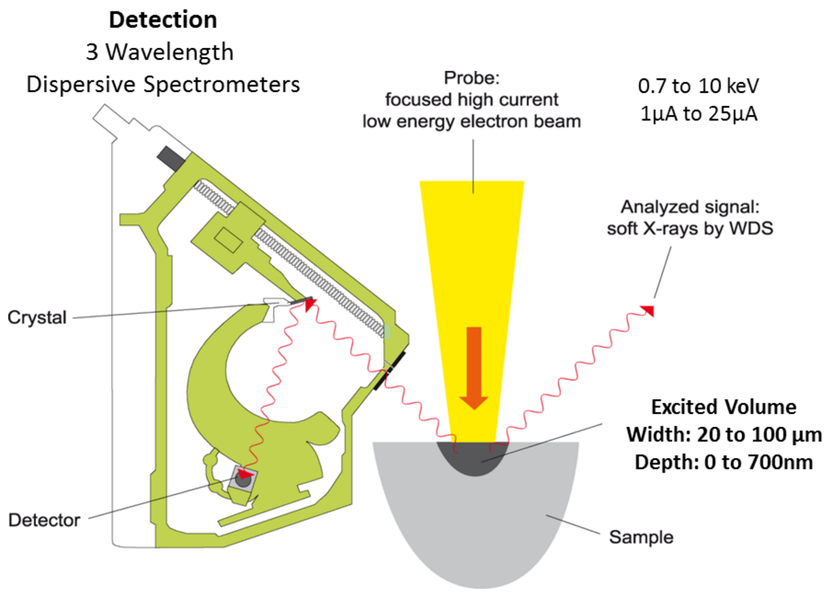
Non-Destructive Compositional Metrology of NAND Memory and Emerging Non-Volatile Memories

Olivier Dulac[1], Anna Meura[1], Anne-Sophie Robbes[1], Mona Moret[1], Ricardo Sousa[2], Loan-Lucian Prejbeanu[2] and David J. Larson[1]
[1]CAMECA, 29 quai des Grésillons, 92622 Gennevilliers Cedex, France
[2]SPINTECH, UMR 8191, 17 rue des Martyrs, Bat. 10-05, 38 054 Grenoble, France

Compositional Metrology by LEXES

Possibility to measure all elements heavier than Be
Dopants and / or main matrix elements

*L*ow energy
*E*lectron induced
X-ray
*E*mission
*S*pectrometry



Elemental composition
Dopant dosimetry
Layer thickness

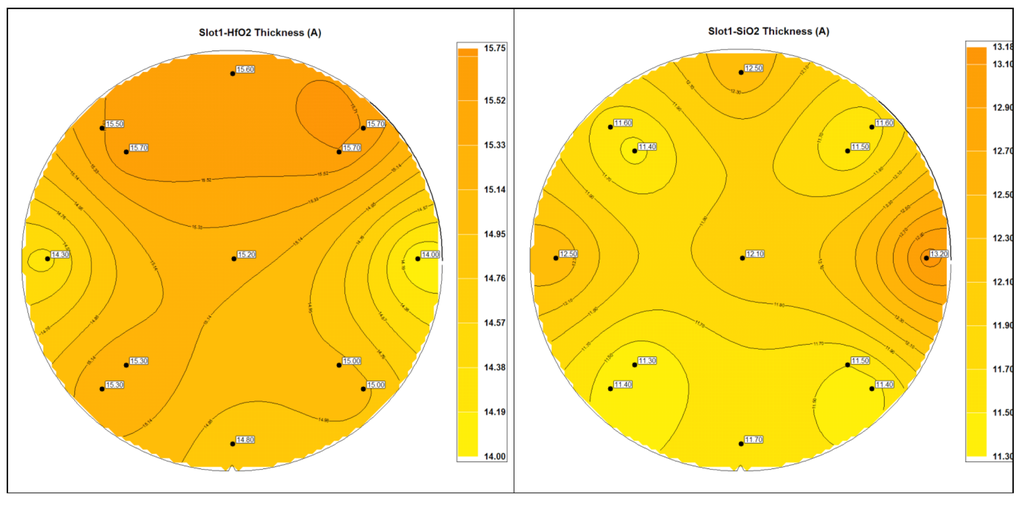
Direct
Non-contact
Buried layers
Patterned wafers

NAND

Hf and AlO_3 layers : - very low thickness
- buried under a Titanium nitride

→ Very difficult to measure using conventional optical techniques!

LEXES is able to detect and measure such layers, even **highly buried**
LEXES detects the non-uniformity of thin film composition with very good repeatability.



HfO_2 Thickness = 15.16 A
RSD = 3.59% Across Wafer

SiO_2 Thickness = 11.83 A
RSD = 5.04% Across Wafer

Emerging non volatile memories characterization

PRAM

→ During PRAM manufacturing it's very challenging to :
- control the stack composition
- monitor the amount of incorporated nitrogen used to adjust the crystallization temperature

Wafer	Ge at%	Sb at%	Te at%	N at%	Thickness (Å)	RSD thickness
1	**19.95**	**19.826**	**44.9114**	**15.3128**	**736.92**	**0.88**
2	**27.08**	**24.875**	**48.048**	N/A	**686.76**	**0.32**
3	**25.94**	**24.089**	**49.971**	N/A	**649.22**	**0.47**

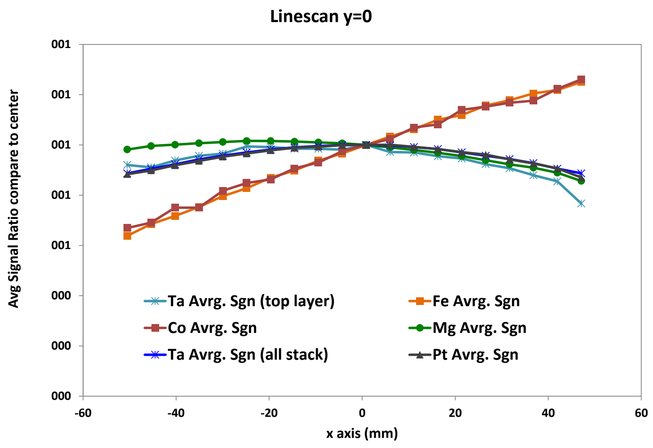
LEXES is able to **detect and monitor** the amount of Nitrogen inside the stack.

LEXES is able to measure the **whole composition** of the stack.

STT RAM

→ For STT RAM manufacturing it's very challenging to:
- control $FeCo_8B_{20}$ and Mg OxNat top layers
- control the stack composition

	Impact Energy	Precision	Non-Uniformity
Ta Avrg. Sgn (top layer)	2keV	1.66%	19.71%
Fe Avrg. Sgn	2keV	1.27%	18.80%
Co Avrg. Sgn	2keV	2.06%	4.80%
Mg Avrg. Sgn	3keV	0.20%	4.31%
Ta Avrg. Sgn (all stack)	4keV	0.37%	6.05%
Pt Avrg. Sgn	4.5keV	0.40%	4.04%



LEXES can **detect and quantify all the elements** of the stack with quite good repeatability.
LEXES can measure the **non-uniformity** over the wafer for all the elements.
Tput ≈ 4.4 wafers/hr (9pts)

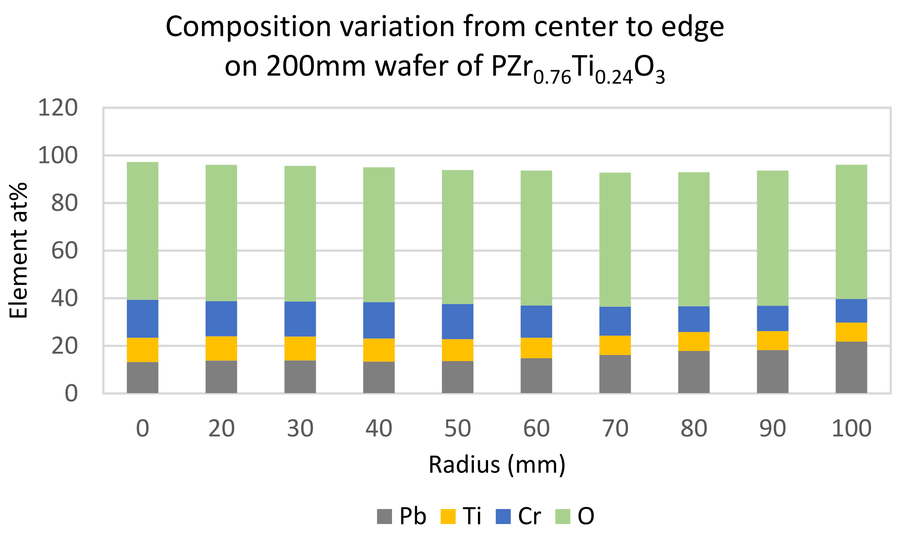
FeFET

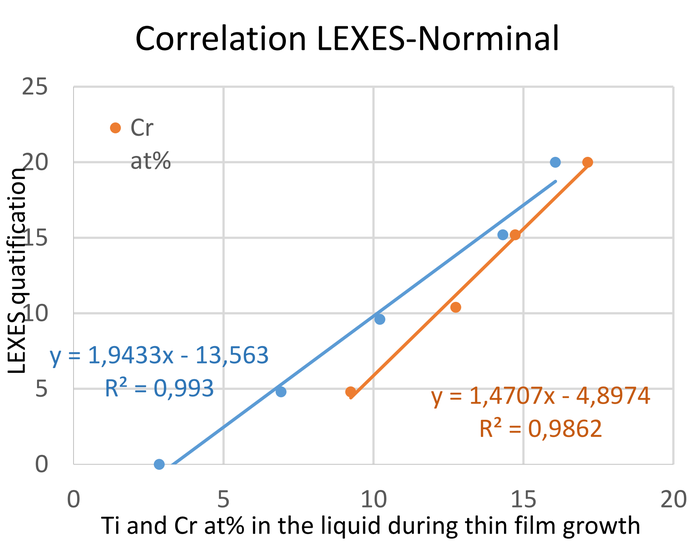
$PZr_xTi_{1-x}O_3$
(x: 0→1)

The replacement of Zr onto the Ti position in the perovskite matrices enhances the piezoelectricity. The ratio Zr/Ti is therefore a crucial parameter to control the electrical properties of the circuit.

→ For FeFET manufacturing, it's very hard to control the target ratio Zr/Ti and the film thickness.

	Detected X-Ray	Impact Energy	Crystal	Precision
Pb	Pb Ma 2345eV	6.5KeV	LPET	0.19%
Ti	Ti Ka 4508eV	6.5KeV	LPET	0.21%
Zr	Zr La 2042eV	4KeV	LTAP	0.36%
O	O Ka 525eV	2KeV	LPC1	0.35%





LEXES performs a **perfect linearity** with the ratio Zr/Ti in the liquid flow during the film growth.

LEXES detects the non-uniformity of thin film composition => help to **predict the final electrical properties** variation.