100mm - membrane carrier tuning for state of the art CMP process development in R&D environments

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A joint R&D work from

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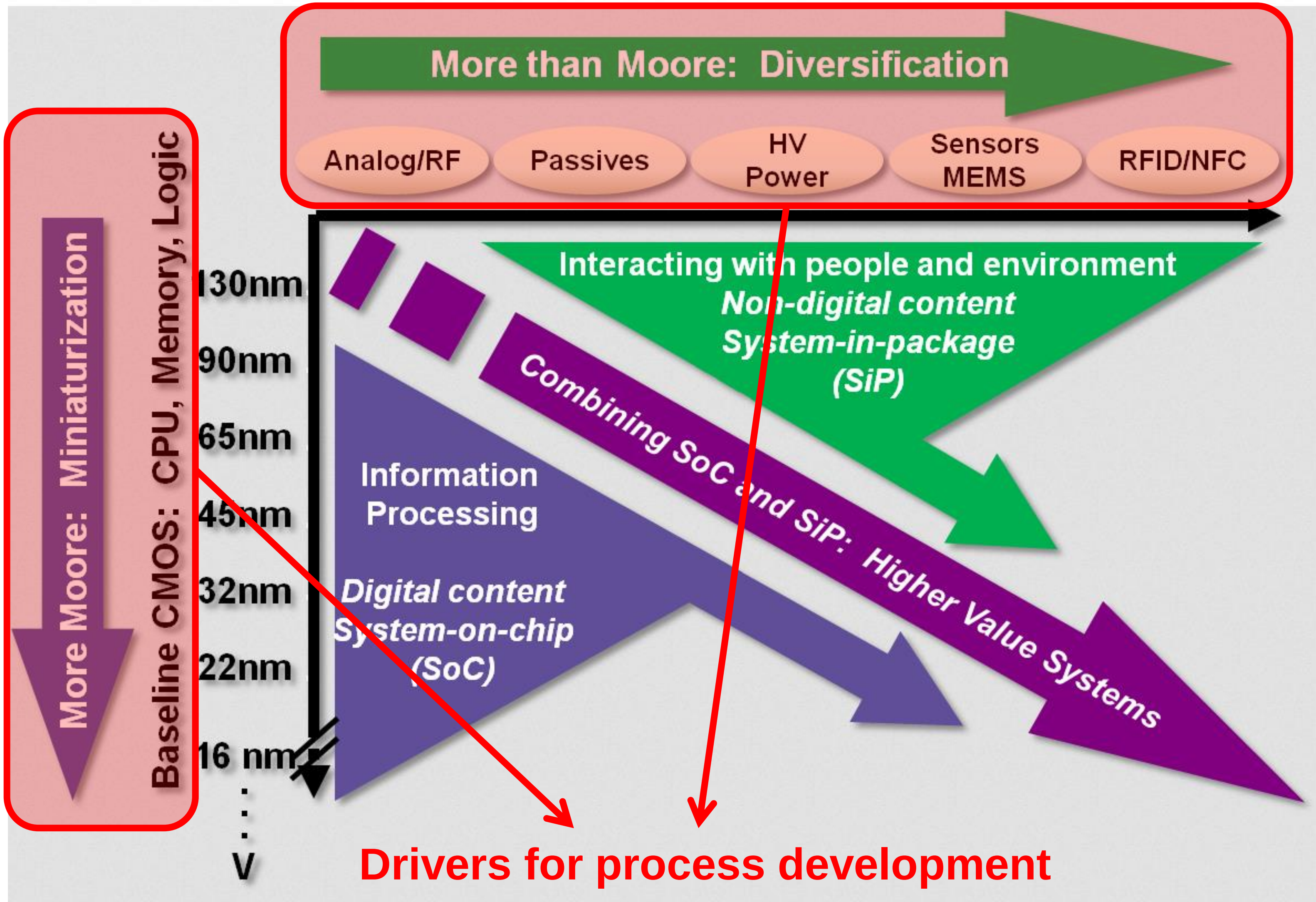
AGENDA

- General background
- Specific motivation
- Membrane carrier design
- Membrane edge impact
- Experimental work and results
- Summary & outlook

Global background



CMP in leading edge & standard CMOS

- CMP is needed for:
  - Planarization
  - Patterning (Cu-based interconnect systems / Tungsten)
- Ongoing downscaling requires:
  - Perfect process control
  - Zero defectivity
  - “Atomic layer” CMP
- Tool platform:
  - Leading edge / state of the art 200mm / 300mm CMP tools
  - Multiple carriers / multiple plates for very high throughput
  - Membrane carriers with multiple polish zones

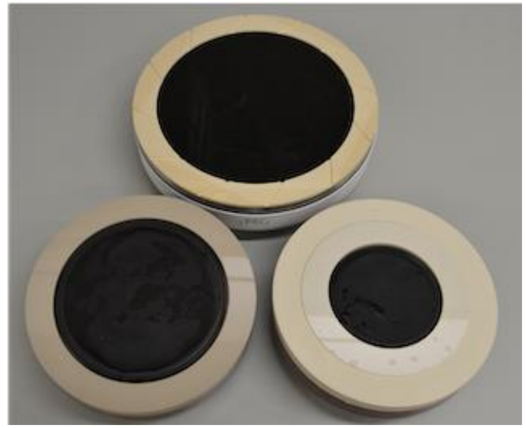
CMP in More than Moore, beyond CMOS, MEMS, IoT, …

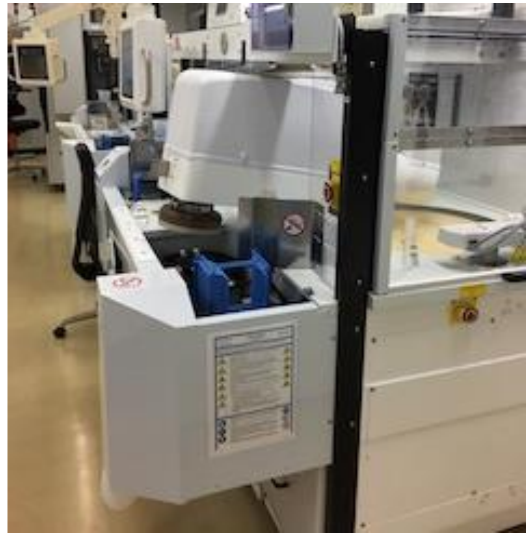
- CMP is needed for:
  - Planarization
  - Patterning
  - Surface restoration, i.e. after wafer thinning
  - Surface perfecting, i.e. for wafer bonding
  - Pattern reveal / TSV reveal
- CMP is faced to new aspects
  - New materials, such as polymers and noble metals
  - Non-CMP-friendly layouts
  - Different substrate thicknesses / bonded wafers (compounds)
  - Thin and fragile wafers

CMP in More than Moore, beyond CMOS, MEMS, IoT, …

- Process requirements
  - Excellent process control
  - Very low defectivity
  - Very low non-uniformity
- Specifics
  - Good number of modest / low-volume applications
  - All wafer diameters – 4 inch (and lower) is back … at least for a while
- Tool platform:
  - Leading edge / state of the art 200mm/300mm tools (multiple plates and carriers, multi-zone membrane carriers → standard wafers, high volumes
  - Retrofitted / upgraded legacy tools → especially for low volumes and wafer sizes below 200mm

Fraunhofer ENAS CMP Lab





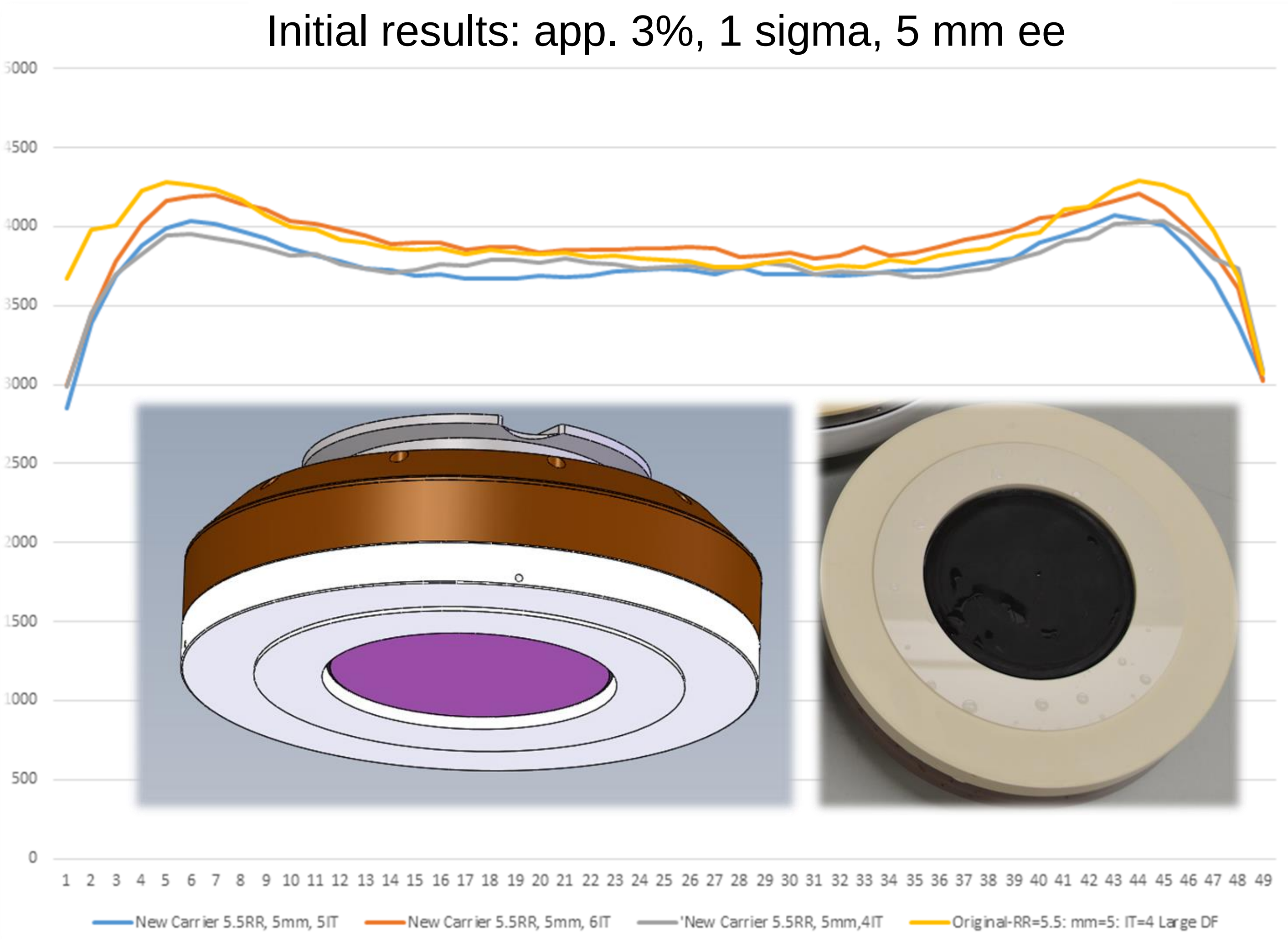
Specific motivation for this work

More and more demanding customer requests, such as:

- Total film thickness variation across the wafer < 100 nm
- Uniform dishing of 2 nm across the entire wafer
- Thin wafer processing
- Compound processing with high internal stress (high bow)
- …

A lot of these requests are related to 150mm and 100mm applications!

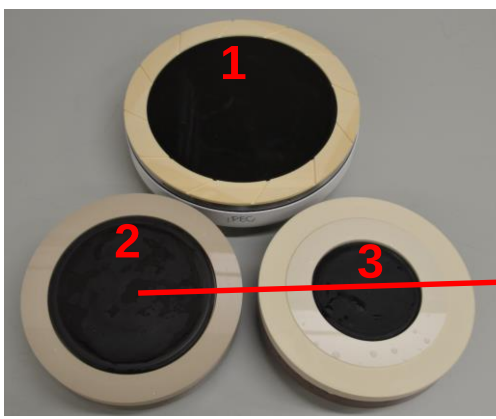
Axus T4 carrier – first versions



Membrane carrier design (standard carrier)

Three independent pressure control systems (standard carrier)

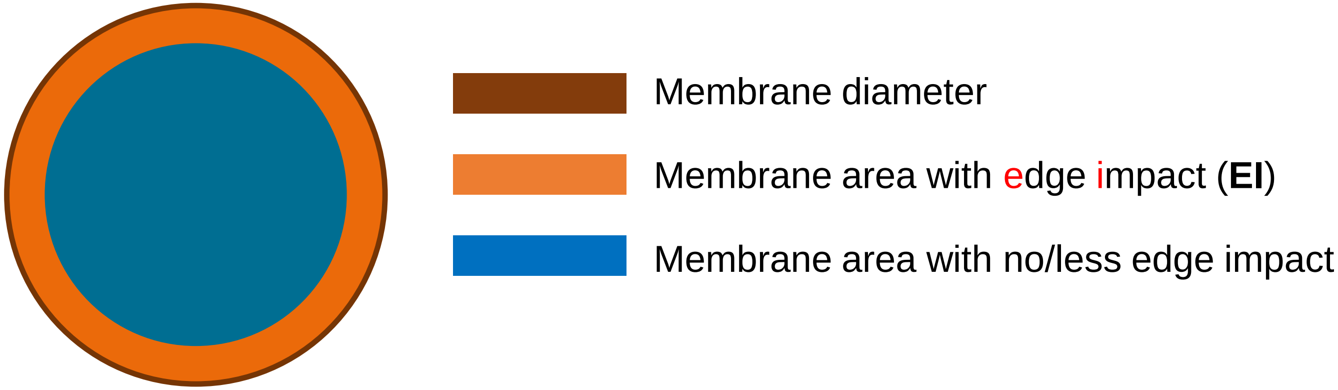
- Retaining ring
- Membrane
  - gives (very uniform) downforce across the entire wafer
  - sealed clamping underneath the retaining ring at its edge (gives lower MRR)
- Inner tube / inner plate
  - wafer chuck/de-chuck (in conjunction with the membrane)
  - edge profile tuning → $P_{IT} \neq P_{MM}$



1) 200 mm Titan carrier (Applied Materials)
2) 150 mm Titan carrier (Applied Materials)
3) 100 mm T4 carrier (Axus Technology)

Inner platen / inner tube 150mm Titan carrier

Impact of edge area vs. carrier (membrane) size



Membrane area calculations

Membrane diameter	(mm)	**100**	**150**	**200**
Total membrane area	(sqcm)	78.54	176.71	314.16
Membrane area at **5 mm EI**	(sqcm)	63.62	153.94	283.53
Edge area	(sqcm)	14.92	22.78	30.63
Edge area percentage	(%)	**19.00**	**12.89**	**9.75**
Membrane area at **3 mm EI**	(sqcm)	69.40	162.86	295.59
Edge area	(sqcm)	9.14	13.85	18.57
Edge area percentage	(%)	**11.64**	**7.84**	**5.91**
Membrane area at **6 mm EI**	(sqcm)	60.82	149.57	277.59
Edge area	(sqcm)	17.72	27.14	36.57
Edge area percentage	(%)	**22.56**	**15.36**	**11.64**

Carrier tuning options

- Segmented membranes – zone carriers (known/proven for 150 / 200 / 300mm)
- Inner platen modifications
  - Thickness
  - Material
  - Edge design
  - Felt ring
    - Thickness
    - Width
    - Position
    - Material

In this work we have investigated the performance of different inner plate types for an Axus T4 carrier.

Experimental

Two inner plate designs (**A** and **B**) have been tested

Modifications / differences:

- Plate thickness (stiffness)
- Edge design
- Felt ring
    - Thickness
    - Width
    - Position

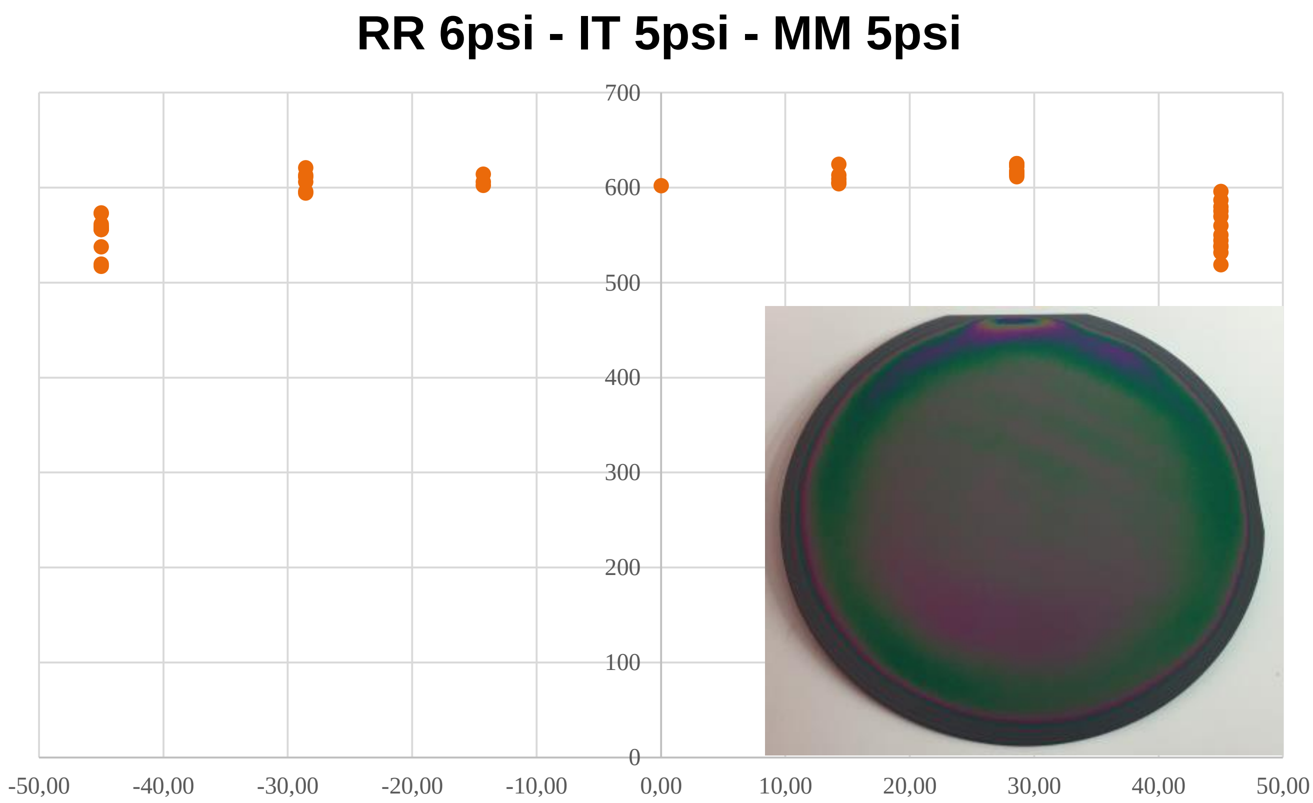
Process setup

- Oxide CMP
- 1.2 µm PE-oxide with <0.7% non-uniformity
- Klebosol 1508 slurry
- 63 rpm platen speed
- 57 rpm carrier speed

New inner-plate model B – pressure setting #1

Incoming film
PE-oxide 1.2µm
Thickness variation < 0.7%

Post-CMP
Remaining thickness: 581.14 nm
Deviation (1 Sigma): 41.03 nm / 5.69%
5mm edge exclusion



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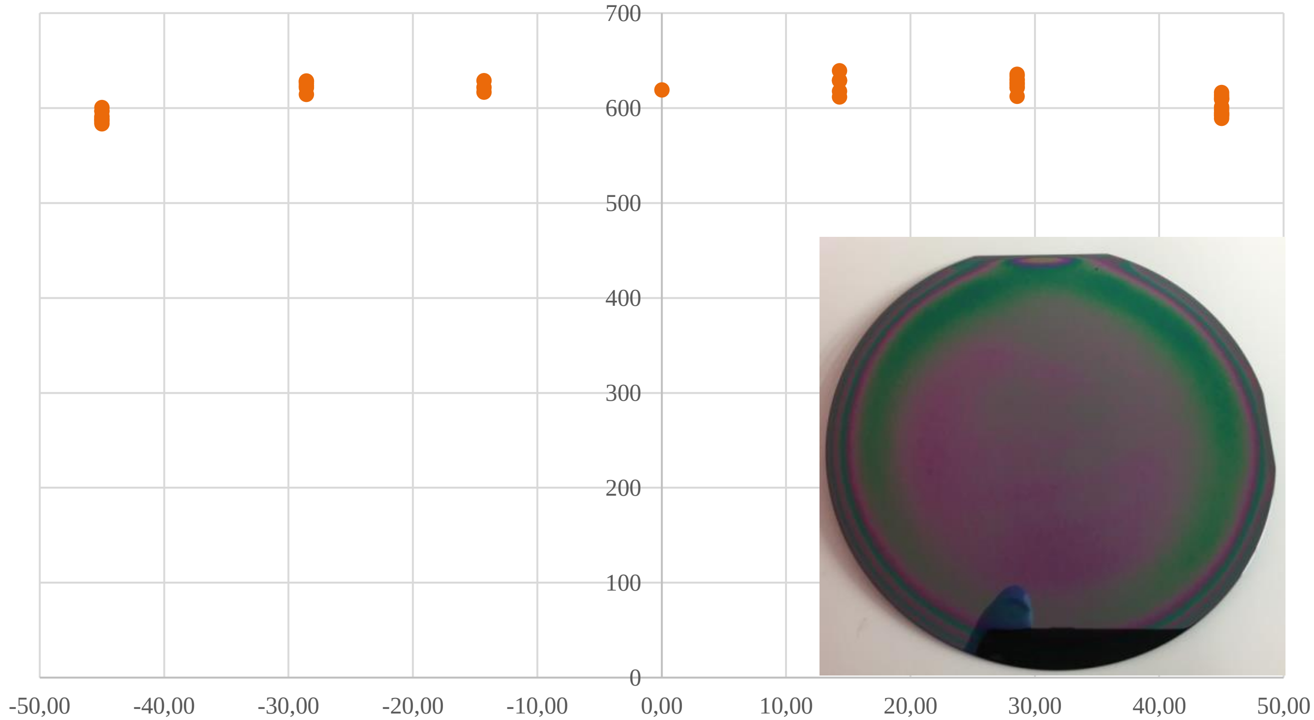
New inner-plate model B – pressure setting #2

Incoming film
PE-oxide 1.2µm
Thickness variation < 0.7%

Post-CMP
Remaining thickness: 609.51 nm
Deviation (1 Sigma): 16.55nm / 2.71%
5mm edge exclusion

RR 5.5psi - IT 5psi - MM 5psi

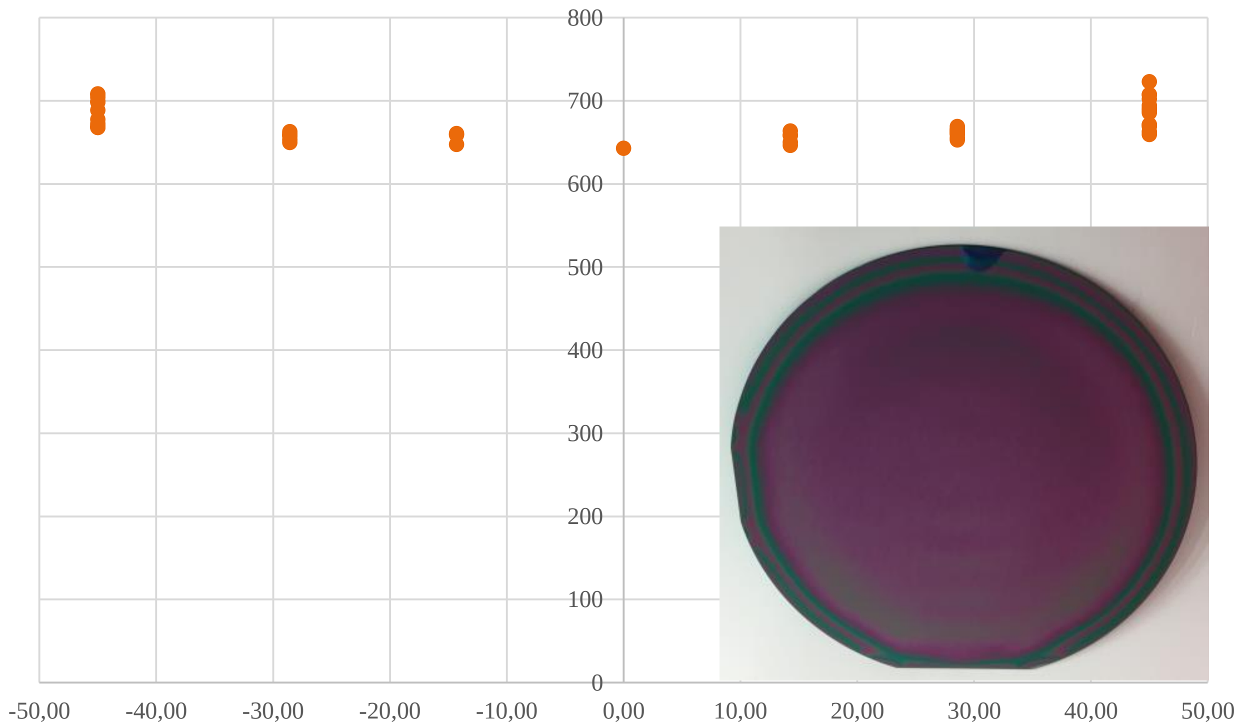


New inner-plate model A – pressure setting #1

Incoming film
PE-oxide 1.2µm
Thickness variation < 0.7%

Post-CMP
Remaining thickness: 672.43 nm
Deviation (1 Sigma): 19.95 nm / 2.97%
5mm edge exclusion

RR 5.5psi - IT 5psi - MM 5psi

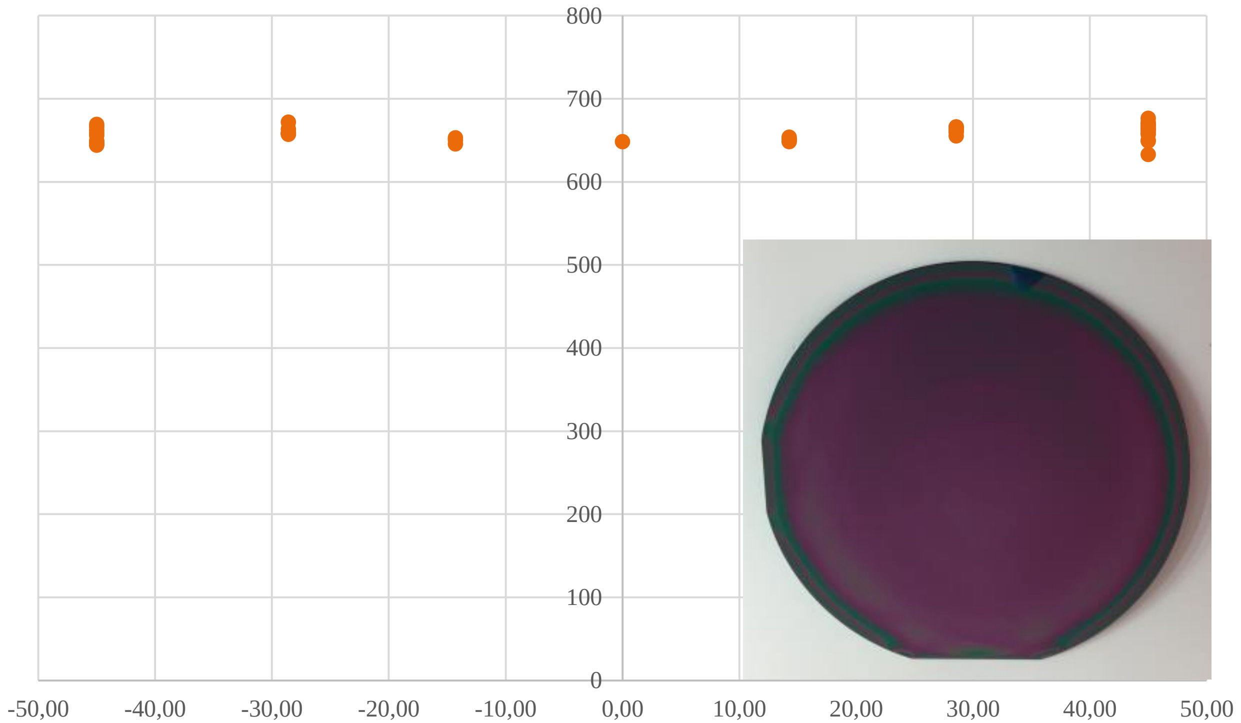


New inner-plate model A – pressure setting #2

Incoming film
PE-oxide 1.2µm
Thickness variation < 0.7%

Post-CMP
Remaining thickness: 657.67 nm
Deviation (1 Sigma): 8.96 nm / 1,36%
5mm edge exclusion

RR 5.5psi - IT 6.5psi - MM 5psi



Summary and outlook

- Process uniformity for standard membrane carriers can be optimized/tuned by choosing appropriate pressure settings for RR, MM, IT (limitations due RR-MM pressure ratio)
- In addition, the design of the inner plate (inner tube) is another knob that can be turned for further uniformity optimization / uniformity control
  - Fast to do, just one part of the head needs to be modified
  - Cost effective
  - Enhances the potential of legacy tools
- Within first experimental trials the non-uniformity of a 100mm Axus T4 carrier could be reduced by a factor of 2 due to inner plate design modifications
- So far, all experiments are done at 5mm edge exclusion → further work is planned to figure out how close we go to the edge
- Segmented membrane / zone carriers for 100mm???
- Not shown in this work: the inner plate design can be used also to handle thin wafers (<300µm)

Thank you for your attention!

We are very willing to share more information with you! If you are interested, please contact:

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