Analysis of buried interfaces of multilayers through at resonance EUV and XRR reflectivity

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Introduction

Multilayers (MLs) are optical coatings widely used in advanced devices for EUV and X-ray science and technology. ML reflectors are deployed as major components in the EUV photolithography [1], soft x-ray microscopy [2], solar corona studies [3], and are also used as filters, polarizers, beam splitters in diverse EUV and X-ray experimental set-ups. ML production and characterization require very critical processes, in particular complete characterization of multilayers parameters such as thickness, interface roughness and stoichiometric ratio of interlayers. In this work, an innovative and non-destructive experimental characterization method is designed, tested and proposed as a complementary technique to other methods.

Objectives

The designed experimental procedures enable: **i)** A systematic integration of XRR and EUV reflectivity (EUVR) measurements, **ii)** structural and optical properties of MLs to be determined with high precision and consistency, **iii)** non-destructive and non-imaging derivations of structural, optical and phase properties of interlayers, **IV)** Extending the method to 6.X nm multilayer analysis

Sample type, Experimental & numerical methods

Table 1: Sample Interior ML structure

Si/Mo	
d	16.40 nm
Γ	0.82
Si	13.45nm
Mo	2.95 nm
N	25

Table 2: ML capping layer structures (CL)

CL1	CL2	CL3
Si (18.72 nm)	Ir (2 nm)	Ir (2 nm)
Mo (3.5 nm)	Mo (2.2 nm)	Si (15.4 nm)
		Mo (2.95 nm)

XRR measurment

Fig 1: X'PERT-PRO diffractometer (V and I of 40 Kv and 40 mA respectively), $2\theta-\omega$) scan, measurments @ Cu $K_\alpha(\approx 1.5\,A°)$

EUVR measurment

At 99 eV, Si L3-edge

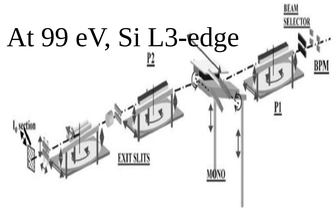

Fig 2: Layout of the BEAR beam line, ELETTRA Synchrotron, Trieste. Photon Energy range: 5 eV - 1600 eV ,average Resolving power ~ 3000

Numerical fit algorithm

- Non-linear least square fit in IMD soft ware (MARQUARDT)
- Numerical fit are performed for both XRR and EUVR measurments
- Fit in Genetic Algorithm (GA) to be done for better fit reliablity (to avoid local minima) in the new version of IMD

Results

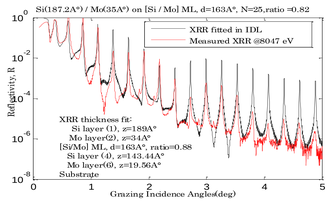

Fig 3: XRR fit for sample 1 D=163 A°, Γ = 0.88 (uncertain)

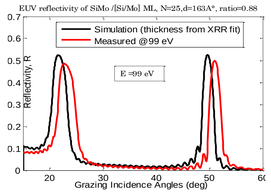

Fig 4: Measured (red) and simulation EUV reflectance for sample 1 (thickness for the simulation are introduced from XRR fit results))

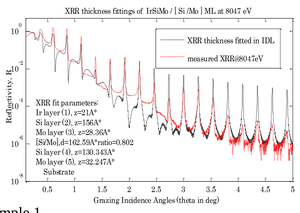

Fig 6: XRR fit for sample 3

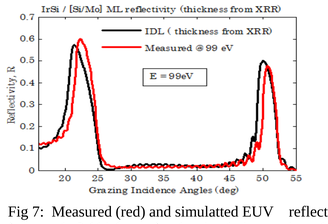

Fig 7: Measured (red) and simulatted EUV reflectance for sample 3 (thickness for the simulation are introduced from XRR fit results)

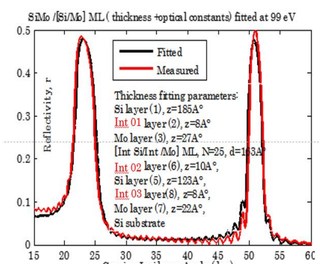

Fig 5: EUV fit layer thicknesses for sample 1

Optical constant fit (in brackets are from CXRO),

Layer	*Values*	*Phases*
Si layer (1)	$\delta = -0.002953[-0.00957]$ $\beta = 0.003648[0.00181]$	
Int 01layer (2)	$\delta = 0.067165$ $\beta = 0.0045000$	$\approx Mo$
Mo layer (3)	unchanged	
[Si /Int 02/Mo/Int 03] x25, N=25, d=163A°		
Int 02 layer (4)	$\delta = 0.024572$ $\beta = 0.0045$	Mo2Si3
Si layer (5)	$\delta = -0.004907[-0.00957]$ $\beta = 0.002033[0.00181]$	
Int 03 layer(6)	$\delta = 0.014751[0.014506]$ $\beta = 0.0035[0.00379]$	MoSi2
Mo layer (7)	unchanged	
Si substrate		

Table 3: EUV fit optical constants for sample1

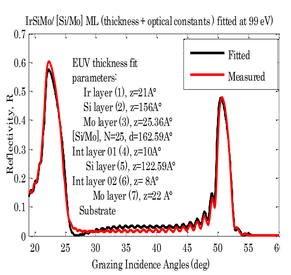

Fig 8: EUV fit layer thicknesses for sample 3

Optical constant fit (in brackets are from CXRO)

Layer	Values	Phases
Ir layer (1)	$\delta = 0.087813[0.079315]$ $\beta = 0.035289[0.034959]$	
Si layer (2)	$\delta = -0.004585[-0.00957]$ $\beta = 0.001181[0.00181]$	
Mo layer (3)	unchanged	
[In 01/Si/Int 02/Mo]x25, N=25, d=162.59A°		
Int 01 (4)	$\delta = 0.025627$[not given] $\beta = 0.0045$	Mo2Si3
Si layer (5),	$\delta = -0.005522[-0.00957]$ $\beta = 0.001633[0.00181]$	
Int 02 (6)	$\delta = 0.015674$[not givne] $\beta = 0.0045[0.00379]$	MoSi2
Mo layer (7)	unchanged	
Si substrate		

Table 4: EUV fit optical constants for sample 3

- ○Layer thickness detemined with in $\pm 2A°$ *error* in an iterative EUV fit
- ○Optical constants of interior layers of Mo and Ir are assumed unchanged@ 99 eV
- ○ β is not sensitive [0.0025-0.0067 can be used for Si]

Conclusion

- ➢GEUVR @ resonance edges + XRR is simpler tecnique to study both structural and optical properties of MLs
- ➢ Non-destructive and non-imaging interlayer phase determination (MoSi2 and MoSi3 are dominant silicides obtained for Si/Mo MLs)
- ➢ Impacts of local interactions (Oxidation,carbon contamination) quantitatively derived
- ➢Sensitivity of Si to local atoms interactions are clearly revealed
- ➢ Thus, applicable to B4C-based MLs for 6.X nm ML reflectors
- ➢ **Limitation:**only reliable to low Z elements (mainly Si, Be and C and B)

References and links

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