

Measurement of the Index Properties of Fluids for 193 nm and 157 nm Immersion Lithography

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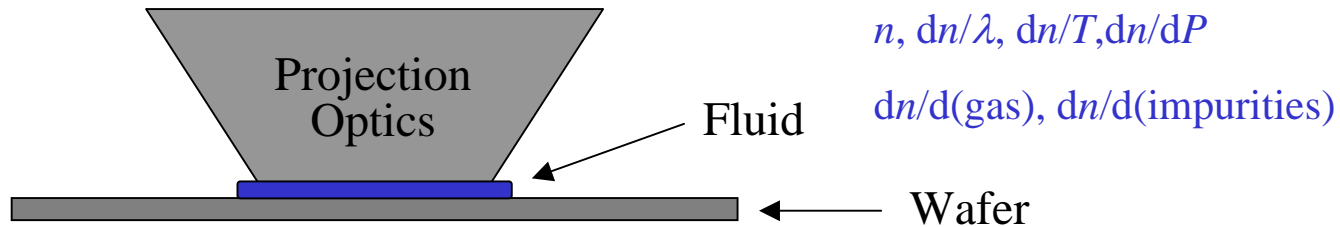
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and International SEMATECH

Immersion Lithography Fluids



- Immersion fluid is optical element.
⇒ Need to know refractive index n and $dn/d\lambda$ to high accuracy!
Need sensitivity to T , P , and contaminants (gases and impurities).

193 nm Immersion Lithography

- 1st candidate fluid: Water – completed.
Burnett, Kaplan, and Harvey, '03 Immersion Workshop;
Burnett and Kaplan, JM3, Jan 2004.
- Explore other high n fluids – mixtures, additives, contaminants.

157 nm Immersion Lithography

- Search for candidate fluids – MIT Lincoln Labs/Dupont.
- Need for full characterization of index properties.

193nm and 157nm Fluid Refractometry Requirements

With SEMATECH support constructed facility for rapidly surveying 193 nm and 157 nm fluids.

Operational Requirements:

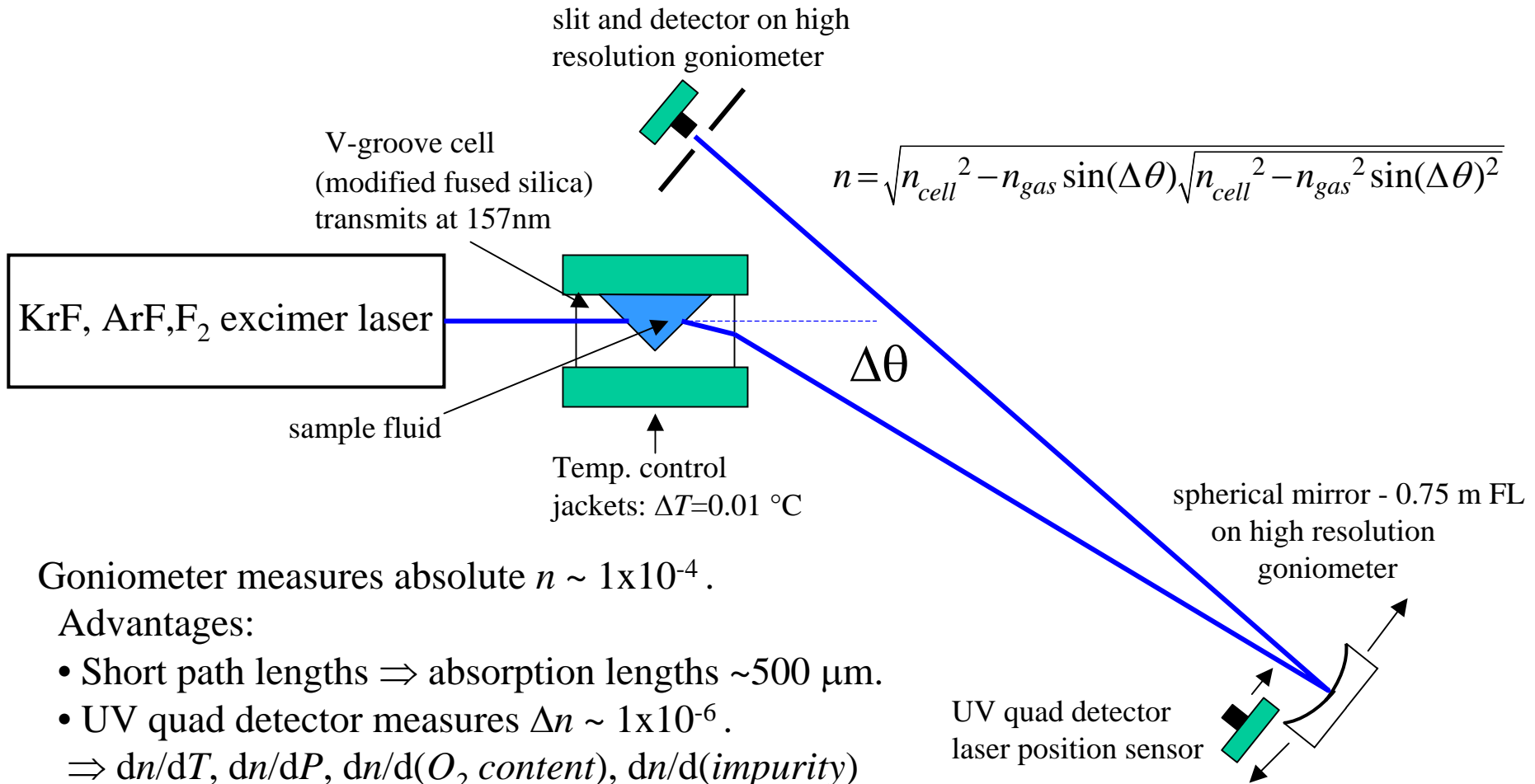
- Operates at both 193 nm and 157 nm (nitrogen purged).
- Load-locked for rapid sample turnaround.
- Introduce liquid into aligned cell in purge environment.
- Measurements on fluids w/ absorption lengths of $\sim 500 \mu\text{m}$.
- System constructed quickly!

Measurement Requirements:

- Quick, moderate-accuracy n measurements ($\sigma \sim 10^{-4}$).
(For higher absolute n accuracy - new min. dev. system ($\sigma \sim 1 \times 10^{-6}$.)
- Quick, high-accuracy Δn measurements ($\sigma \sim 1 \times 10^{-6}$).
 $\Rightarrow dn/dT, dn/dP, dn/d(O_2 \text{ content}), dn/d(\text{impurity})$
- Stringent temperature control (0.01 °C).

VUV Hilger-Chance Refractometer

For any fluid with absorption lengths $\geq 500\mu\text{m}$ at 193nm or 157nm:
quickly measures n with moderate accuracy, Δn with high accuracy.



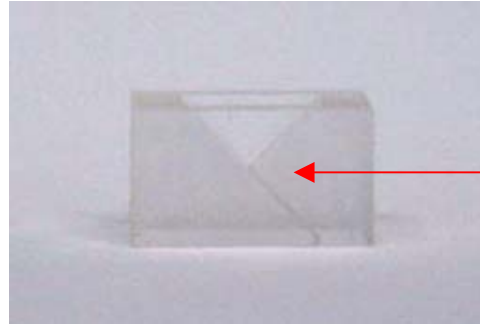
Goniometer measures absolute $n \sim 1 \times 10^{-4}$.

Advantages:

- Short path lengths \Rightarrow absorption lengths $\sim 500\ \mu\text{m}$.
- UV quad detector measures $\Delta n \sim 1 \times 10^{-6}$.
 $\Rightarrow dn/dT, dn/dP, dn/d(O_2\ \text{content}), dn/d(\text{impurity})$
- Remote loading, automation \Rightarrow rapid measurements.

V-Groove Cell

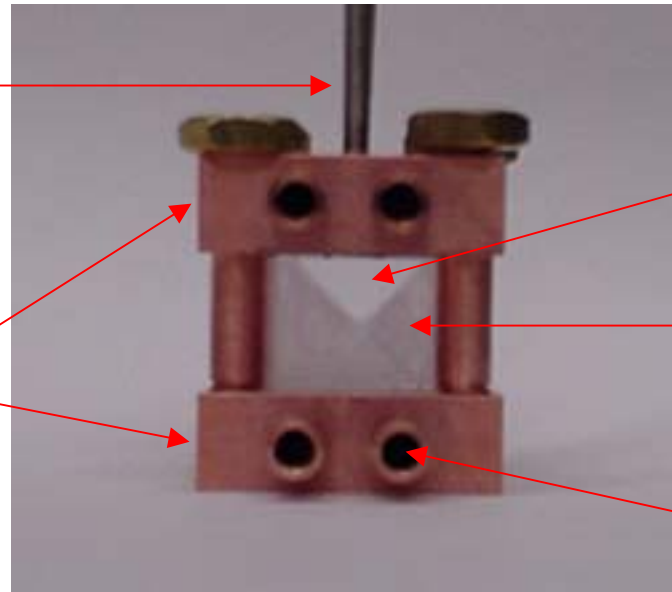
Bare fused silica cell



Modified fused silica
(transmits at 157nm)

Temperature-controlled cell sealed from atmosphere

Sealed ports for
introducing fluid



Sample fluid

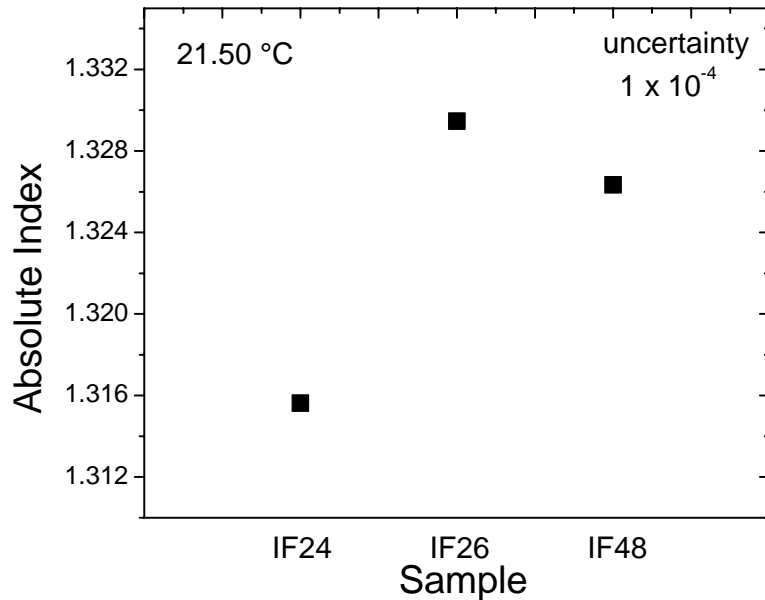
Water jackets for T
control to 0.01 °C

Fused silica cell

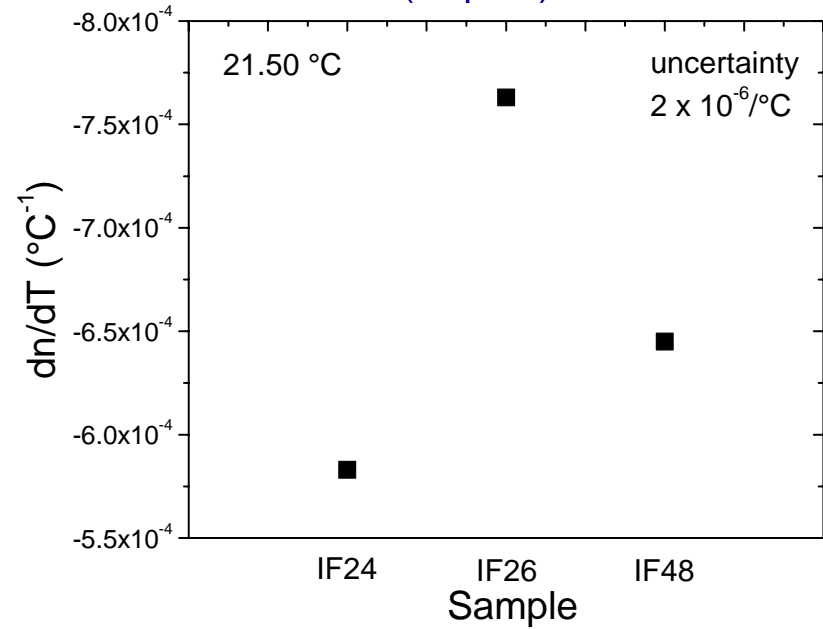
Hose connections

Refractive Properties of Sample Fluorofluids

Fluorofluid (Dupont) 157 nm Absolute Index



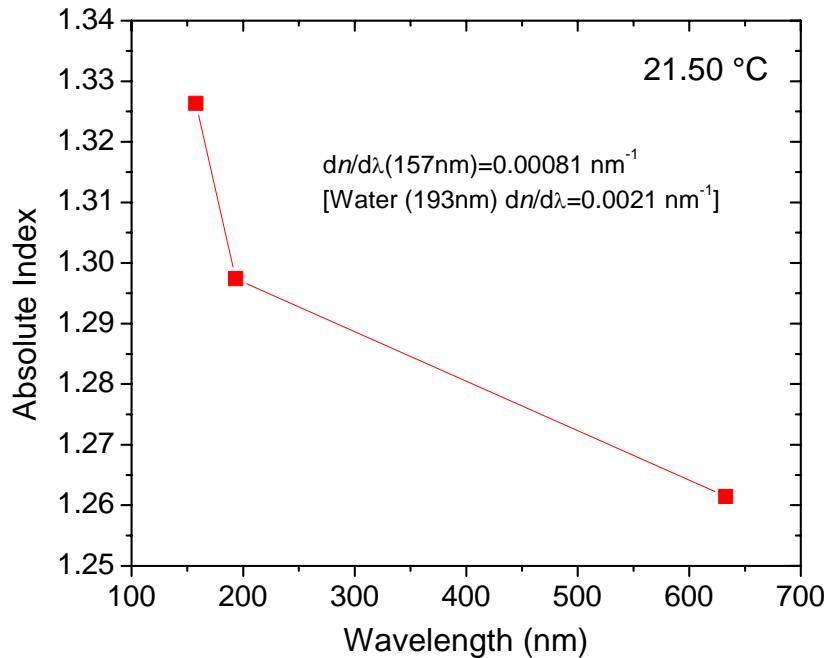
Fluorofluid (Dupont) 157 nm dn/dT



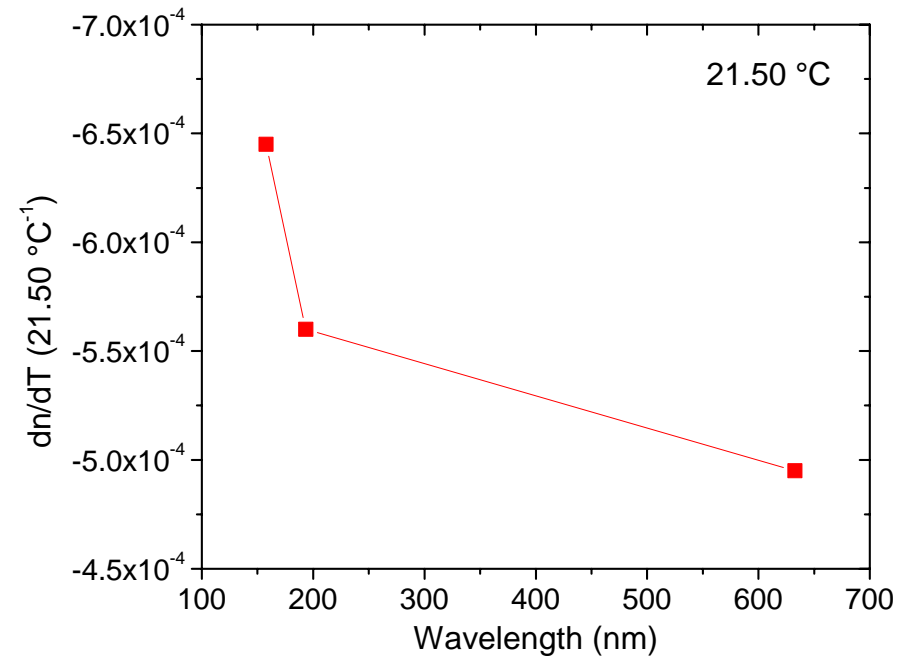
Sample	Abs./cm@157nm	n (21.5 °C)	dn/dT (°C) (21.5 °C)
IF24 (157 nm)	0.36	$1.315,62 \pm 1 \times 10^{-4}$	$-5.83 \times 10^{-4} / ^\circ\text{C}$
IF26 (157 nm)	1.10	$1.329,46 \pm 1 \times 10^{-4}$	$-7.63 \times 10^{-4} / ^\circ\text{C}$
IF48 (157 nm)	1.00	$1.326,34 \pm 1 \times 10^{-4}$	$-6.45 \times 10^{-4} / ^\circ\text{C}$
Water (193 nm)		$1.436,62 \pm 2 \times 10^{-5}$	$-1.00 \times 10^{-4} / ^\circ\text{C}$

Dispersions of Sample IF48

Fluorofluid (Dupont IF48) Absolute Index



Fluorofluid (Dupont IF48) Thermo-Coefficient



Conclusions

- Completed construction of a unique VUV refractometry facility enabling rapid surveying of index properties of fluids near 193 nm and 157 nm (actually any λ down to below 157nm).
- Begun measurements of 157 nm fluids, feeding back to design.
- Begun construction of high accuracy min. dev. system ($\sigma \sim 1 \times 10^{-6}$).

193 nm Measurements:

- Survey alternate 193 nm fluids and impurity effects.

157 nm Measurements:

- Survey 157 nm transmitting fluids to select properties, e.g. high n .

Will participate in immersion fluid characterization efforts at 193 nm and 157 nm with SEMATECH, industry, institutes/universities.