UNIVERSITY OF TWENTE.

Foundation for Fundamental Research on Matter

Fabrication of Adaptive Mirrors for Extreme Ultraviolet Lithography

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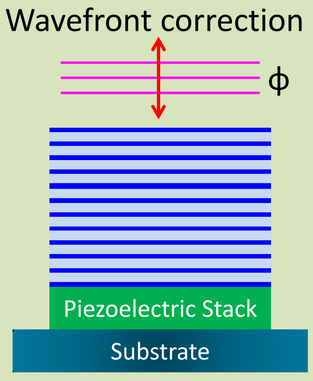
INTRODUCTION

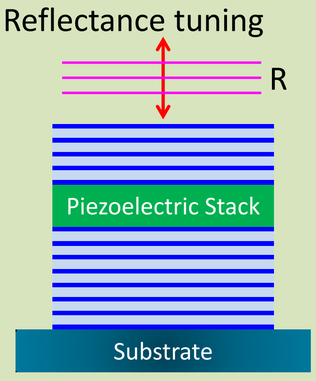
- 70.3% world record reflectance is measured with Mo/Si multilayer mirrors (MLM) at FOM Institute DIFFER[1]
- 29.7% of the radiation is absorbed or scattered
- Stability requirements for optics leads to:
  - Future need for adaptive systems
  - There is a big potential in piezoelectric based systems

APPROACH

A. Wavefront correction



B. Reflectance tuning

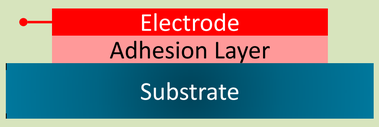


TASKS

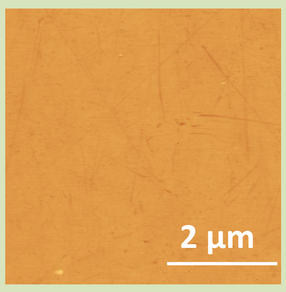
- Design of multilayer mirrors with integrated piezoelectric elements
- Development of fabrication process
- Evaluation of applicability and compatibility with EUV lithography
  - Total reflectance
  - Smoothness

A. WAVEFRONT CORRECTOR

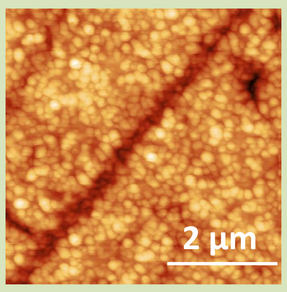
1) Sputtering and annealing



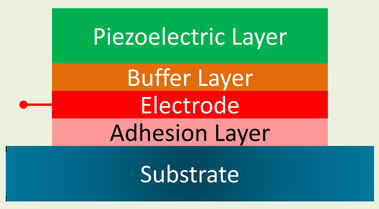
Surface Roughness
σ^2_{RMS} 1.05 nm



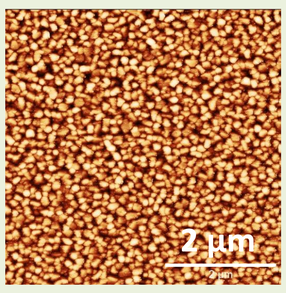
Annealing @650° C 1 hour
σ^2_{RMS} 12 nm



2) Pulsed Laser Deposition



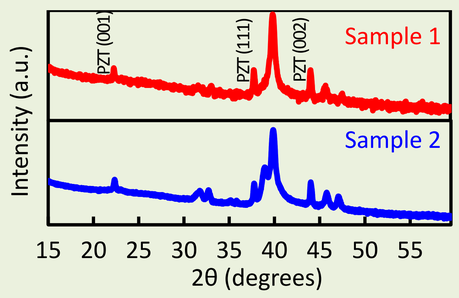
Sample 1
O_2 pressure 0.023 mbar
σ^2_{RMS} 14 nm



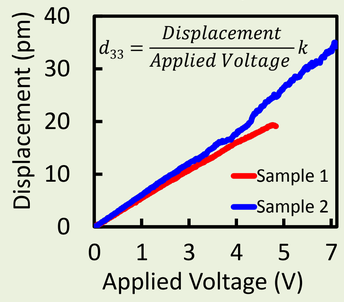
Sample 2
O_2 pressure 0.110 mbar
σ^2_{RMS} 15 nm

- XRD scans indicate textured piezoelectric film growth
- Piezoelectric coefficient (d_{33}) is measured locally as 40 pm/V compared to target value 60 pm/V using piezoelectric force microscopy

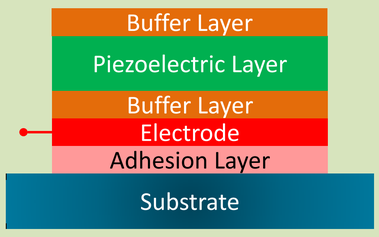
XRD scans



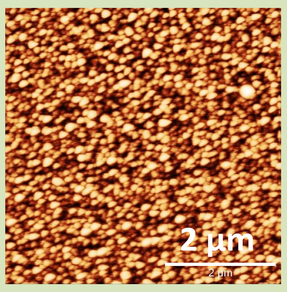
Piezo. response



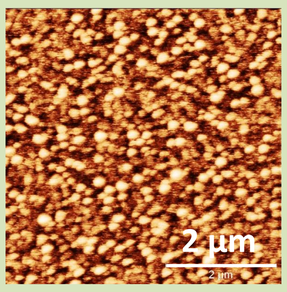
3) Pulsed Laser Deposition



Sample 1
O_2 pressure 0.023 mbar
σ^2_{RMS} 10 nm



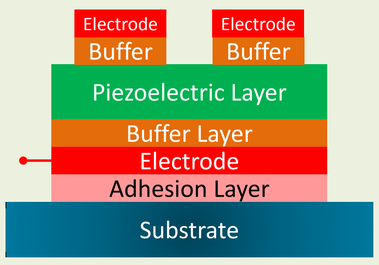
Sample 2
O_2 pressure 0.110 mbar
σ^2_{RMS} 7 nm



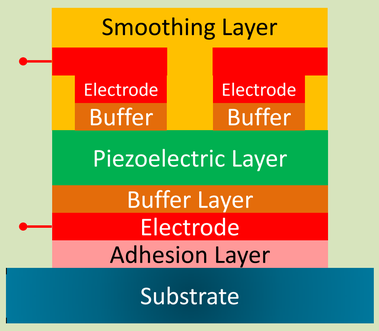
CONCLUSIONS

- Reasonable smoothness is obtained before any polishing step
- To be done: Patterning electrodes, polishing, multilayer mirror deposition and testing

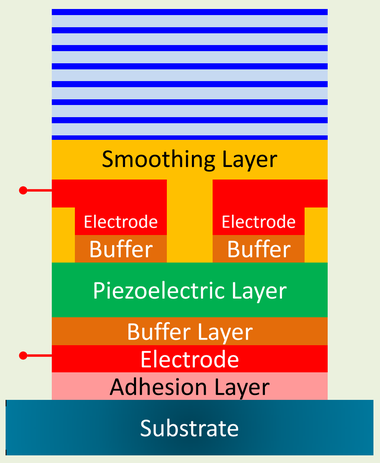
4) Sputtering and etching electrodes



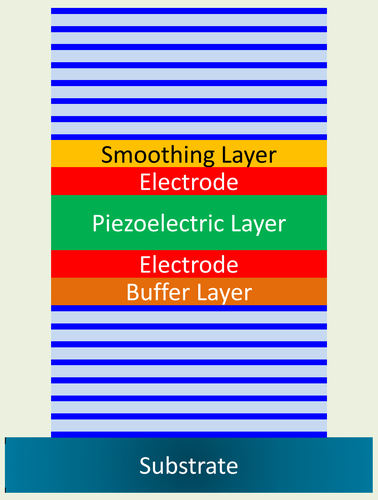
5) Electrode connections and polishing



6) Multilayer mirror deposition

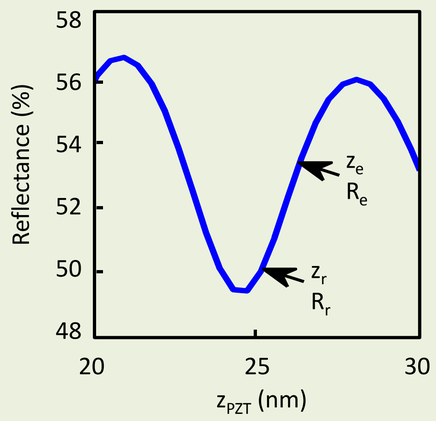


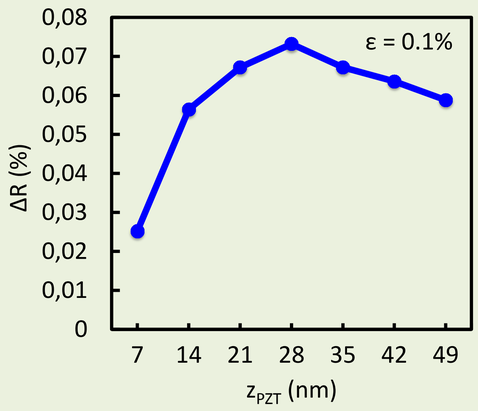
B. REFLECTANCE TUNER



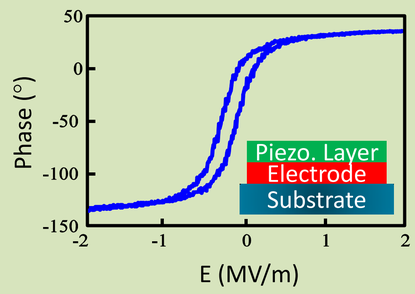
- Incoming radiation is partially reflected from top and base MLM's.
- It can be modeled as an etalon
- Reflectance can be tuned by changing the thickness of the piezoelectric layer

$$z_e = z_r(1+\varepsilon)$$
ε: max. strain
$$\Delta R = R_e - R_r$$

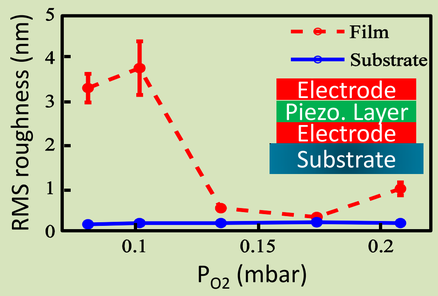




Piezoelectric phase loop



Optimization of surface roughness



CONCLUSIONS

- Reflectance tuning is limited by the maximum strain of the piezoelectric films
- Smooth piezo. films can be fabricated
- Shorter wavelengths will be explored

[1] J. Bosgra, E. Zoethout, A.M.J. van der Eerden, F. Boekhout, J. Verhoeven, R.W.E. van de Kruijs, A.E. Yakshin, F. Bijkerk, "Structural properties of sub nanometer thick Y layers in EUV multilayer mirrors", *submitted to JAP*, (2011).

[2] M. Bayraktar, W. A. Wessels, C. J. Lee, F. A. van Goor, G. Koster, G. Rijnders, F. Bijkerk, "Design of active multilayer mirrors for reflectance tuning at extreme ultraviolet (EUV) wavelengths", *submitted to J. Phys. D.*, (2012).

[3] G. Rijnders, D.H.A. Blank, "Materials science - Build your own superlattice", *Nature*, 433, 7024, 369-370, 2005.

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