

157 nm Session

Status of CaF₂ Lens Blanks Status of EAPSM Blanks

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Outline

■ CaF₂ Lens Blank Status

- Critical challenges
- Overview of major improvements
- Selected results
 - <100> stress birefringence
 - features determining flare
- Future work
 - Productivity
 - Quality
- Conclusion

■ EAPSM Blank Status

- Basic design
- Tunability
- Results
- Conclusion / Future work

Critical Challenges for CaF₂

Quality

- Refractive index homogeneity
- Stress birefringence
- Flare

Quantity

- Productivity

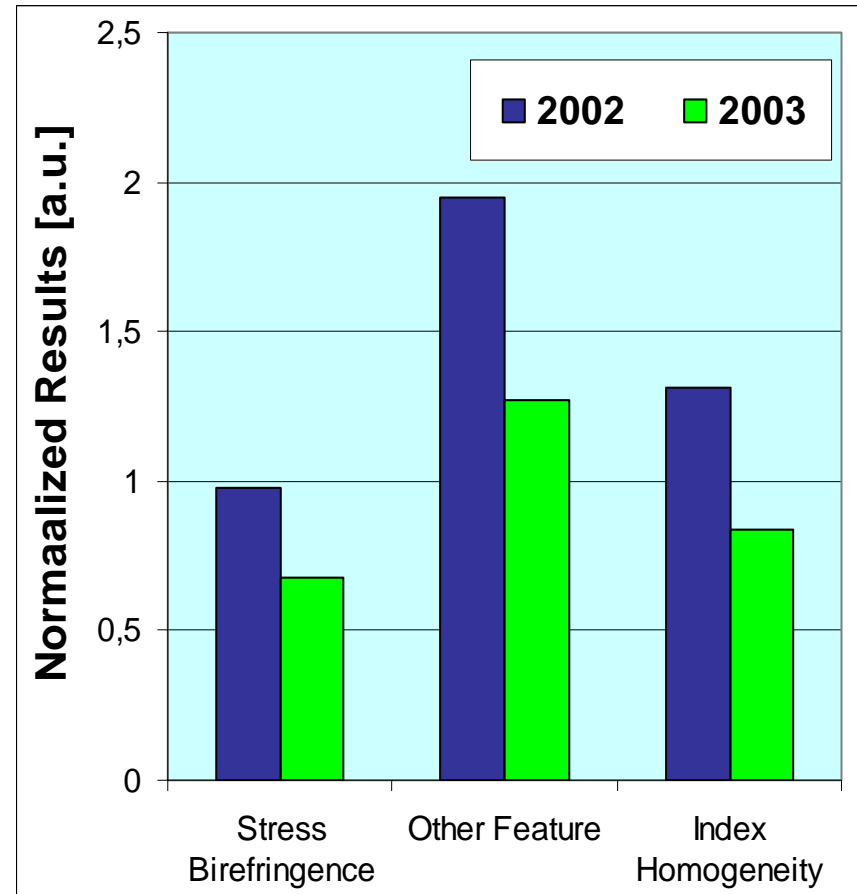
Commercialization

- Investment volume for production vs. utilization
 - 193 nm: small quantity per system, fairly limited dimensions, volume
 - 157 nm: high quantity/system, large dimensions

CaF₂ Quality

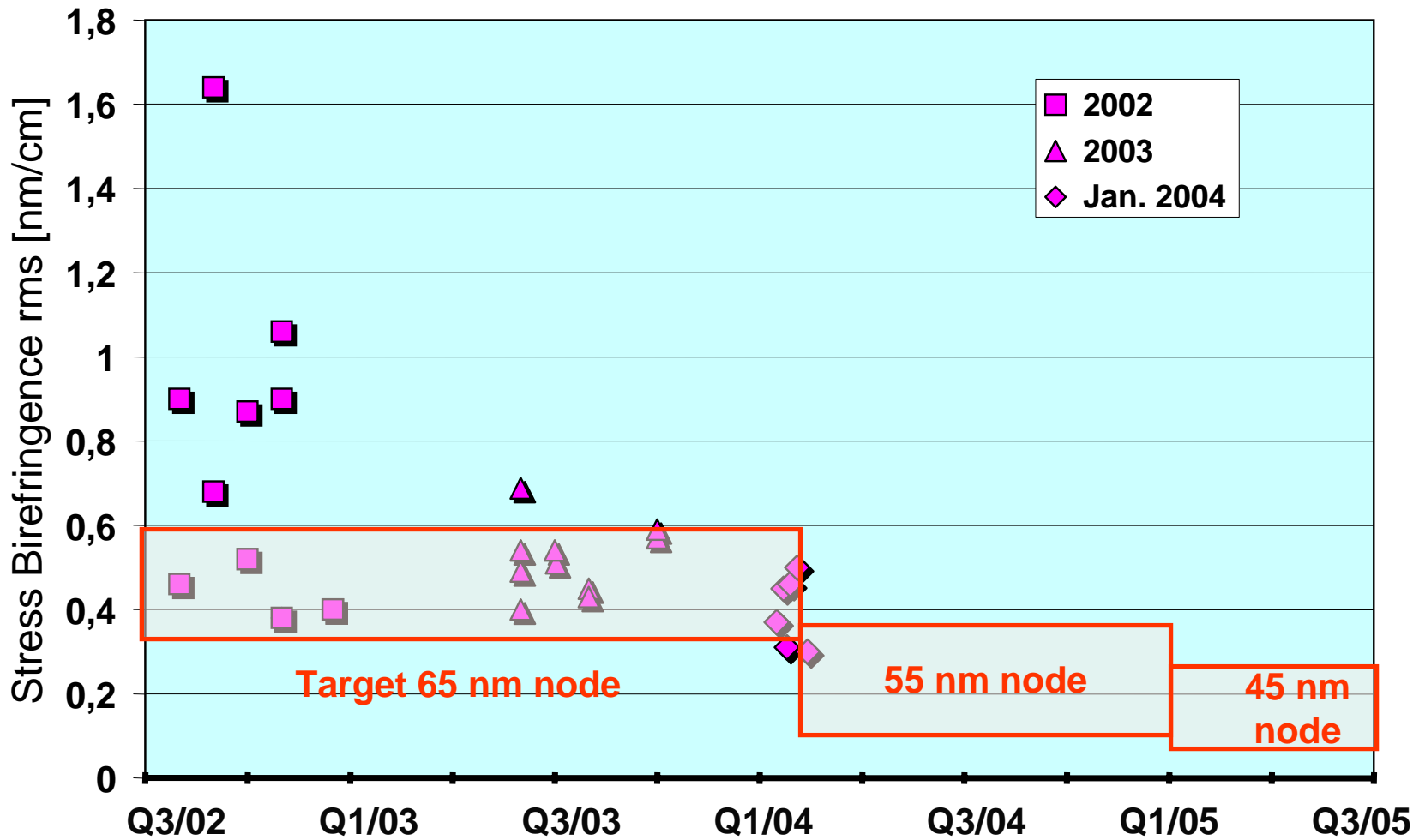
Improvements were demonstrated in all areas

- Average results of all produced CaF₂ lens blanks
- Results normalized to the tightest specification for each shown feature
- Ongoing activity will provide for next improvement



CaF₂ Quality

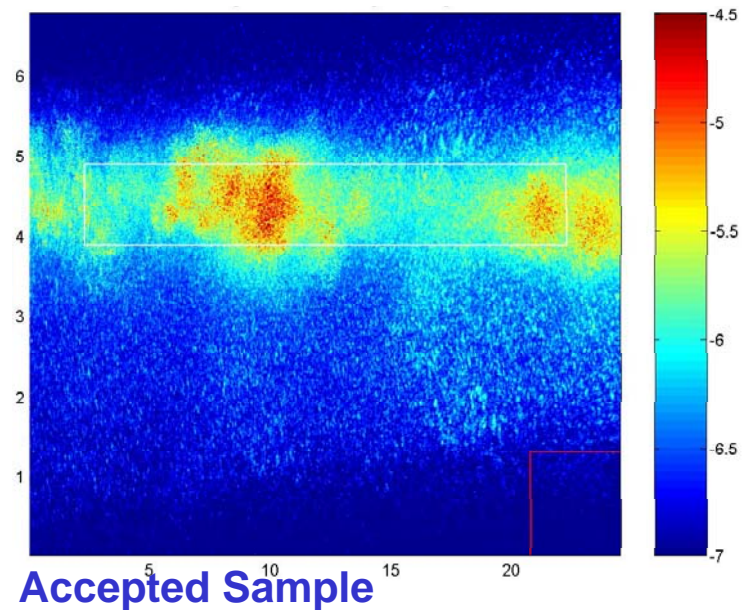
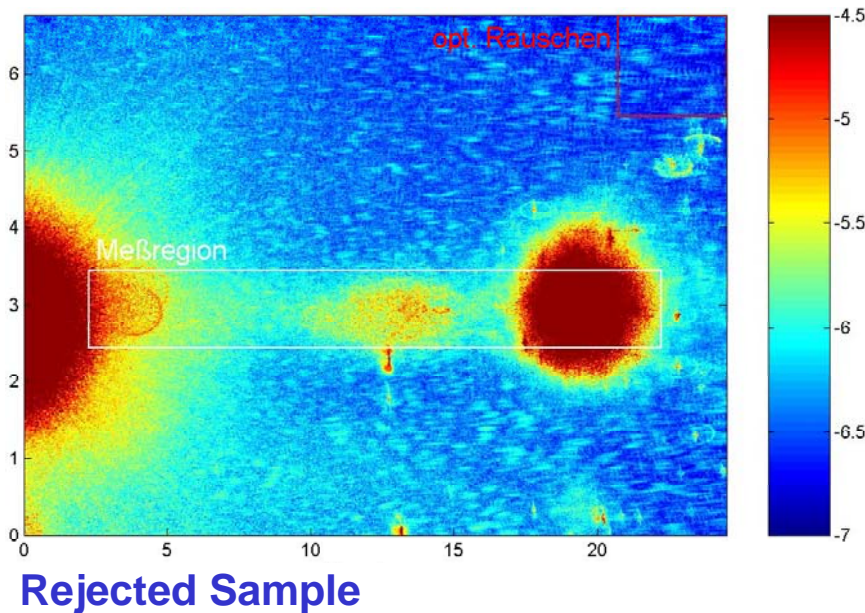
Stress birefringence reduction for (100) lens blanks



Flare

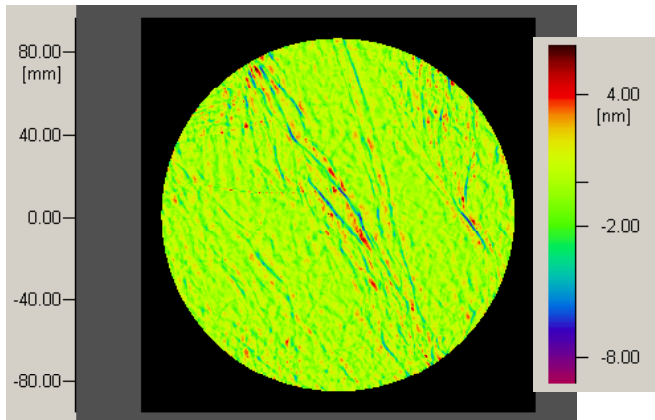
New straylight metrology enables faster learning

- In 2003 an efficient quantitative method for measuring forward bi-directional scattering (BSDF) was developed and implemented

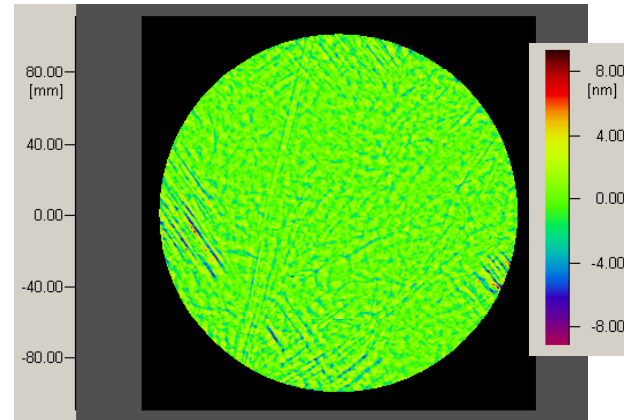


Flare

Reduction of low spatial frequency inhomogeneity

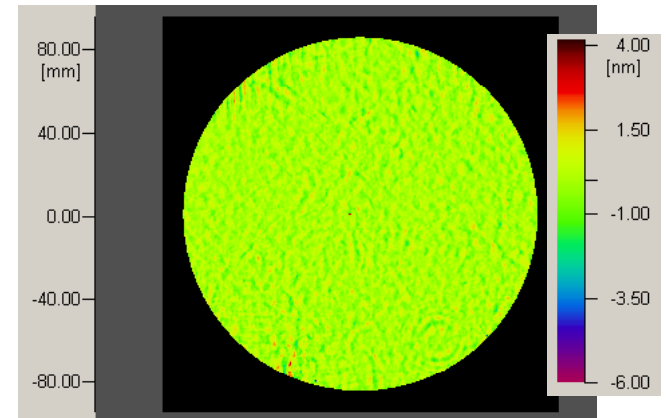


a.u. 1



0.96

- Several improvements were necessary for $\langle 100 \rangle$ lens blanks
- 60% improvement demonstrated



a.u. 0.38

Productivity

Developmental work focused on improved raw materials

- In 2003 two programs identified
- Productivity potential expected to be >2 for 2005 production
- 1 program ongoing
- 1 program canceled due to high costs / limited 157 nm technology visibility

R&D Program	Aim	193	157	Status
#1	Gain in productivity by improved raw materials / processes	✓	✓	started
#2	Gain in productivity by equipment modifications		✓	stalled

Quality

Ongoing developmental work

- 6 major activities running
- Support necessary improvements for CaF₂ utilization at the 45 nm node
- Support both 193 and 157 nm grade material

	Activity	Addressed Features	First results	Final results
1	Annealing I	Stress bir., striae, homogeneity	Q3/04	Q1/05
2	Annealing II	Stress bir., striae, homogeneity	Q3/04	Q1/05
3	Machining, handling	Stress bir., striae	Q3/03	Q1/05
4	Growth	crystal real structure, striae homogeneity	Q1/04	Q2/05
5	Pre-ingot I	crystal real structure, striae homogeneity	Q2/04	Q4/04
6	Pre-ingot II	crystal real structure, striae, straylight, homogeneity	Q4/04	Q3/05

CaF₂ Status Conclusion

- Overall progress in production technology leads to improved material quality
- Lens blank specifications for 65 nm node can be met today (ArF & F2)
- Ongoing improvements will allow very soon to meet the lens blank requirements for an intermediate 55nm node
- Developmental efforts are fully supporting the achievement of lens blank requirements for the 45 nm node with ArF IML technology
- Availability of CaF₂ lens blank material for 157 nm volume ramp at the 45 nm node or below depends on a reliable insertion scenario

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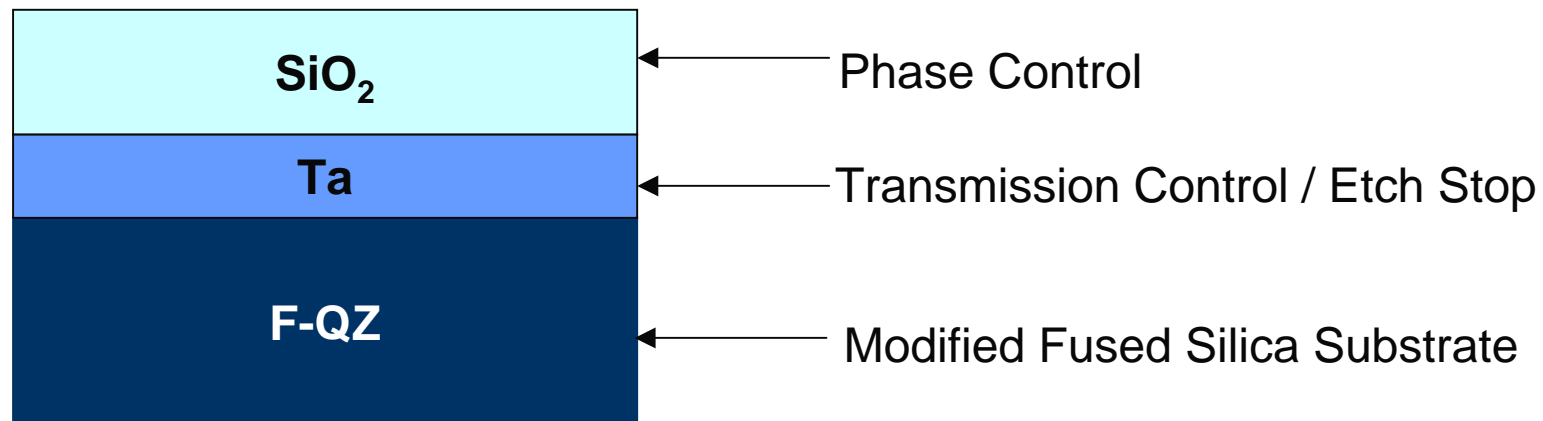
■ EAPSM Blank Status

- Basic design
- Tunability
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EAPSM Blanks

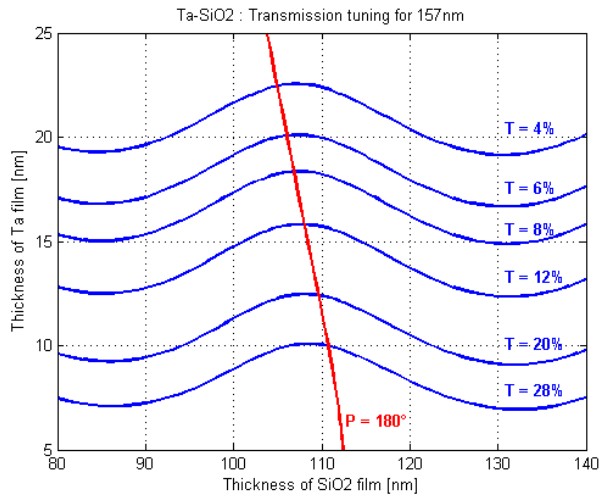
Basic Design

- bilayer system
- Independent control of phase and transmission features
- wavelength adjustable 157/193 nm

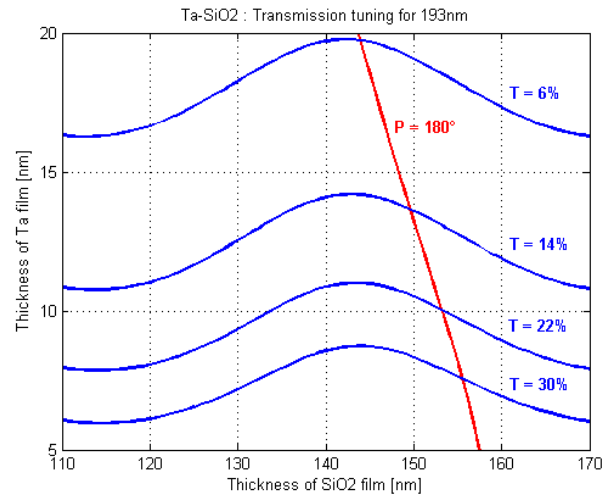


Transmission tunability of the PSM layer

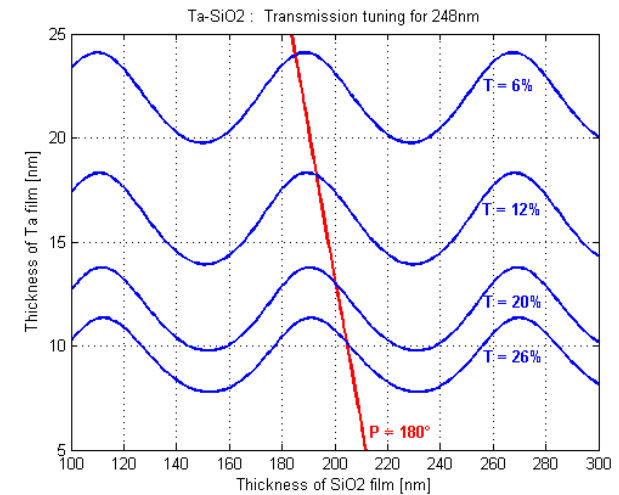
157 nm



193 nm



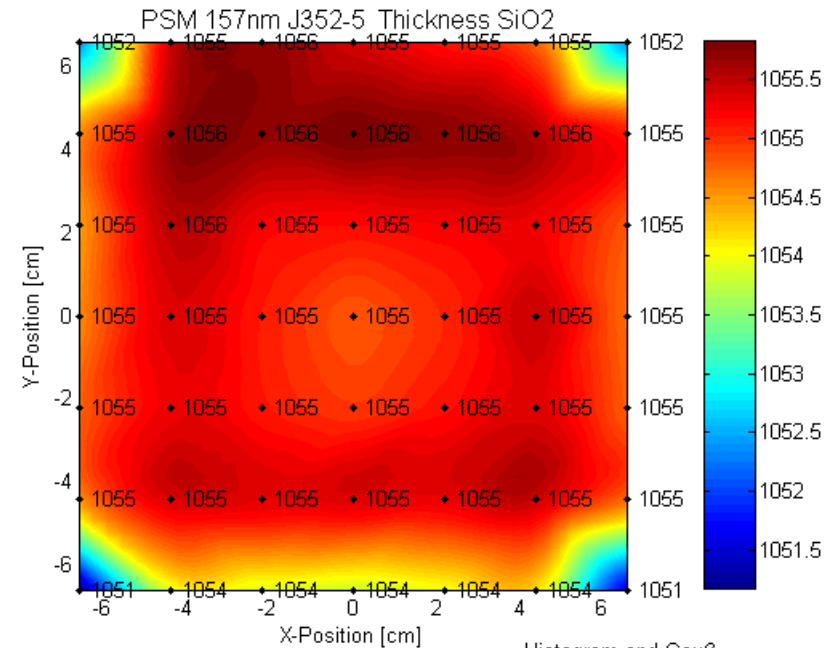
248 nm



- Assumption: minimum Ta layer thickness of 10 nm for etch stop
- Achievable maximum transmission:
 - 28% for 157 nm PSM
 - 22% for 193 nm PSM
 - 26% for 248 nm PSM

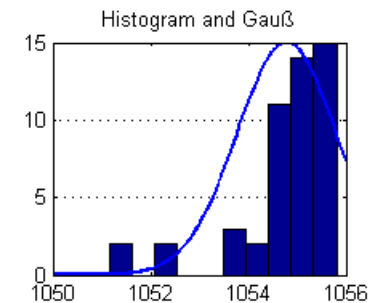
The 157nm PSM Ta/SiO₂ system is designed for 6% transmission and meets a phase uniformity of $\pm 1^\circ$

- Laser durability demonstrated; transmission change $< 0.2\%$ after total dose of $5\text{kJ}/\text{cm}^2$
- Chemical durability for multiple cleans using 90°C sulfuric acid – hydrogen peroxide mixture is well acceptable
 - 0.25° phase loss per clean
 - 0.08% transmission increase per clean
- Phase uniformity of $\pm 1^\circ$ achieved
- Defect-free blanks demonstrated



Statistics:

Mean: 1054.780762
 Std: 1.022964
 Min: 1051.159546
 Max: 1055.804688
 Range: 4.645142
 Range/Mean: 0.44 %
 Std/Mean: 0.10 %



EAPSM Blank Status

Conclusion / Future work

- Robust design for 157 EAPSM identified, beta-products available
- Uniformity requirements for transmission & phase are met
- Low defect level demonstrated
- Future work
 - Defect reduction / yield improvement
 - Improvement of cleaning efficiency
 - Establishment of dry etch process
 - Evaluation of mask process performance
- 157 nm EAPSM blank availability benefits from the parallel developmental work of high transmission (20%) EAPSM blanks for ArF technology