PillarHall LHAR Silicon Chips by Chipmetrics

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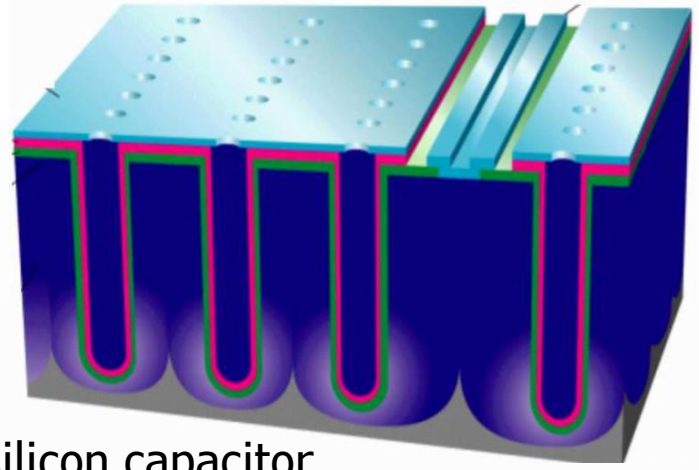
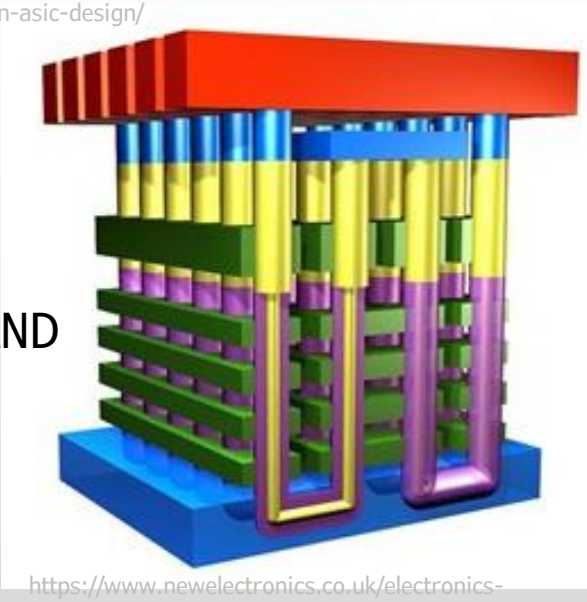
3D is a megatrend

- **To improve performance and energy efficiency of microdevices**
- **Applications e.g.**
  - **Semiconductors: 3D-NAND, DRAM, TSVs, FinFET, GAAFET, etc ..**
  - **Photonics, MEMS, microfluidics, etc**



3D silicon capacitor

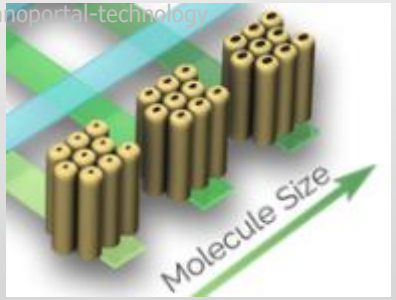
https://anysilicon.com/overview-and-types-of-capacitors-in-asic-design/



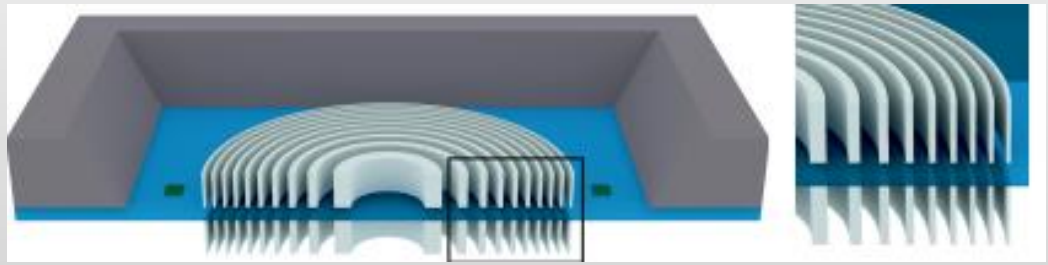
3D NAND

https://www.newelectronics.co.uk/electronics-technology/3d-structures-to-dominate-the-flash-memory-market/155486/

Nanoprecision Medical Ltd
https://www.nanoprecisionmedical.com/technology/nanoportal-technology



Microfluidics

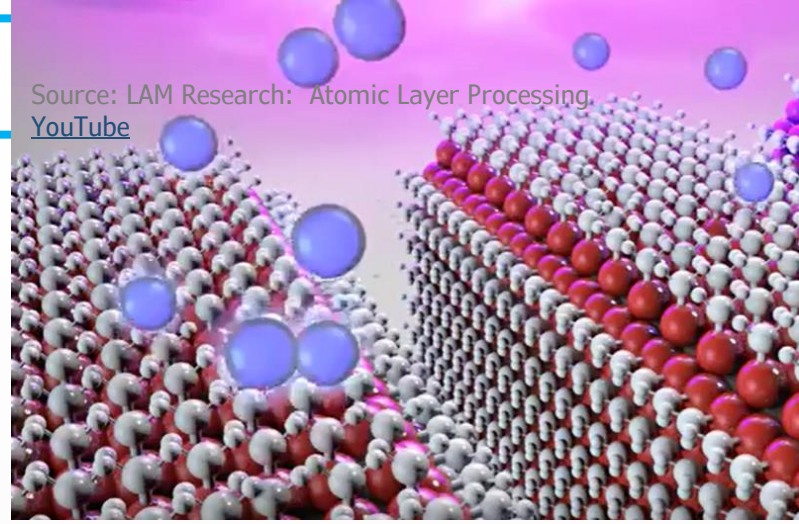


Mohacsi et al Optics Express (2015) https://doi.org/10.1364/OE.23.000776

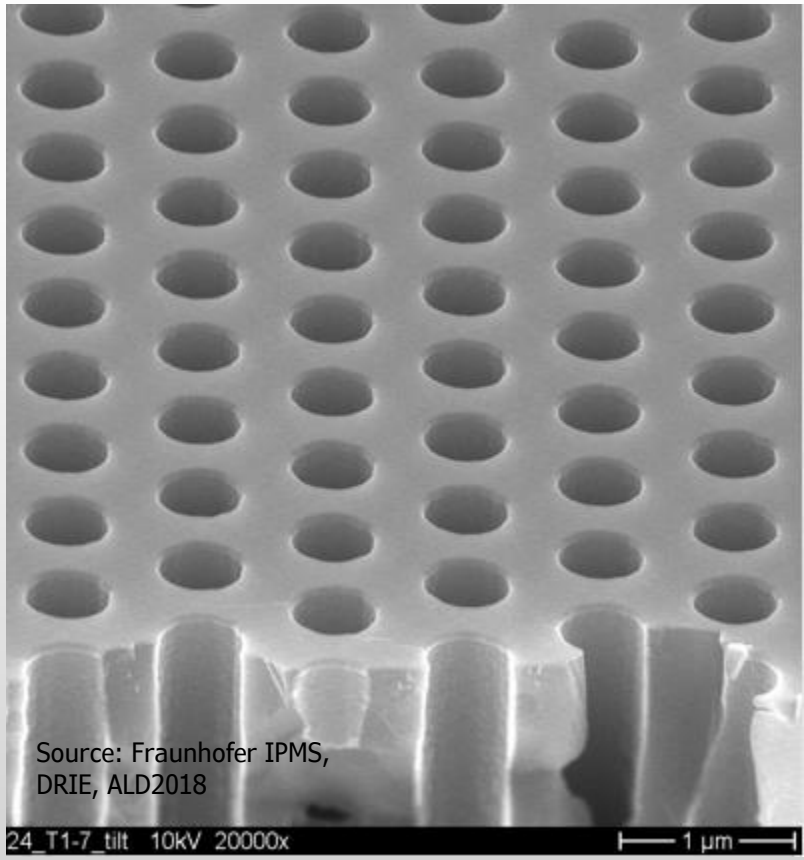
Photonics

Atomic Layer Deposition (ALD) is a Technology for Conformal Thin Films

- For high quality manufacturing of 3D microelectronics and advanced materials
- Boosting 3D vertical scaling trend
  - 3D-NAND, 3D-DRAM, TSVs, FinFET, GAAFET, PCRAM, FeRAM, etc ..



Source: LAM Research: Atomic Layer Processing, YouTube

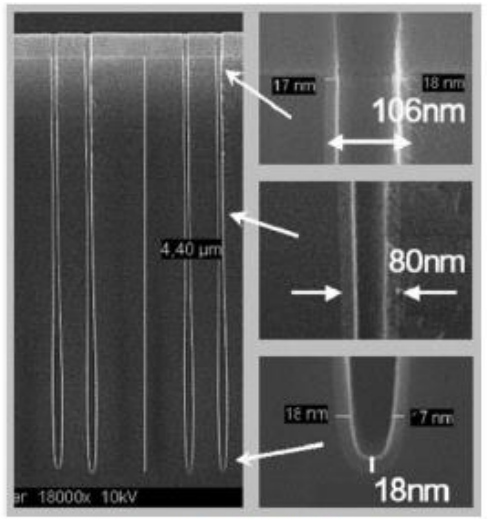


Source: Fraunhofer IPMS, DRIE, ALD2018

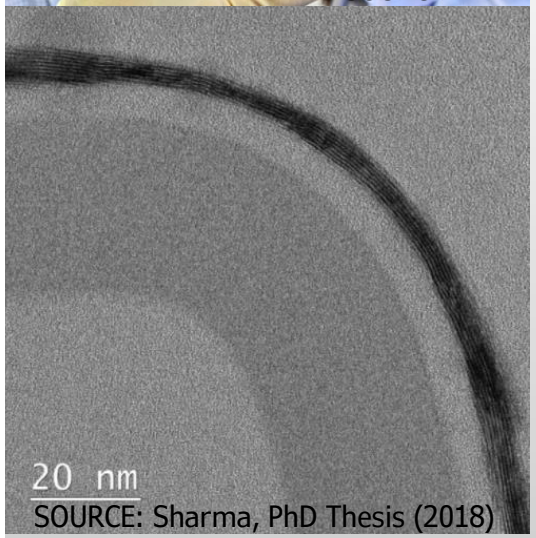
CHIPMETRICS

3D THIN FILM METROLOGY IS A PROBLEM


SOURCE: VTT



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



SOURCE: Sharma, PhD Thesis (2018)

Needs cross-sectioning

- Destructive. Special tools and users.
- Slow. Expensive. Slow.

3D substrates not accessible

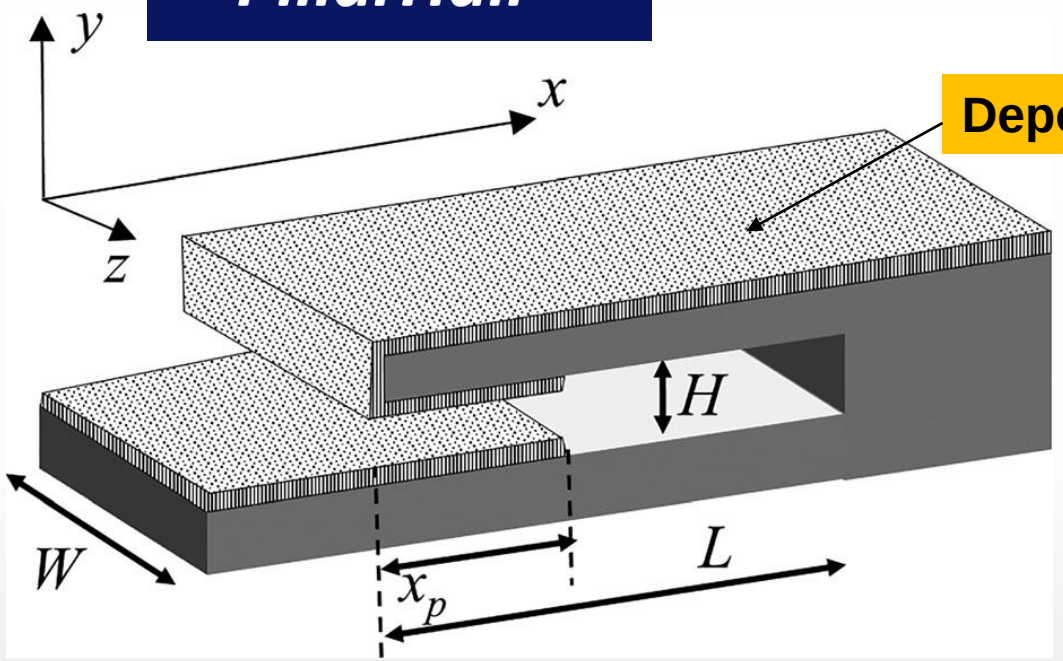
- Proprietary. Inaccurate quantification.
- Expensive. Lack of standards.

Huge parameter space in ALD

- Importance of speed

Lateral High Aspect Ratio (LHAR) Test Structure and Method

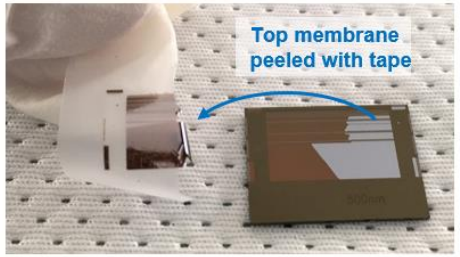
PillarHall®



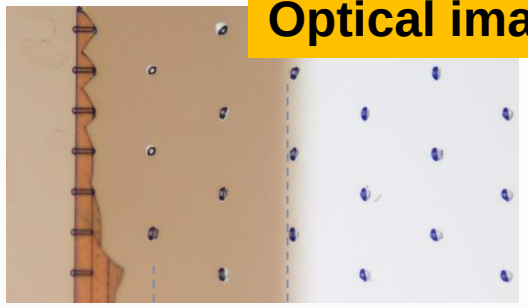
Deposit thin film

Analyses after removal of top membrane

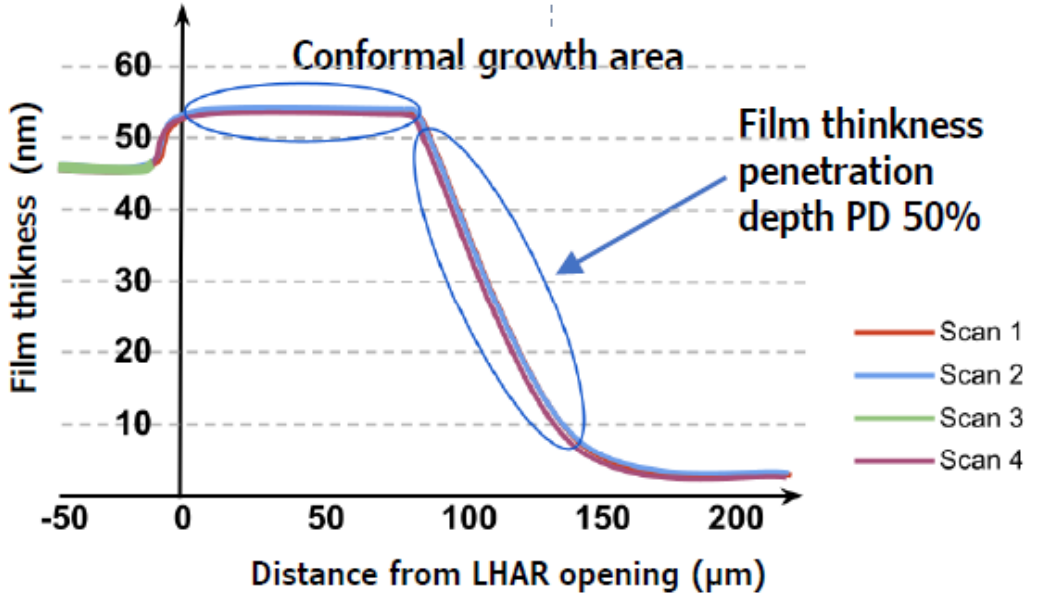
PillarHall® line scans: route to understanding and optimising process fundamentals



Optical imaging



Specroscopy line-scans



ASPECT RATIO

10000:1; 2000:1; 1000:1; 200:1; 100:1;
40:1; 20:1; 10:1; 2:1

Ylilammi et al. Journal of Applied Physics ***123****, 205301 (2018)*

Measure: film thickness as a function of film penetration depth

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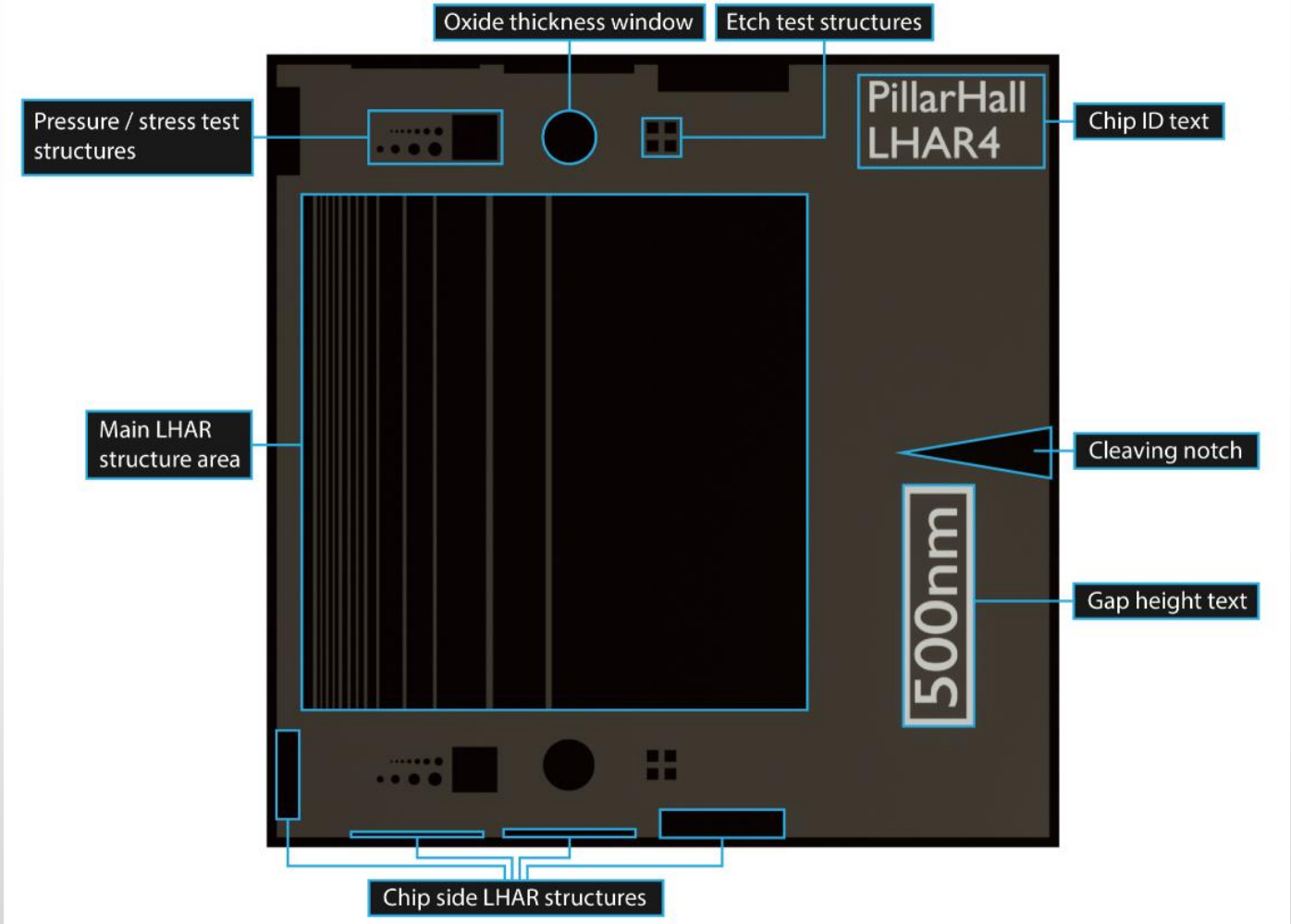
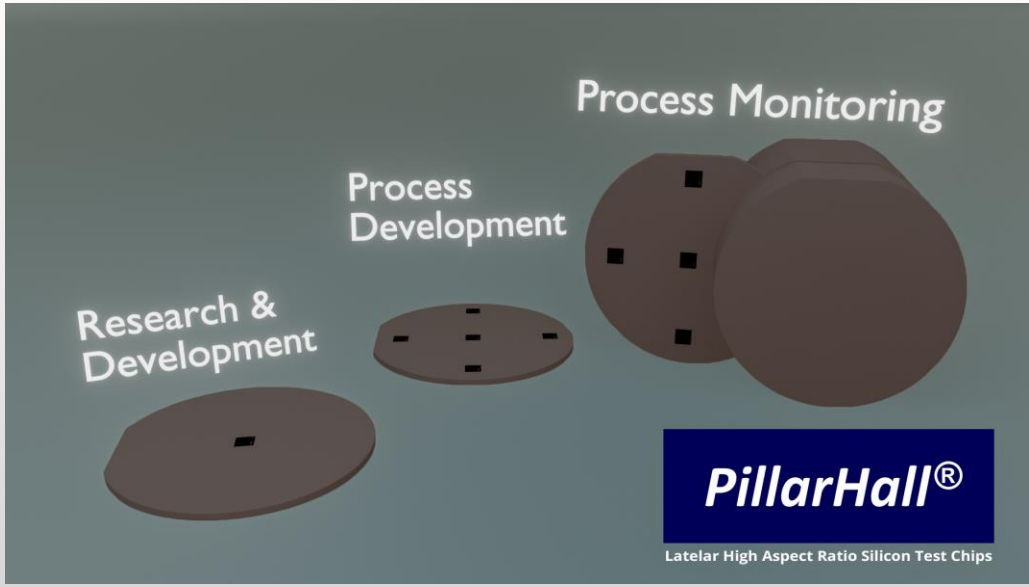
LHAR4 Test Chip





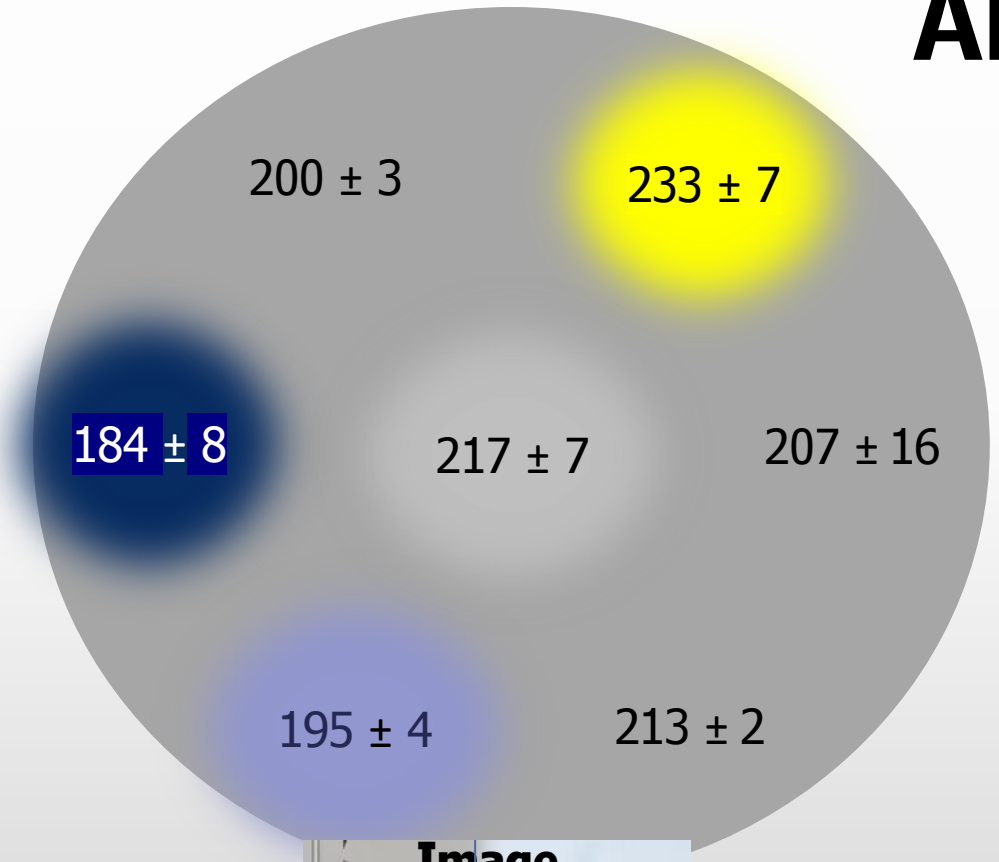
Wafer Level Conformality

VTT process, 500 cycles

150 mm wafer.

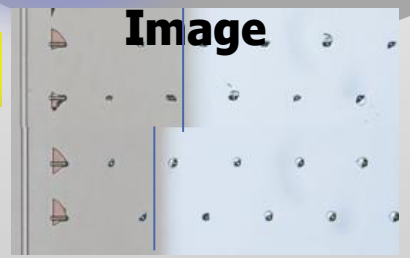
ALD Al_2O_3

PD50% (AR)



max 233 ± 7

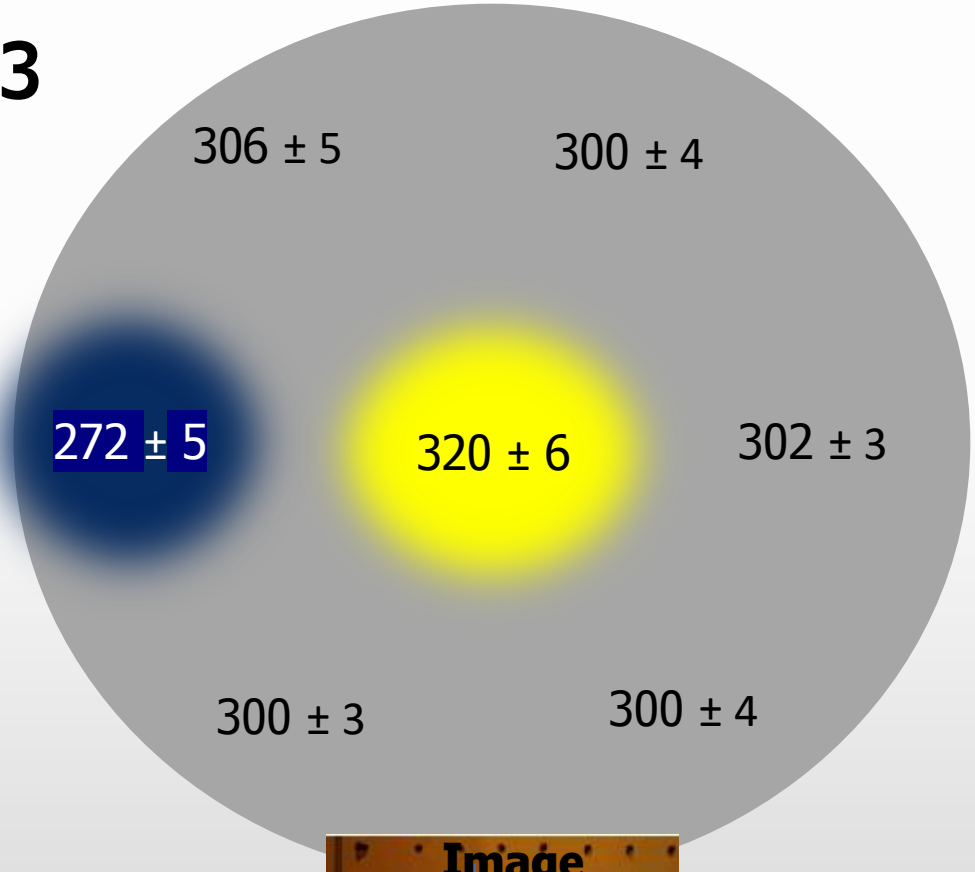
min 184 ± 8



$\Delta_{min\text{-}max}$=21 %

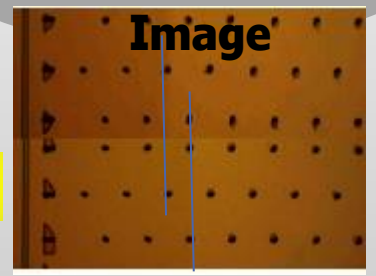
UEF process, 125 cycles

200 mm wafer.



min 272 ± 5

max 320 ± 6



$\Delta_{min\text{-}max}$=15 %

High Aspect Ratio (HAR) geometry correlation

How to compare PillarHall data to the HAR target?

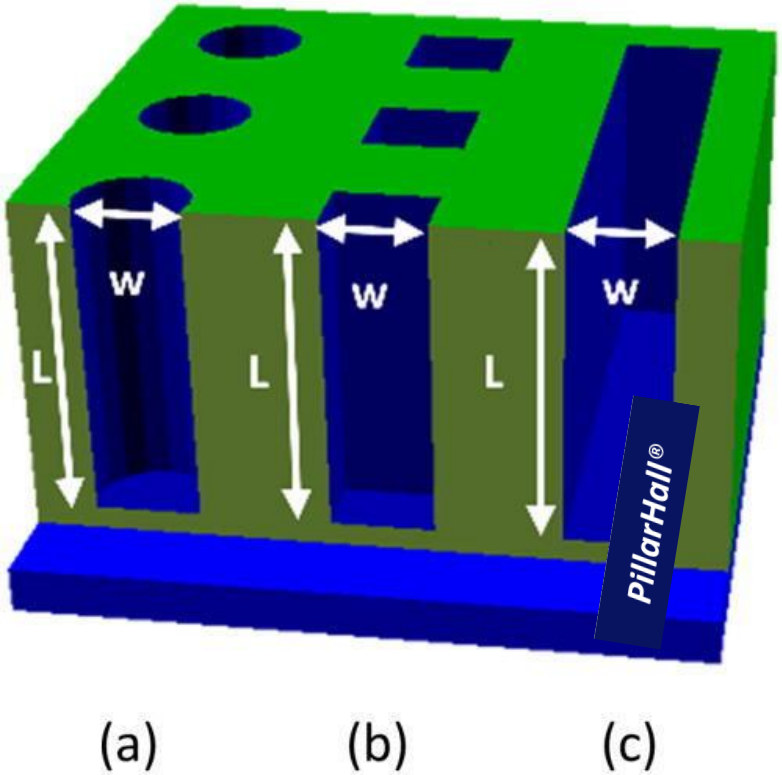


Fig.1. High Aspect Ratio geometries:
(a) Cylindrical hole, (b) a square hole, (c) trench, with width w, and depth L

BREAKING: HAR comparison calculator tool available by Chipmetrics

Equation: $a = \frac{Lp}{4A}$

with
a being aspect ratio,
L (m) being the depth of the cavity,
p (m) being its perimeter, and
A (m^2) being the cross-sectional area.

For trenches, the equation reduces to

$a=L/2w,$

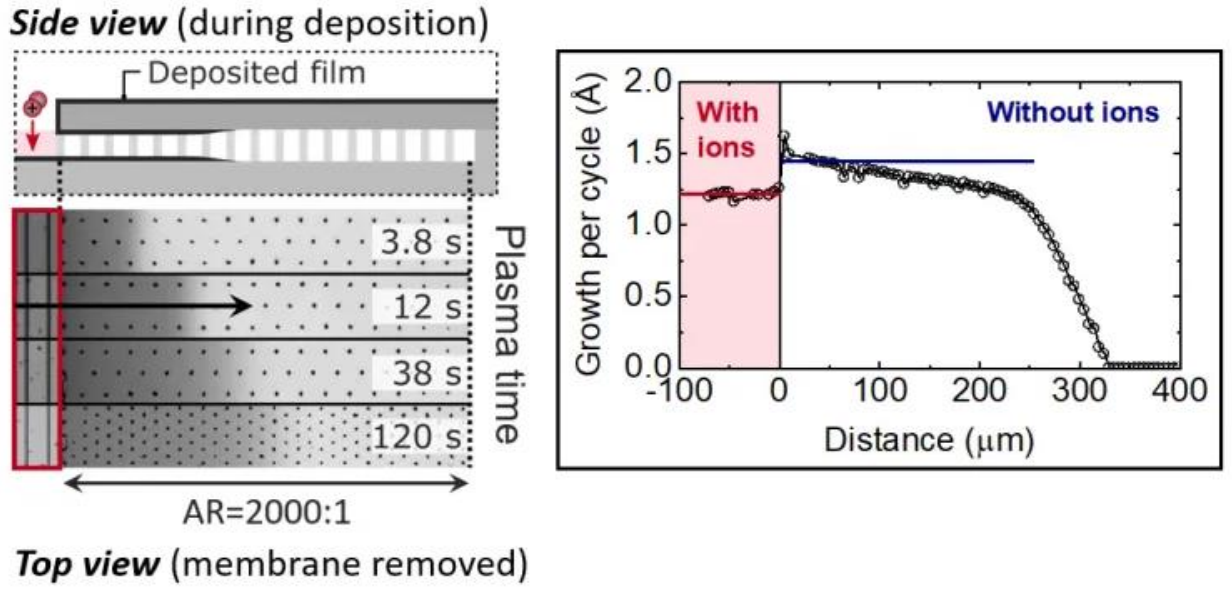
while for holes it reduces to

$a=L/w.$

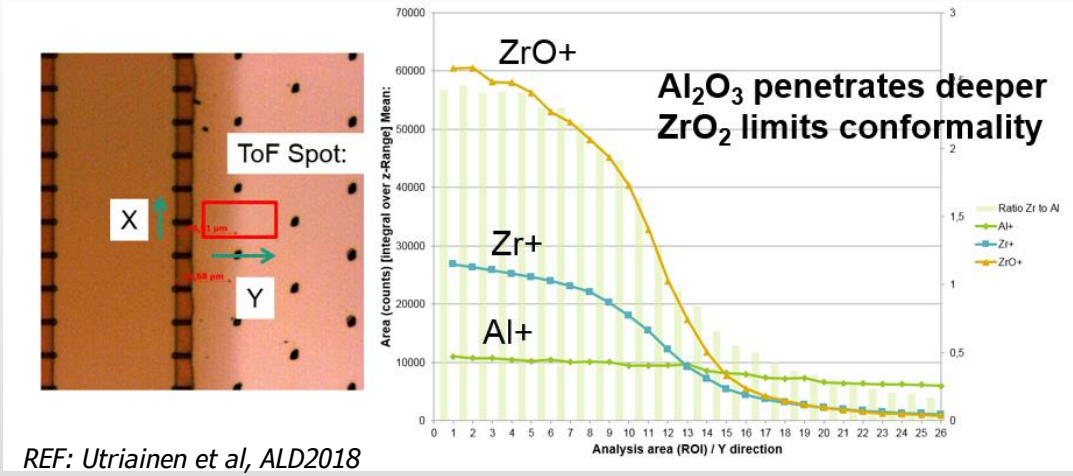
CHIPMETRICS

PillarHall in Research

- **Conformality in thermal & plasma ALD**
  - Understanding conformality
  - Extracting sticking coefficients
  - Extracting plasma recombination probabilities
- **Conformality in CVD**
  - Surface-inhibiting growth
  - Metal CVD conformality
- **Properties of the film on the trench wall**
  - Compositional dopant mapping
  - Wet etch rate
- **Film stress in the microscale**



REF: Arts, K., in https://www.atomiclimits.com/2020/11/11/understanding-plasma-ald-why-ions-matter-and-should-be-considered/



REF: Utriainen et al, ALD2018

And more..

Scientific article references are listed in **www.pillarhall.com/references**

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FINAL SLIDE

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NOTE: New OPEN DATA platform for ALD saturation profiles

https://zenodo.org/communities/ald-saturation-profile-open-data/?page=1&size=20

This is a place where you can share data with other scientists