ANALYSIS OF LIGHT SOURCE INDUCED CONTAMINATION FILMS BY EXTREME ULTRAVIOLET REFLECTOMETRY

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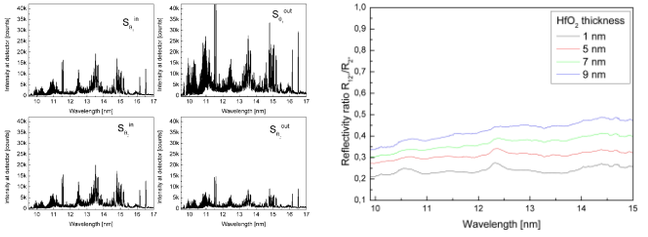
INTRODUCTION

Modern nanotechnology is constantly raising demands to quality and purity of thin films and interlayer interfaces. As thicknesses of employed layers decrease to single nanometers, traditional characterization tools are no longer able to satisfy throughput, precision or non-destructibility. Extreme ultraviolet (EUV) and soft X-ray reflectometry has not only demonstrated the ability to detect sub-nm thickness variations but also was shown to be very sensitive to chemical composition changes. Since the laboratory radiation sources in this wavelength range often emit in a relatively broad spectral range, a spectroscopic EUV reflectometry has been developed with the added benefit of a rapid measuring time on the order of milliseconds to seconds. Here the extension of the method to multi-angle measurements will be presented. It allows to reduce a number of fit parameters in the analysis model, making the method suitable for complex samples of unknown composition. The tools performance will be shown exemplary by analysis of high-k based layered systems measured under grazing incidence angles between 2 and 15°. The suitability of the tool to the industrial relevant application of analysis of contamination films will be depicted by experimental results on EUV light induced test samples.

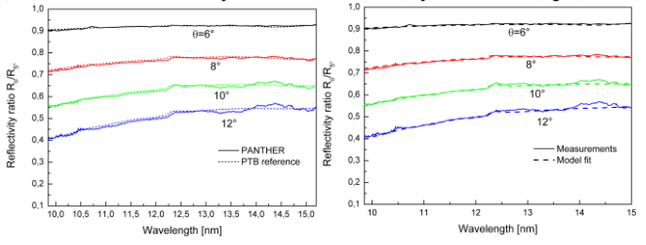
MULTI-ANGLE MEASUREMENTS

$$R_{\theta 2} = \frac{S_{\theta 2}^{out}}{S_{\theta 1}^{out}} \cdot \frac{S_{\theta 1}^{in}}{S_{\theta 2}^{in}} \cdot R_{\theta 1} \quad (1)$$

$$\frac{R_{\theta 1}}{R_{\theta 2}} = \frac{S_{\theta 1}^{out}}{S_{\theta 2}^{out}} \cdot \frac{S_{\theta 2}^{in}}{S_{\theta 1}^{in}} \cdot \frac{R_{\theta 2}^{mirror}}{R_{\theta 1}^{mirror}} \quad (2)$$



Typical set of measured spectra, used for the reflectivity calculations with θ_1=2° and θ_2=12° (left) and measured reflectivity ratio for different HfO_2 layer thicknesses (right)



Comparison of measurements by laboratory-based PANTHER and by PTB at a synchrotron (left) and measured reflectivity ratio for different incidence angles in comparison with fitted model of the layer system (right)

EUV REFLECTOMETER

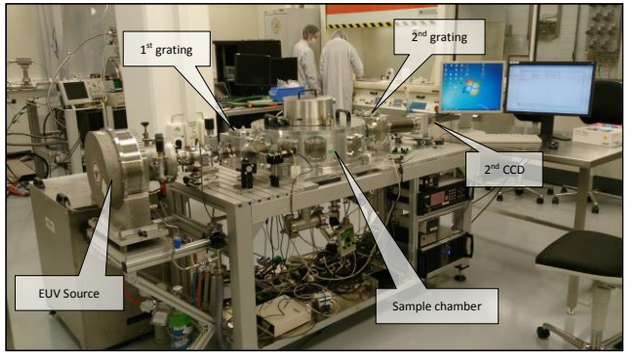
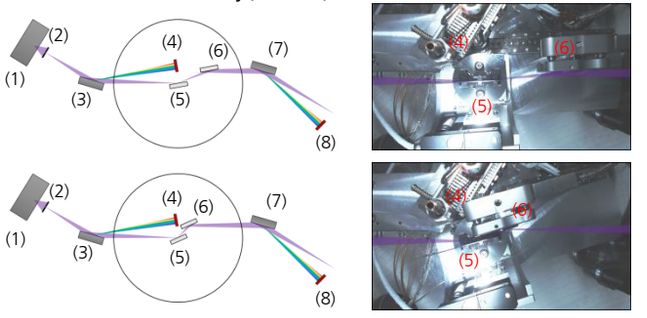
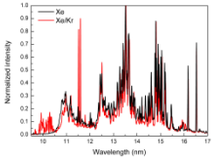


Photo of the Polychromatic Angle-resolving Non-destructive Tool for High-speed Extreme ultraviolet Reflectometry (PANTHER)

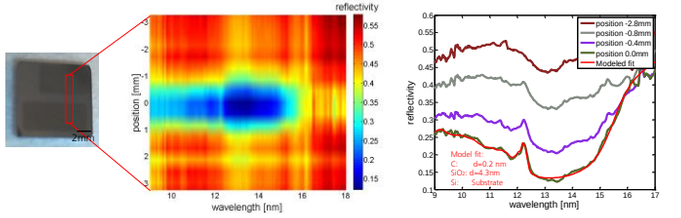


Sketch (left) and photo (right) of the hardware realization for multi-angle operation, exemplary for 2° (top) and 15° (bottom) incidence angle with EUV source (1), imaging slit (2), 1st grating (3), 1st CCD (4), sample (5), deflection mirror (6), 2nd grating (7) and 2nd CCD (8)

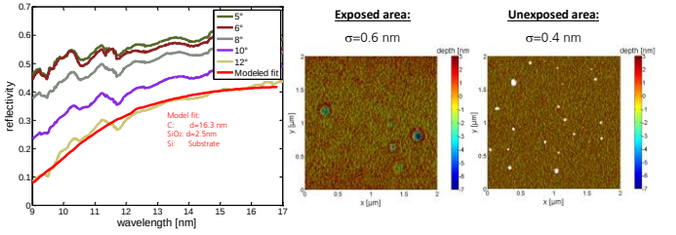


- Working gas: Xe/Kr mixture
- Wavelength range: 9 - 18 nm
- Spectral resolution: 0.02 nm
- Incidence angles: 2 - 15°
- Angular resolution: 0.05°
- Pulse-to-pulse measurements
- Pulse duration: 150 ns
- Repetition rate: 50 Hz

CONTAMINATION INVESTIGATIONS



Photograph of LPP source-induced contamination layers on a sample with marked investigated area (left), measured reflectivity of contamination area in dependence of illumination spot position on sample (middle) and comparison of reflectivity in different contaminated areas of the sample with exemplary modeled reflectivity (right)



Measured reflectivity and exemplary modeled fit of DPP source-induced contamination on top of a silicon substrate for different incidence angles (left) and Atomic Force Microscopic investigations of the contaminated substrate (middle) and of an uncontaminated substrate (right)

SUMMARY

- EUV spectroscopic reflectometry is a powerful tool for analysis of thin films and film stacks
- Multi-angle measurements increase precision of layered systems identification
- This work had been chosen by the European Regional Development Fond (ERDF) co-financed operational program for NRW with the scope "regional competiveness and employment" 2007 – 2013

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