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Presentation Outline

- Disclaimer
- New fluid criteria
- Why new fluids?
 - Benefits
- Some recent results
- Future activities

Disclaimer

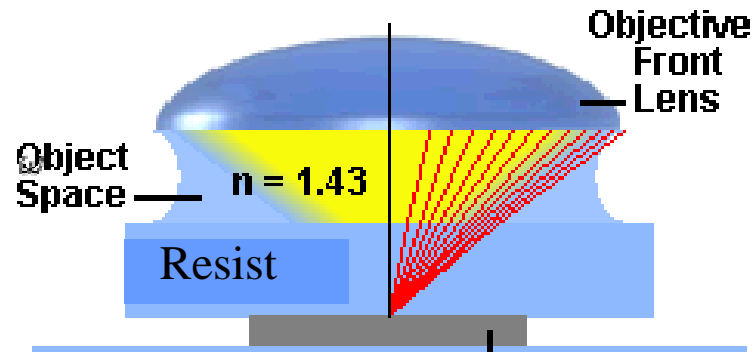
- 193nm lithography with water is the present immersion fluid
- This initial work is intended to seed the idea of “other” fluids” as a replacement for water for DOF improvements

New fluid criteria

- Water based?
- Higher RI than H₂O @ 193nm
- No effect on resist performance
 - Increase leaching, intermixing, etc.....
- Not photoactive or degradable
- No bubble formation
- No added defects or residues
- No additional fluid heating (absorbance, aberration impact)
- No increase in fluid viscosity (Reynolds number)
- Cost vs. degassed water?
- Others?

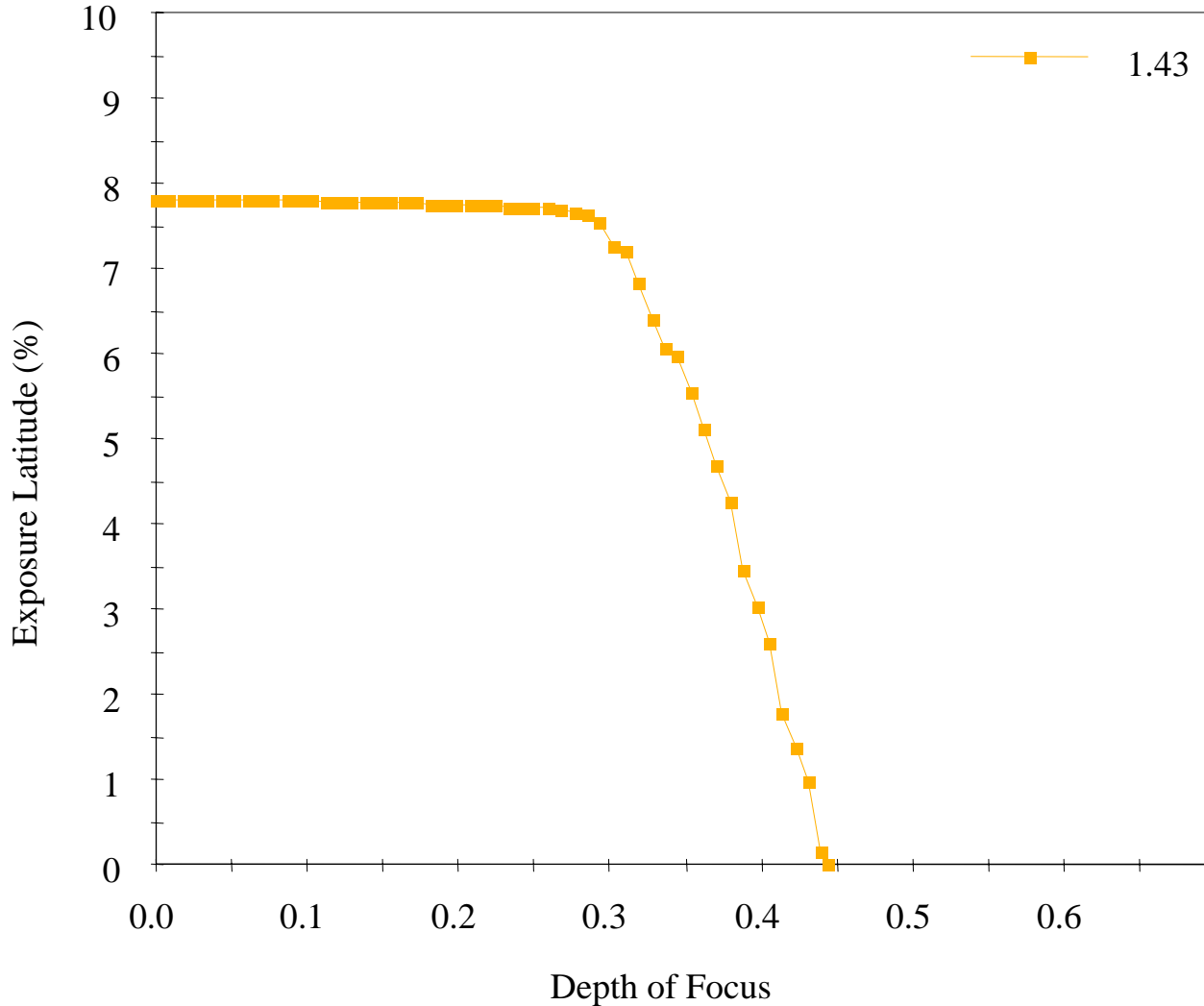
Why new fluids?

- Improvements in DOF
- Provides opportunity for higher NA system



- What's the right materials? Organic, inorganic?

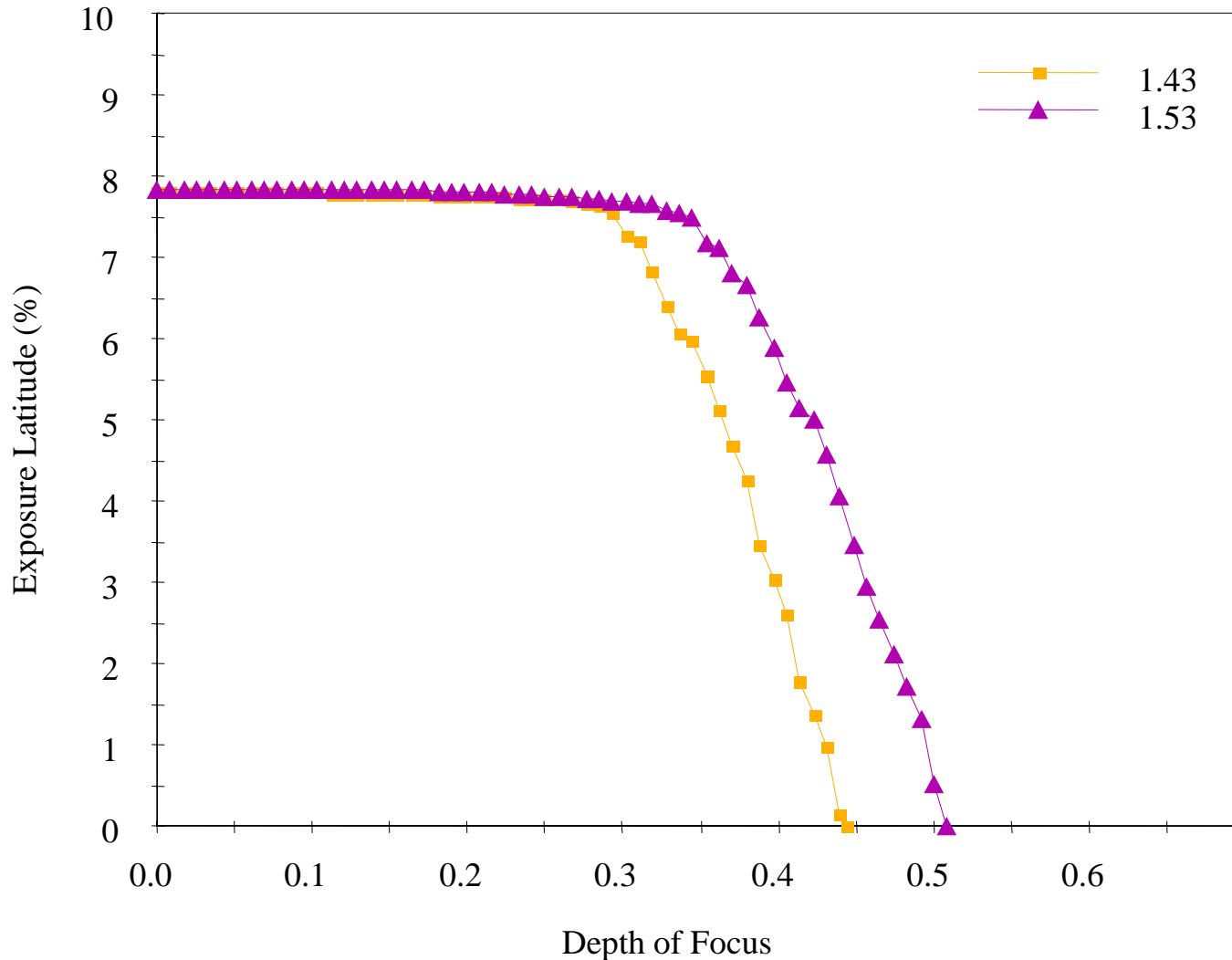
Improvements in DOF



- Resist RI of 1.7 with fluids of 1.43
- 45nm on 90nm for 1.2NA with alt PSM
- Vector simulation TE polarized
- Low σ

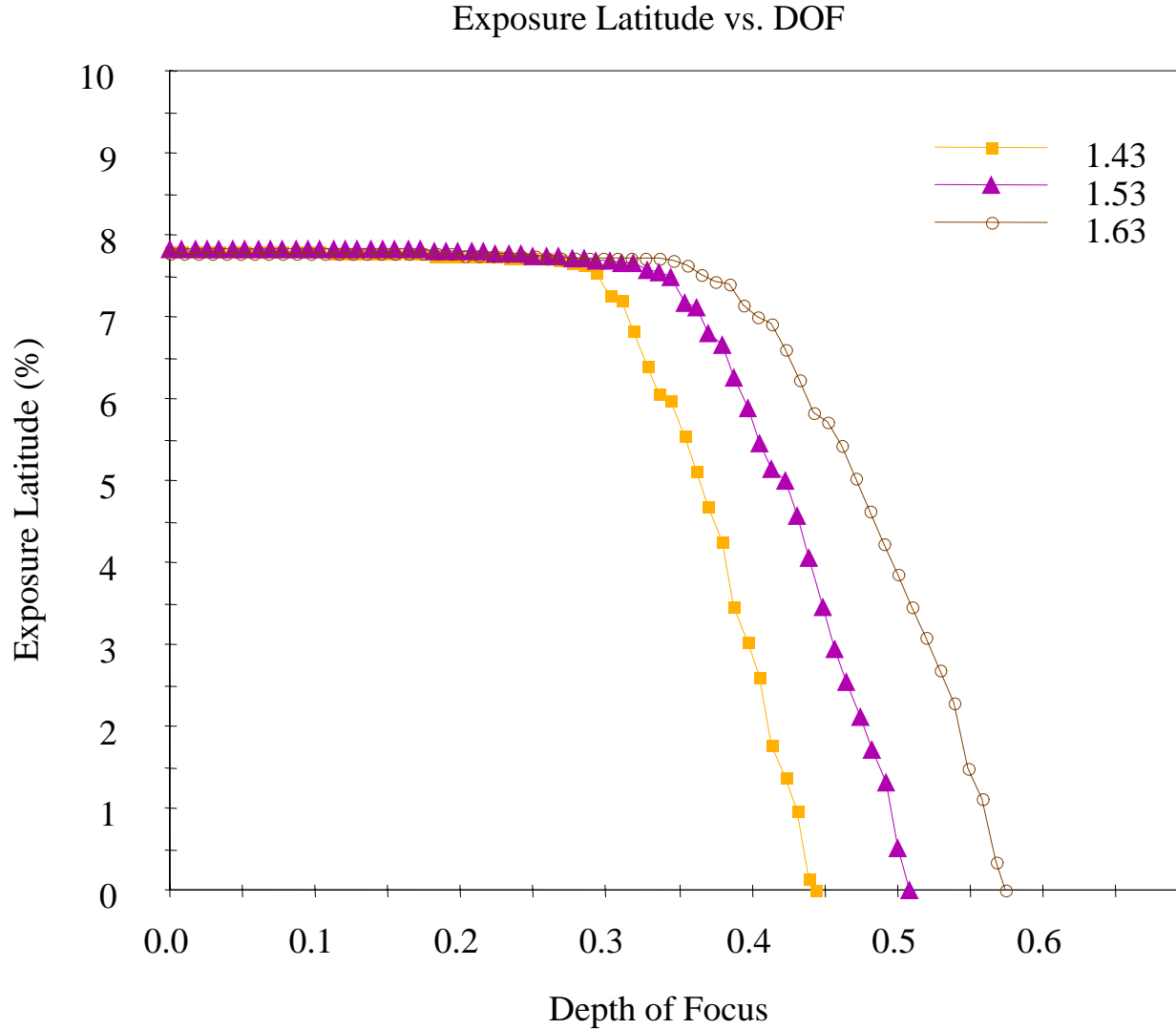
Improvements in DOF

Exposure Latitude vs. DOF



- Resist RI of 1.7 with fluids of 1.43 to 1.53.
- 45nm on 90nm for 1.2NA with alt PSM
- Vector simulation TE polarized
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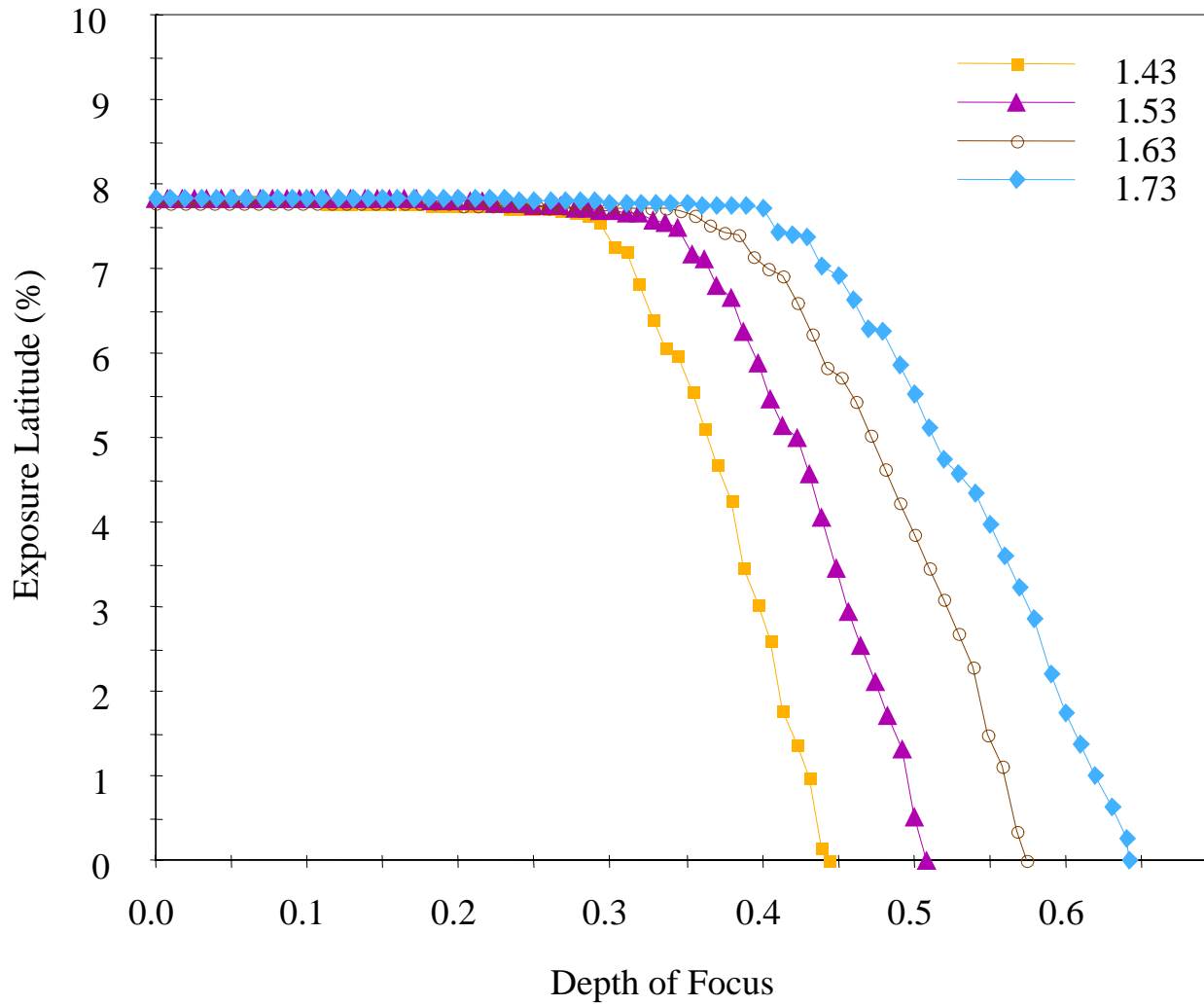
Improvements in DOF



- Resist RI of 1.7 with fluids of 1.43 to 1.63.
- 45nm on 90nm for 1.2NA with alt PSM
- Vector simulation TE polarized
- Low σ

Improvements in DOF

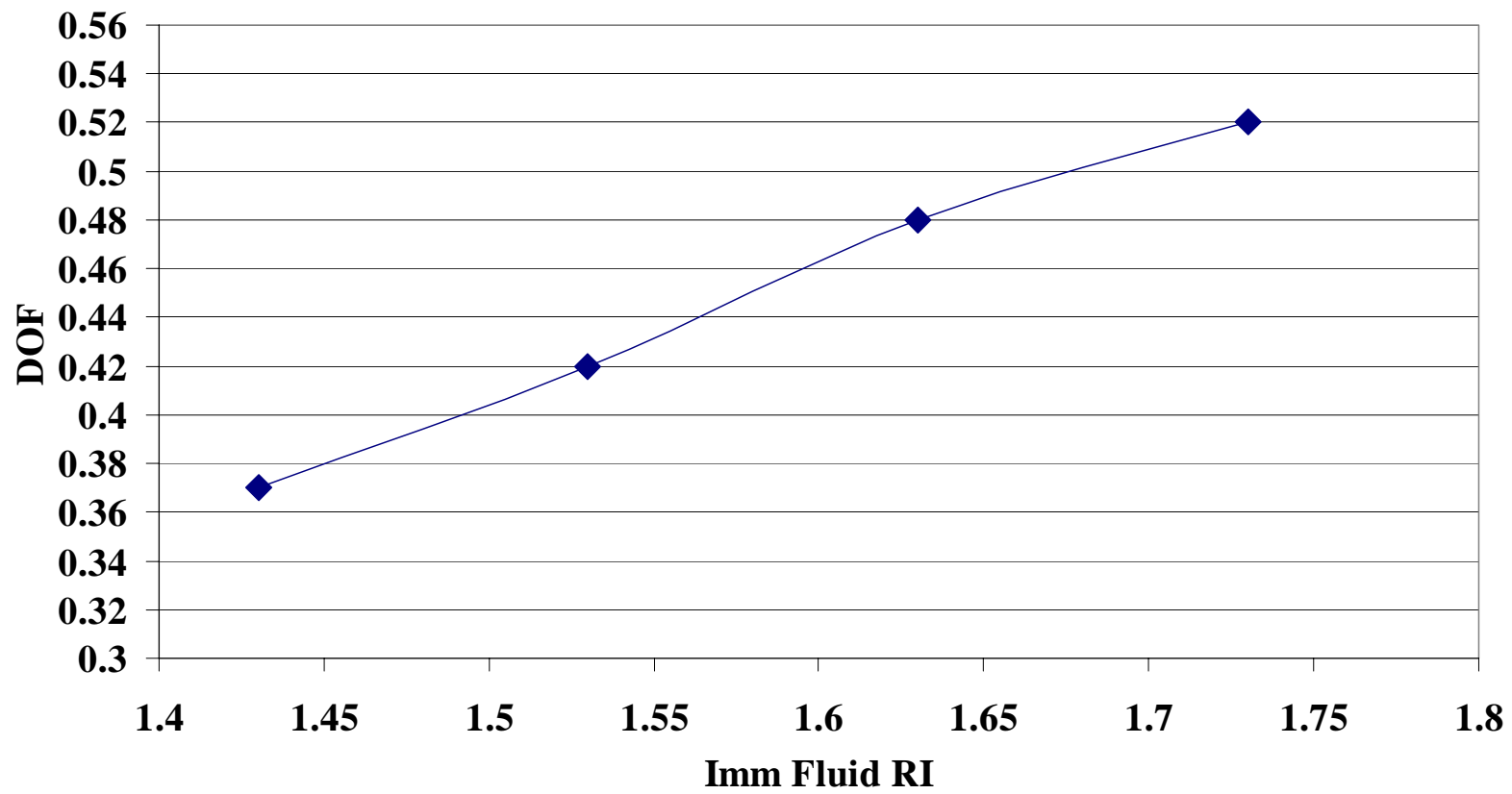
Exposure Latitude vs. DOF



- Resist RI of 1.7 with fluids of 1.43 to 1.73.
- 45nm on 90nm for 1.2NA with alt PSM
- Vector simulation TE polarized
- Low σ
- ~33% increase in DOF demonstrated for higher RI fluids

Why new fluids?

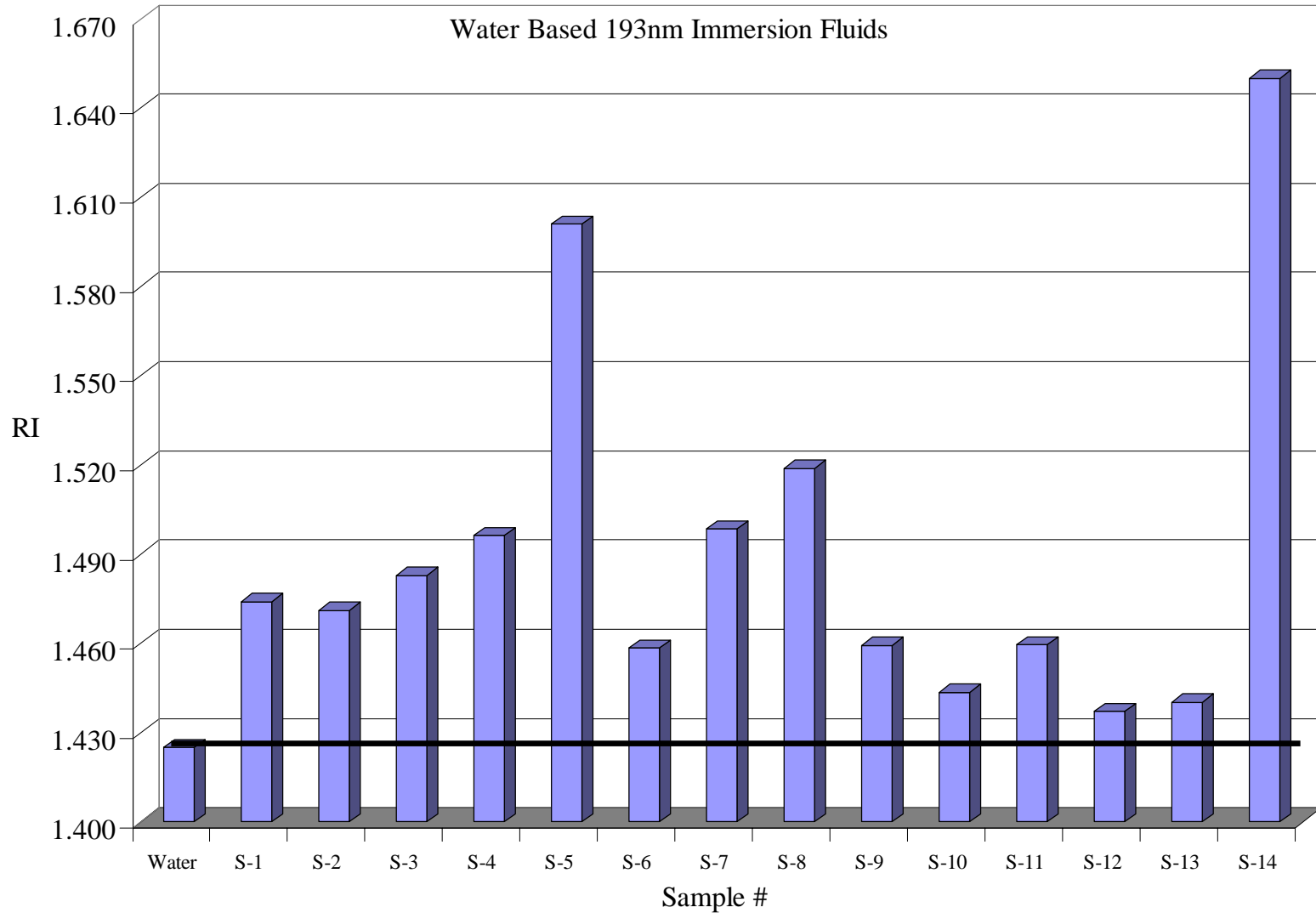
DOF vs Immersion Fluid for 1.2NA at 45nm 1/2 pitch



- ~ 30% improvement in DOF

Recent Results

Higher Refractive Index Fluids



- All samples are water based organic compounds

Conclusions & Future Activities

- Higher refractive index fluids will improve DOF
- First investigations into new fluids
- Continue to research new materials
- Understand photochemistry
- Imaging with new fluids

Effects of Immersion Lithography on Diffusivity during PEB:

Stewart Robertson-Shipley

Will Conley-Motorola/ISMT

Andy Romano-Clariant

Yongfa Fan, Anatoly Bourov-RIT

Does Immersion impact Diffusivity

- Difficult to separate acid diffusion and quencher diffusion
- Techniques previously explored
 - Ion Conductivity
 - Linewidth change versus PEB time
 - Estimation from exposure latitude or FEM Data
 - Analysis of residual standing waves in DRM trace

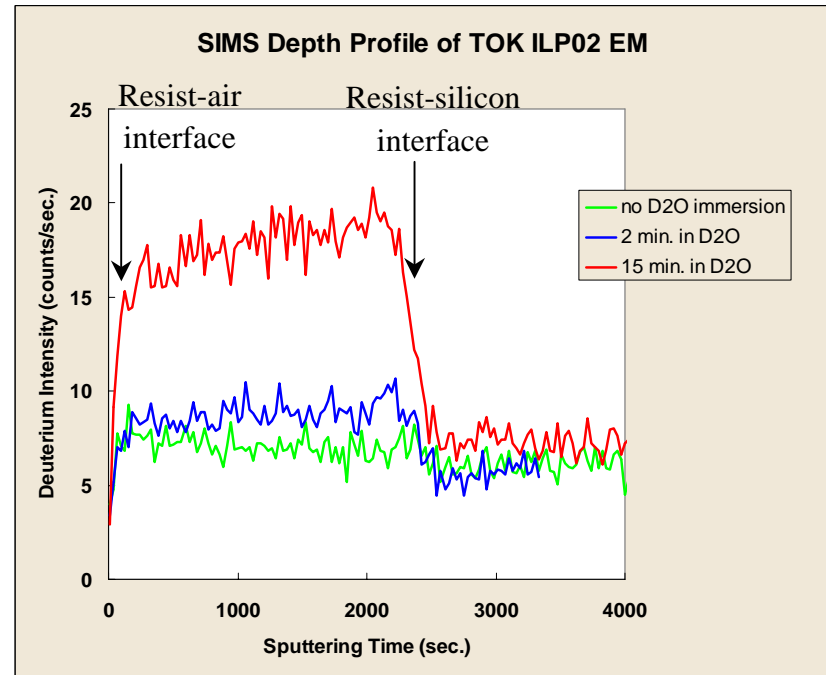
TOK Resist Water Uptake - D₂O/SIMS analysis

Secondary Ion Mass Spectrometry

- surface bombardment with an ion beam followed by MS of emitted secondary ions
- Continuous analysis during sputtering provides depth profile
- Cs⁺ primary ions in this case

Experimental protocol

- spin-coat and PAB resist films
- immerse in 99.9% deuterated water for specified time
- blow dry
- Immediately transfer to SIMS vacuum chamber and carry out analysis



Summary of results

- D₂O is not retained post-immersion
- fraction of D is retained, presumably from exchange with polymer R-OH
- Residual D is nonvolatile
- D content increases proportional to immersion time
- *Uniform distribution of D with depth in film*

V. Deline, W. Hinsberg, F. Houle

SEMATECH Imaging Work

- Purpose:
 - Study base and generate acid diffusion with respect to decreasing $\frac{1}{2}$ pitch
 - $\frac{1}{2}$ pitches 65nm to 40nm
 - Materials
 - Clariant T518 polymer
 - TOK 6 Polymer
 - TOA
 - TPS-Nf
 - TPS-Tf

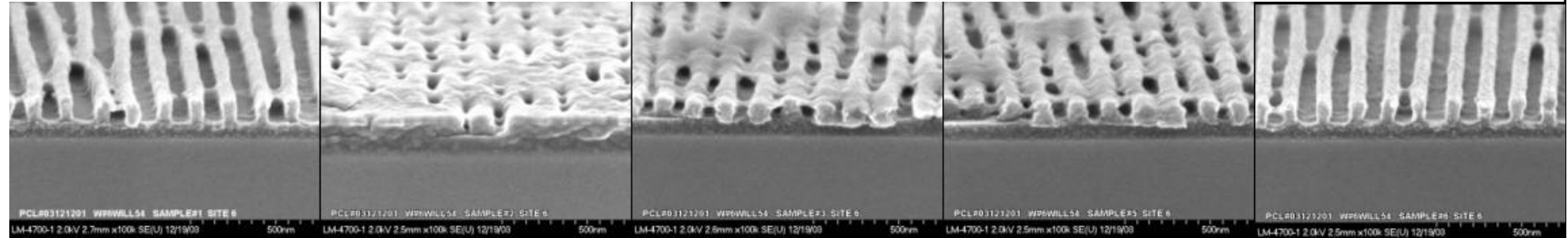
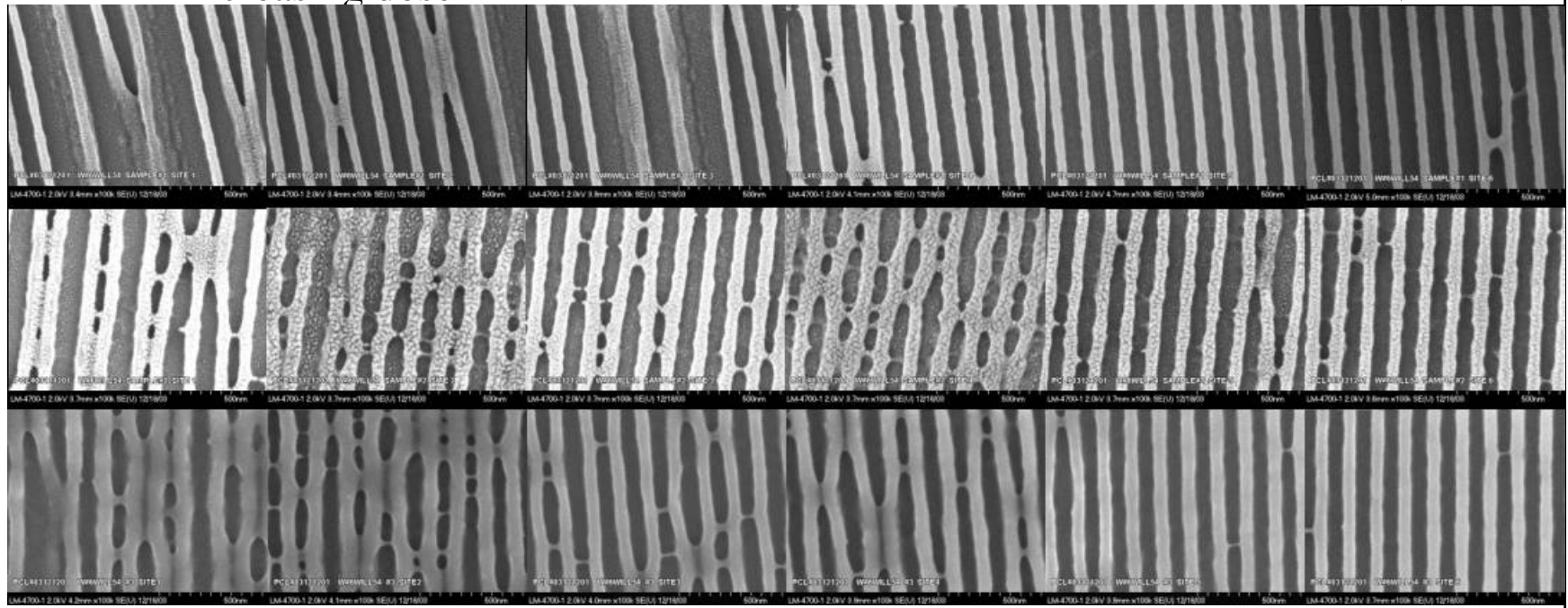
So Far

- Exposed samples with PEB time variation, both wet and dry – (Shipley materials)
 - *Random number generator*
- 3 variations of Clariant formulations with increasing base concentration (materials discussed at last RAG).
 - Exposure latitude samples – wet & dry
 - Results (next slide)

Top Down Images of IL for 60nm 1/2p

Increase
Base
conc

Increasing dose



- Uniformity problems
- Contamination

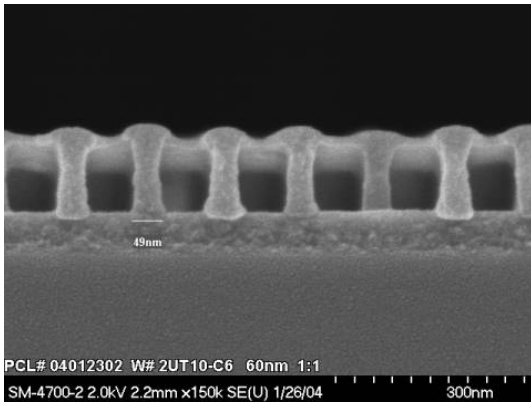
Additional Imaging

- Improvements in beam uniformity
- Formulations with fixed PAG and vary quencher concentration
- 60nm $\frac{1}{2}$ pitch at ~6 doses

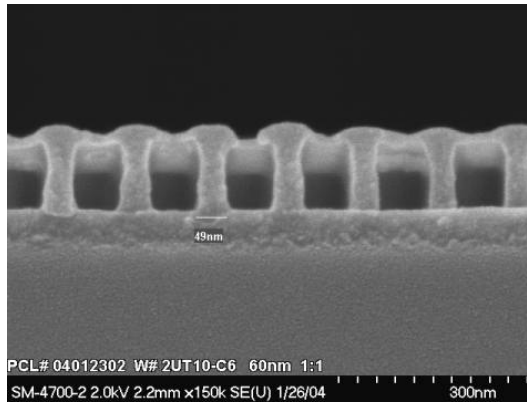
Materials of Various PAG and Quench Loadings

60nm 1/2 pitch, 150nm film thickness

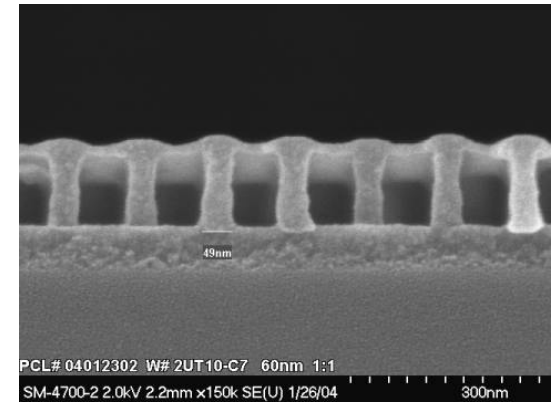
3%



15'' (49nm)

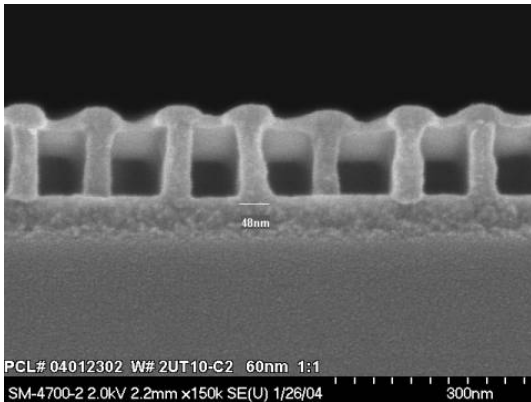


17'' (49nm)

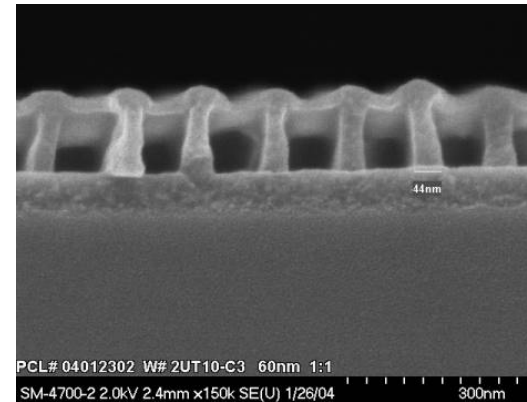


19'' (49nm)

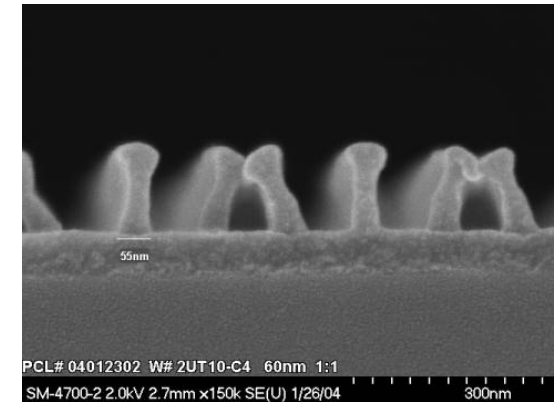
5%



10'' (48nm)



12'' (44nm)



14'' (45nm)

Acid Diffusion Study

- Reproducibility of dose, PEB process and delay time currently limit linewidth versus PEB time method and EL method
- Need projection tool capability for FEM method
- FEM data when Exitech*i* available
 - Better dose uniformity
 - Focus variation capability

Immersion Resist Conclusions & Future Activities

General Conclusions

- IL systems are a good tool for early learning
- All materials imaging down below 50nm
 - 38nm ½ pitch!
- Burst-type model describes the major leaching mechanism. More subtle aspects need to be understood.
- Radio isotope labeled PAG data consistent with burst-type model.
- New water based immersion fluids can offer more DOF

Future Immersion Activities

Immersion Project Direction

- **Phase 3 (Feb'04 to Dec'04)**

- Additional research in further improvements and fundamental mechanisms in the extension of immersion lithography
 - Acid diffusion
 - Polarization
 - New immersion fluids
 - *Fluid surface interactions with resist*
 - Resist materials for sub-65nm ½ pitch imaging
 - Pattern collapse
 - Contacts for sub-100nm
 - Laser durability/contamination test bed for evaluating final optic with different coatings, water content & contaminants

- **Phase 4 (Jan'05-Dec'05)**

- Small field ~1.2NA immersion system
- New immersion fluids
- Resist materials