved system meets budget for 30,000 h

## Acknowledgements

This work is part of the FOM Industrial Partnership Programme I10 (XMO) which is carried out under contract with Carl Zeiss SMT AG, Oberkochen and the `Stichting voor Fundamenteel Onderzoek der Materie (FOM)'. We acknowledge financial support from the `Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO)' and SenterNovem (EXEPT project).

[1] I. Nedelcu, R.W.E. van de Kruijs, A.E. Yakshin, F. Bijkerk, Physical Review B (Condensed Matter and Materials Physics) 76/24 (2007) 245404.
[2] S. Bruijn, R.W.E. van de Kruijs, A.E. Yakshin, F. Bijkerk, *In-situ* study of the diffusion-reaction mechanism in nanometer scale layered films - To be published