DEPARTMENT OF INFORMATION ENGINEERING
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Multilayer design for EUV lithography

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Multilayer design for the EUV lithography

OUTLINE

- **INTRODUCTION** (req's for ML optics)

- **ML design optimization algorithm**

- **EXPERIMENTAL TESTS**

- **CONCLUSIONS**

Multilayer design for the EUV lithography

Photolithography is the process of image transfer from a mask onto a substrate (e.g. semiconductor slice) coated by a thin layer of photosensitive resist

Process evaluation criteria:

RESOLUTION: minimum developed geometry with repetibility

EFFICIENCY: number of wafers processed per unit of time

CLEANLINESS: process free from defects

Multilayer design for the EUV lithography

Problems:

- intensity and spectral purity of the source
- cleanliness of the source
- life-time of optics
- optimization of optics efficiency : peak and spectral

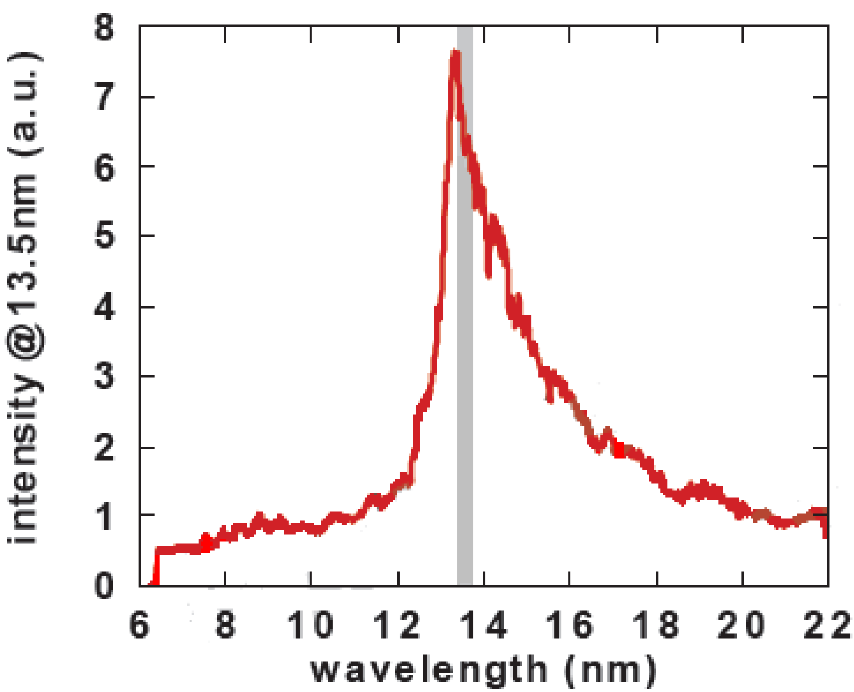
Multilayer design for the EUV lithography

PERFORMANCE IMPROVEMENT FOR EUVL MULTILAYERS

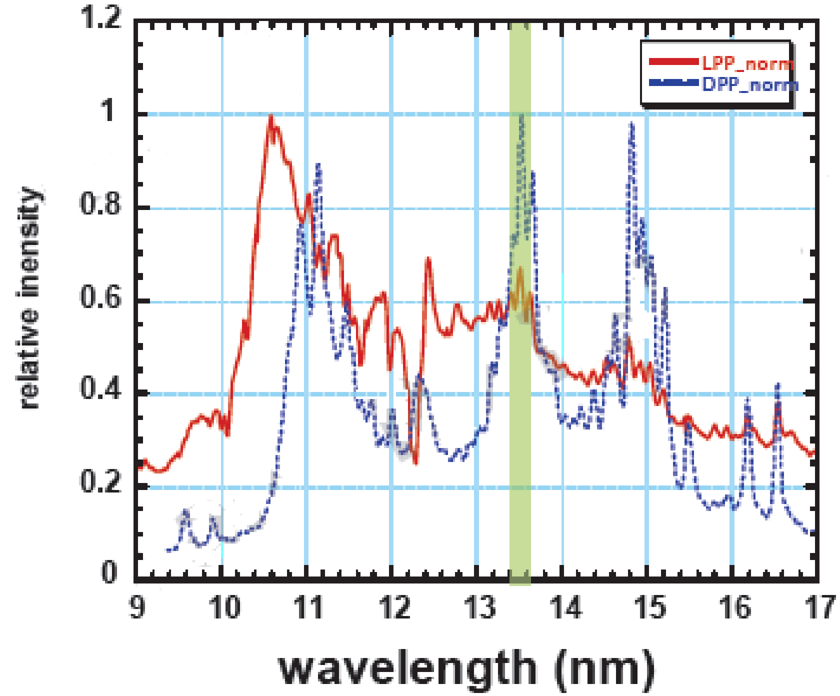
- Highest reflectivity
- Highest reflectivity for multiple mirror systems
- Highest integral reflectivity, best matching with source spectrum
- Capping layer system to protect the coating by the harsh environmental EUVL conditions
- Interface structures to accomplish best interface gradient index and ML thermal stability

Multilayer design for the EUV lithography

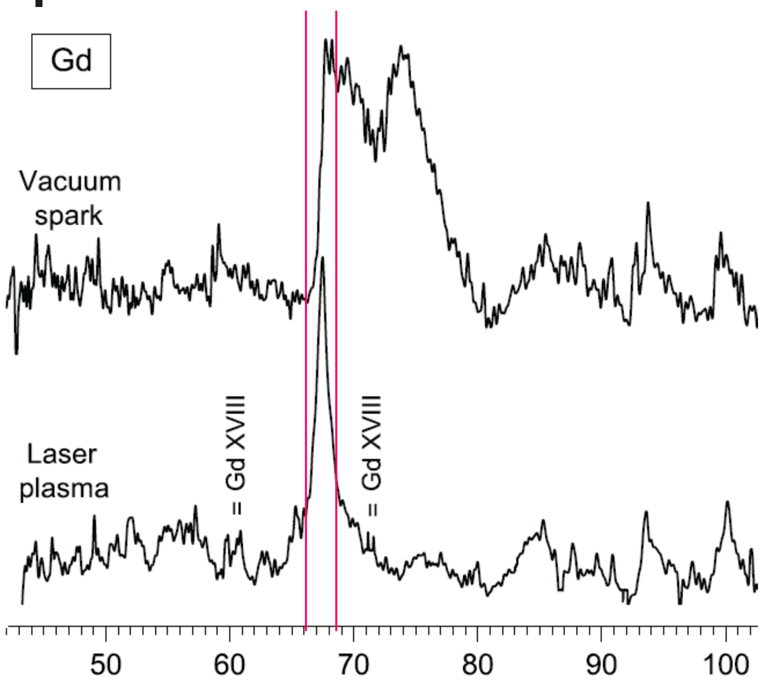
Sn

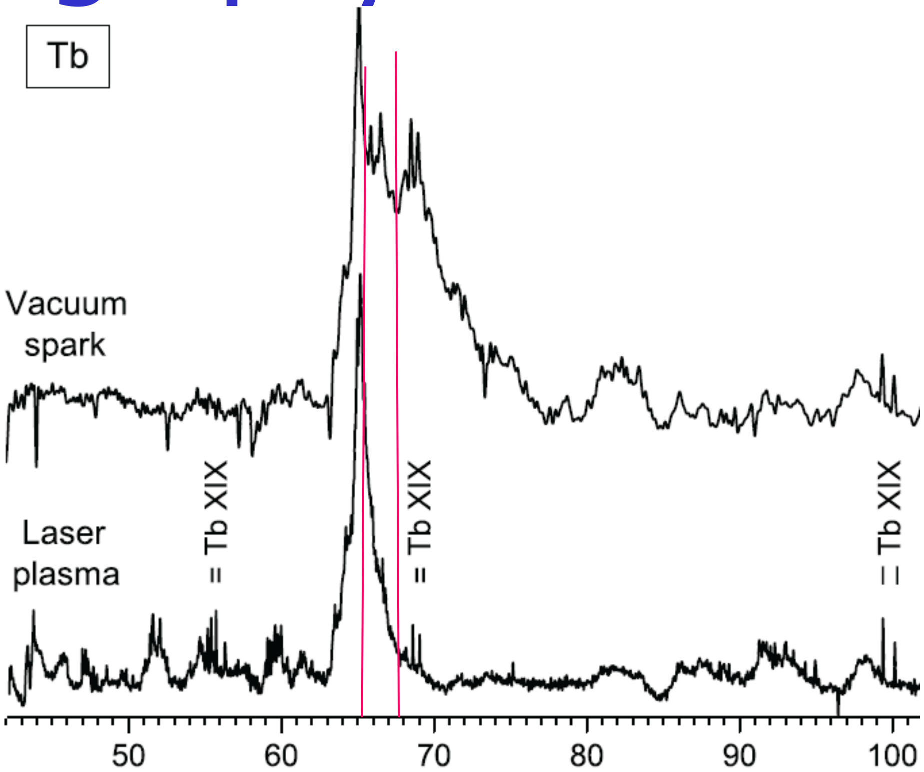


Xe



Multilayer design for the EUV lithography



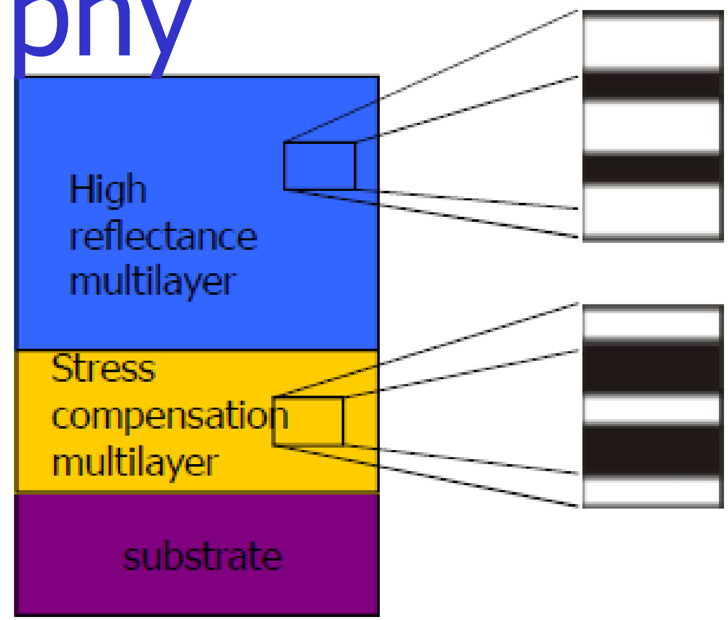


S.S. Churilov et al., Phys. Scr. 80 (2009) 045303

Multilayer design for the EUV lithography

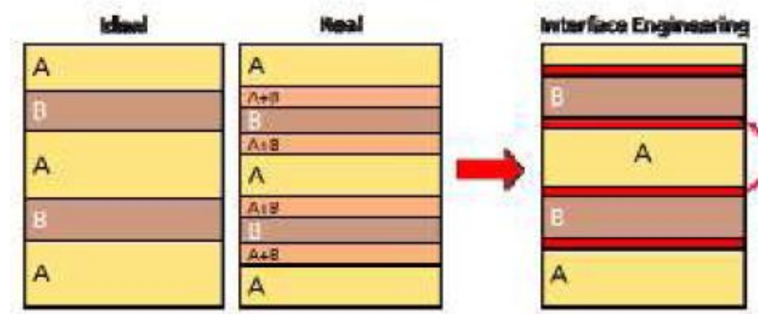
ML Structures composed by reflective MLS over Stress compensating MLS

- Mirkarimi et al. Opt. Eng. 38, 1999
- E. Zoethout SPIE 5037, 2003

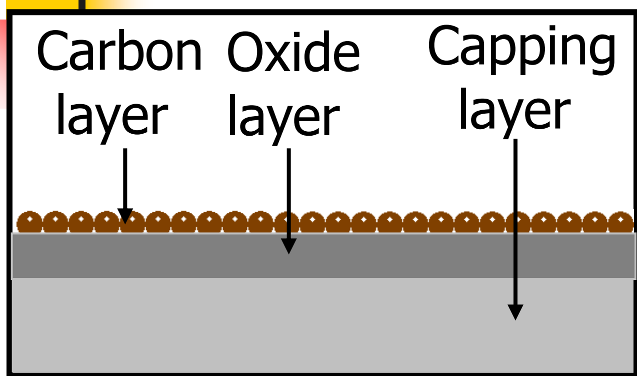


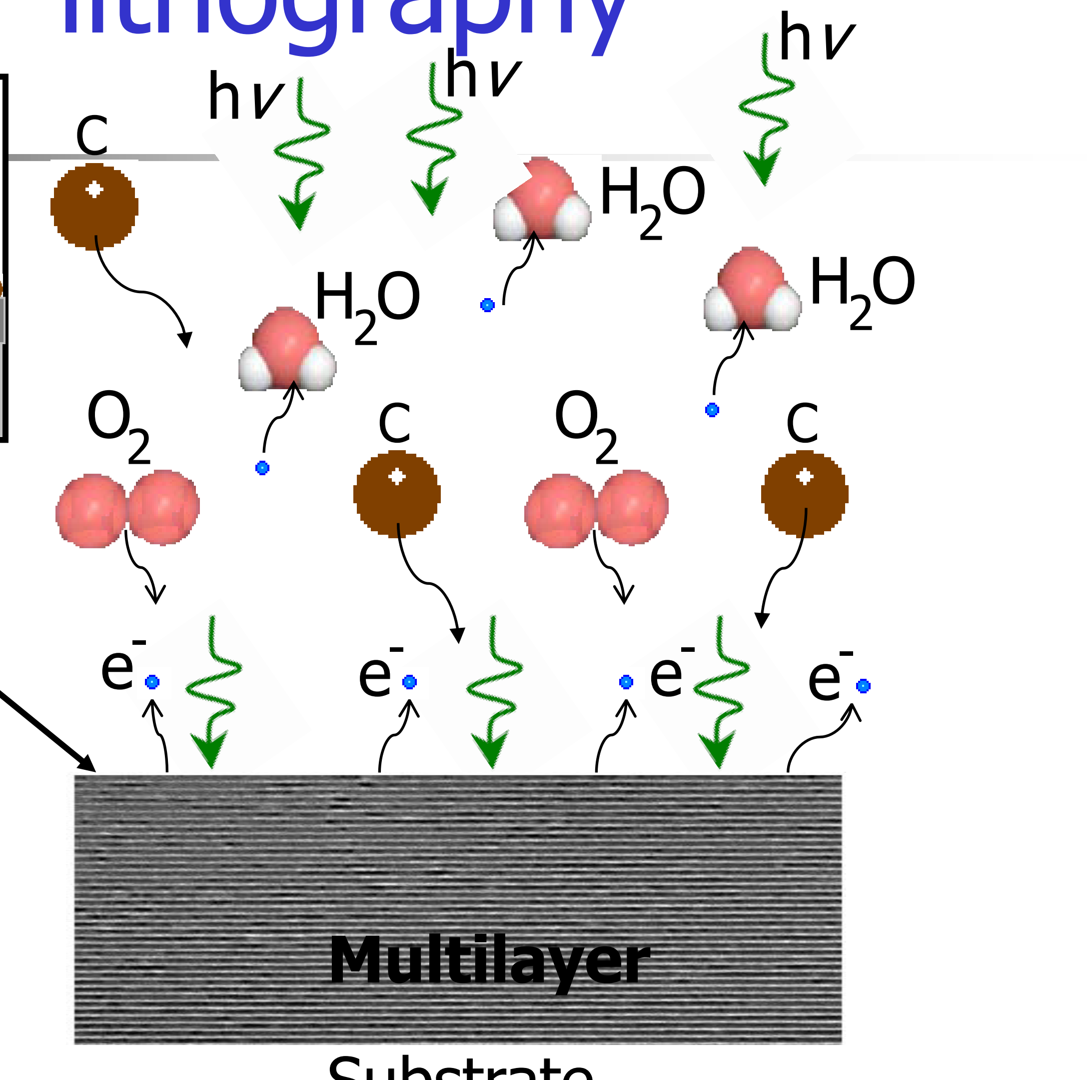
MLS Interface engineering

- Yulin et al. MEE 83, 2006



Multilayer design for the EUV lithography





Capping layer

Ru/B_4C
Ru/Mo
S. Bajt et al. 2001

Optimization algorithm

State of the art

1) Local optimization algorithm with starting point distributed into the domain to overcome local minimum/maximum

2) Global optimization algorithm (Genetic algorithm or simulated annealing)

Our approach

Algorithm structured according to evolutive strategy → Is an algorithm conceived expressly for the multilayer domains

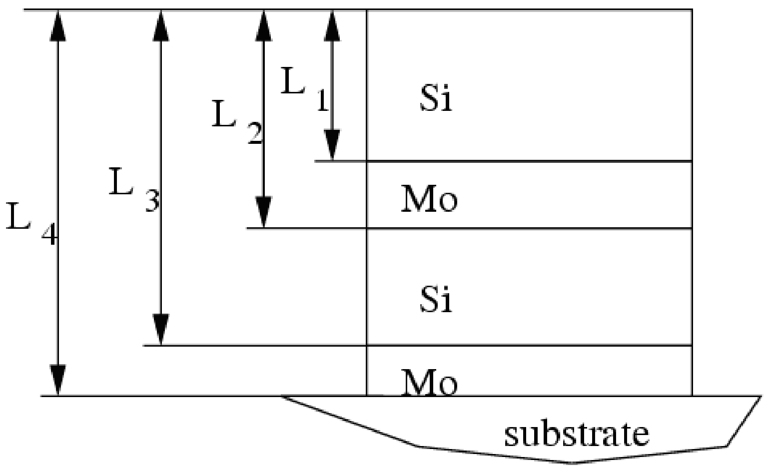
↓

The algorithm acquire domain knowledge during the evolution

Optimization algorithm

- A generic ML structure is identified as a point of a N-dimension vector space with components given by the position of the

$\overline{x}$

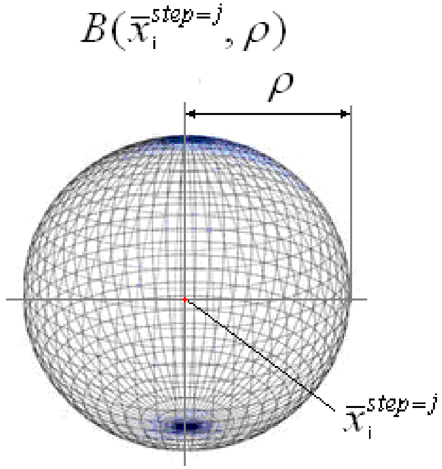


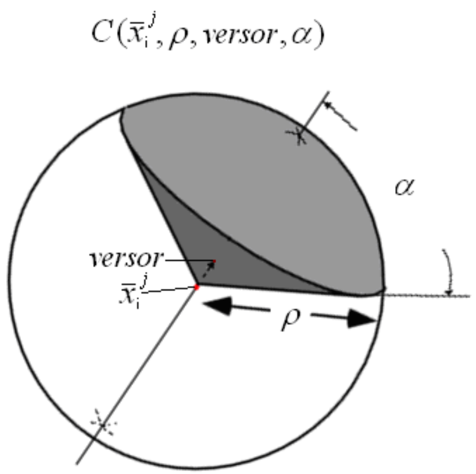
$$\left\|\overline{x}\right\| = \sqrt{\sum_{i=1}^{N}\left(L_i^{\overline{x}}\right)^2}$$

$$d(\overline{x}_1, \overline{x}_2) = \left\|\overline{x}_1 - \overline{x}_2\right\| = \sqrt{\sum_{i=1}^{N}\left(L_i^{\overline{x}_1} - L_i^{\overline{x}_2}\right)^2}$$

patent: PCT/EP2007/060477

Optimization algorithm



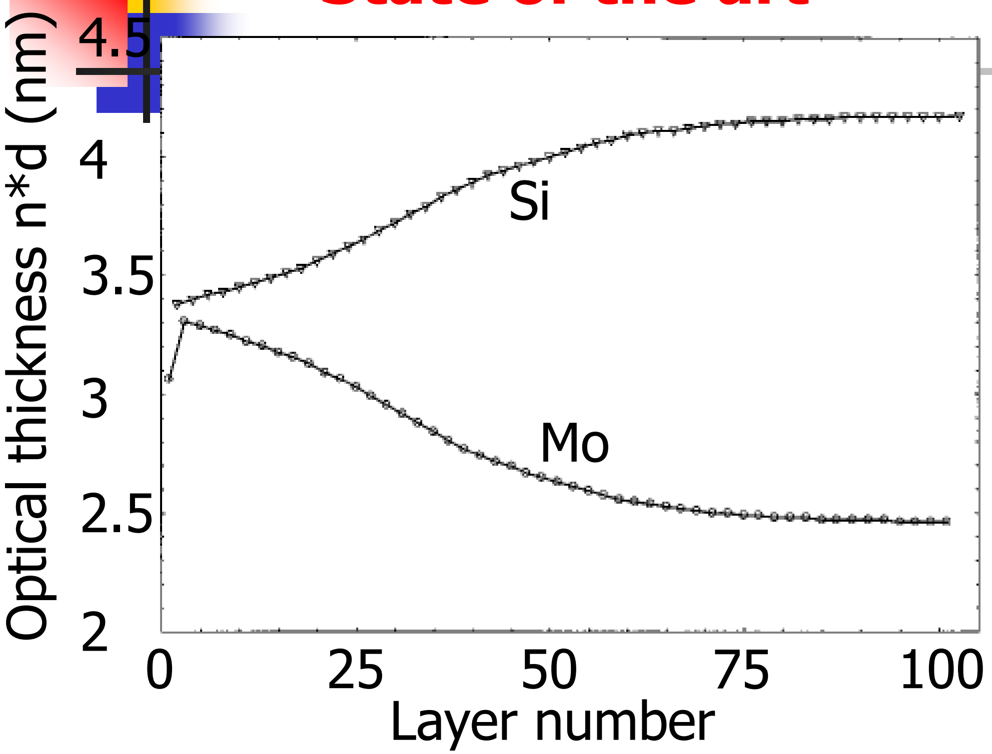


MERIT FUNCTION

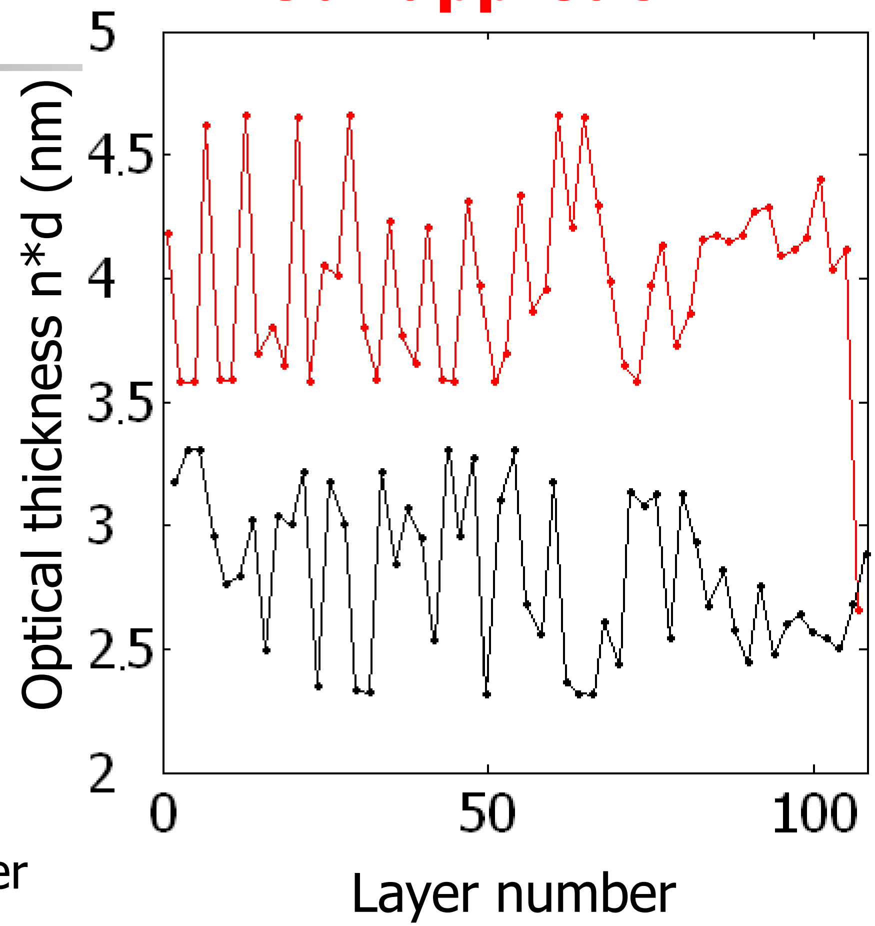
HIGHEST INTEGRATED (R^N)*(I) REFL.

A-periodic multilayer structure characteristics

State of the art



Our approach

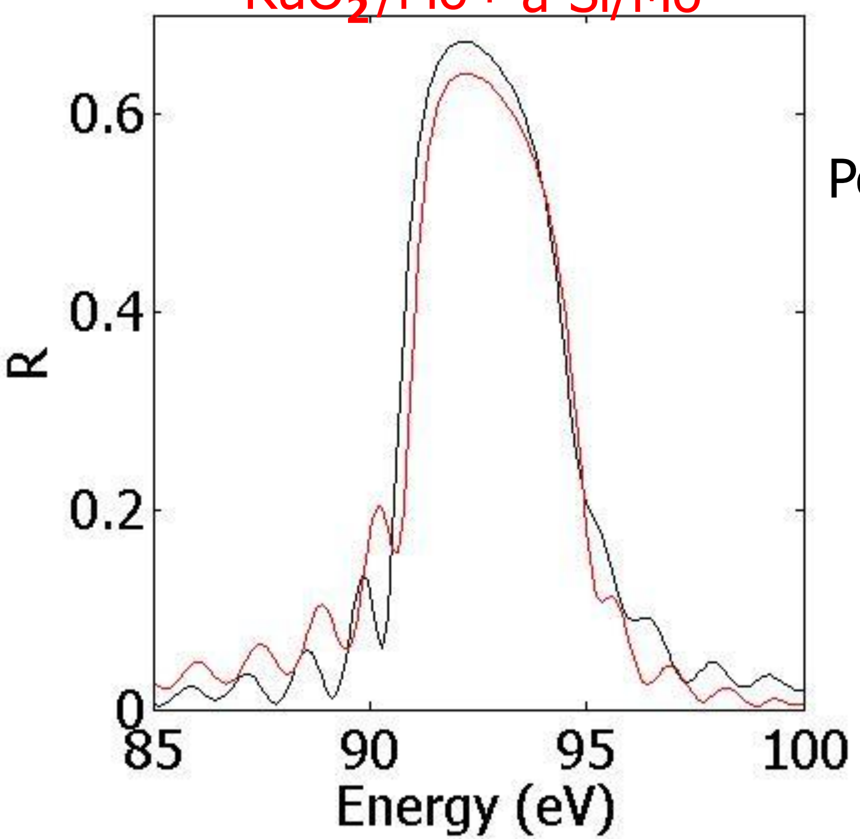


Layer thickness profiles in 50-period optimized Mo/Si stack with 1.5 nm Ru capping layer. Layer 0 corresponds to the substrate surface.

M. Singh and J. J. M. Braat Appl. Opt. **39** 13 2000

Theoretical results

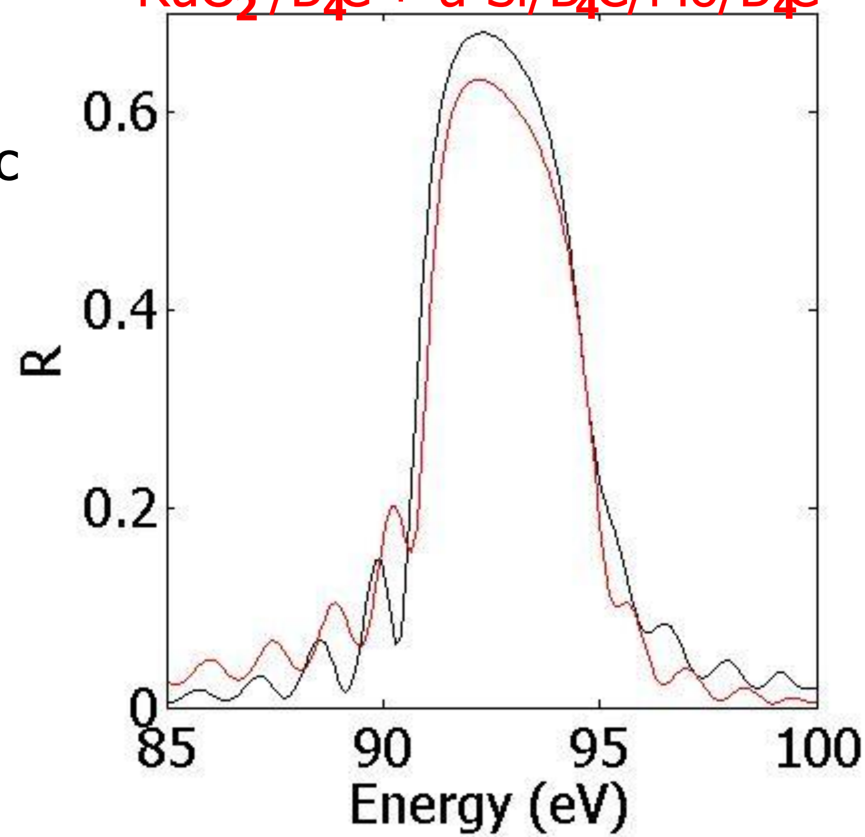
Capping layer | Structure
RuO_2 /Mo+ a-Si/Mo



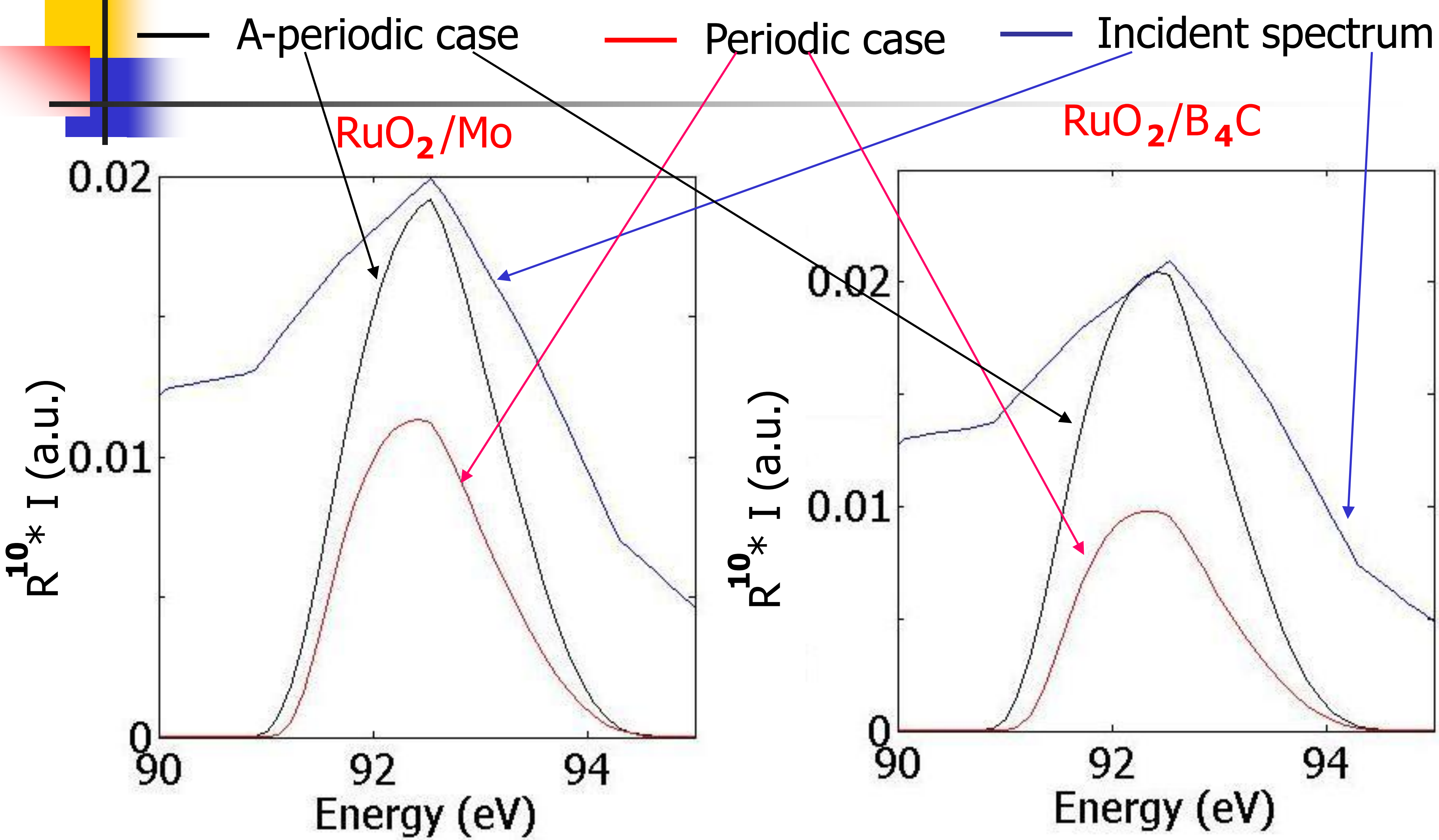
A-periodic case

Periodic case

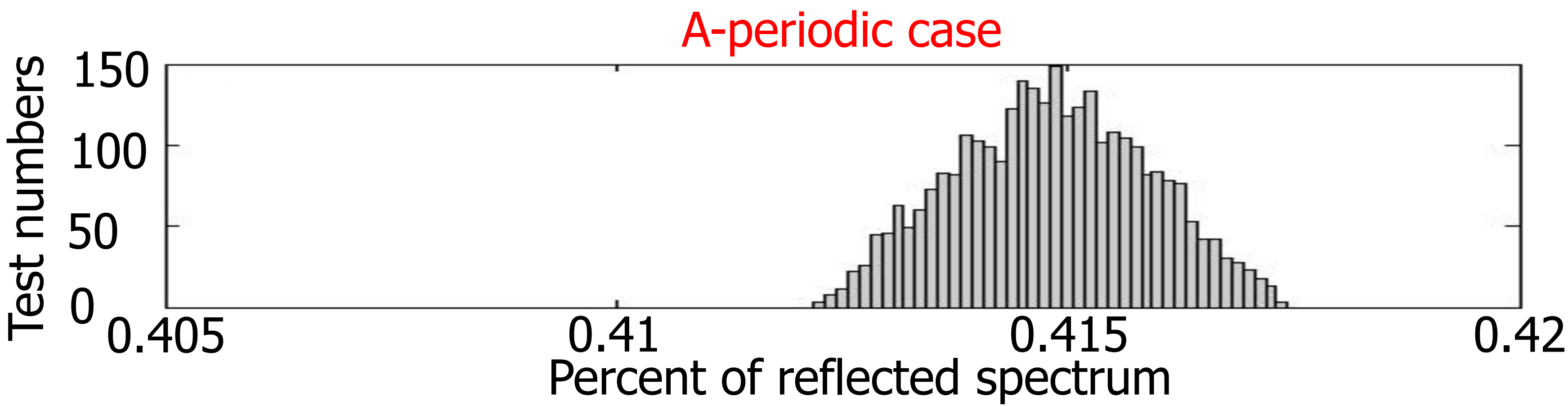
Capping layer | Structure
RuO_2 /B_4C + a-Si/B_4C/Mo/B_4C

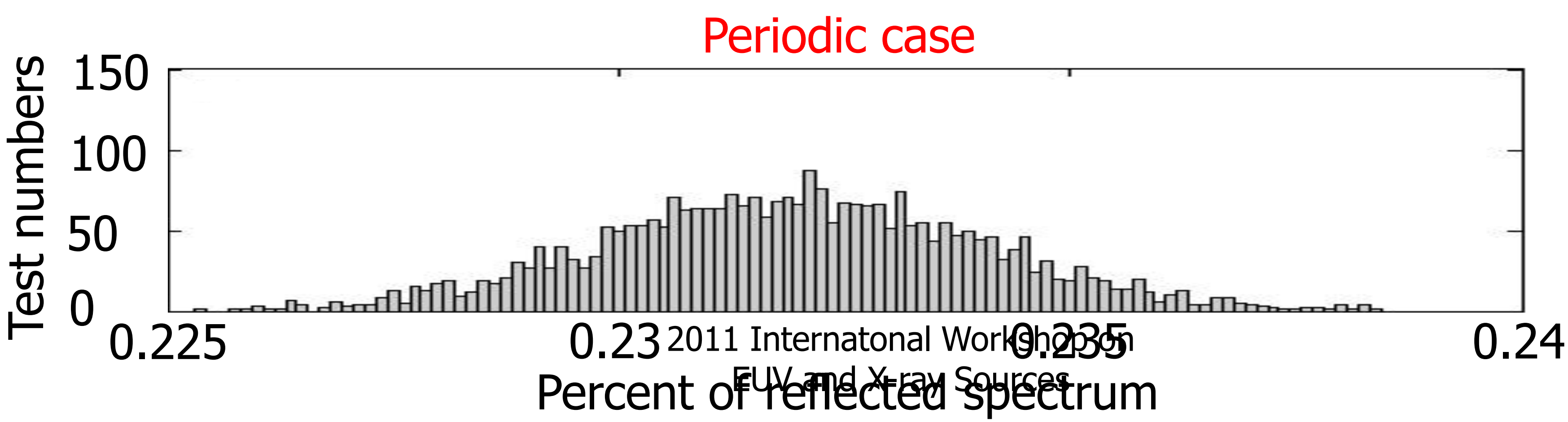


Efficiency improvement



Design stability (case RuO /Mo capping layer)





Experimental Tests

• Periodic and a-periodic structures (Si/Mo) with RuO /Mo (20/20) capping layer have been optimized and deposited (RXO LLC)

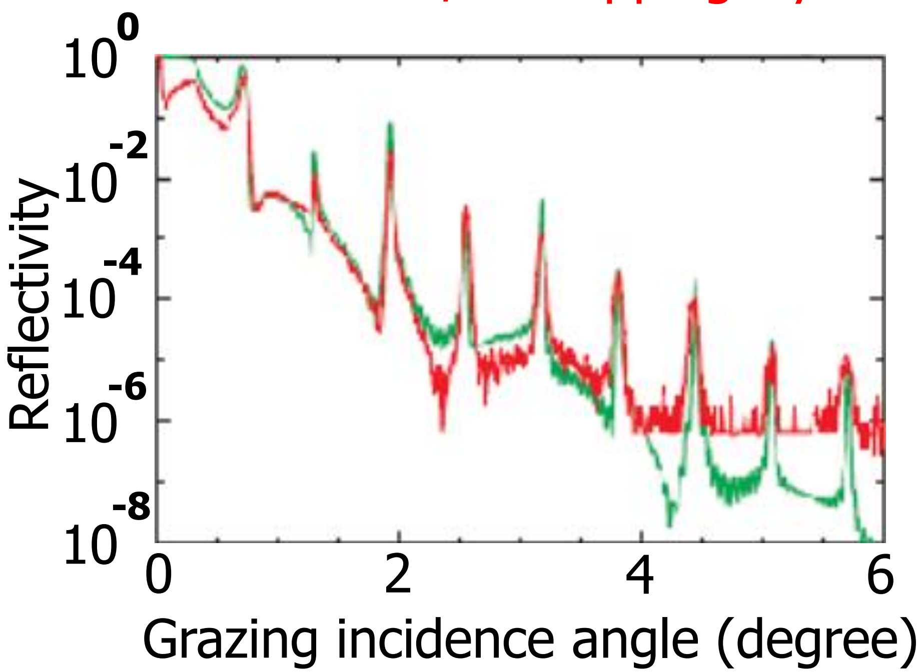
• Pt/Mo (10/20) and Si/Mo (40.5/20) capping layers have been deposited on the same structures, to check the effect on performances

• Reflectivity measurements have been performed soon after deposition and a few months later

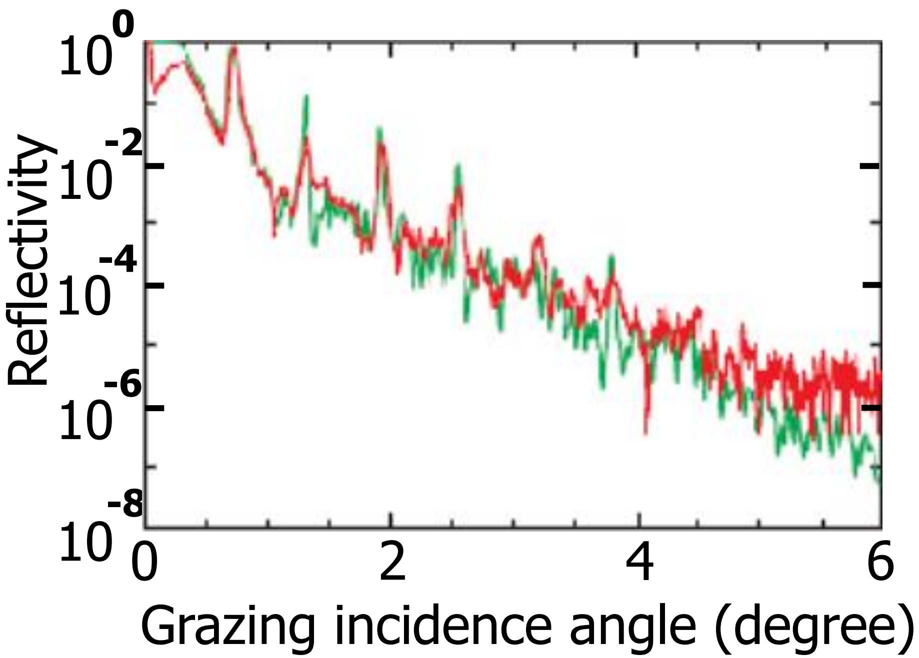
• Secondary electron emission measurements have been performed

XRR

Periodic Ru/Mo capping layer



A-periodic Ru/Mo capping layer



Fitting result

Measured data

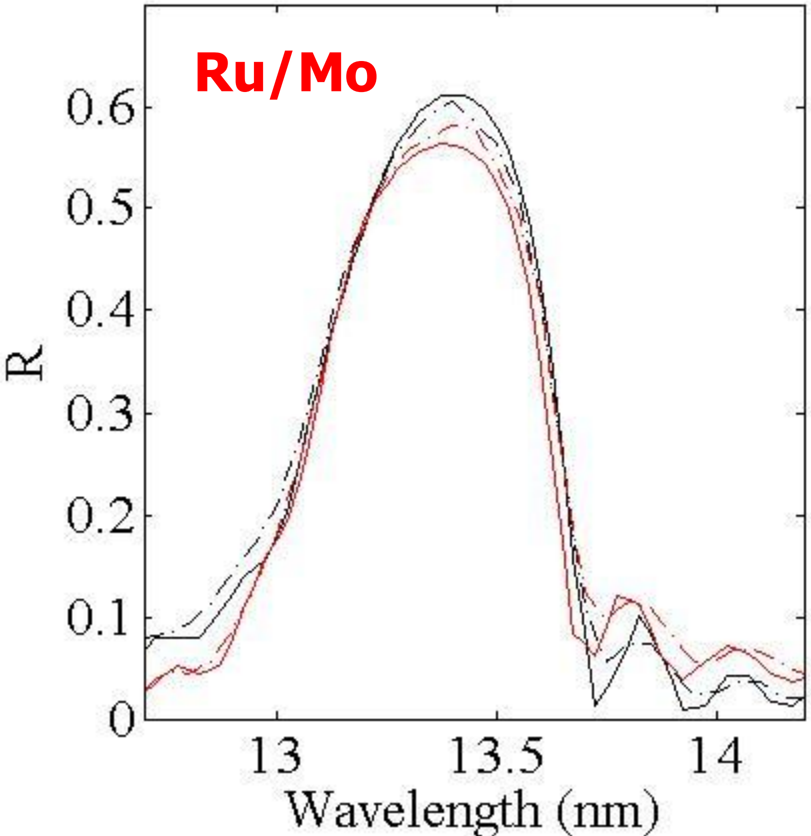
Reflectivity measurements

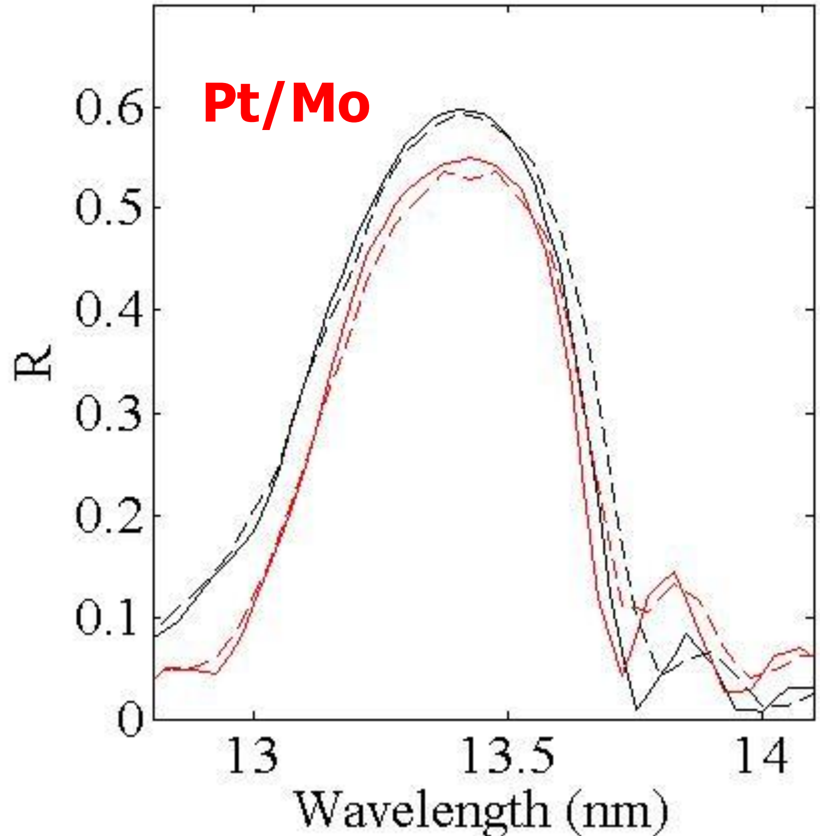
A-periodic at ELETTRA

A-periodic at RXOLLC

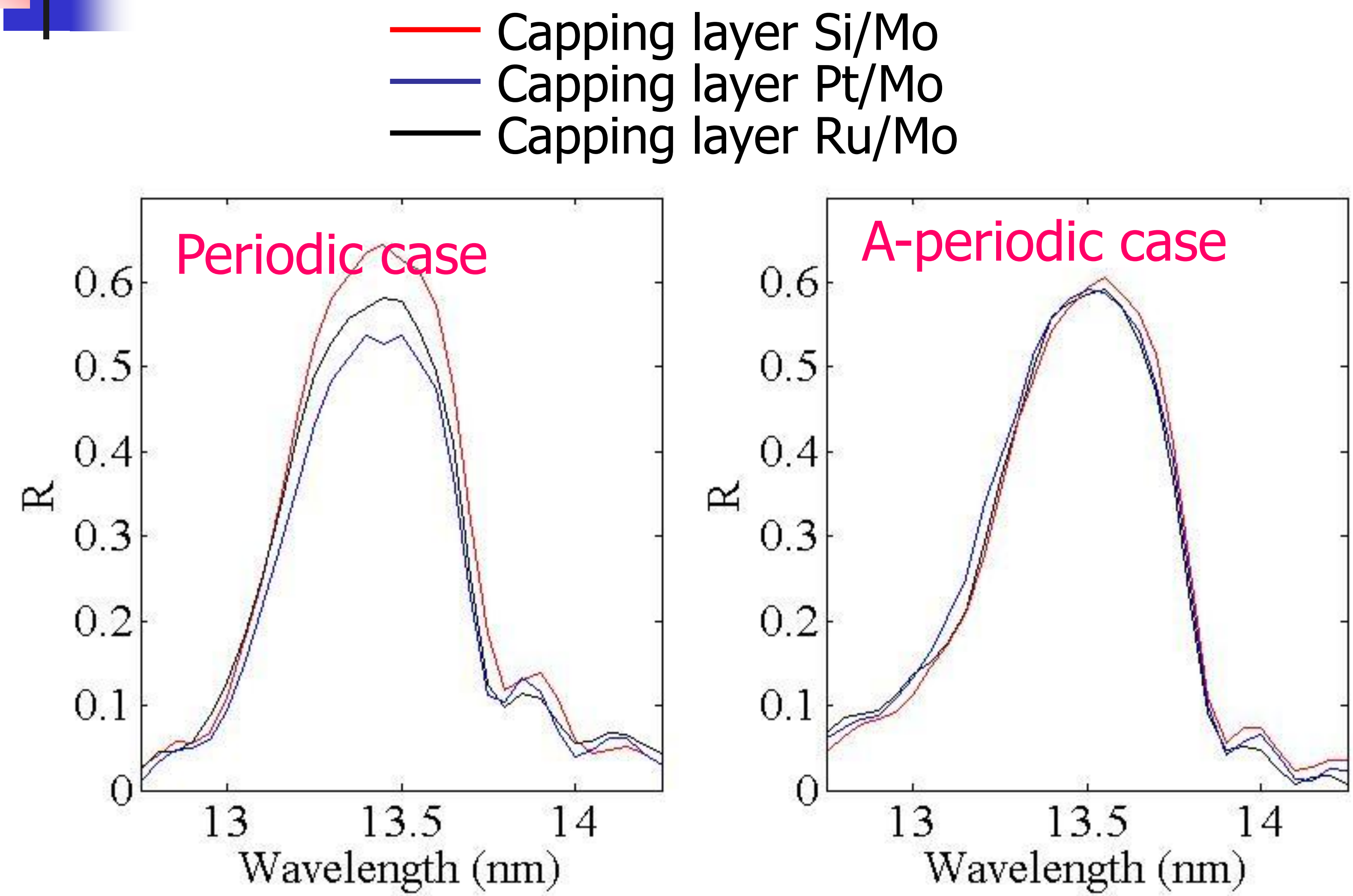
Periodic at ELETTRA

Periodic at RXOLLC



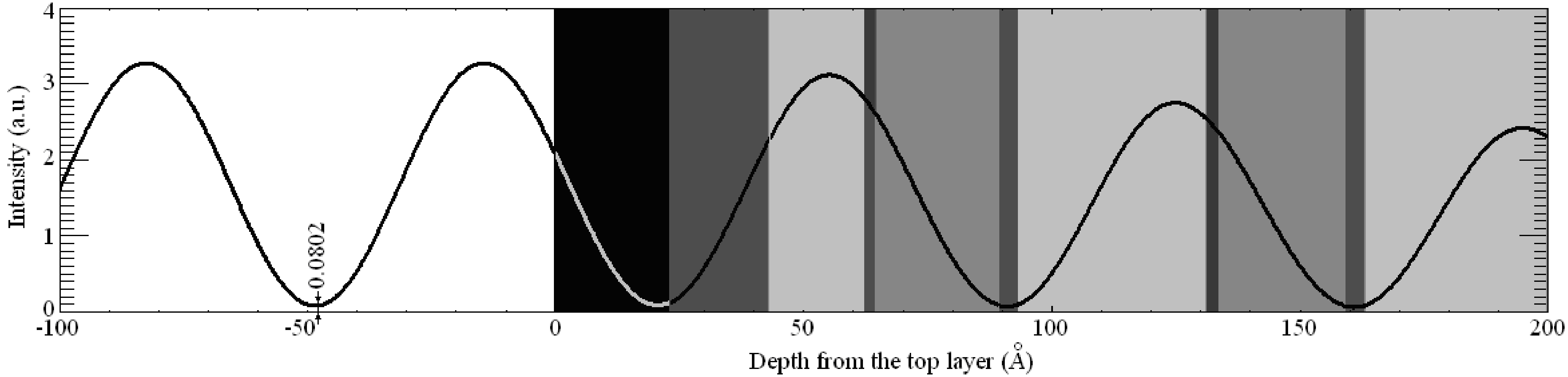


Reflectivity measurements

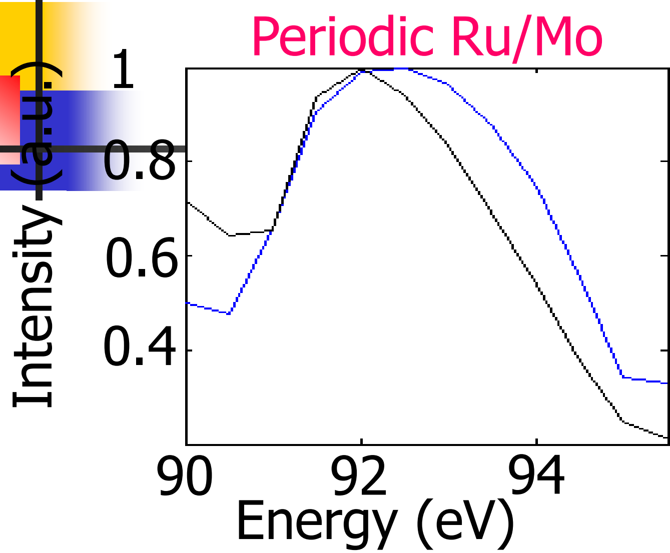


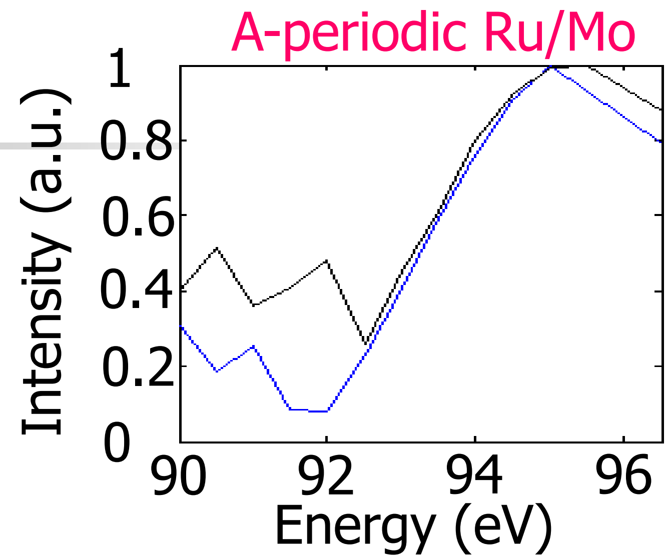
Reflectivity measurements

Area underneath the standing wave curve in the capping layer must be minimized in the whole spectral range!



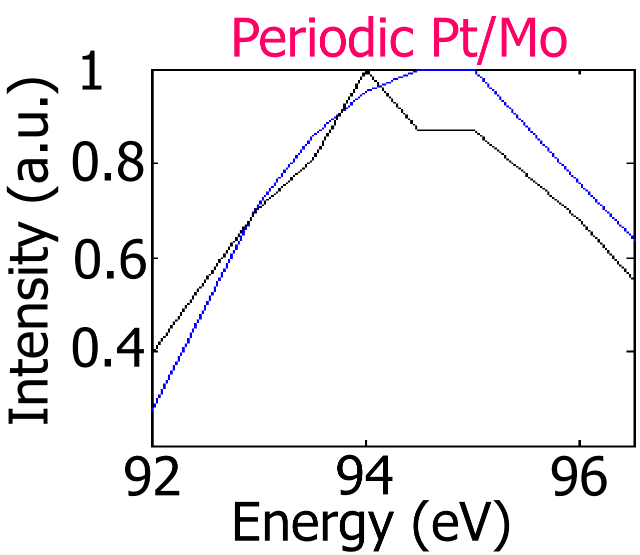
Photoemission

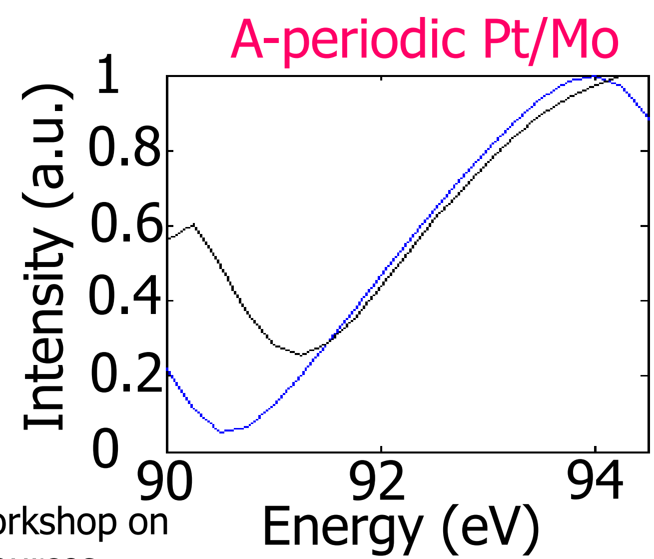




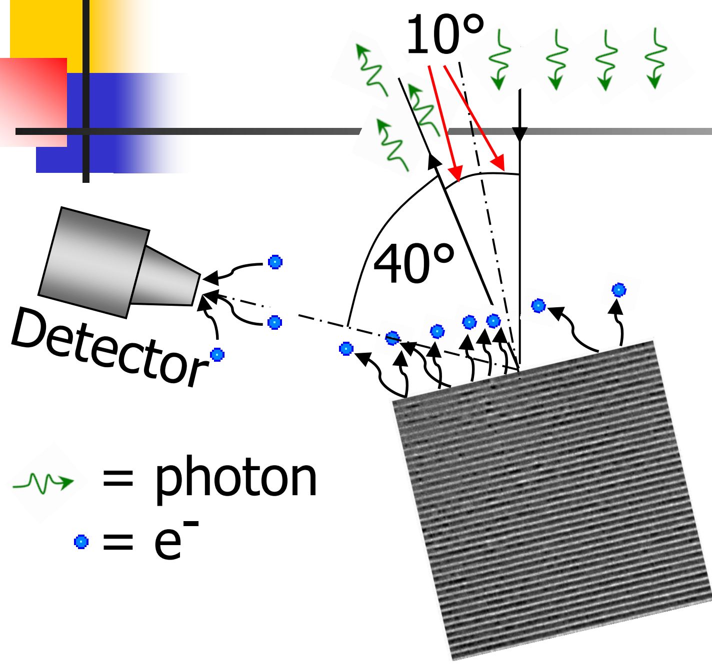
Experimental data

Theoretical data

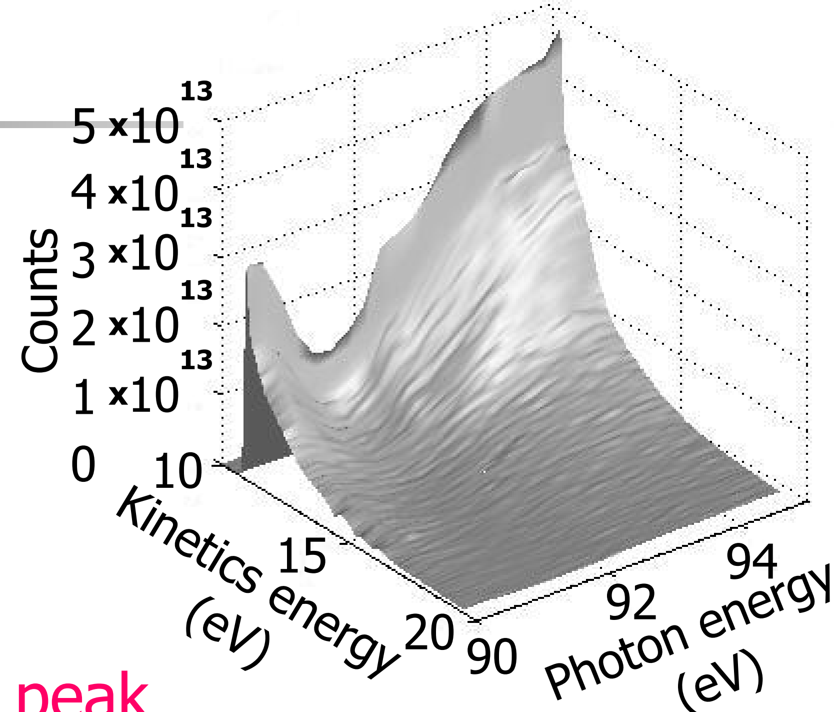




Photoemission



A-periodic Pt/Mo case



Response at the reflectivity peak

$$\frac{\text{A-periodic c-layer Ru/Mo}}{\text{Periodic c-layer Ru/Mo}} = 54\ \%$$

$$\frac{\text{A-periodic c-layer Pt/Mo}}{\text{A-periodic c-layer Ru/Mo}} = 5.7\ \%$$

$$\frac{\text{A-periodic c-layer Pt/Mo}}{\text{Periodic c-layer Pt/Mo}} = 2.2\ \%$$

$$\frac{\text{Periodic c-layer Pt/Mo}}{\text{Periodic c-layer Ru/Mo}} = 142\ \%$$

Conclusions

patent: PCT/EP2007/060477

Standing wave shift → **Insensibility to the capping layer optical properties**

Standing wave shift → **Oxidation slow down**

Standing wave shift → **High reflectivity**

Chaotic distribution → **High reflectivity**

Chaotic distribution → **Best match with the source**

Chaotic distribution → **Stability to typical thickness deposition errors**

CONCLUSIONS

- ML DESIGN DEVELOPMENT BASED ON A-PERIODIC STRUCTURES

- ROLE OF STANDING WAVE FIELD DISTRIBUTION IN THE MLS

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THANK YOU