NanoStructures

MPS 1

Inexpensive Anti Reflective Passivated Solution

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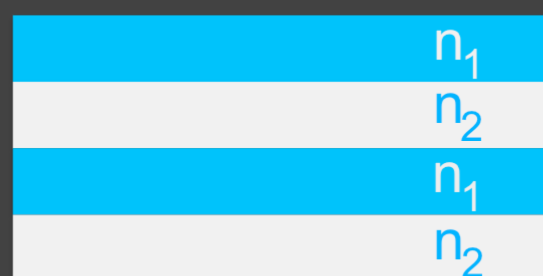
What are Anti-Reflective Coatings?

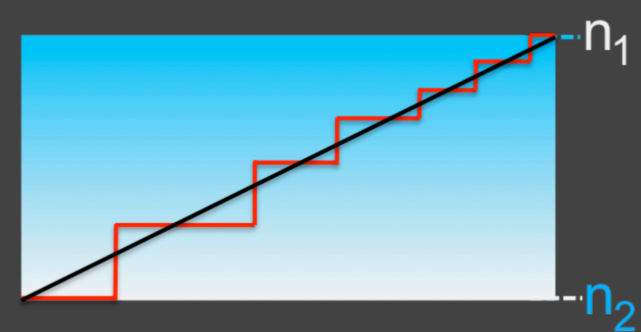
Current Technologies

Current Technologies

- Low refractive index nanoparticle system
- Alternating refractive indices
- Gradient refractive index (GRIN)

$n \to 1$





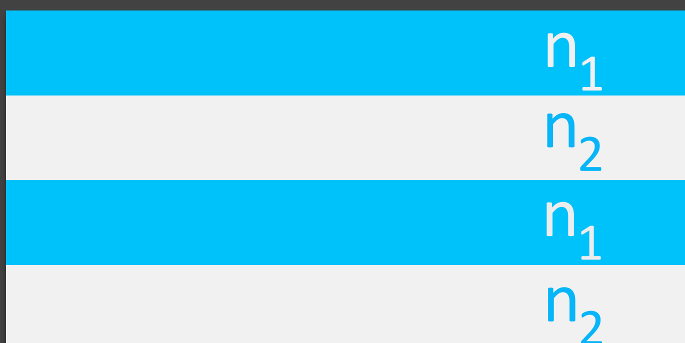
Low Refractive Index Nanoparticle System

$$n \rightarrow 1$$

Drawbacks

- Wavelength specific anti-reflectance
- Angle sensitive anti-reflectance

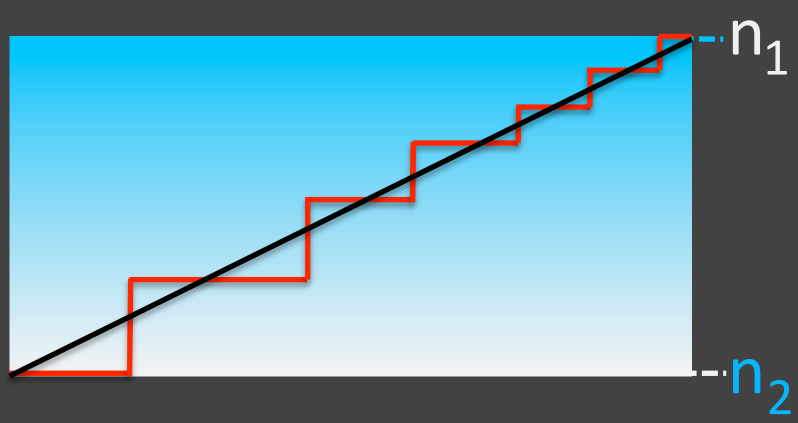
Alternating Refractive Indices



Drawbacks

- Expensive – requires CVD
- Time consuming – requires multiple layers

Gradient Refractive Index



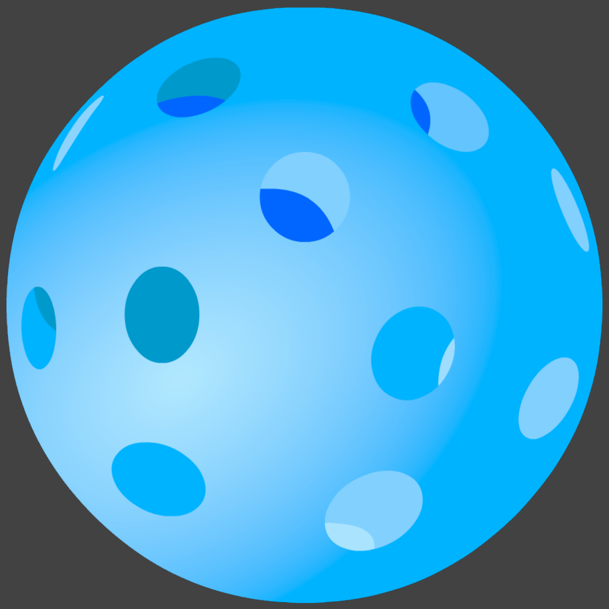
Drawbacks

- Expensive – requires vacuum deposition
- Quality/Quantity tradeoff
- Required materials do not all exist

Our Inspiration

MPS NS

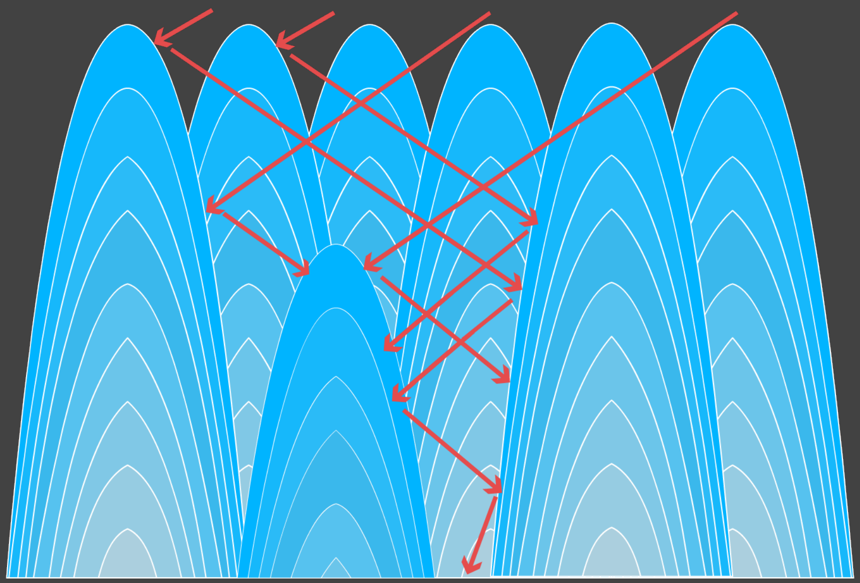
Mesoporous Silica (MPS) Nanoparticles



Advantages

- Tunable refractive index
- Easily fabricated – no specialized deposition
- Durable
- Made of glass

Anti-Reflective NanoStructures (NS)



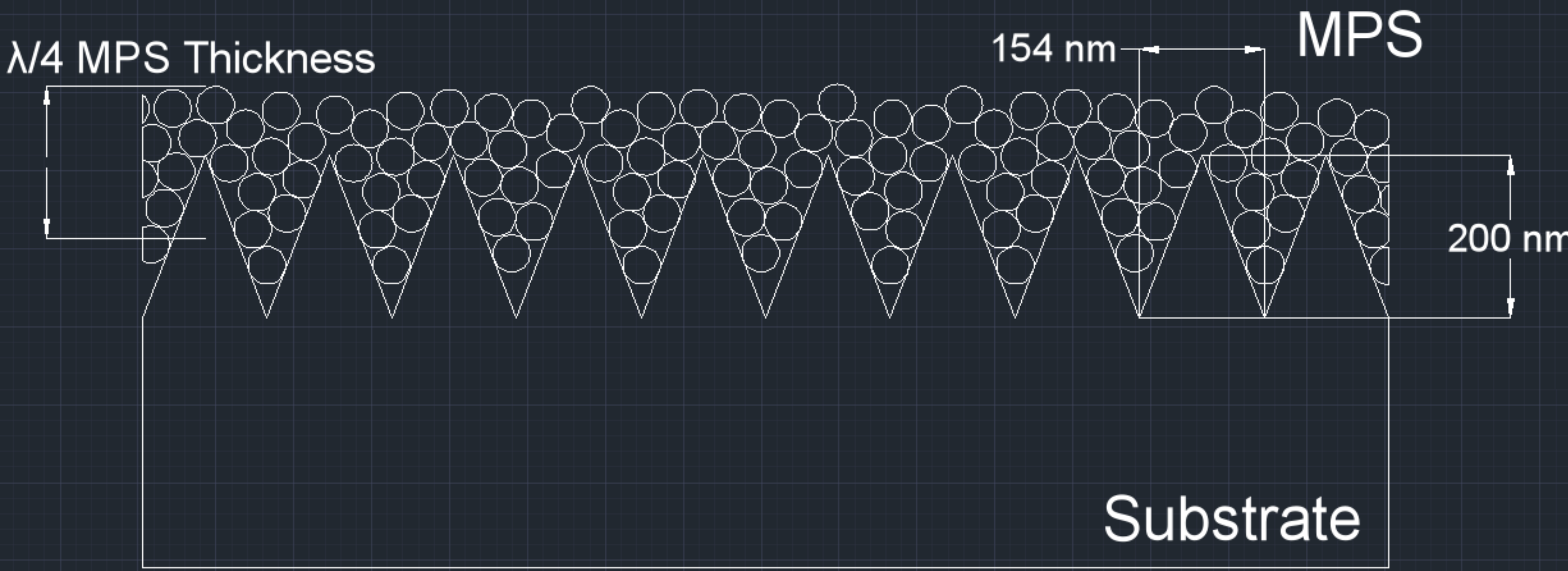
Advantages

- Removes interface – minimal reflectance
- Inexpensive – injection molding
- Randomly distributed structures – defect immune

Disadvantages

- Fragile – contact sensitive
- Increased scattering from structures

Our Solution



MPS passivation film

$\lambda/(4\ n_{MPS})$ film thickness

NS – AR coating and MPS bonding site

Advantages

- Inexpensive – injection molding/NIL
- Easily fabricated – spray coating/dip coating
- Durable – MPS scratch resistance
- Improves adhesion – increased contact area

Disadvantages

- Multi-step process
- Expensive initial mold
- MPS transmission variance throughout visible spectrum

Applications

Camera lenses

Optical glasses

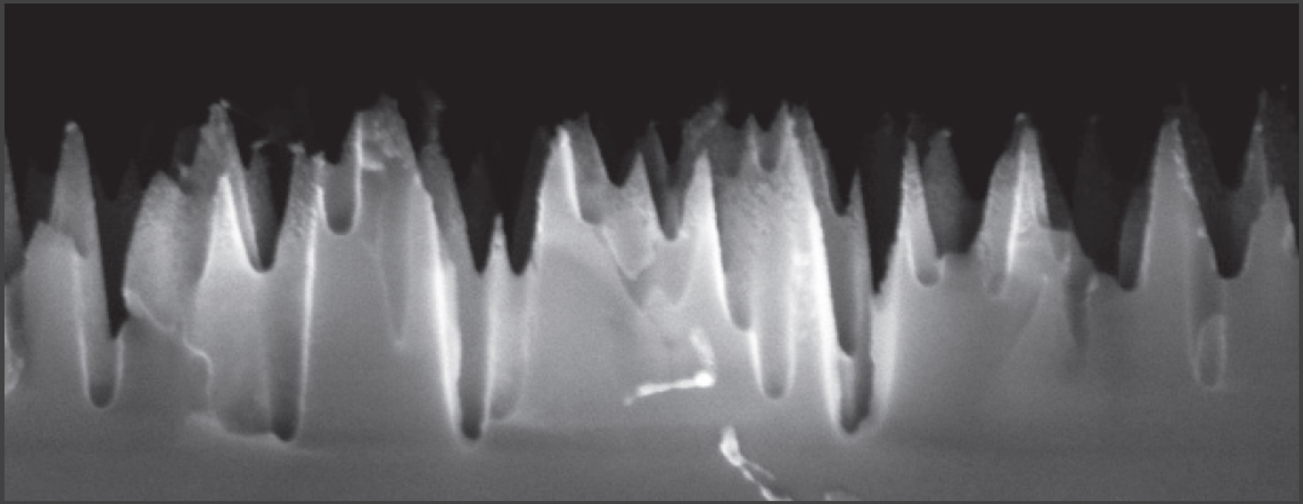
Screens (TV, Mobile phone)

Telescopes

Microscopes

Fabrication

Silicon Master Mold



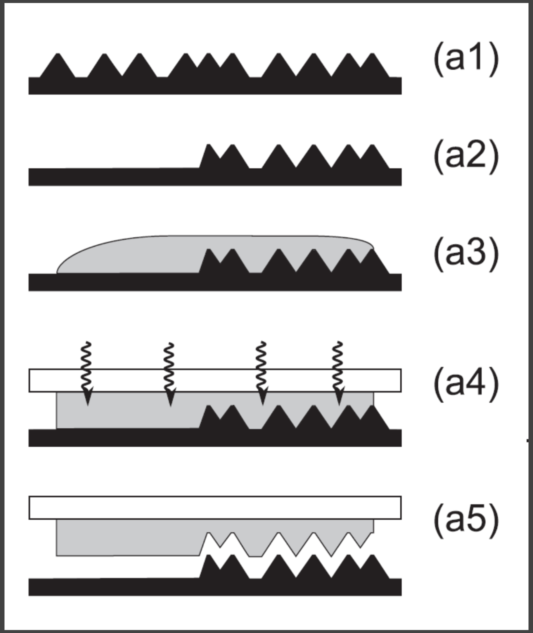
Reactive Ion Etch

- $O_2 + SF_6$
- Variable aspect ratio – gas flow-rate adjustment

Anti-Stiction Coating

- FDTS application via molecular vapor deposition

Pattern Transfer Process



(a1) Black silicon mold

(a3) Place polymer onto substrate

(a4) UV expose polymer

(a5) Release negative

MPS Dip Coating Solution

Binder Procedure

1L of Isopropanol

50mL of TEOS

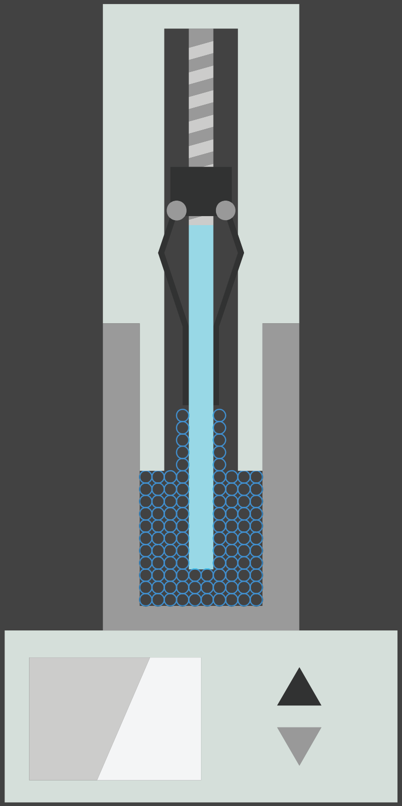
25mL of 0.1M Hydrochloric Acid

MPS Procedure

Dilute 5.6wt% of MPS down to 1.5wt%

Combine MPS and Binder (10, 35 and 60% binder ratio)

Dip Coating Deposition



Chemical Requirements

MPS and Binder solution mixture

Deposition Methods

Spin coating – low velocity

Spray coating/dip coating

Validation and Verification

Testing Regime

Substrates

- Ormocomp
- Norland Optical Adhesive
- Polycarbonate
- PMMA

Transmission/Durability Tests

- Blank substrate
- Unprotected NS
- MPS thin film
- NS + MPS thin film

Consumer Requirements

Primary

- Reduce reflectivity versus blank substrates
- <10% Reflection – 0° to 45°
- Minimal contact durability
- UV curable

Secondary

- MPS spray deposition
- <5% Reflection – 0° to 45°
- Moderate contact durability

Tertiary

- Mass production – hot embossing/injection molding
- Intensive contact durability
- <1% Reflection – 0° to 45°

Characterization

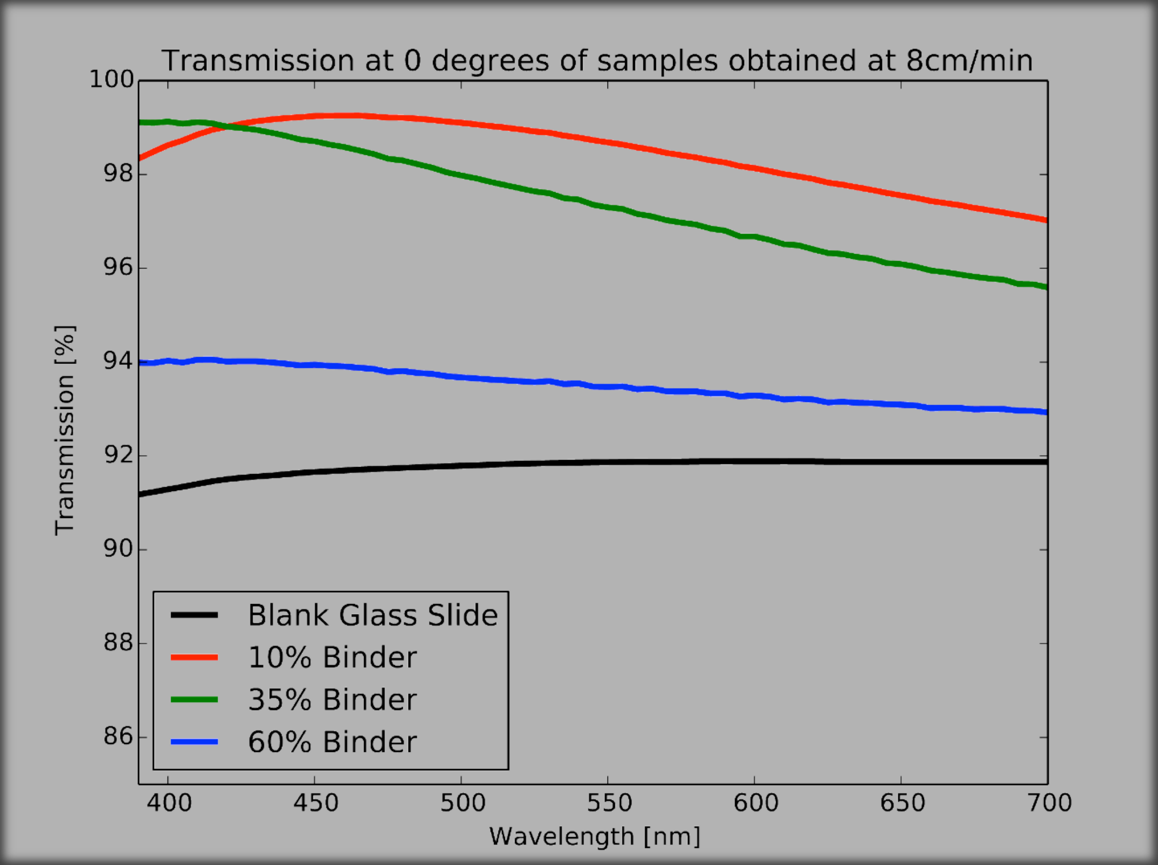
SEM	–	Surface imaging/deposition profile
Optical tests	–	Transmission testing using UV-Vis
Scratch test	–	Using Mohs Hardness Test
Hardness test	–	Berkovich Nanoindentation

Trade-offs

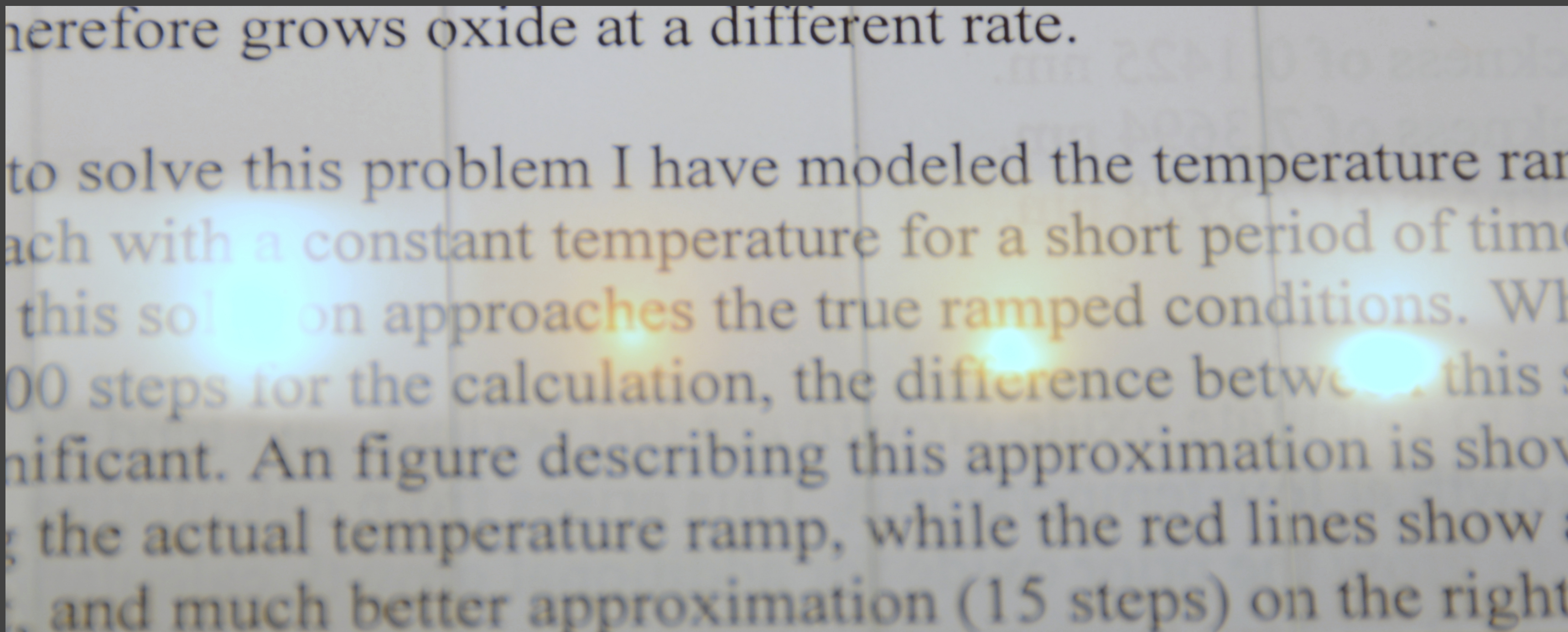
Scratch resistance	–	Optical quality
Cost of polymer	–	Cost of curing process
MPS cost	–	Optical quality

Test Results

Mesoporous Silica Layer

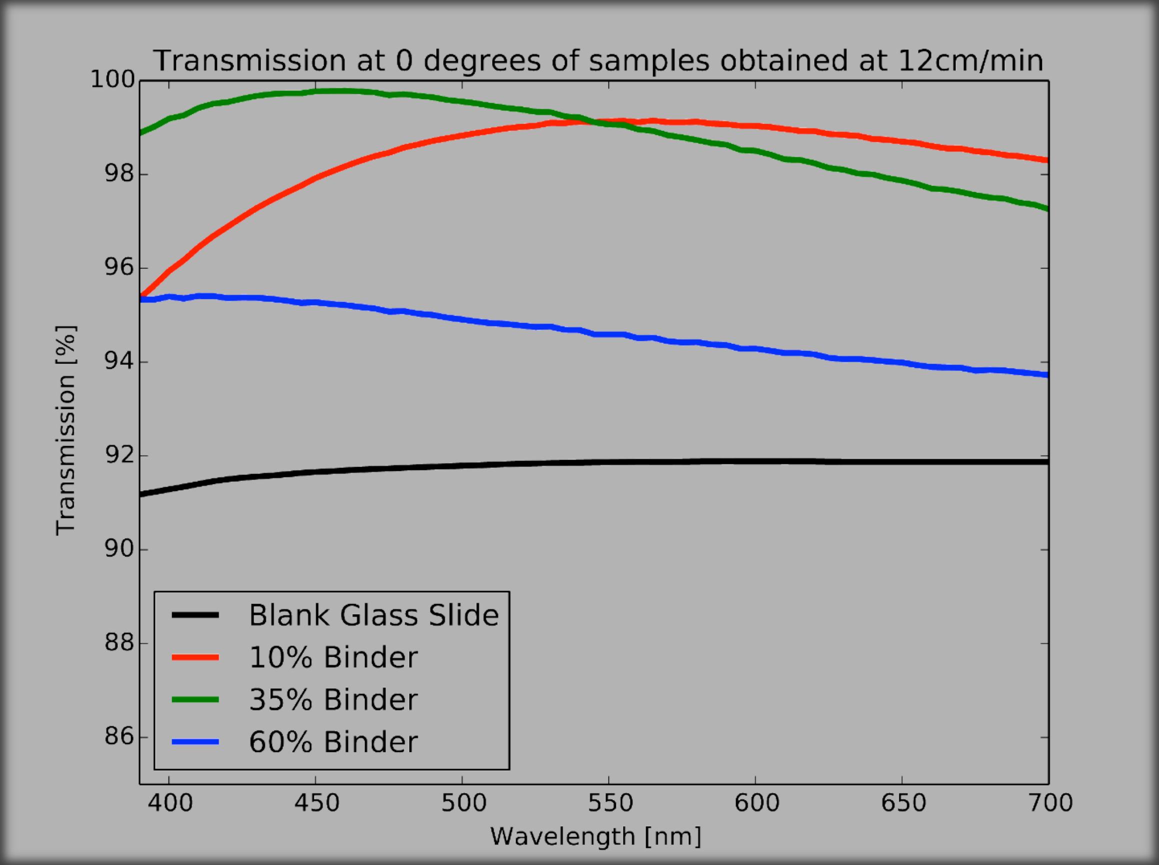


Mesoporous Silica Layer

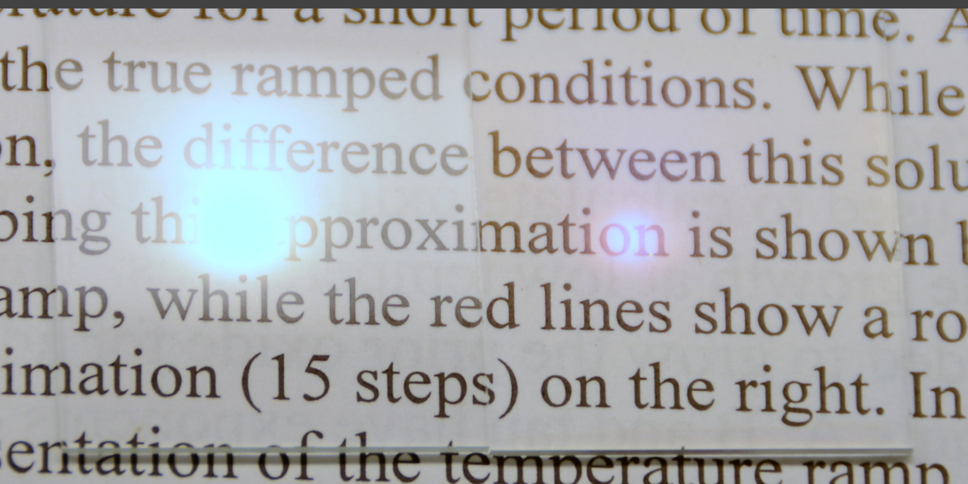


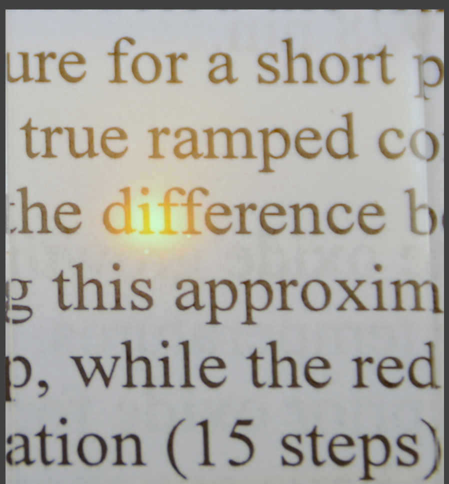
Glass Slide	10% Binder	35% Binder	60% Binder
	80 mm/min	80 mm/min	80 mm/min

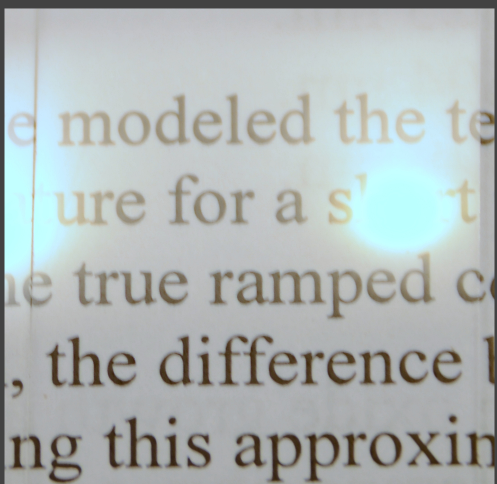
Mesoporous Silica Layer



Mesoporous Silica Layer

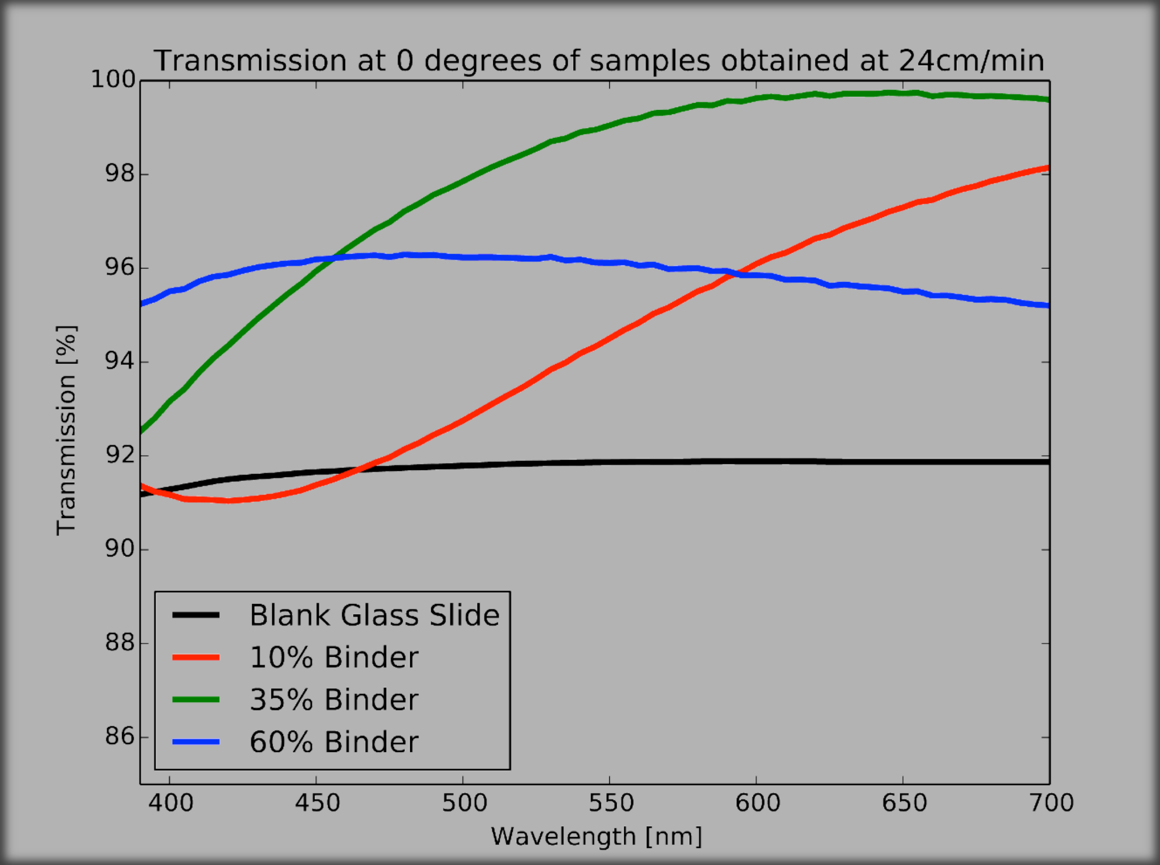




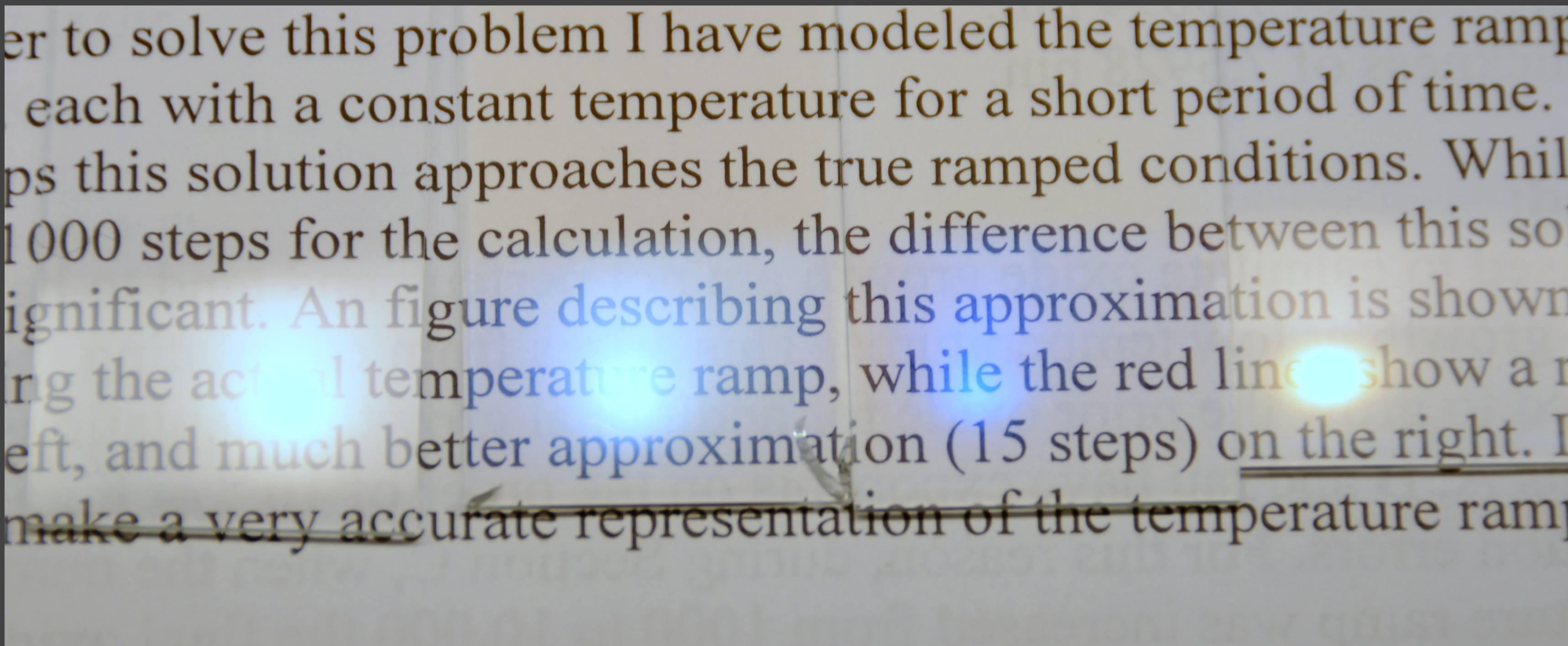


Glass Slide	10% Binder	35% Binder	60% Binder
	120 mm/min	120 mm/min	120 mm/min

Mesoporous Silica Layer

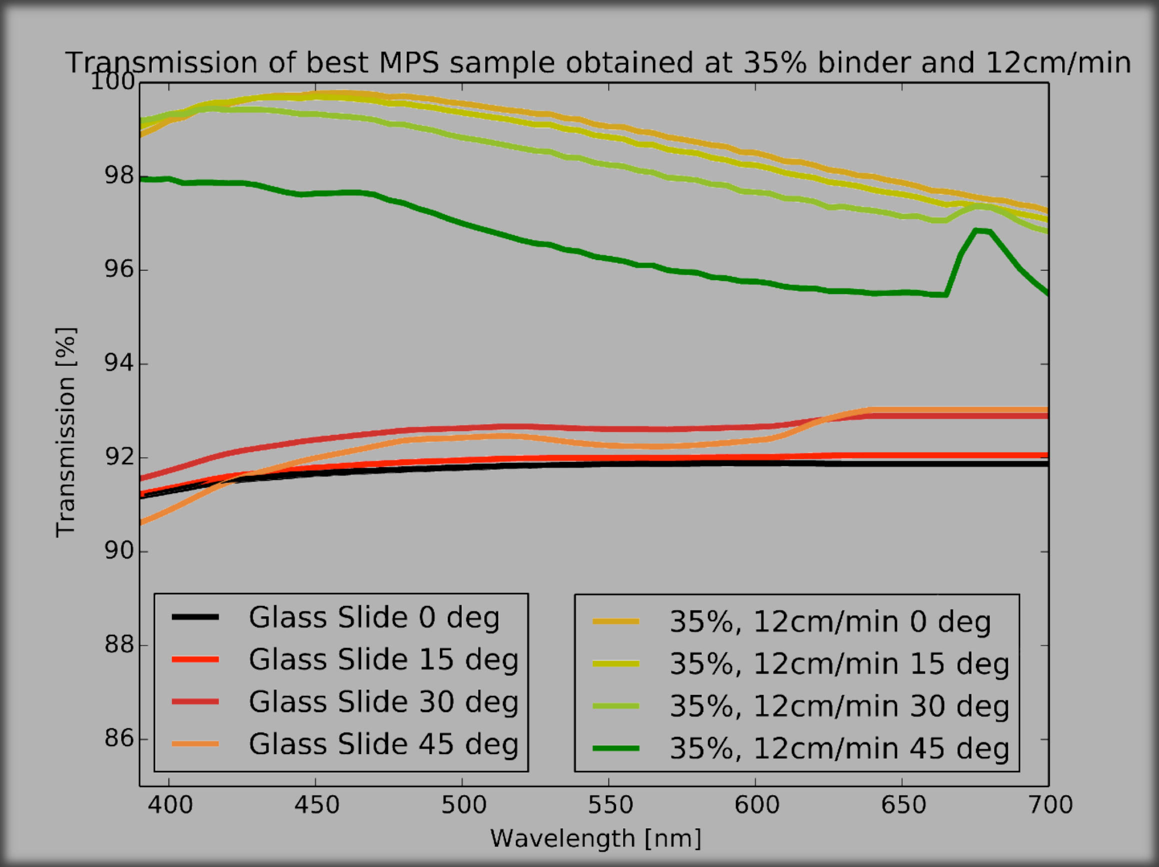


Mesoporous Silica Layer

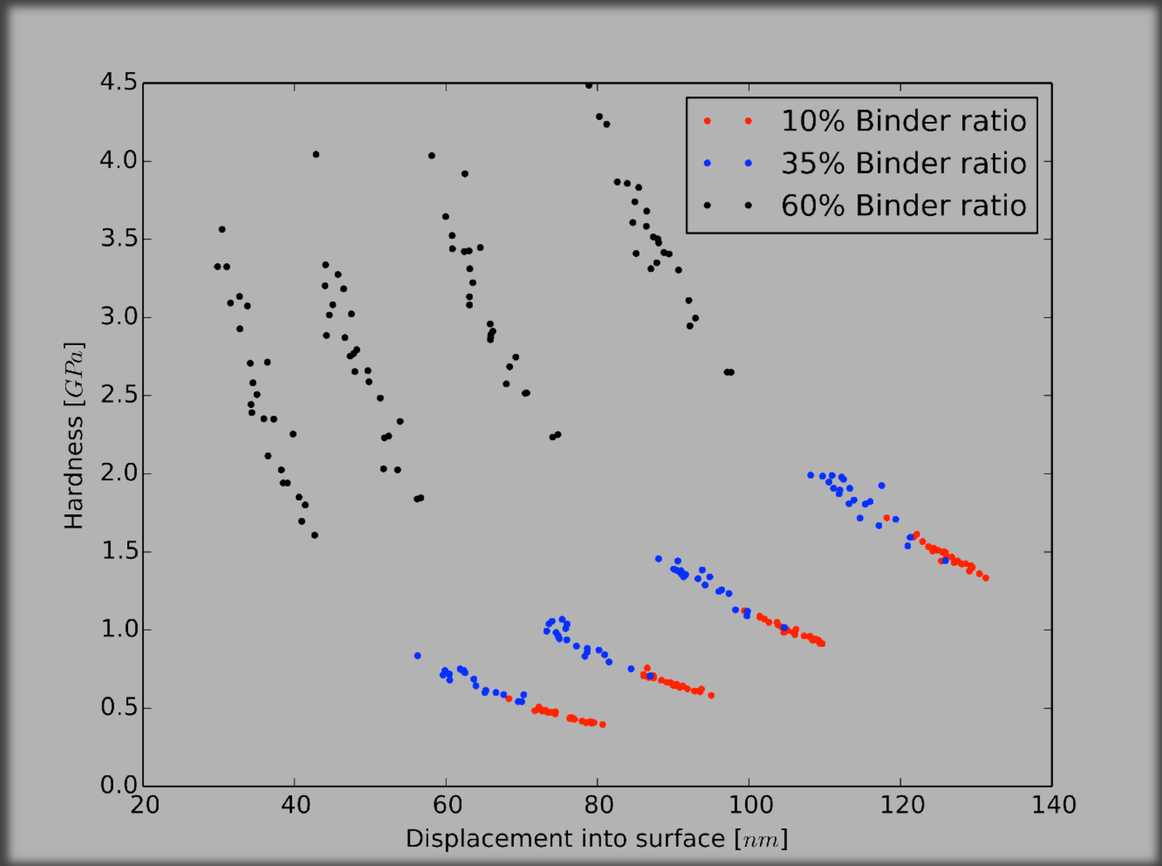


Glass Slide	10% Binder	35% Binder	60% Binder
	240 mm/min	240 mm/min	240 mm/min

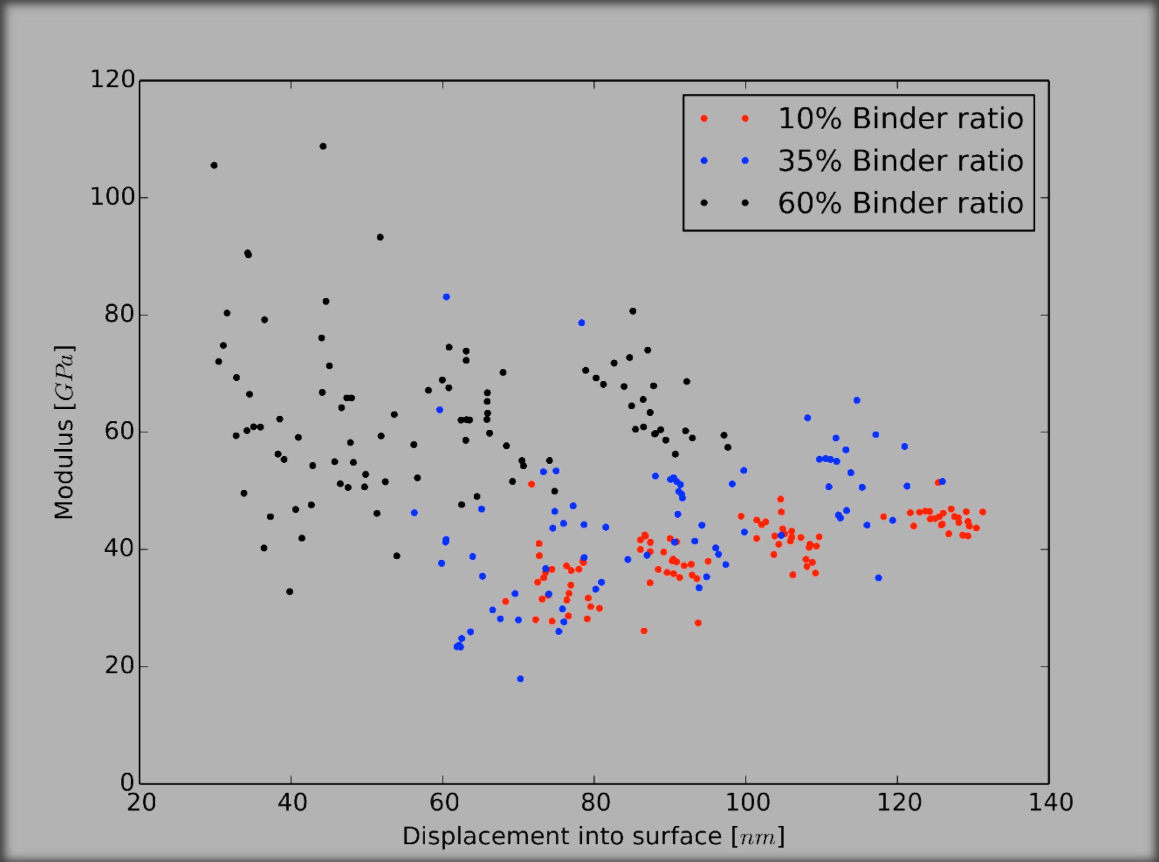
Mesoporous Silica Layer



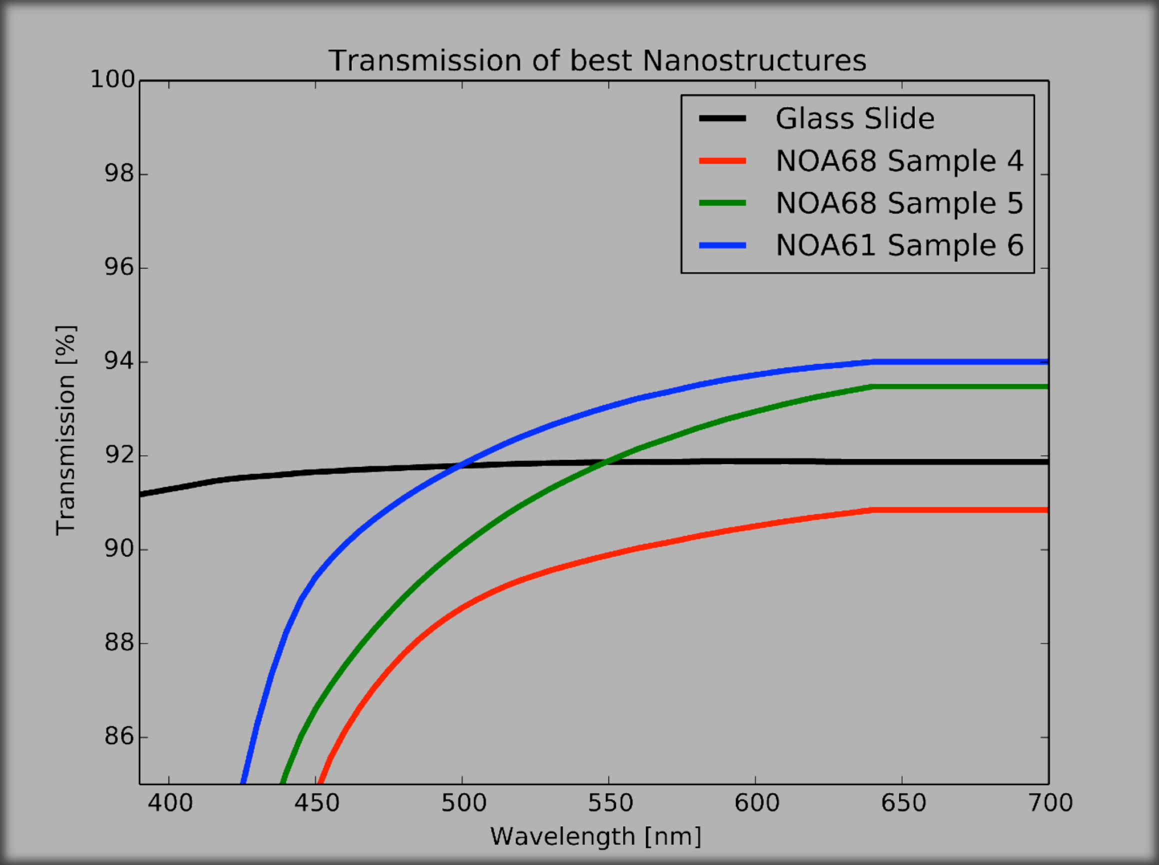
Mesoporous Silica Layer



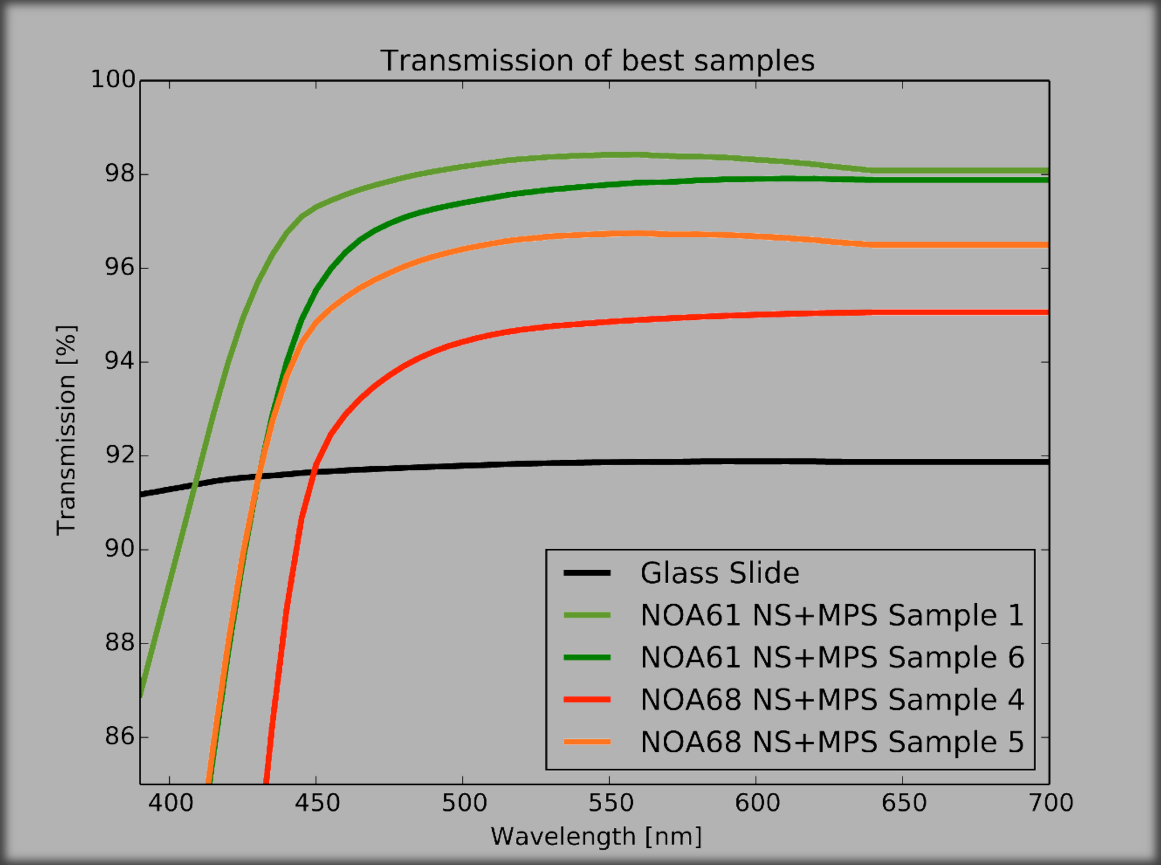
Mesoporous Silica Layer



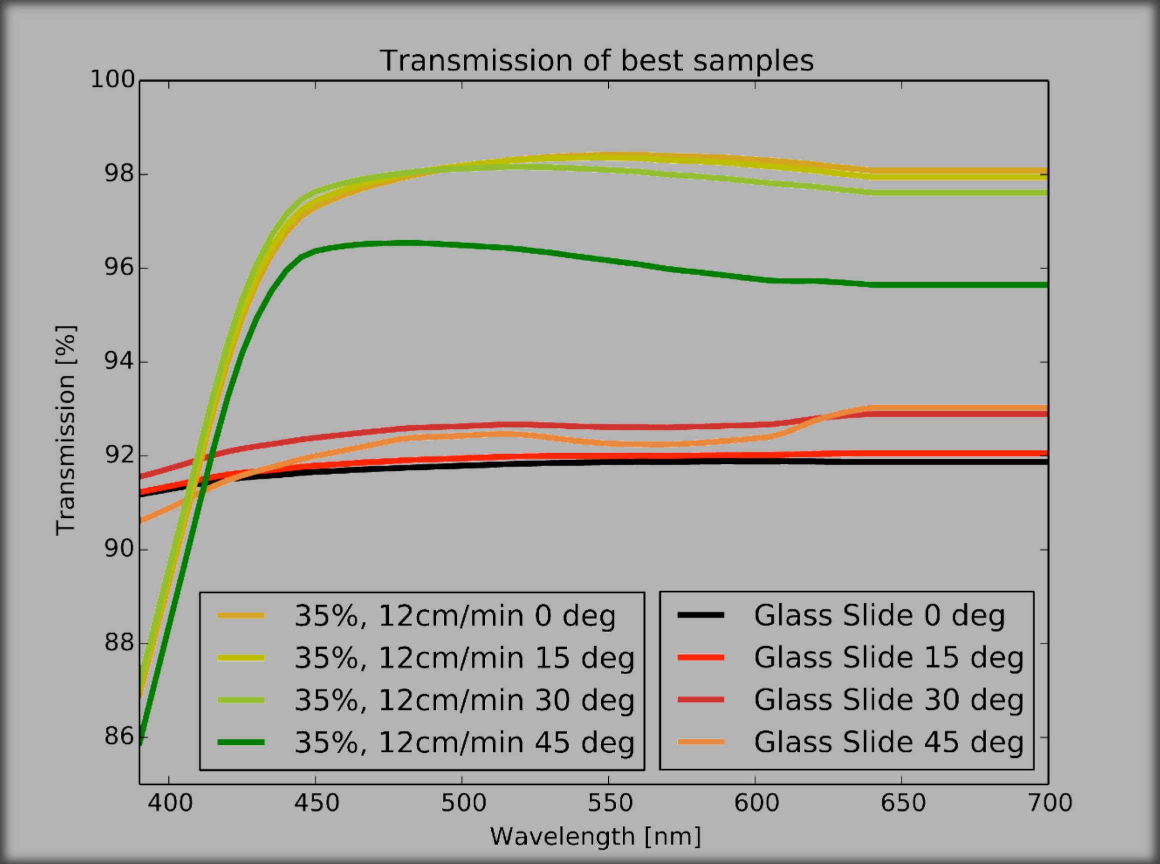
Nanostructures



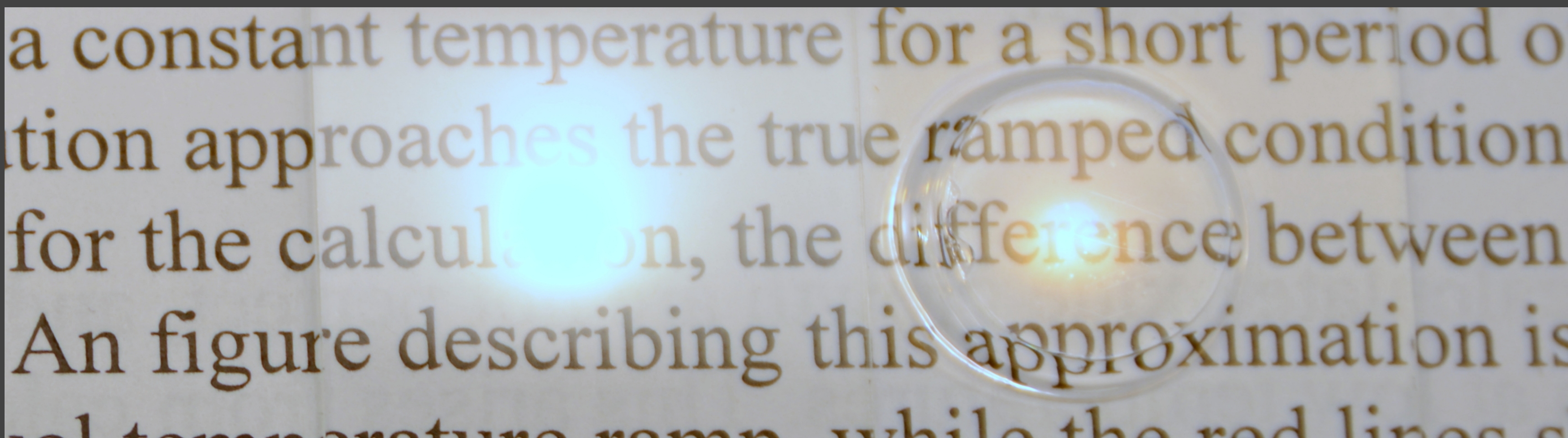
Nanostructures + MPS



Nanostructures + MPS



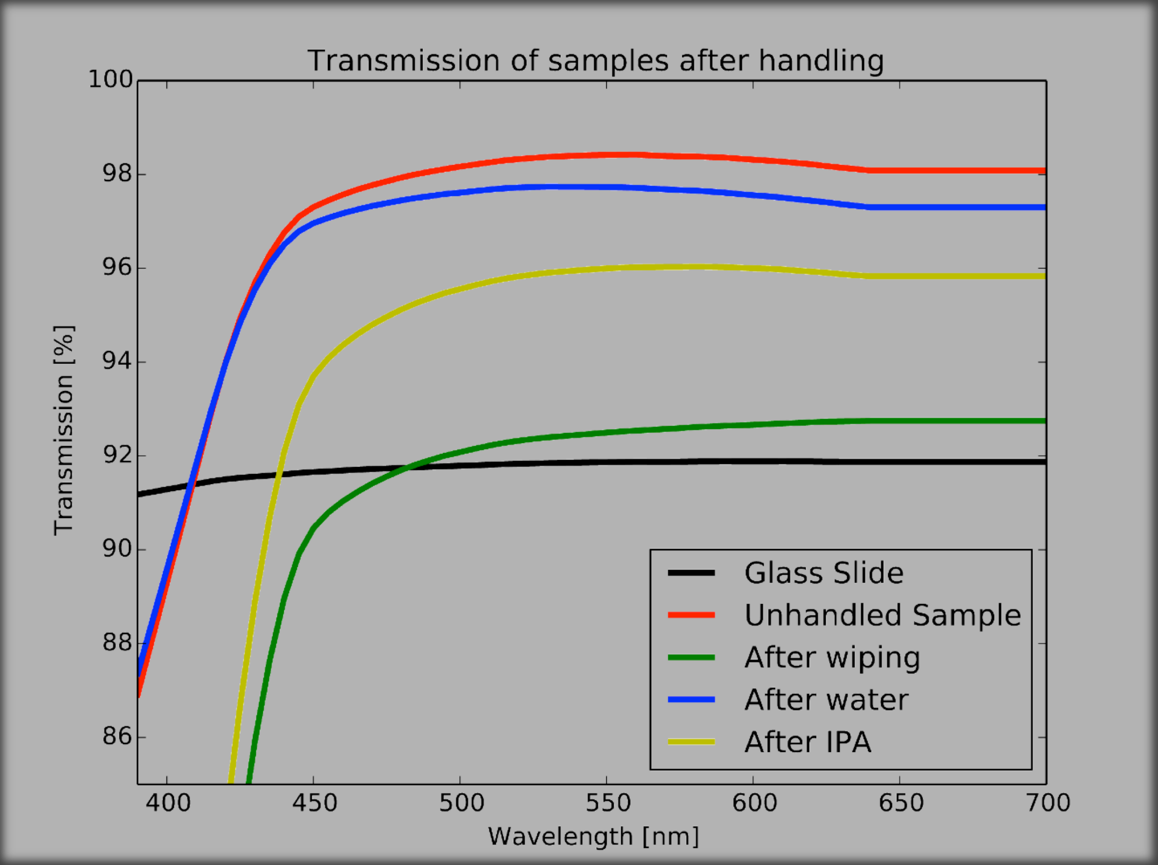
Nanostructures + MPS



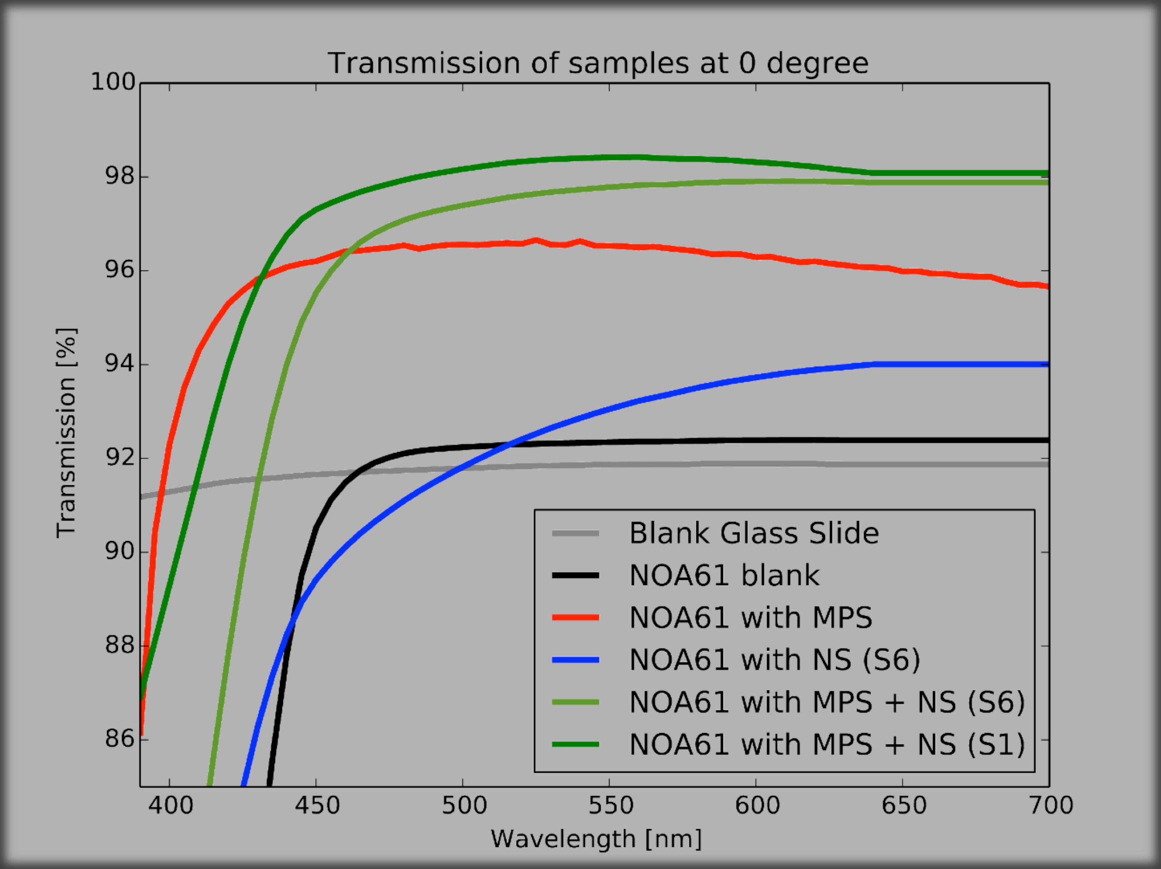
Glass Slide

35% Binder
120 mm/min

Handling Results

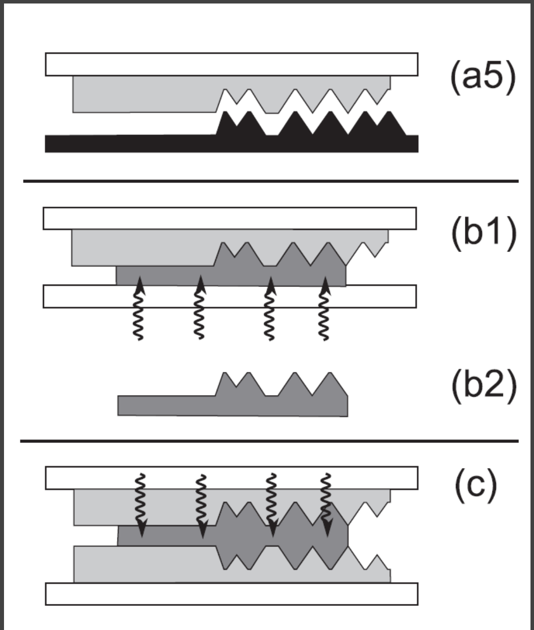


Result Summary



Future Work

Pattern Transfer Process



(b1) Imprint negative onto sample and expose

(b2) Release structures

(c) Double side AR method

Pattern Transfer Process

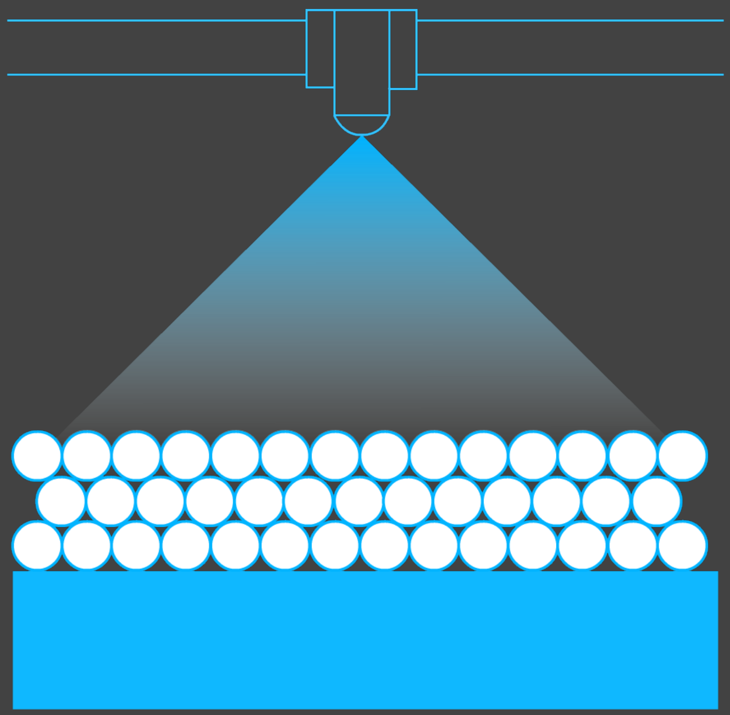
Nano Imprint Lithography

UV curing	Ormocomp, NOA
Hot embossing	Polycarbonate, PMMA

Injection Molding

Injection	Polycarbonate

Spray Coating Deposition



Chemical Requirements

MPS and Binder solution mixture

Benefits

Mass Production

Faster Deposition

Questions?

References

Christiansen, A.B. et al. "Minimizing Scattering from Antireflective Surfaces Replicated from Low-aspect-ratio Black Silicon". Applied Physics Letters, 2012, 101:131902, DOI:10.1063/1.4754691

Moghal, J. et al. "High-Performance, Single-Layer Antireflective Optical Coatings Comprising Mesoporous Silica Nanoparticles". ACS Applied Materials & Interfaces, 2012, 4:2:854-859, DOI:10.1021/am201494m