

Inexpensive **Anti Reflective** Passivated Solution

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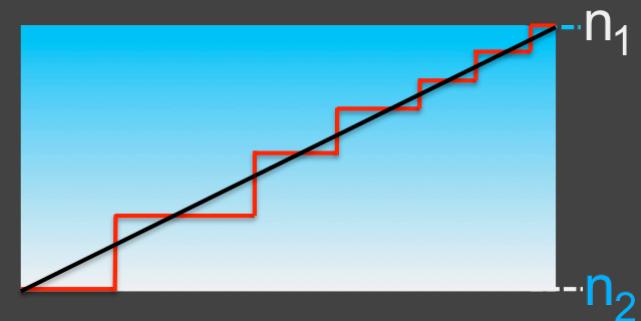


Current Technologies

Current Technologies

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

$n \rightarrow 1$



Low Refractive Index Nanoparticle System

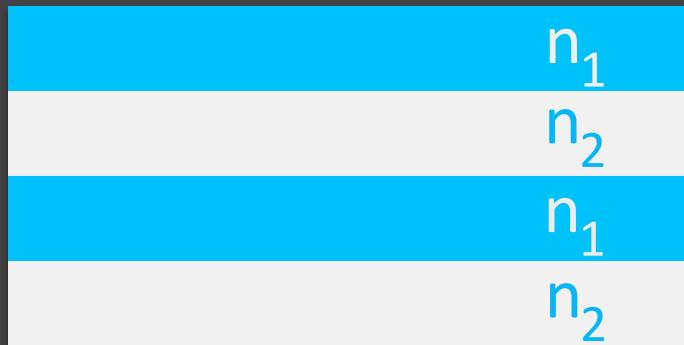
$n \rightarrow 1$

Drawbacks

Wavelength specific
anti-reflectance

Angle sensitive
anti-reflectance

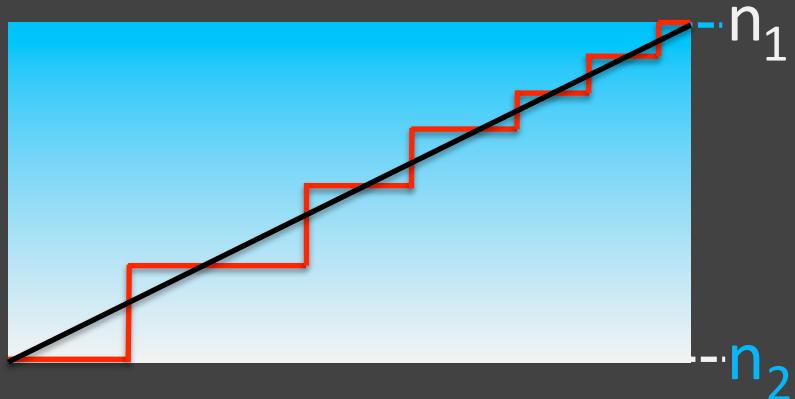
Alternating Refractive Indices



Drawbacks

Expensive – requires CVD
Time consuming – requires multiple layers

Gradient Refractive Index

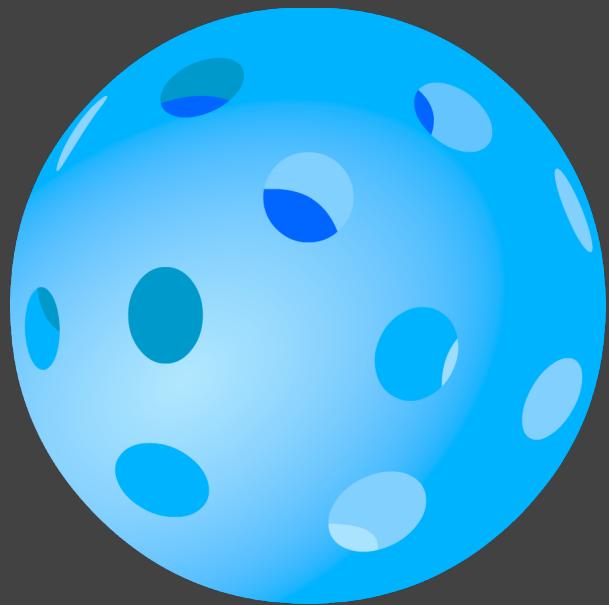


Drawbacks

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

Our Inspiration

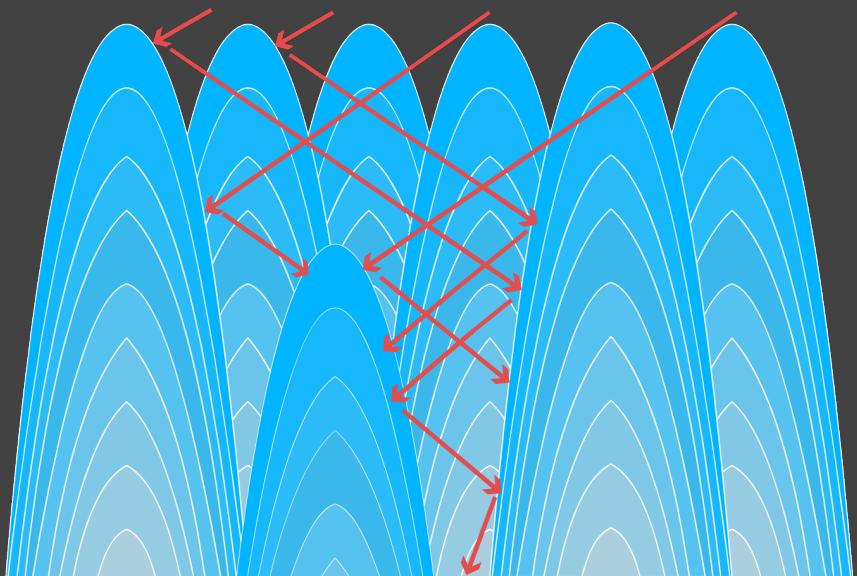
Mesoporous Silica (MPS) Nanoparticles



Advantages

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

Anti-Reflective NanoStructures (NS)



Advantages

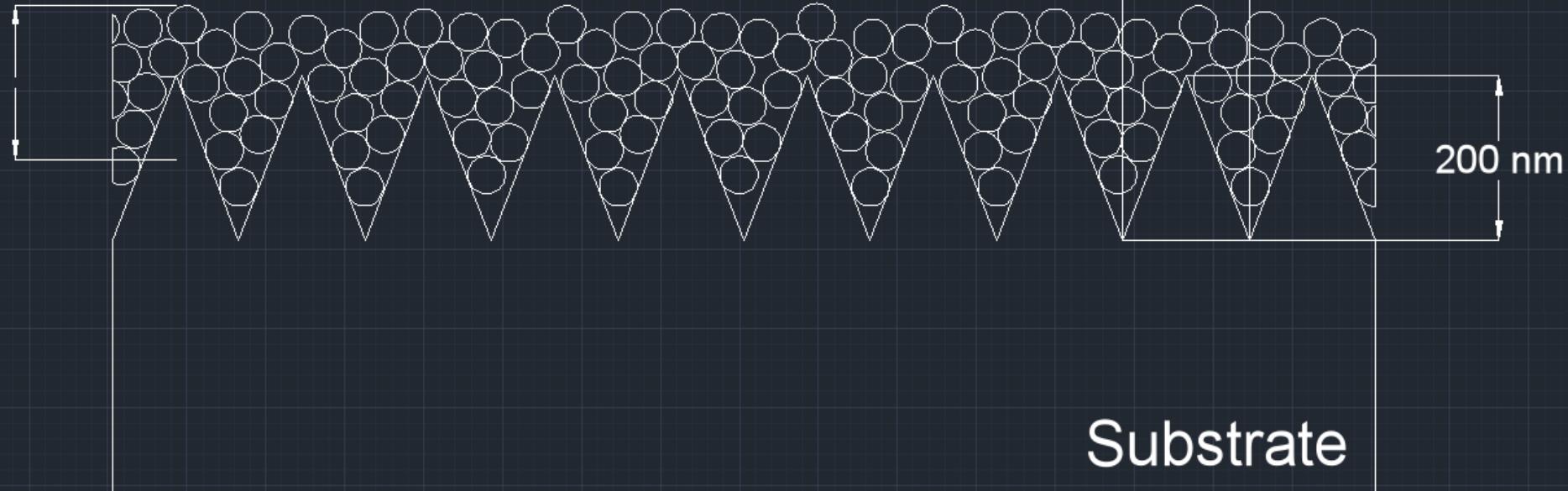
Removes interface – minimal reflectance
Inexpensive – injection molding
Randomly distributed structures – defect immune

Disadvantages

Fragile – contact sensitive
Increased scattering from structures

Our Solution

$\lambda/4$ MPS Thickness



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)

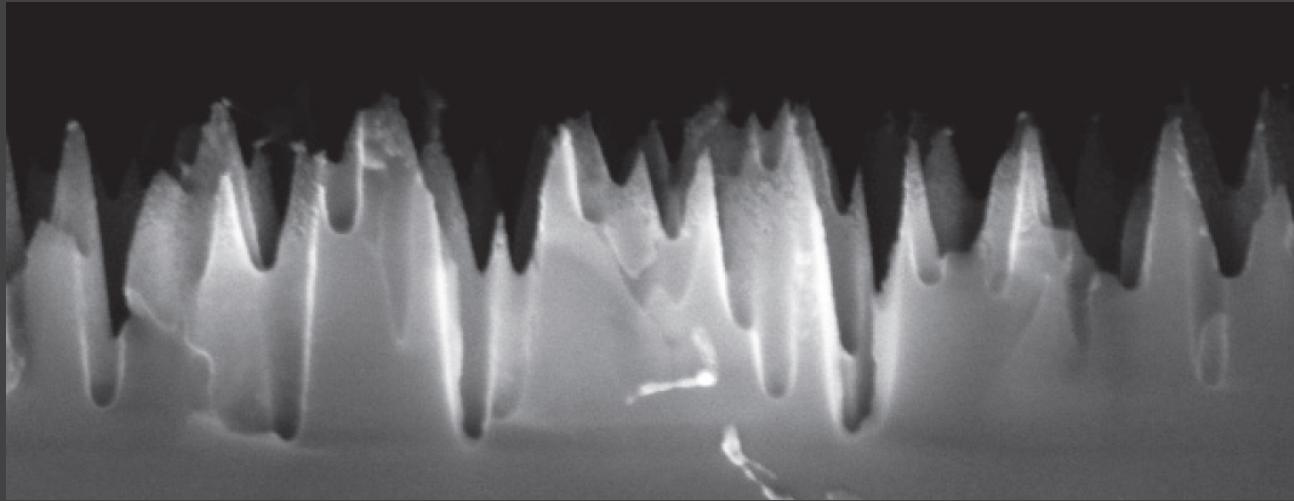
Telescopes

Microscopes



Fabrication

Silicon Master Mold



Reactive Ion Etch

$O_2 + SF_6$

Variable aspect ratio –
gas flow-rate adjustment

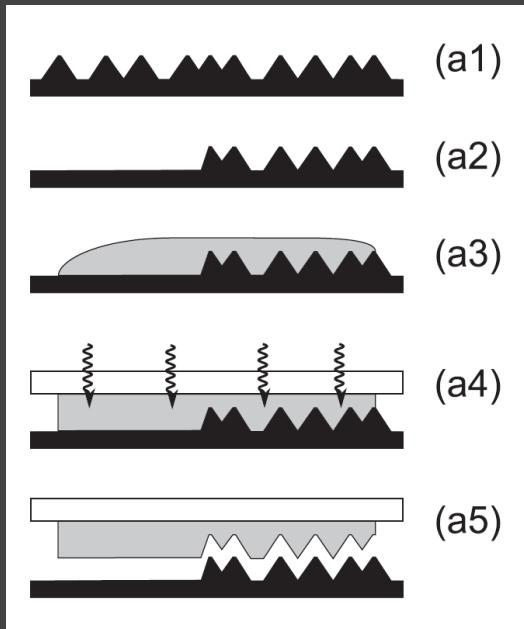
Anti-Stiction Coating

FDTs application via
molecular vapor
deposition

NS Fabrication

MPS 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

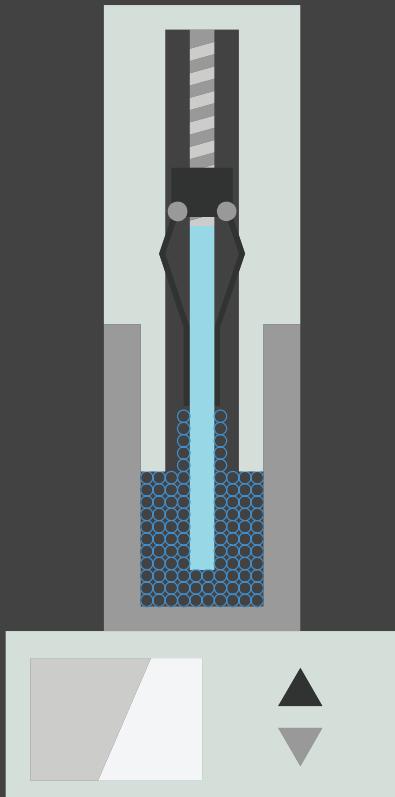
25mL of 0.1M Hydrochloric Acid

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

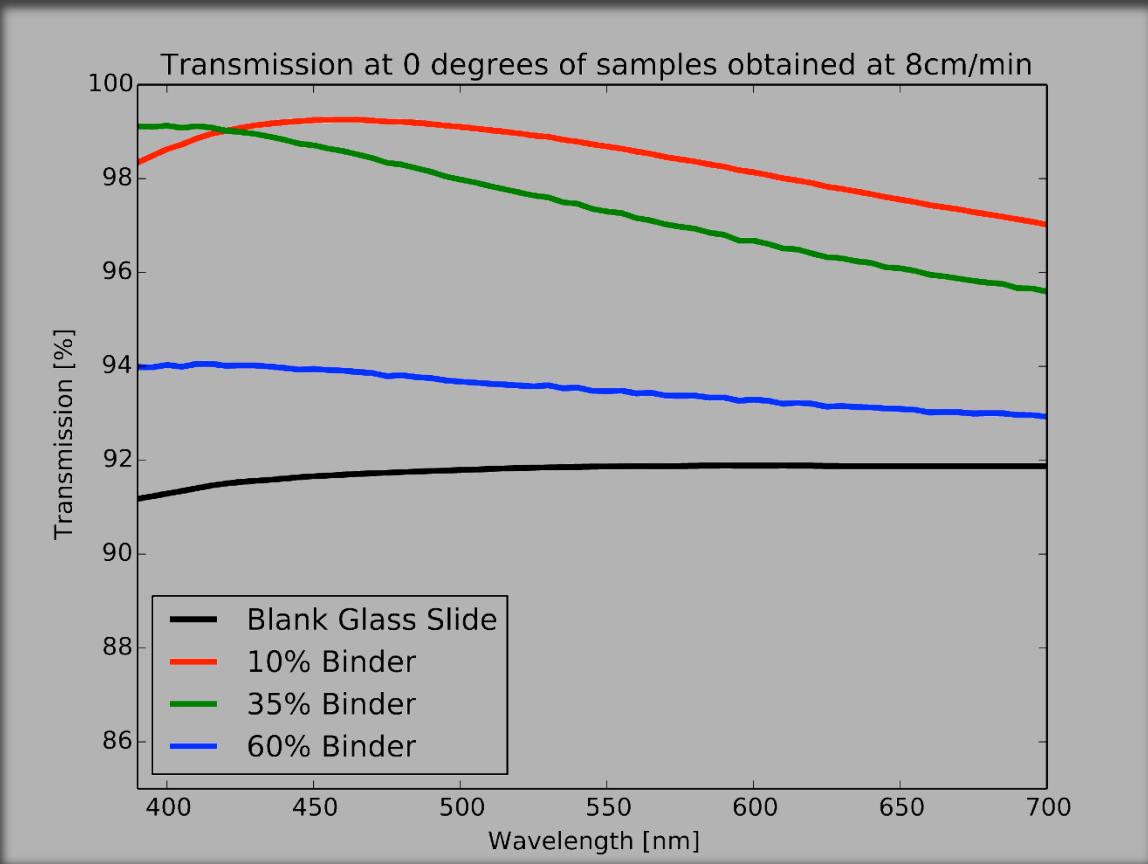
- SEM** – Surface imaging/deposition profile
- Optical tests** – Transmission testing using UV-Vis
- Scratch test** – Using Mohs Hardness Test
- Hardness test** – Berkovich Nanoindentation

Trade-offs

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

Test Results

Mesoporous Silica Layer



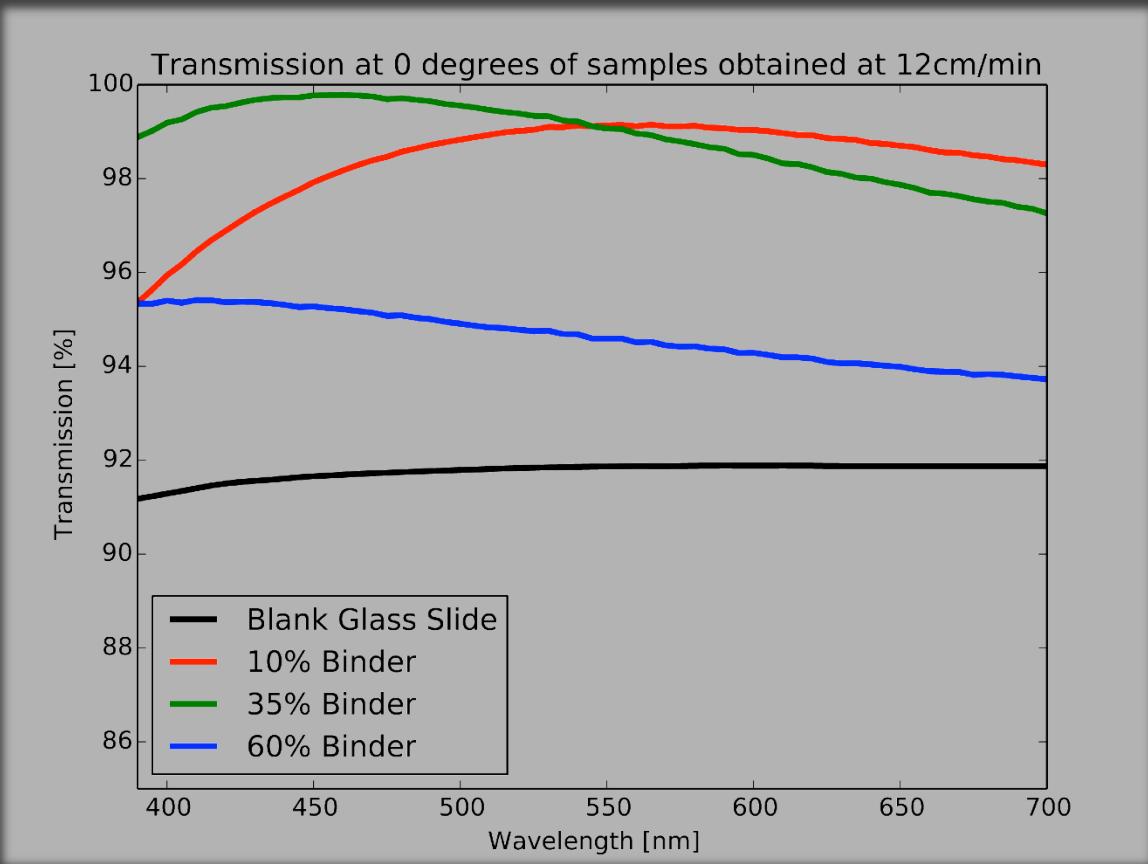
Mesoporous Silica Layer

therefore grows oxide at a different rate.

to solve this problem I have modeled the temperature ramp with a constant temperature for a short period of time. This solution approaches the true ramped conditions. With 100 steps for the calculation, the difference between this is significant. An figure describing this approximation is shown below. The black line shows the actual temperature ramp, while the red lines show a poor approximation (100 steps) on the left and much better approximation (15 steps) on the right.

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

Mesoporous Silica Layer



Mesoporous Silica Layer

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Glass Slide

10% Binder

35% Binder

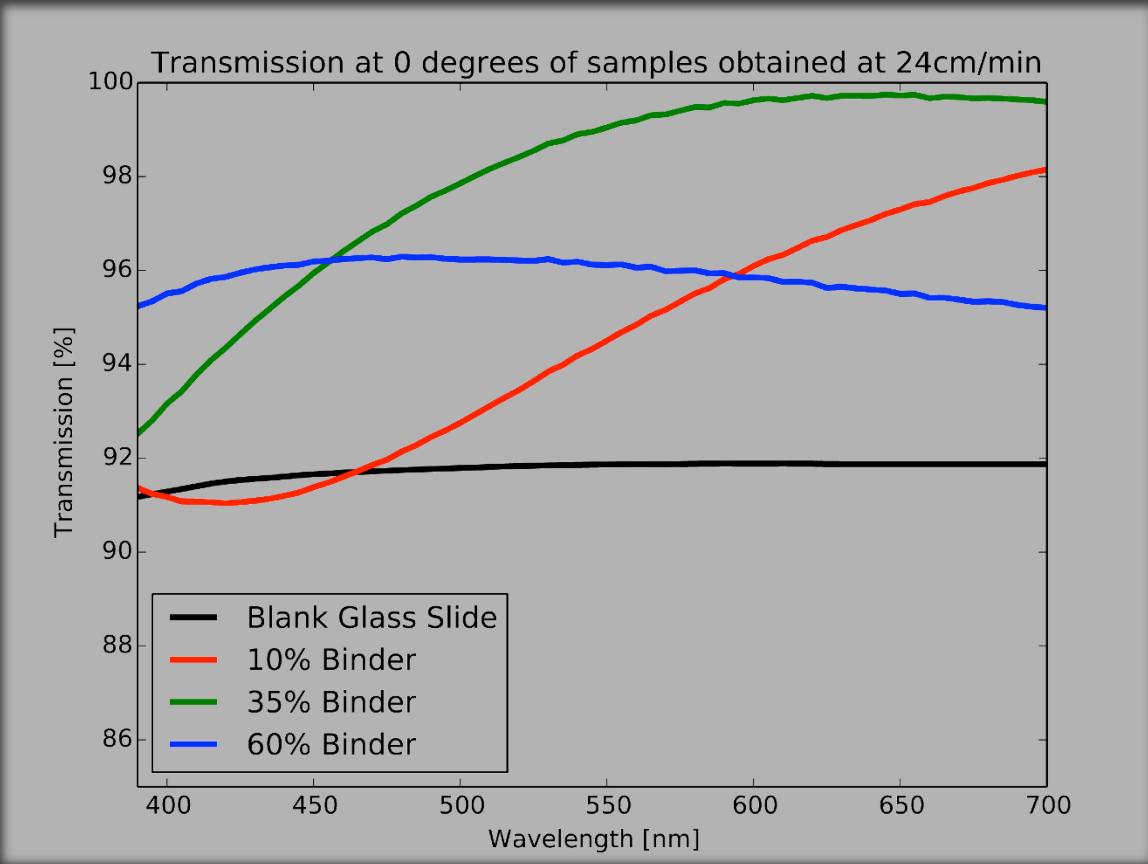
60% Binder

120 mm/min

120 mm/min

120 mm/min

Mesoporous Silica Layer

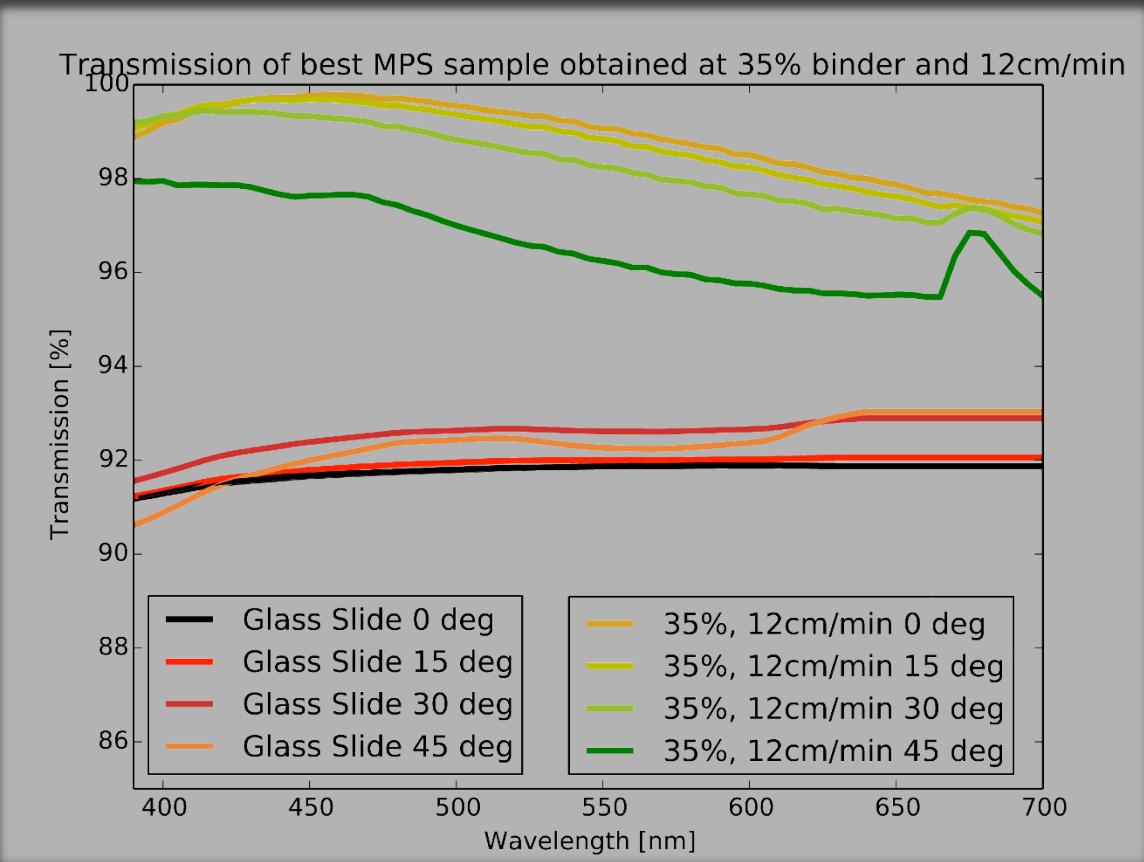


Mesoporous Silica Layer

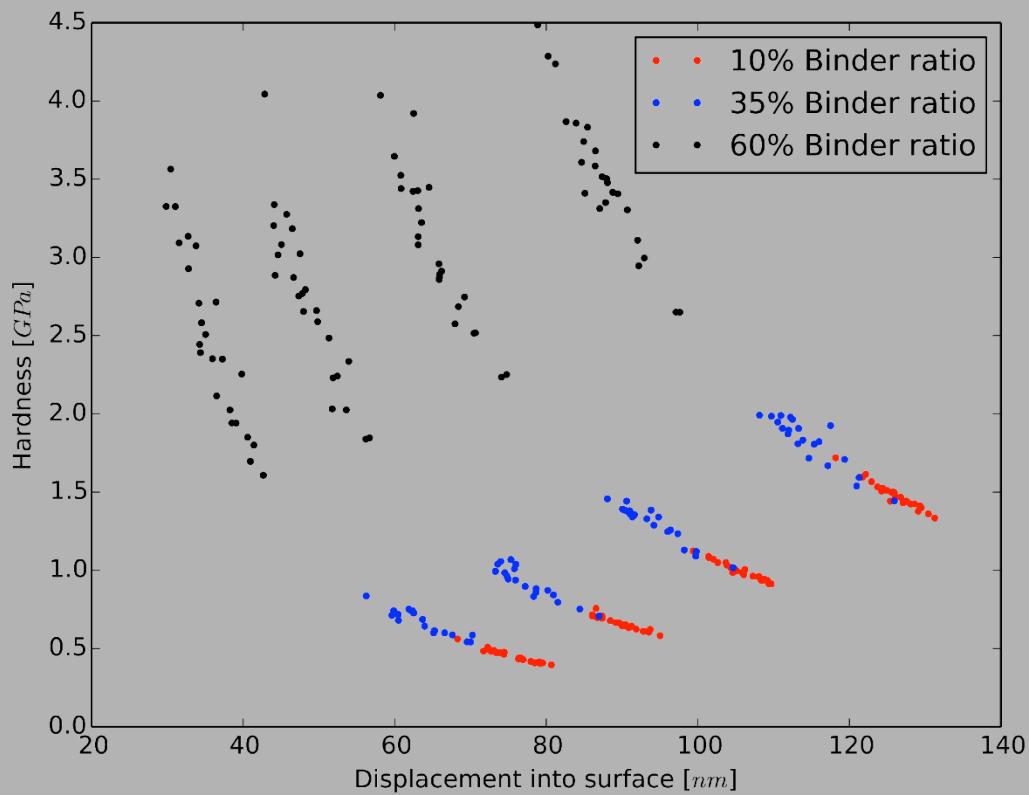
In order to solve this problem I have modeled the temperature ramp as a series of steps, each with a constant temperature for a short period of time. As the number of steps increases this solution approaches the true ramped conditions. While it takes approximately 1000 steps for the calculation, the difference between this solution and one with 15 steps is insignificant. A figure describing this approximation is shown below. It shows the actual temperature ramp, while the red lines show a rough approximation (15 steps) on the left, and much better approximation (15 steps) on the right. It is clear that the 15 step approximation on the right makes a very accurate representation of the temperature ramp.

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

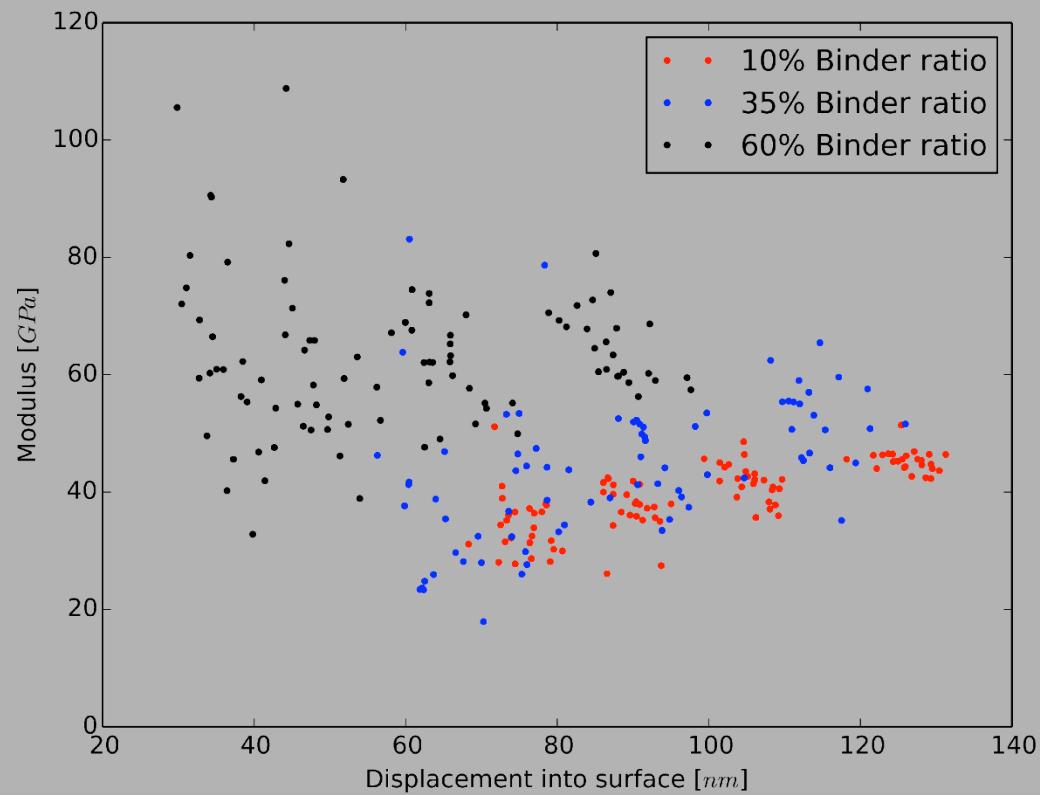
Mesoporous Silica Layer



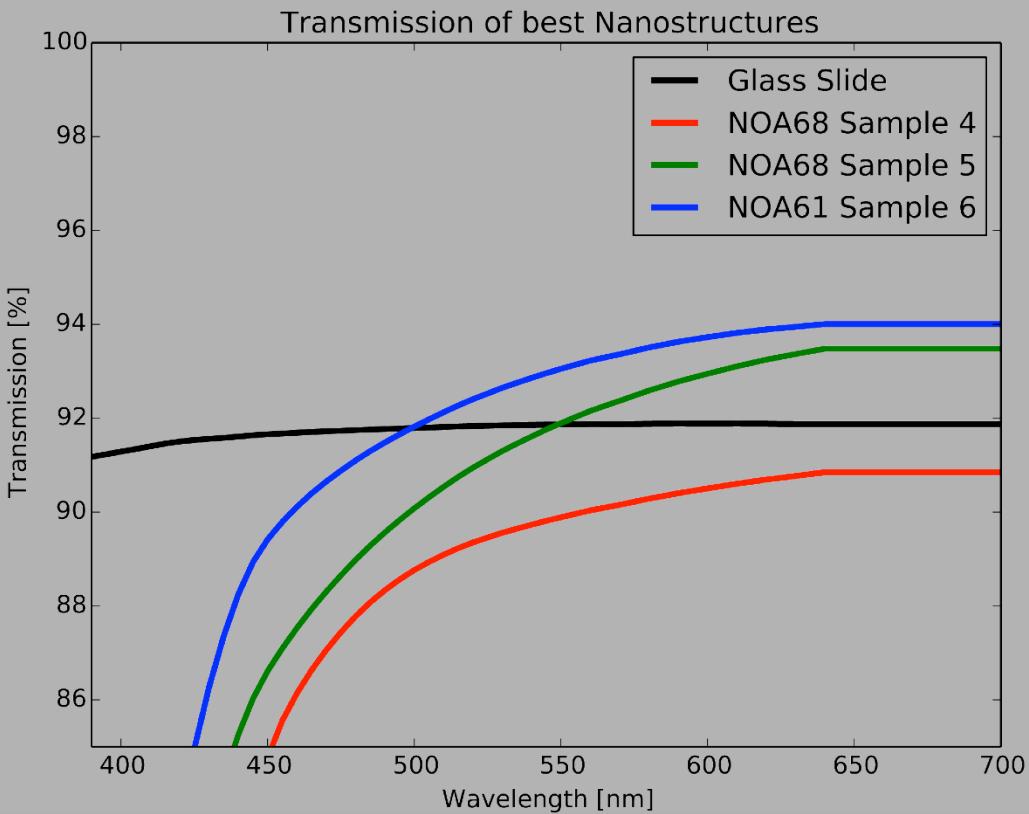
Mesoporous Silica Layer



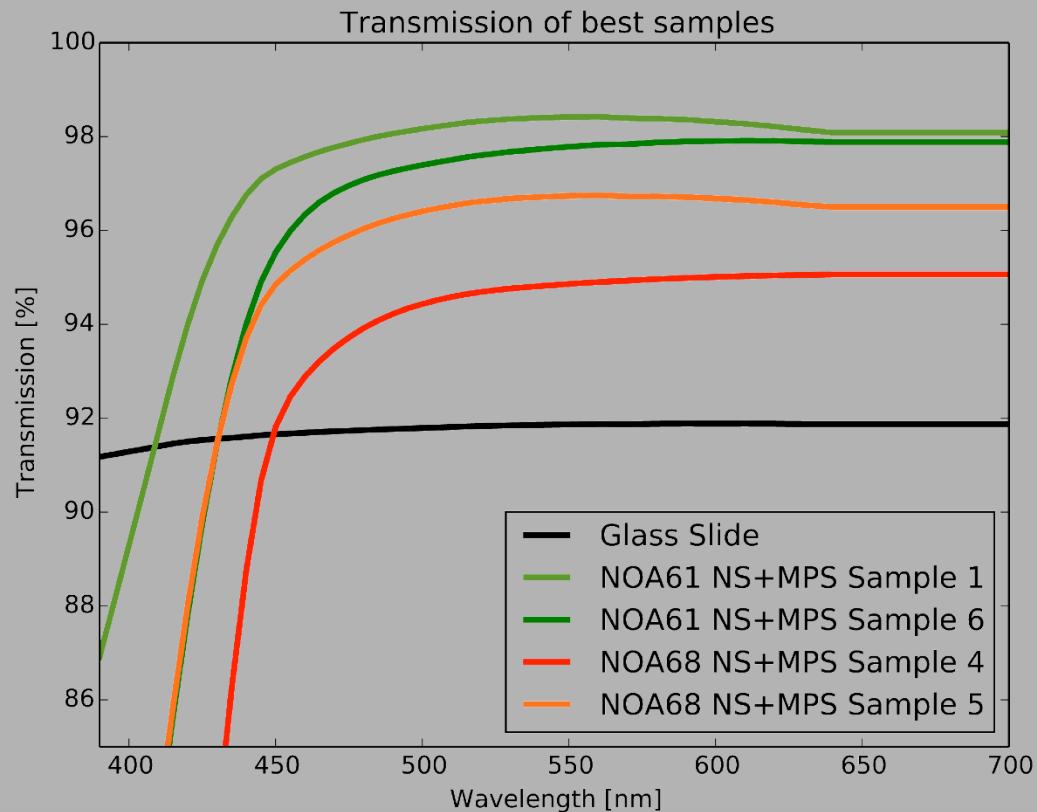
Mesoporous Silica Layer



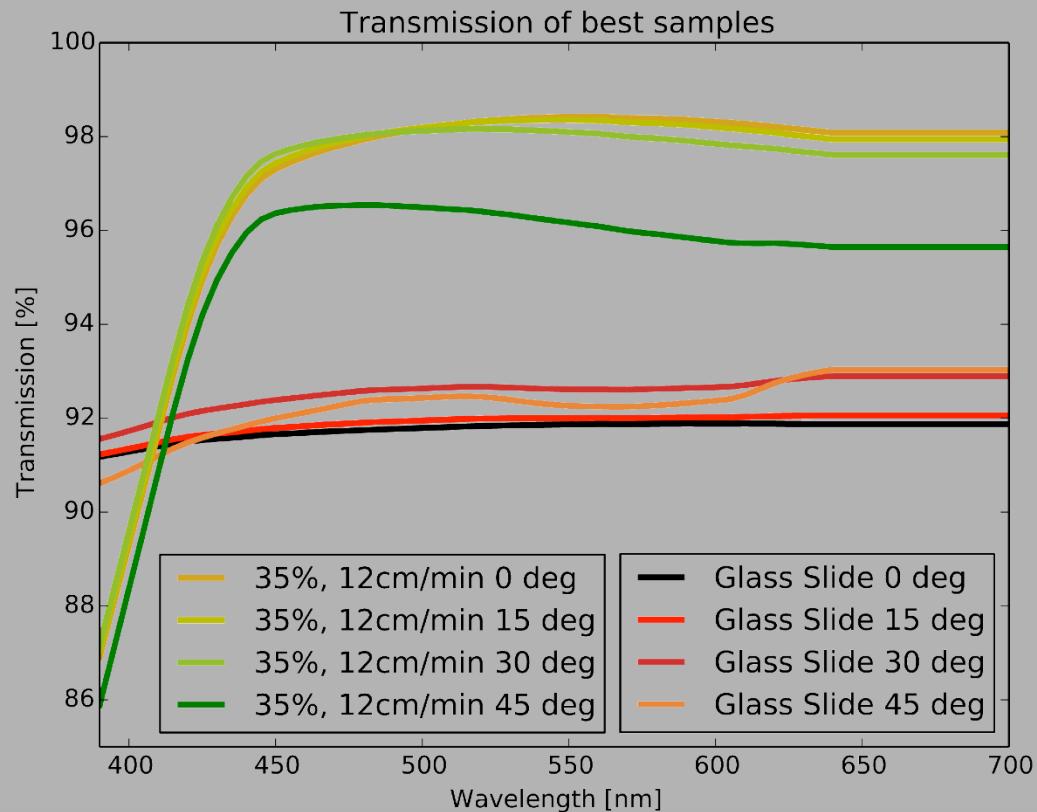
Nanostructures



Nanostructures + MPS



Nanostructures + MPS



Nanostructures + MPS

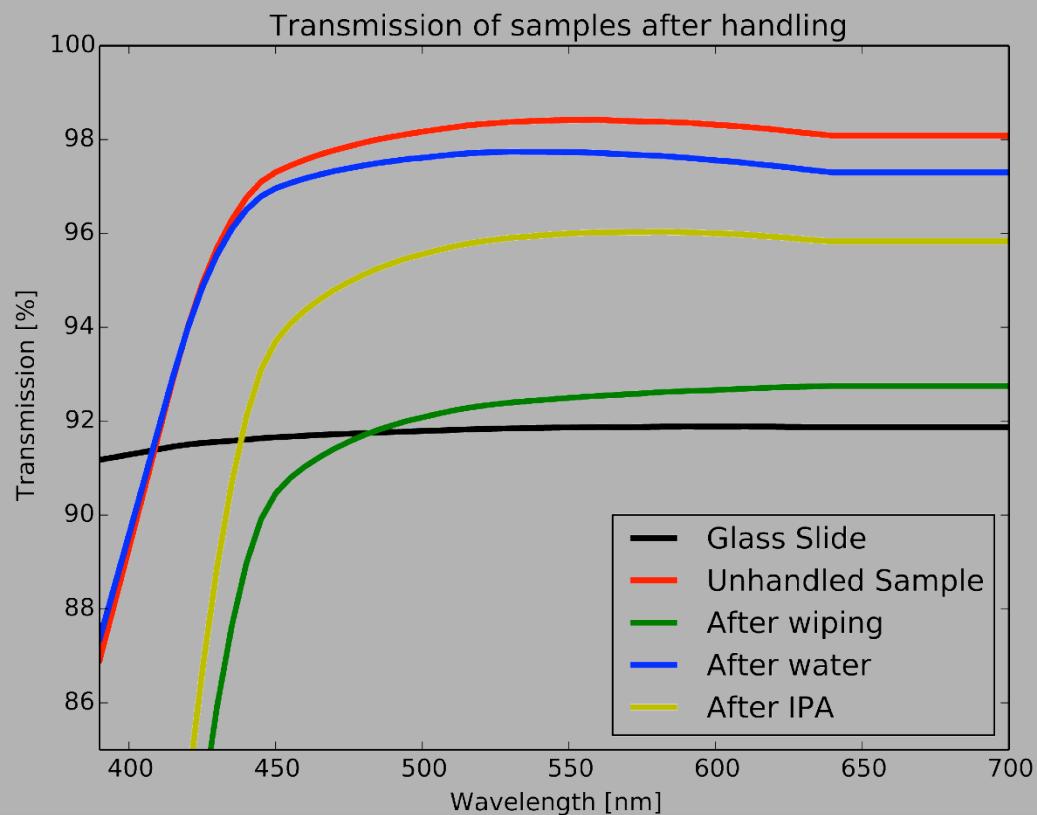
a constant temperature for a short period of time approaches the true ramped conditions for the calculation, the difference between An figure describing this approximation is a cold temperature ramp, while the red lines sh

Glass Slide

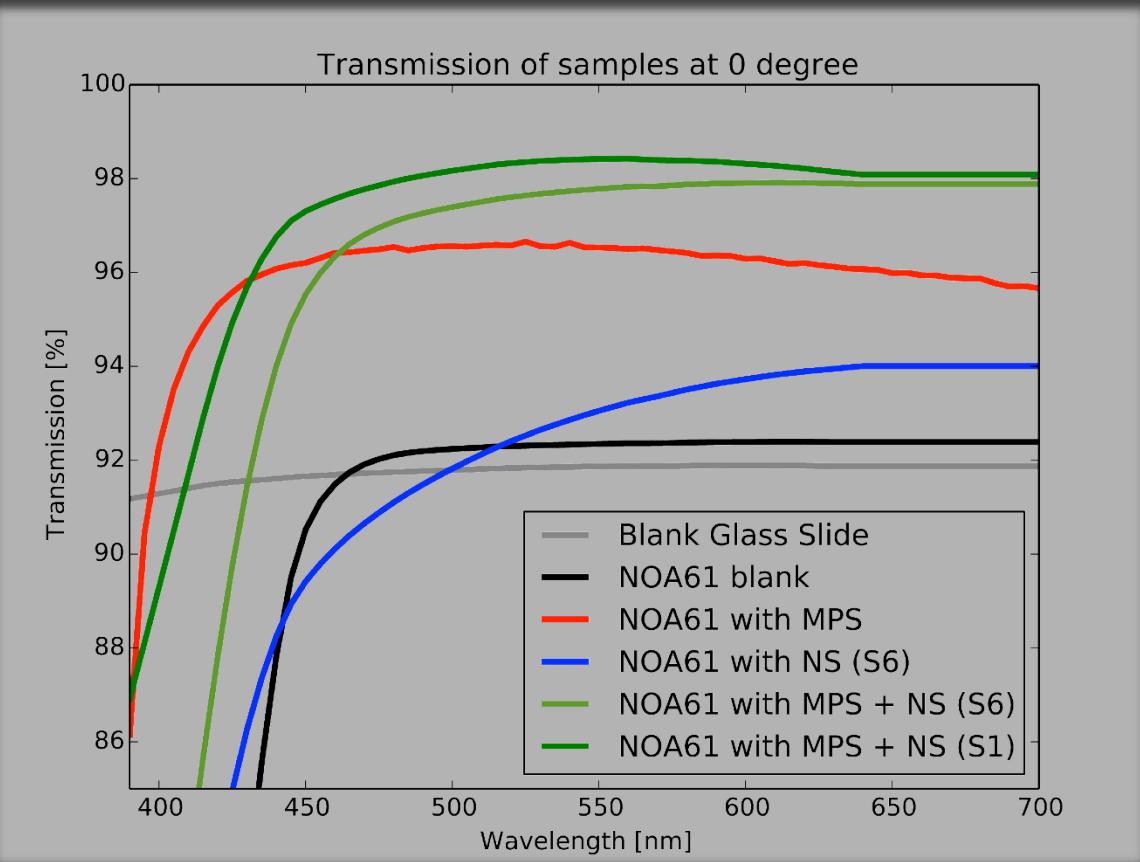
35% Binder

120 mm/min

Handling Results



Result Summary

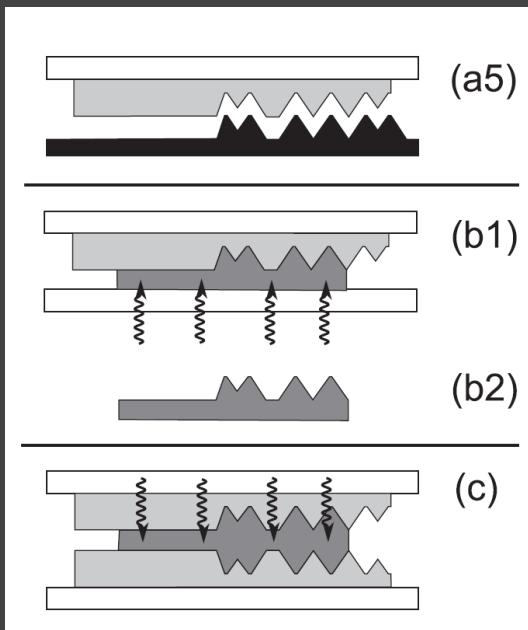


Future Work

NS Fabrication

MPS Deposition

Pattern Transfer Process



- (b1) Imprint negative onto sample and expose
- (b2) Release structures
- (c) Double side AR method

NS Fabrication

MPS Deposition

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Pattern Transfer Process

Nano Imprint Lithography

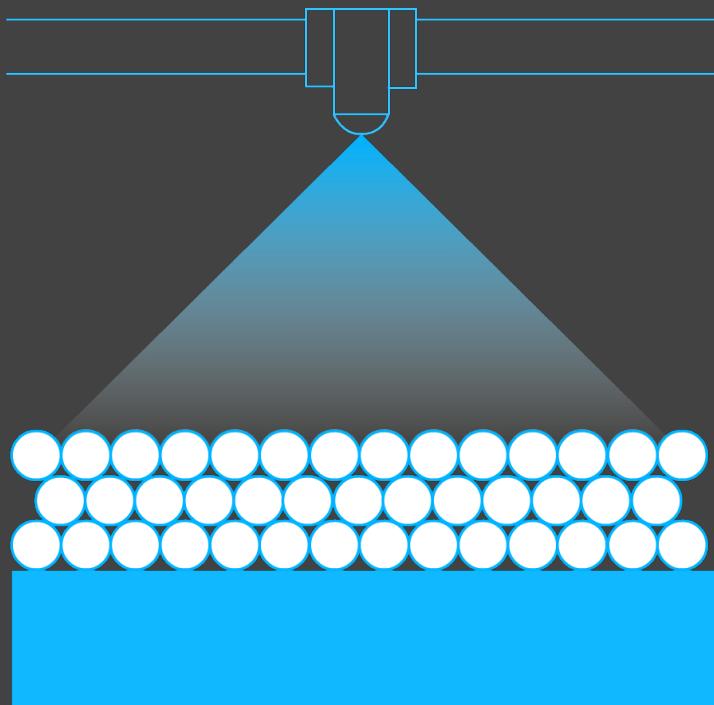
UV curing Ormocomp, NOA

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