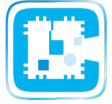


PillarHall®

METROLOGY TOOLBOX FOR ALD PROCESSING IN HIGH ASPECT RATIO STRUCTURES

- Anish Philip, ALD Scientist
- Email: anish.philip@chipmetrics.com
- Tel +358 50 539 7516
- www.chipmetrics.com

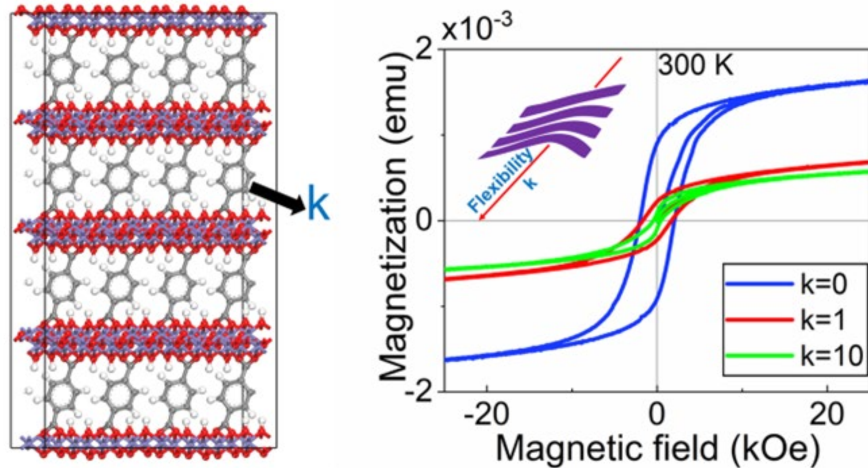
Short intro

Senior ALD Scientist
Chipmetrics

2018-2022 : Postdoc (ALD-MLD, Aalto)

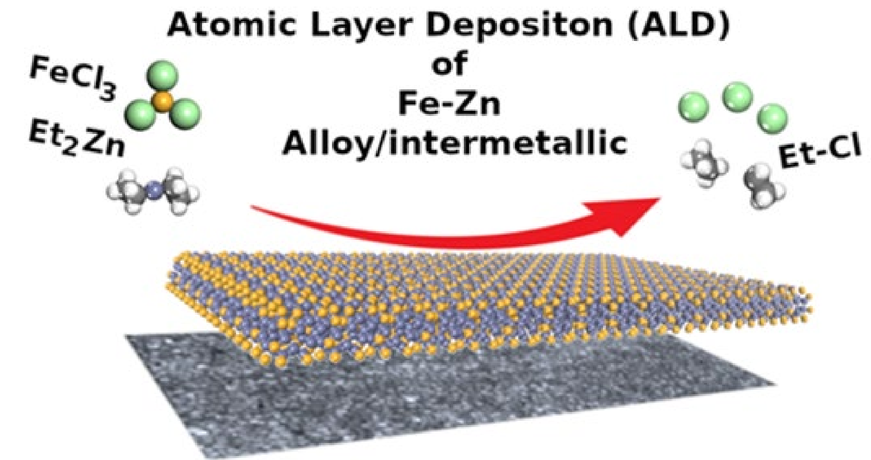
2022- : Chipmetrics

Flexible magnets



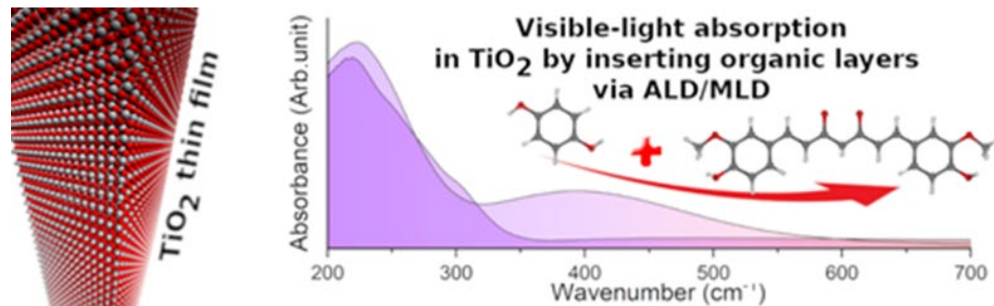
Philip, A et al., ACS Appl. Mater. Interfaces 12, 21912 (2020)

Metallic and intermetallic thin films



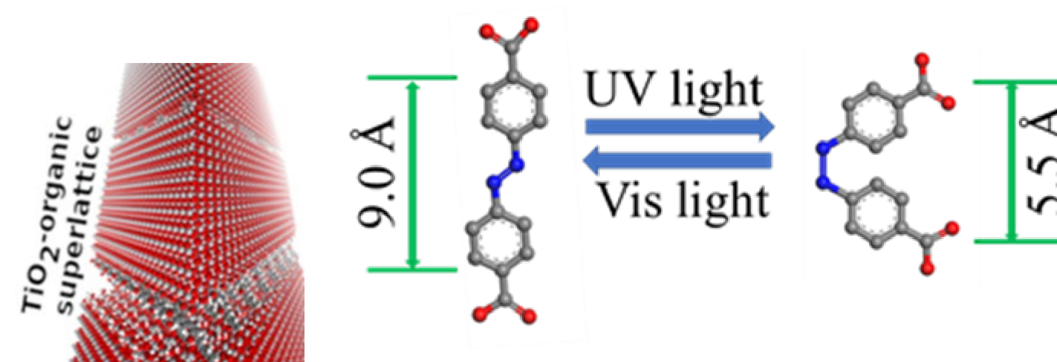
Ghiyasi,R et al., Chem. Mater. 34, 5241(2022)

Antiviral coating



Philip, A et al., ChemNanoMat 7,1(2021)

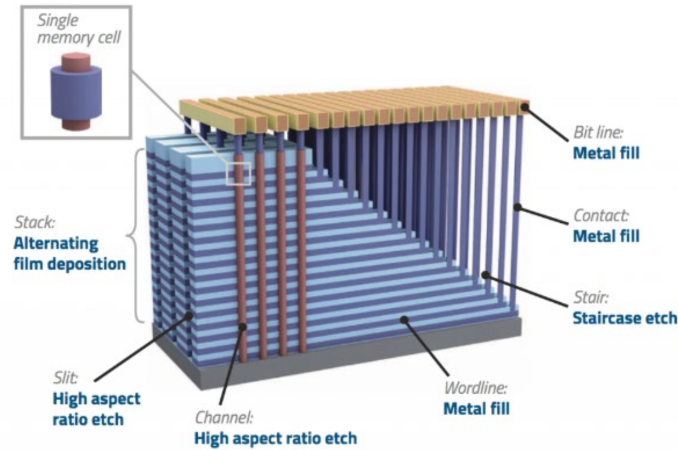
Photoresponsive materials



Philip, A et al., J.Mater. Chem. C 10, 294 (2022)

Khayyami, A et al., Angew. Chemie Int. Ed. 58, 13400(2019)

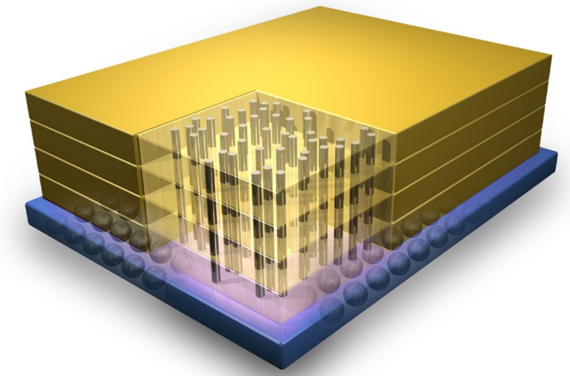
High aspect ratio (HAR) structures demands in today's microelectronics



3D NAND

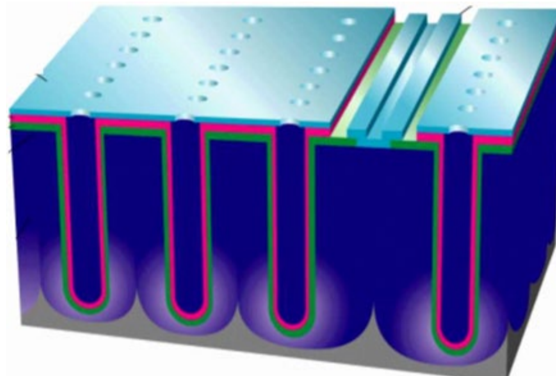
H Singh. Overcoming challenges in 3D NAND volume manufacturing(https://sst.semiconductor-digest.com), 2017

Complex 3D geometry & Miniaturization of devices



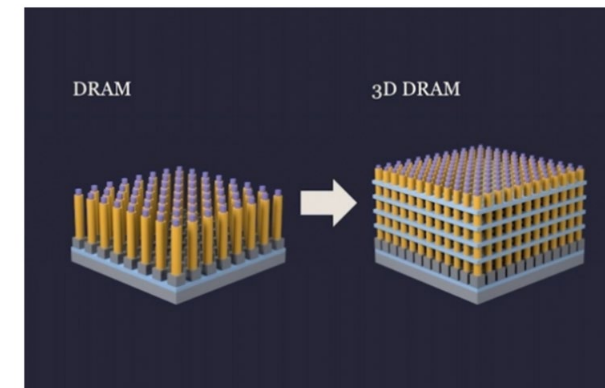
Through-silicon vias

https://www.nist.gov/image/3d-hmc-pic1jpg



3D silicon capacitor

https://anysilicon.com/overview-and-types-of-capacitors-in-asic-design/

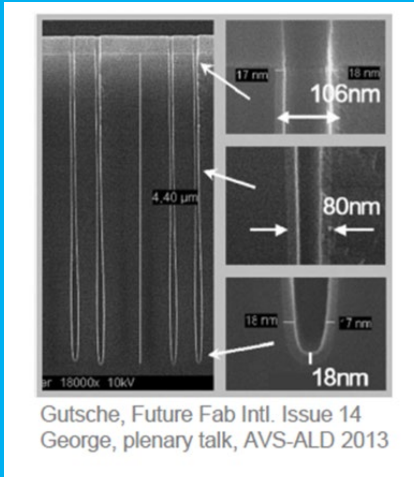


3D DRAM

http://www.businesskorea.co.kr/news/articleView.html?idxno=86318

3D Thin Film Metrology

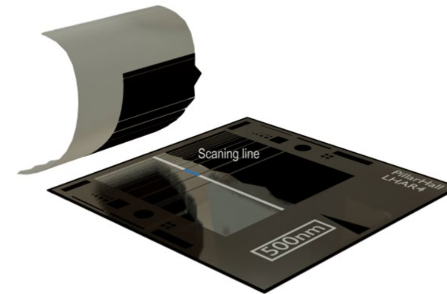
Cross-sectional sampling
Destructive. Slow. Expensive.



Gutsche, Future Fab Intl. Issue 14
George, plenary talk, AVS-ALD 2013

- ❑ Expensive analytical tools, FIB+HRSEM/TEM: 5-20 M€
- ❑ Service/labour fee: 1000-3500 €/slice
- ❑ Time to result: 1 day to few weeks
- ❑ Tiny area measurement
- ❑ AR limitations; AR max 50:1 for dry etched vertical cavity

PillarHall LHAR method



PillarHall®

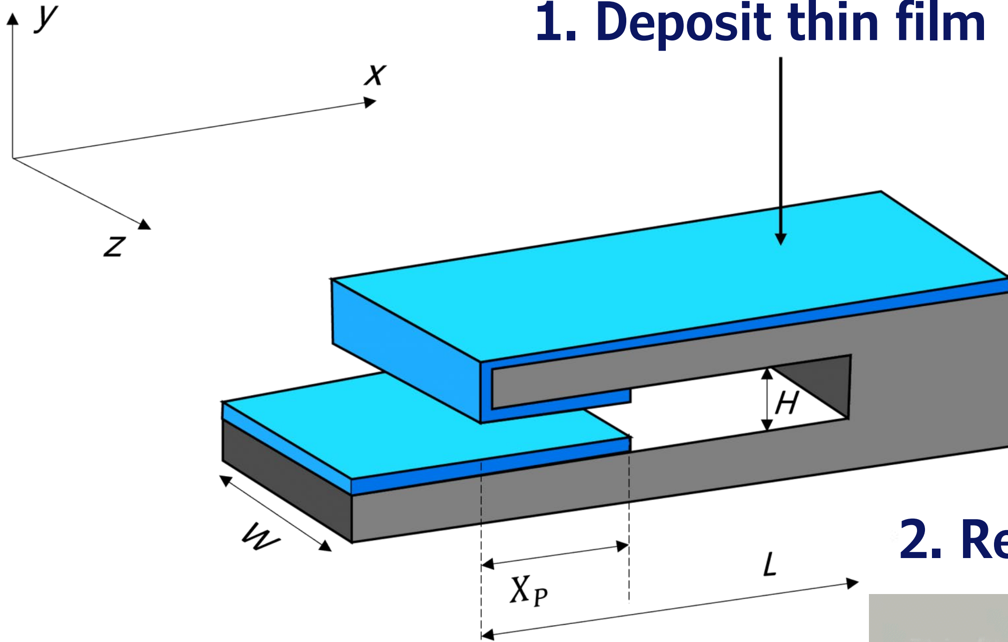
Cost effective, user friendly and better accuracy

- ❑ No cross-section
- ❑ Compatible to conventional lab tools
- ❑ Time to result: < 5 min
- ❑ Extreme high aspect ratio trenches for highly accurate data (AR up to 10000)
- ❑ Large area and wafer level imaging

PillarHall®

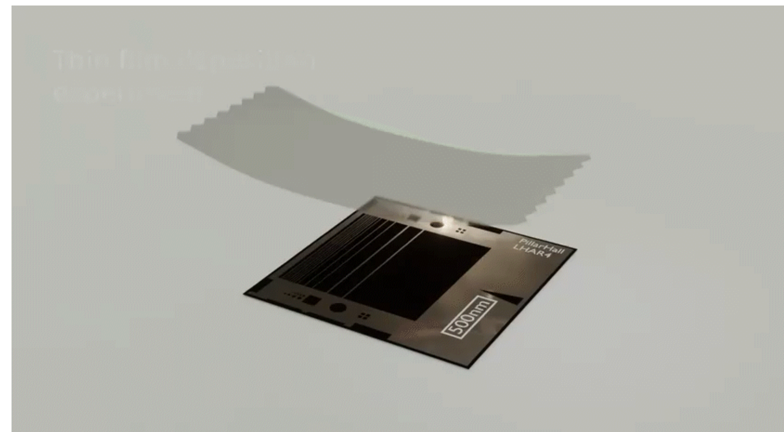
Lateral High Aspect Ratio (LHAR) Test Structure and Method

1. Deposit thin film



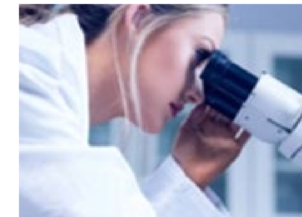
PillarHall®

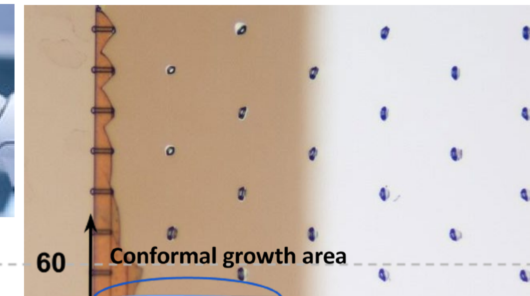
2. Remove the top membrane

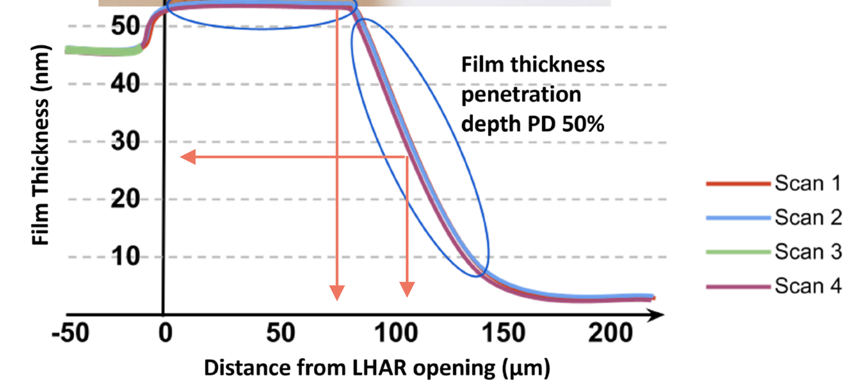


3. Measure

Film thickness as a function of the film penetration depth

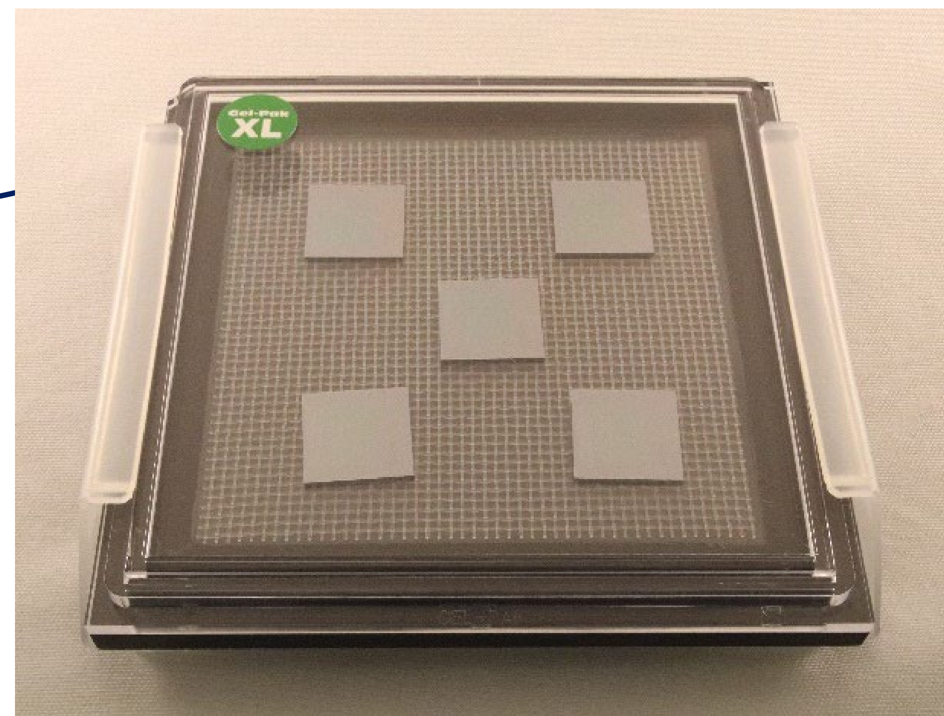




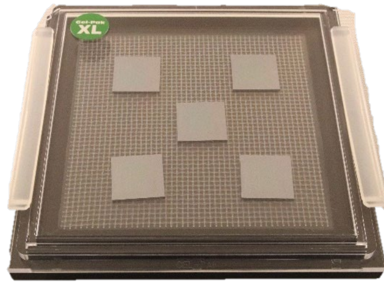


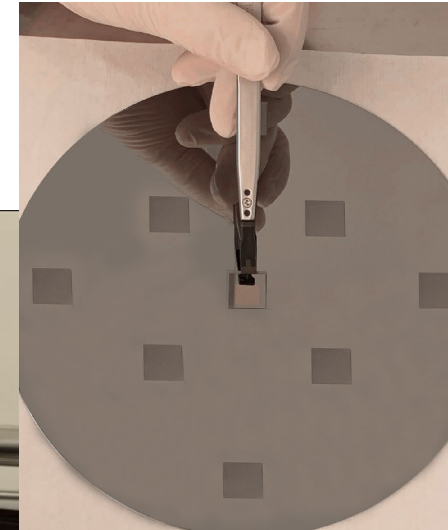
Product and Delivery

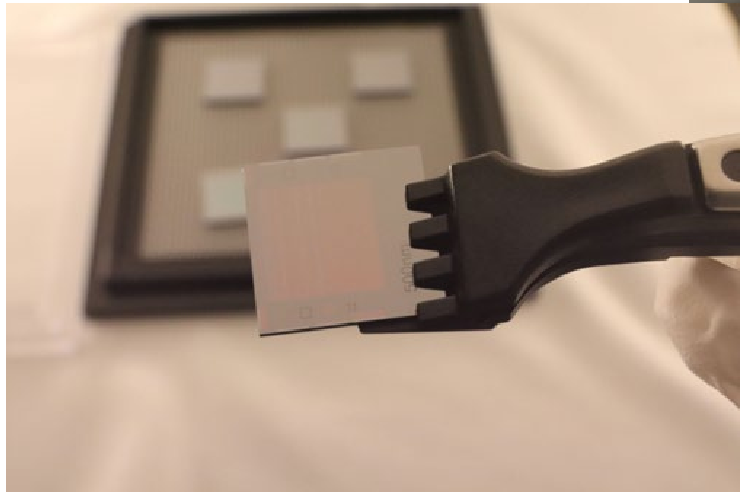
- PillarHall LHAR4 and Chipmetrics VHAR1
- Chip size: 15x15 mm
- MOQ: 5 chips in vacuum release tray (VRT) box
- Delivery time: within 7 days from our inventory



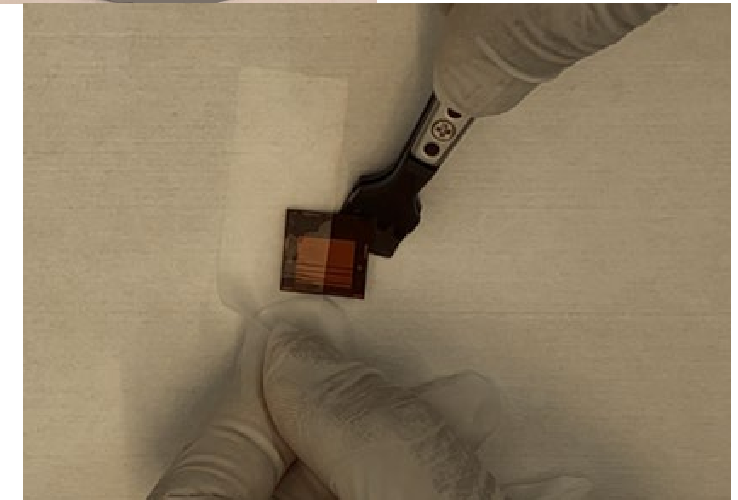
PillarHall chips; From Chipmetrics to your process monitoring



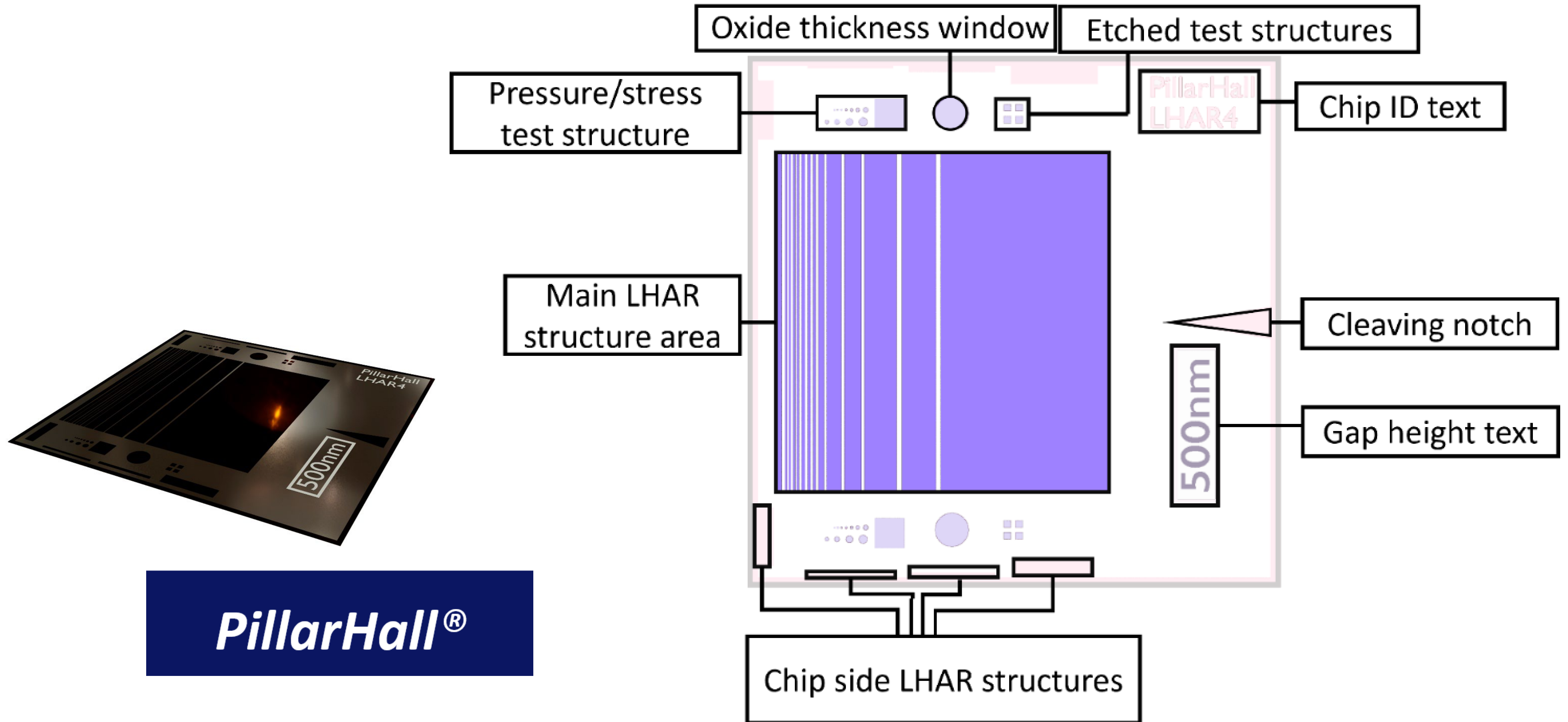




ALD/CVD deposition



Chip Layout LHAR4



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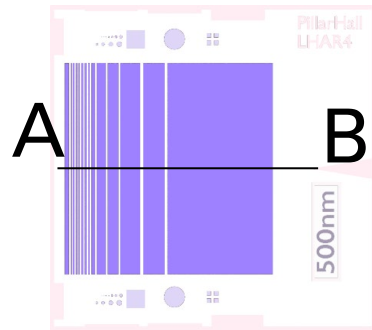
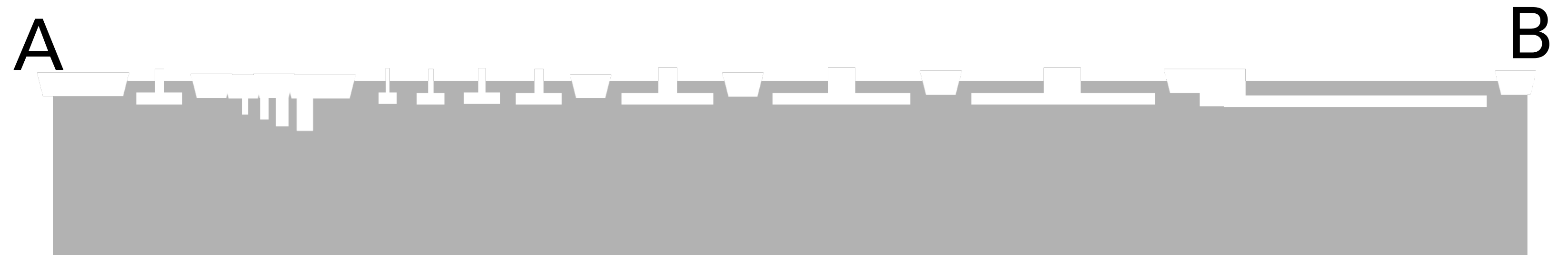
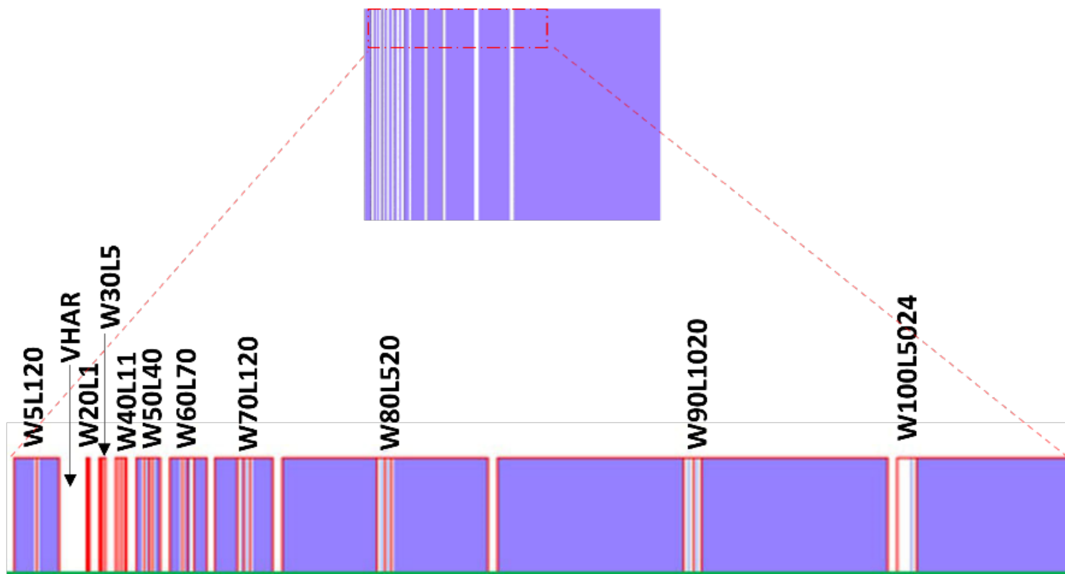
Chip Layout LHAR4





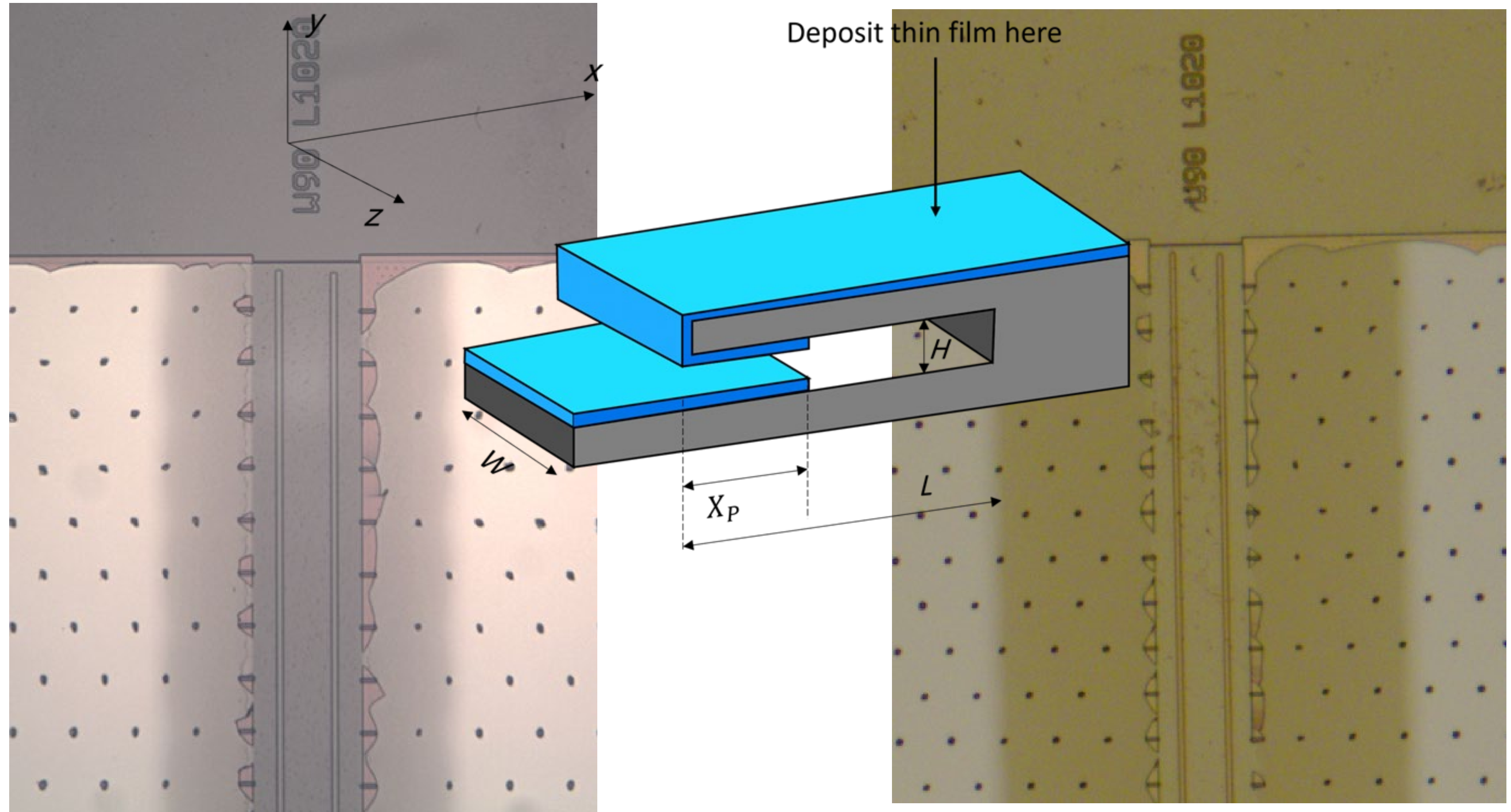


LHAR test structures and their positions on the chip.

LHAR Structure ID	2-directional LHAR	Gap lenght (L), µm	Opening width (w), µm	Aspect Ratio AR (L/H)
W100 L5024	No	5024	100	10 048 : 1
W90 L1020	Yes	1000	90	2 000 : 1
W80 L520	Yes	520	80	1 040 : 1
W70 L120	Yes	120	70	240 : 1
W60 L70	Yes	70	60	140 : 1
W50 L40	Yes	40	50	80 : 1
W40 L11	Yes	11	40	22 : 1
W30 L5	Yes	5	30	10 : 1
W20 L1	Yes	1	20	2 : 1
W5 L120	Yes	120	5	240 : 1

Combines all planar surface analytical tools

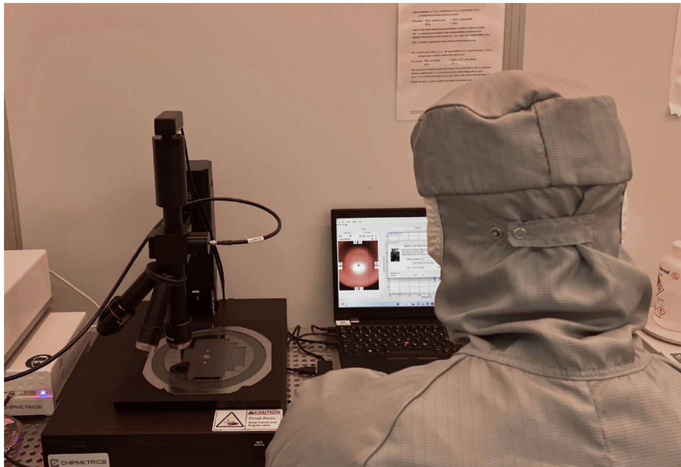
Thickness>15 nm, microscope imaging

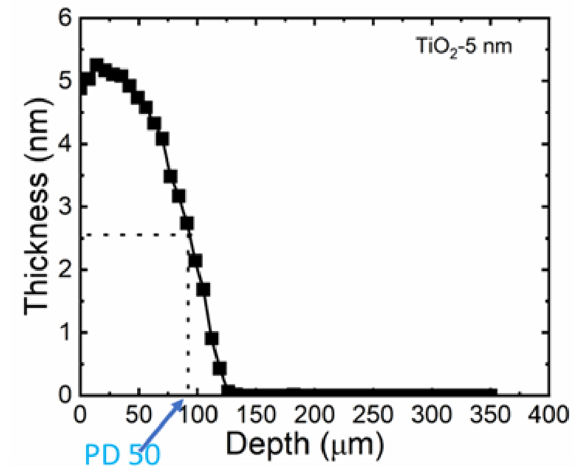


Conformality vary with thin film processes

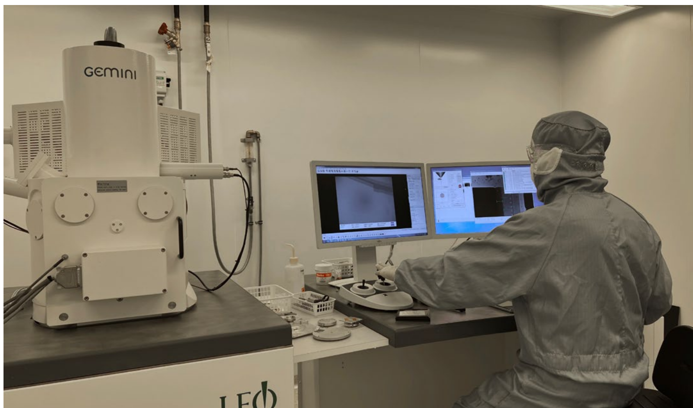
Combines all planar surface analytical tools

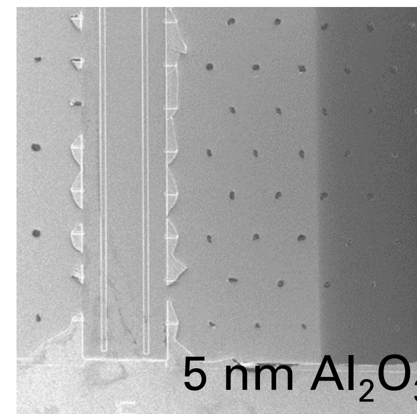
Line-scan reflectometer (UV-Vis-NIR)



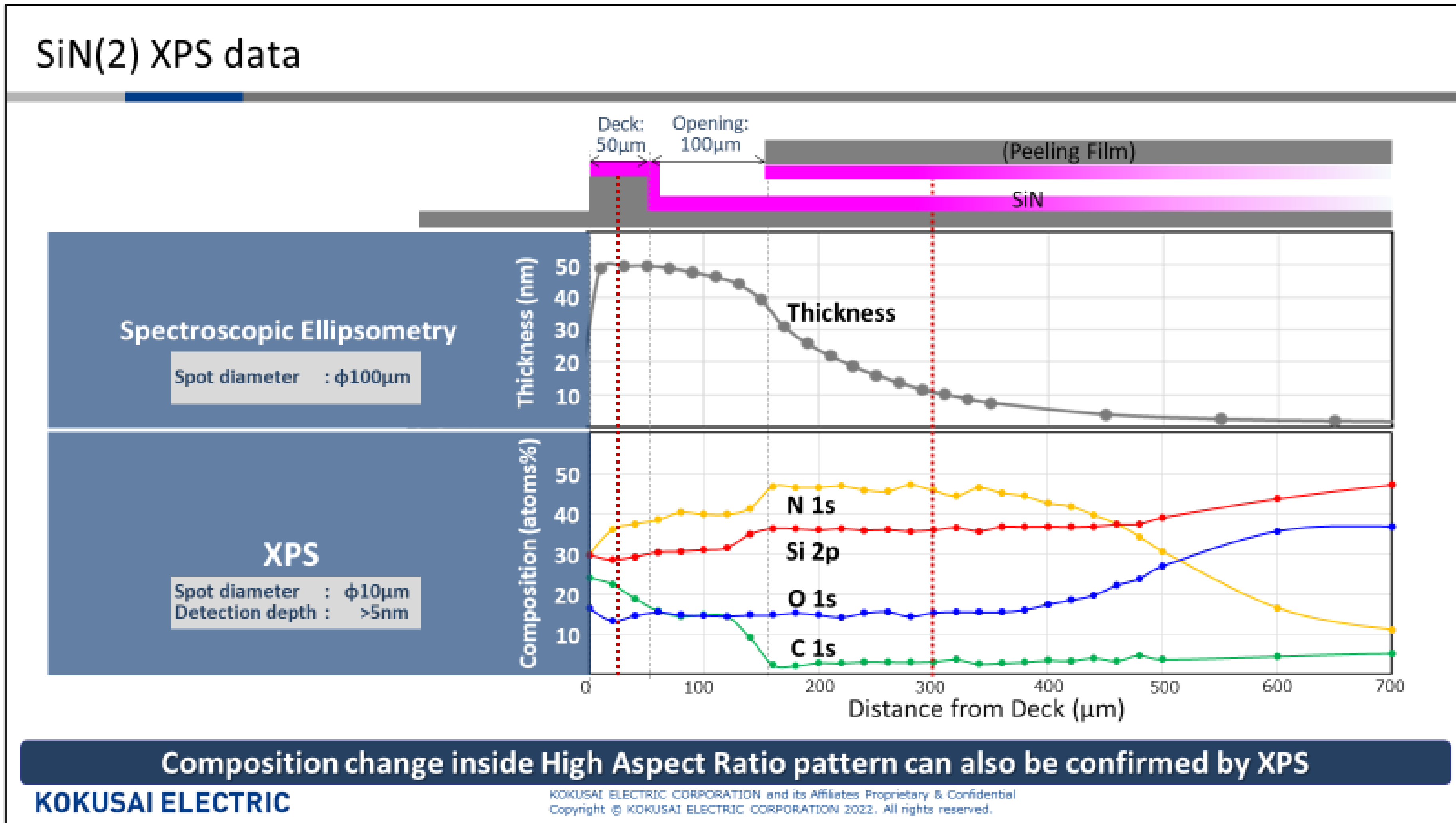


Top-view SEM





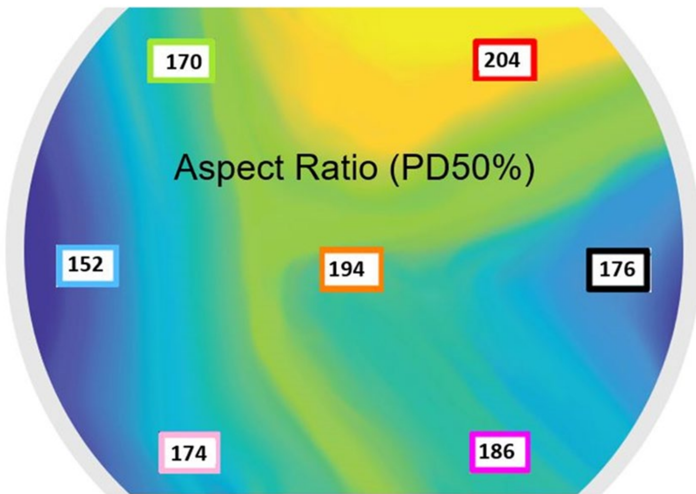
Structural or elemental composition measurement possibility



https://chipmetrics.com/2022/11/15/kokusai-electric-relies-on-patterned-3d-substrates-in-thin-film-process-metrology/

Wafer-level process monitoring

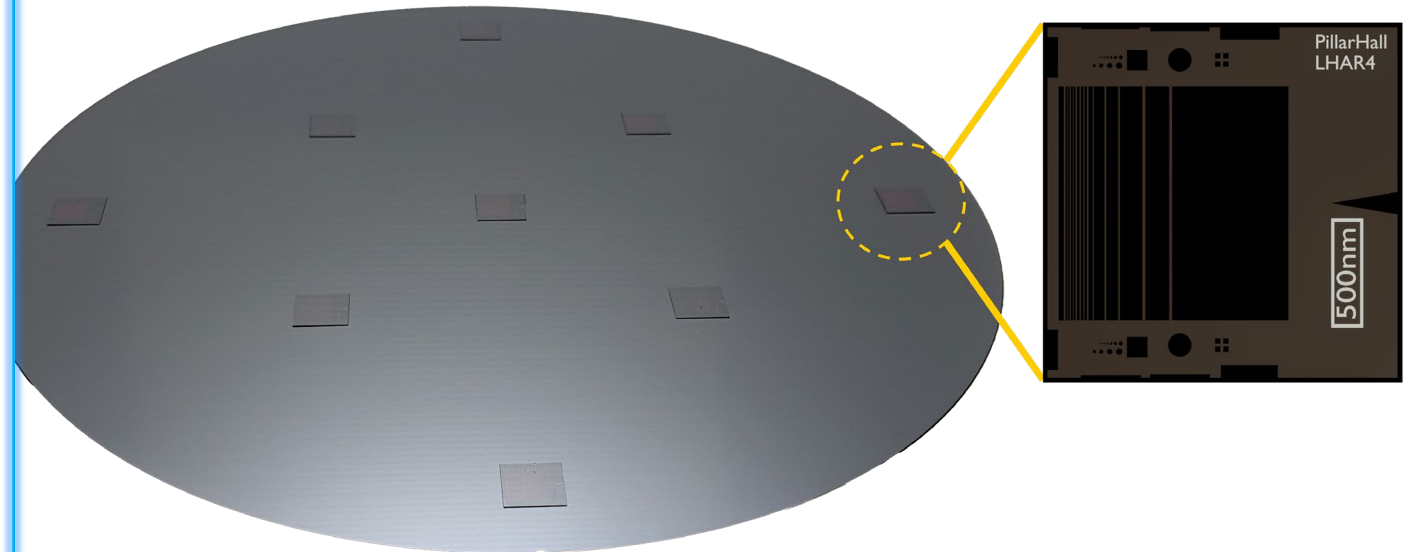
Wafer level conformality Using LHAR chips



The film penetration depth measured from PillarHall LHAR4 chips in seven locations on the carrier wafer

Pocket wafers for semiconductor processes

- Wafer size 300 mm, 200 mm, 150 mm
- 9 pockets for 15x15 mm test chips
- Chips bonded with liquid-glass adhesive
- Compatible up to 450 deg process temperature



Software tools

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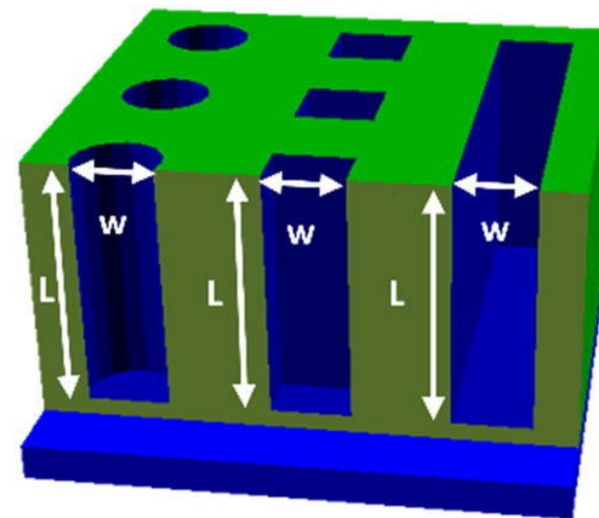
PREDICT THE CONFORMALITY IN THE TARGET 3D STRUCTURES



HAR Comparison Tool v2.9

PD Calculator with Thickness				
PillarHall			Target Hole	
Gap Height (nm)	Measured Film Thickness (nm)	Measured PD (µm)	Diameter (nm)	Estimated PD (µm)
w_{PH}	d_{PH}	L_{PH}	w_T	L_T
500	20	100	200	17,4

PillarHall Result Predictor Using Target Design Parameters							
Target Hole			PillarHall				
				Equivalent		Measured	
Diameter (nm)	PD length (µm)	Film Thickness (nm)	Gap Height (nm)	Film Thickness (nm)	PD (µm)	Film Thickness (nm)	PD (µm)
w_T	L_T	d_T	w_{PH}	d_{PH}	L_{PH}	d_{PH}	L_{PH2}
50	20	5	500	100,0	400,0	25	450,0

Menu

TRENCH TO TRENCH COMPARISON

TRENCH TO HOLE COMPARISON

DESIGN OF EXPERIMENT TOOL

Benefits of PillarHall Technology

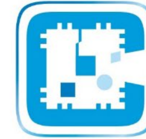
- R&D: **Design tool** for the next generation 3D device process libraries
- Process monitoring for ALD, ALE, CVD and MLD

Fast data source enables

- FAB: **Response fast to process failures** and avoid losses
- FAB & R&D: Fast repeated measurement when needed

Easy to use

- FAB & R&D: Process engineer learning cycle focuses on unit process – not complex measurement tools



CHIPMETRICS

Market Leader of Test Chips for 3D Thin Films

www.Chipmetrics.com
info@chipmetrics.com

+358 40 753 7415
Yliopistokatu 7, Joensuu, Finland

#PillarHall
#TestedWithPillarHall

@Chipmetrics