Complementary Methodologies for Thin Film Characterization in One Tool - a Novel Instrumentation for 450 mm Wafers

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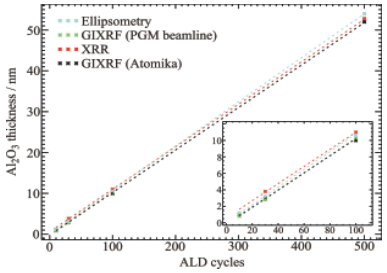
Advantages and success of complementary metrology

The scaling down of critical dimensions for the manufacture of nanoelectronics requires the continuous introduction of new materials. The request for validation, assurance, and support using differing analytical methods is driving the integration of multiple methods into one tool. The goal of the design study was to highlight all aspects, e.g. economic and scientific, of the design and the realization of a metrology platform for wafers with a diameter of 450 mm. The criteria studied are the

- analytical performance of the methods, which includes the determination of structural and compositional information including material parameters of surfaces on wafers with a diameter of 450 mm
- complementarity of the analytical techniques, which means the usage of different analytical techniques to assess the surface to improve the reliability and traceability of the results
- tool performance (e.g. spatial resolution, measurement speed, mechanical components)
- costs

Analytical performance

A complementary analysis of Al_2O_3 layers on silicon with varying thicknesses is shown in the figure. The determined thicknesses of X-ray reflectivity, total reflection, as well as grazing incidence X-ray fluorescence and ellipsometry are in accordance with each other, which demonstrates the success of the complementary analysis.

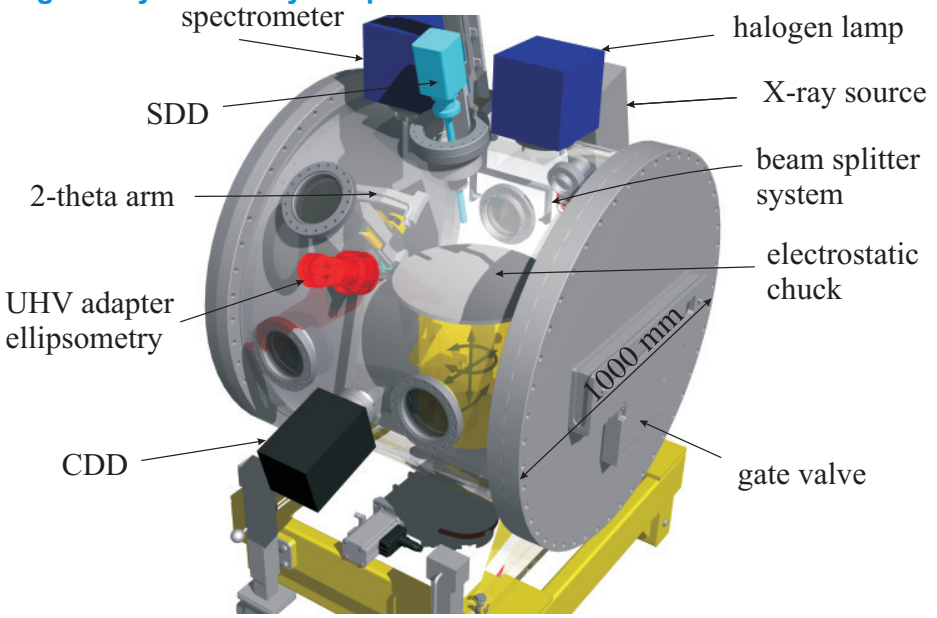


Complementarity of the analytical techniques

The support and validation matrix shows how a method (rows) can help another method (colums) to improve or complement the results.

Methods	TXRF	GIXRF	XRF	XRR	XRD	GISAXS	VUV reflectometry/ ellipsometry
TXRF		Surface contamination	Additional information on surface contamination	Additional information on surface contamination	Additional information on surface contamination	Nanoparticle composition	Additional information on surface contamination
GIXRF	Absolute angle calibration		Validation measurands	Element depth pro les near the surface	Element depth pro les near the surface	Nanoparticle composition	Element depth pro les near the surface
XRF	Validation measurands	Validation measurands		Information on material composition	Information on material composition	Nanoparticle composition	Information on material composition
XRR	Layer thickness and roughness as input parameters for modeling	Layer thickness and roughness as input parameters for modeling	Contamination/spectral diffraction artefact		Layer thickness, roughness, density	Substrate surface layer	Layer thickness, roughness, layer structure as input parameter for modeling
XRD	Information on material morphology, identi cation of diffraction artefacts	Information on material morphology, identi cation of diffraction artefacts	Information on material morphology, identi cation of diffraction artefacts	Information on material morphology		Information on material morphology	Information on material morphology
GISAXS	Particle size distribution	Particle size distribution	——	Particle size distribution	Particle size distribution		Particle size distribution
VUV re□ectometry/ ellipsometry	Precise layer thickness as input for the quanti cation or simulation of models	Precise layer thickness as input for the quanti cation or simulation of models	Precise layer thickness as input for the quanti cation or simulation of models	Precise layer thickness as input for the quanti cation or simulation of models	Precise layer thickness as input for the quanti cation or simulation models	Information on structures and dimensions for scatterometry measurement	

Design study of an analytical platform for 450 mm wafer



Tool performance and costs

Method	Application	Spatial resolution	Acquisition time	Strenght of the method	Costs per Method
TXRF	elemental (B-U) contamination	1mm² / 1cm²	50 s – 1000 s / point	highest sensitivity on smooth surfaces	~ 300 k€
GIXRF / XRF	depth profiling, nanolayer analysis	0.5 mm² / 1cm²	100 s – 5 h / point	depth sensitivity	~ 300 k€
XRR	layer thickness	to 1 mm²	1000 s – 5 h / point	nanolayer characterization	~ 300 k€
XRD	crystal structure	0.5 mm² / 1cm²	1000 s – 5 h/ point	lattice constant / stochiometry	~ 300 k€
GISAXS	nanostructures	0.5 mm² / 1cm²	10 min / frame	particle size distribution	~ 600 k€
Ellipsometry	layer thickness, optical constants	35 µm × 35 µm	10 s / 1 min / point	fast layer characterization	~ 300 k€
Vacuum UV Reflectrometry	layer thickness	3 mm - 50 µm	3s-10s /point	fast nanolayer characterization	~ 500 k€

Positioning stage

To integrate all analytical methods into one vacuum chamber, a new approach for the design of the positioning stage was considered and a patent has recently been submitted (Nr.: 10 2012 000 736.1).

The 5-axis positioning stage enables a 2D mapping of the whole wafer surface, as well as height and incident angle adjustment.

Acknowledgement

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