

## Note on Smooth-On Crystal Clear 200 Urethane

Purchased from:

- <http://www.douglasandsturgess.com/>
- <https://shop.sculpt.com/smooth-on-crystal-clear-200-2-gallon-kit.html?id=4458645>

Possible other vendors:

- <https://www.reinforcedplasticslab.net/View/Crystal-Clear-200>
- <https://www.reynoldsam.com/product/crystal-clear/>
- <https://www.settechny.com/View/Smooth-On-200-Silicone-Epoxy-technology>
- <https://theengineeringguy.com/crystal-clear-200/>

Pressure chambers:

- <https://www.woodcraft.com/products/pressure-pot-for-resin-casting-california-air-tools>
- <https://www.reynoldsam.com/product/pressure-chamber/>

## 10-7-2021 (PH)

Printed 3D model of calibration phantom (Module Phantom\_rev X2.STEP) overnight

## 10-8-2021 (BH)

Cast 3D printed phantom mold in PDMS

- Recipe:
  - ~350 mL of total PDMS (90:10 weight ratio)
- Methods:
  - Laser cut 3 100x70mm and 2 65x70 sheets from  $\frac{1}{8}$ " acrylic stock to create container to cast in
  - Tacked down 3D printed part to bottom of mold with 2 small dots of super glue
  - Coated entire inside of mold and 3D printed part with universal mold release spray
  - Mixed and degassed (through several vacuum cycles) in 1 L container
  - Cast and let sit overnight
  - Baked for 4 hours at 60 C in oven next day
  - Broke walls apart to access mold
- Outcomes:
  - Although PDMS came out okay, it was too brittle for future use as a mold
  - Did not let release agent dry long enough (or used too much of it) and so all surfaces except for side facing air were uncured
    - Fixed this by using a small blow torch, however, in future probably better to just place in hot oven at 200 C or hotter



#### 10-9-2021 (BH)

Cast 40g test samples of Mold Star 15 Slow, Dragon Skin 20, Mold Max 15T

- Recipe:
  - Made sure to thoroughly mix up each container prior to use
- Methods:
  - Around 15-20
- Outcomes:
  - Mold Star 15 has lots of chunkies in it, likely not good any more
  - Mold Max 15T was brand new and unopened
  - Suggests that durometer of shore 15A to 20A would be good for casting

#### 10-11-2021 (BH)

Cast 3D printed phantom mold in DragonSkin 20

- Recipe:
  - 350 g total of Dragon Skin 20 (50:50 weight ratio)
- Methods:
  - Laser cut 3 100x70mm and 2 65x70 sheets from  $\frac{1}{8}$ " acrylic stock to create container to cast in
  - Tacked down 3D printed part to bottom of mold with 4-6 small dots of super glue
  - Coated entire inside of mold and 3D printed part with very thin layer of universal mold release spray, and let it dry for at least 30 minutes
    - Also used wax release agent on outer surfaces of 3D printed part
  - Mixed mixed and degassed (1 vacuum cycles) split into two 1 L containers
  - Cast and let sit overnight
  - Broke walls apart with fine blade to access mold
- Outcomes:

- Too much super glue used, only 1-2 small dots needed
- Excess wax/release agent formed in corners of camera optic recesses, and so these features did not come out very well



10-12-2021 (BH)

Cast clear epoxy (EasyCast by Castin'Craft bought at TAP) version of phantom with new TiO<sub>2</sub> and Ivory Black

- Measured volume of phantom to be ~135 mL
- Targeting  $\mu_s' = 1 \text{ mm}^{-1}$  and  $\mu_a = 0.02 \text{ mm}^{-1}$  (what GowerLabs uses)
- Recipe:
  - ~118 mL of total epoxy (50:50 volume ratio)
  - 0.85 g of TiO<sub>2</sub> (from Sigma-Aldrich, 7.2 g/L)
  - ~0.015 g (0.111 g/L) of Carbon black (should have been 0.0066 g (0.056 g/L), but added too much)
- Methods:
  - Warmed up both resin and harder to 30 C in oven, per instructions

- Measured out dry powders together and fully mixed the two
- Added ~10 mL of resin and mixed thoroughly
- Added remained (to final volume of ~59 mL) of resin, mixed thoroughly and then placed in sonication bath for 30 minutes
- Mixed in ~59 mL of hardener and mixed thoroughly by hand for 1-2 minutes
- Vacuumed the mixture, but I don't think this had an benefit
- Slowly cast into the Dragon Skin 20 mold
- Let sit for 24 hours at room temperature before removing
- Outcomes:
  - Came out of mold easily, only issue was tiny air bubbles that formed or were trapped where the camera module actually connects
  - All TiO<sub>2</sub> and Ivory Black fully incorporated, none appear to settle on bottom



10-13-2021 (BH)

Created test set of superficial holes to demonstrate flow phantom concept

- 6 rows of 5 holes each 30 total
- Each row would be connected together
- $\frac{1}{8}$ " (3.18 mm) diameter holes
- 5 mm on center spacing in each direction
- First row 5 mm below location of camera optics/aperture



10-14-2021 (SV)

Cast phantom mold in Mold Star 30

- Recipe:
  - 360 g total of Mold Star 30 (50:50 weight ratio)
- Methods:
  - Re-glued previously used acrylic container
  - Made an acrylic guide to position 3D printed part in center of container



- Tacked down 3D printed part to bottom of mold with 2 small dots of super glue.
- Coated entire inside of mold and 3D printed part with very thin sprayed layer of universal mold release spray, and let it dry for about 30 minutes
- Mixed silicone vigorously for 4-5 minutes. Let sit for about 10 minutes while bubbles floated to surface
  - Used up about half of each container
- Cast and let sit overnight
- Broke walls apart with fine blade to access mold
- Outcome:
  - Silicone demolded well. Bubbles visible on all flat surfaces, but inside mold surface is almost bubble free.
    - Will try vacuum degassing and less vigorous mixing next time
  - Shore 30A hardness seems appropriate

10-15-2021 (SV)

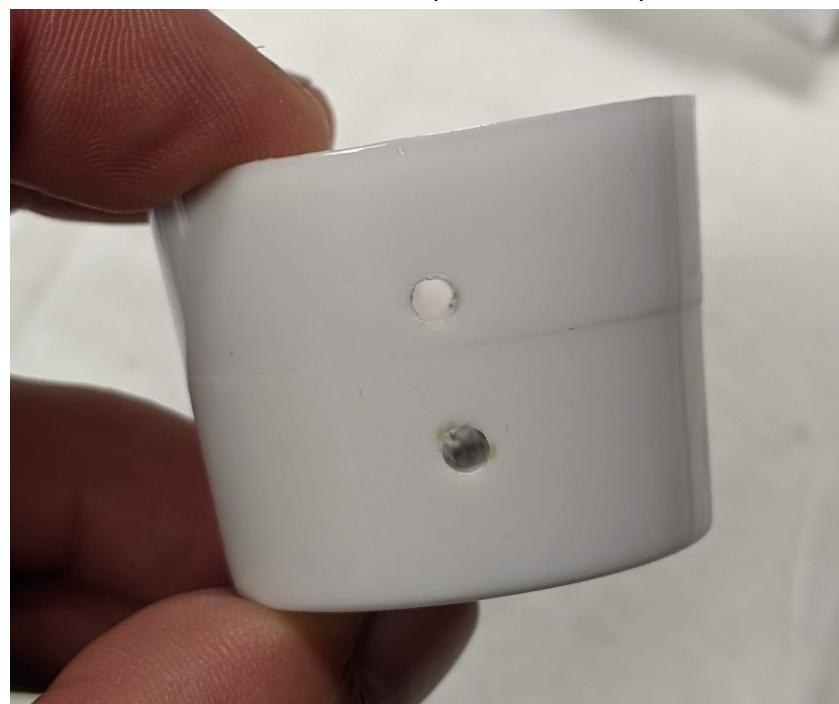
Cast Crystal Clear 200 polyurethane version of phantom with new TiO<sub>2</sub> and Ivory Black. Also cast into flow phantom test article for molding with PTFE and PP rod.

- Targeting  $\mu_s' = 1 \text{ mm}^{-1}$  and  $\mu_a = 0.02 \text{ mm}^{-1}$  (what GowerLabs uses)
- Recipe:
  - ~190 mL of total polyurethane
    - 100g of A
    - 90g of B
  - 1.37 g of TiO<sub>2</sub> (from Sigma-Aldrich)
  - 0.0106 g of Carbon black
- Methods:
  - Measured out dry powders and mixed the two
  - Added ~10 mL of part B and mixed thoroughly
  - Added additional B to total part B mass of 90g, mixed thoroughly and then placed in sonication bath for 30 minutes
  - Mixed in 100g of part A, stirred for 2 min
  - Skipped vacuum degassing because mixture appeared to be bubble-free
  - Poured into Mold Star 30 mold and flow phantom test article
    - Temp: 73 F, RH 45%
- Outcome:
  - Phantom did not turn out well. One side is noticeably bowed in, and much of the surface is covered in small bubbles and a fine web-like pattern. Phantom was cut for inspection, and the interior seems to be uniform and bubble-free. Will try pre-heating the mold and vacuum degassing the urethane next time.





- Flow phantom test was successful No visible bubbles or surface defects. Pulled out both PP and PTFE rods with pliers. PTFE required less force to remove.



10-19-2021 (SV)

Mixed large batch of absorber and scatterer in 1:129 ratio.

- Recipe:
  - 10 g TiO<sub>2</sub>
  - 0.0775 g carbon black
- Usage:

- Add 7.763 mg of mixture for each mL of resin

Cast Crystal Clear 200 polyurethane version of phantom with pre-mixed scatterer/absorber.

- Recipe:
  - 150 g of polyurethane - 144.8 mL @ 1.036 g/mL
    - 79 g of A
    - 71 g of B
  - 1.124 g of powder mix
    - 7.76 g/L TiO<sub>2</sub>
    - 0.0602 g/L carbon black
- Methods:
  - Preheated silicone mold in oven at 100 C for 3+ hours. Used black (non-vacuum) oven with thermocouple for temperature measurements, set to about 4.5 on the control knob.
  - Mixed dry powders with ~10 mL of part B
  - Added more part B for total part B mass of 71.05 g
  - Placed part B mixture in sonication bath for 30 minutes
  - Mixed in 78.95 g of part A, stirred gently for 2 min
  - Vacuum degassed in large container
  - Poured into Mold Star 30 mold
    - 73 F, 43% RH
- Results:
  - Amount of polyurethane was about 10% too low, due to resin that stuck to small mixing container and large degassing container.
  - Phantom came out great. Only imperfections are a few bubbles on the top surface (as cast) and some small bumps on the module side.
  - Vacuum degassing didn't seem to have much effect - only a small amount of bubbling and expansion was observed

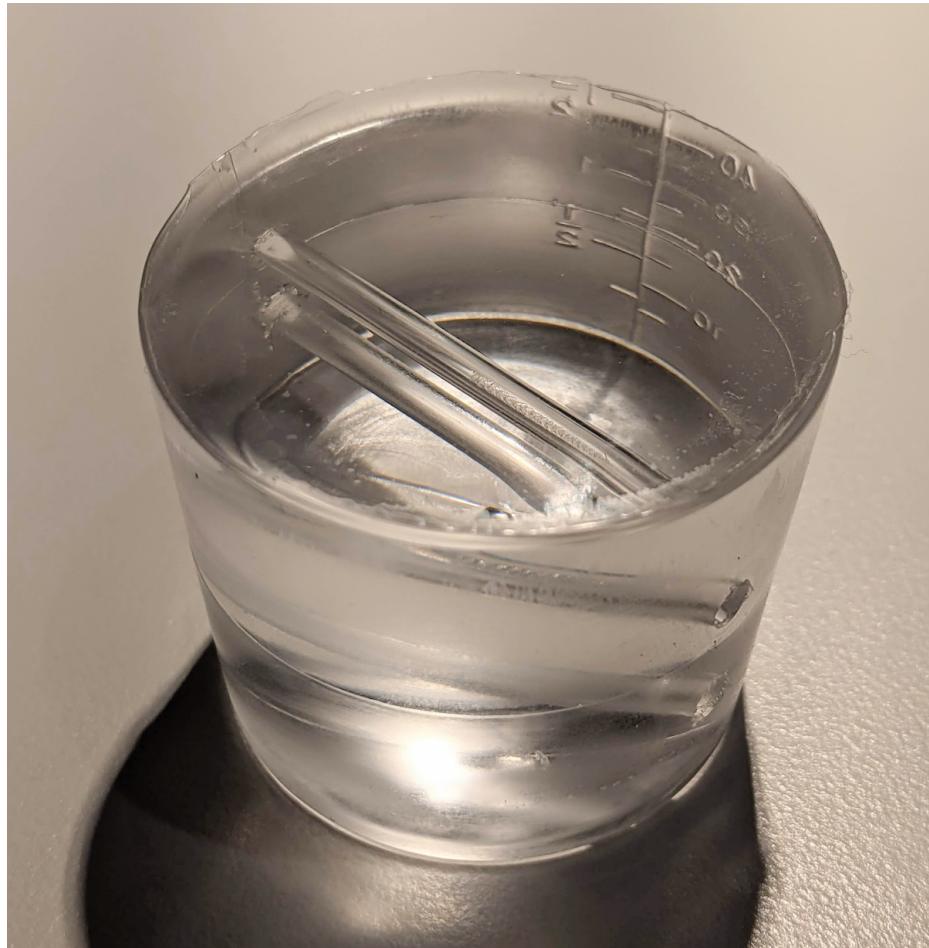


10-22-2021 (SV)

Cast Crystal Clear 200 polyurethane test sample with stainless and aluminum rods.

- Recipe:
  - 47.5 g of polyurethane
    - 25 g of A
    - 22.5 g of B
  - No additives - clear
- Methods:
  - Coated rods with mist of Mann Ease Release 205
  - Mixed A and B, stirred gently for 2 min
  - Vacuum degassed the mixture because many small bubbles were present
  - Poured into cup with Al and SST rods stuck through (no sealant on holes)
    - 73 F, 44% RH
- Results:
  - Successfully demolded both rods
  - SST rod took about 1 to 3 kg of force to demold
  - Al rod took about 4 to 8 kg of force - applied by pushing down on phantom with the rod resting on a metal block.

- Difference in force is probably associated with surface roughness. SST is polished, Al has a textured anodization coating

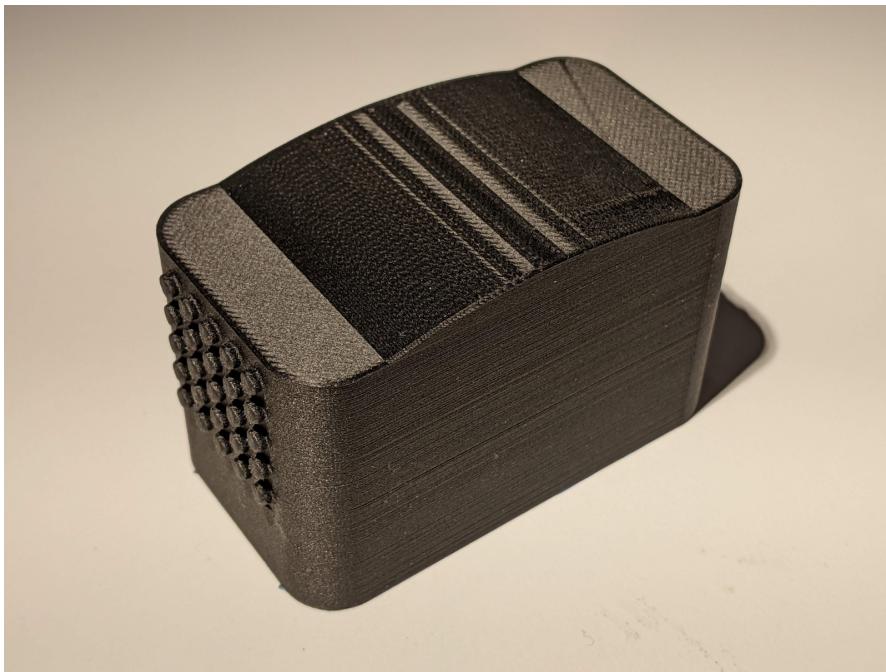


10-28-2021 (SV)

Cast flow phantom mold in Mold Star 30

- Recipe:
  - 400 g total of Mold Star 30 (50:50 weight ratio)
- Methods:
  - Re-glued previously used acrylic container
  - Tacked down 3D printed part to bottom of mold with 4 small dots of super glue.
  - Coated entire inside of mold and 3D printed part with very thin sprayed layer of universal mold release spray, and let it dry for about 30 minutes
  - Mixed silicone moderately fast for 4-5 minutes.
  - Vacuum degassed - material expanded to ~3x volume before collapsing
  - Cast and put into oven at 60 C
  - Demolded 2.5h after mixing
  - Broke walls apart with fine blade to access mold
- Outcome:
  - Demolding was not a problem, mold was able to stretch over protrusions.

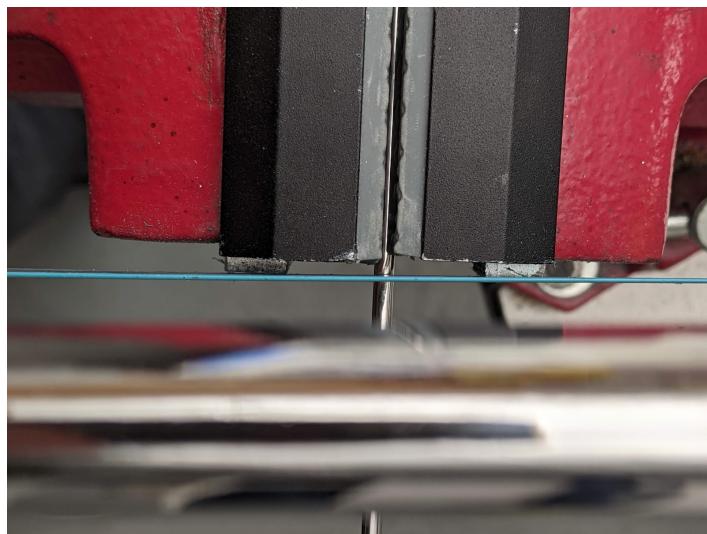
- Some large voids formed between the 3D printed positive and the top surface of the silicone
  - Suspected cause is thermal expansion of air inside hollow 3D printed part escaping through pinholes.
  - Mitigation could include sealing the 3D print, printing with solid fill, or curing without heat
- Had ~100ml of silicone left over



10-29-2021 (SV)

Cut  $\frac{1}{8}$ " stainless steel rod into 25 segments for molding tubular cavities into the phantom

- Part:
  - $\frac{1}{8}$ " diameter 304 stainless steel rod with polished finish #8 (McMaster Carr)
  - Cut into 25 segments of length 74 mm (+0.0 -0.3)
- Methods:
  - Cut to rough length (~75 mm) with hacksaw. Rod supported in vice with soft jaws. Metal jaws used as a guide for the saw.



- Sanded both ends square and set final length using a jig on the disk sander.



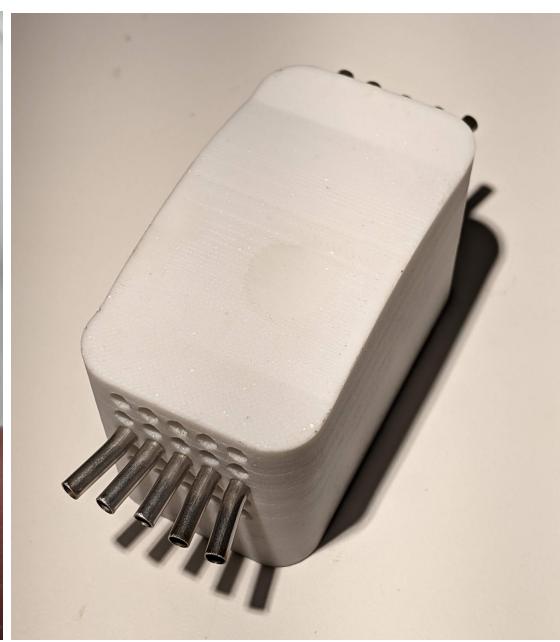
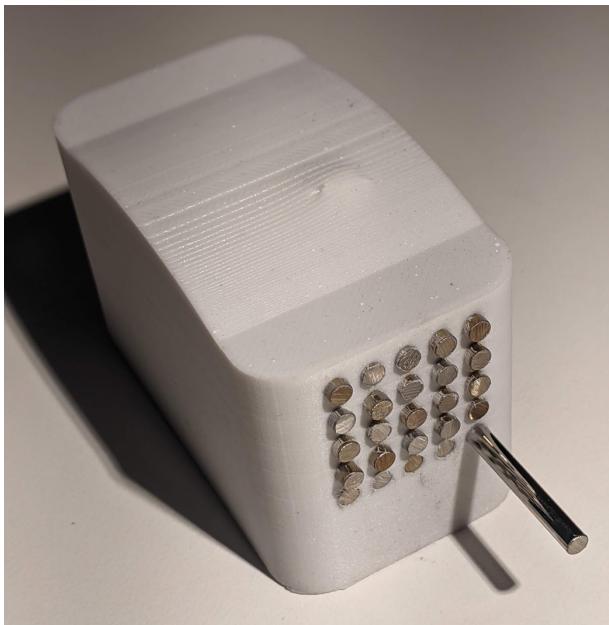
- Chamfered corners manually with sandpaper on flat surface

### 11-1-2021 (SV)

Cast static phantom and flow phantom prototype in Crystal Clear 200 polyurethane

- Recipe:
  - 300 g of polyurethane -289.6 mL @ 1.036 g/mL
    - 158 g of A
    - 142 g of B
  - 2.248 g of powder mix
    - 7.76 g/L TiO<sub>2</sub>
    - 0.0602 g/L carbon black
- Methods:
  - Coated sst rods with universal mold release
  - Inserted rods into silicone mold
  - Lightly sprayed inside of mold with more universal mold release
  - Preheated silicone molds in oven at 100 C. Used black oven at ~4.5.
  - Mixed dry powders with ~10 mL of part B
  - Added more part B for total part B mass of 142 g
  - Placed mixture in sonication bath for 30 minutes
  - Mixed in 158 g of part A, stirred gently for 2 min
  - Poured into both molds fresh out of the oven

- Temp 72 F, RH 46%
- Results:
  - Small specks of TiO<sub>2</sub> visible on top surfaces of both phantoms
  - Static phantom casting successful. Labeled #2 on bottom.
  - Flow phantom has some problems:
    - Bump on curved surface due to voids in silicone mold
    - Some sst rods slipped from their locations and produced angled channels
  - Most sst rods were easy to remove. A few required more pressure or light hammering to unstuck
  - Bump on surface was smoothed out with a file



11-3-2021 (SV)

Post-processed flow phantom

- Methods:
  - Sanded faces with channel openings in them
  - Filed bump off of top surface
  - Cleaned up and chamfered flow channel openings
  - Opened up holes with #29 drill bit (0.136") to 8 mm depth
- Results:
  - Drilled holes excessively deep - should be 6 mm

Cut and bent SST stubs for hooking up to rubber tubing:

- Methods:
  - Best rough cut technique seems to be with diamond tile saw and acrylic fence for consistent length
    - Band saw works but distorts tube
    - Hack saw jams
    - Tube cutter is very slow and squashes tube
    - Dremel tends to cut at an angle
    - Jeweler's saw tends to jam and cut slowly
  - Sanded to final length (74mm) with jig on disk sander
  - Chamfered inside edges with center drill or round deburring tool
  - Chamfered outside edges manually on stationary belt sander
  - Bent to 8° and 16° using two segments of drill rod inside tube, or one segment of drill rod and one twist drill
    - Annealed drill rod not stiff enough - permanently deformed
    - First segment inserted 8mm
    - Second segment inserted 9 mm
    - ~ 2mm bend allowance

Printed new master for flow phantom

- Changes:
  - Extra row of channels (5x6)
  - All channels raised for 5 mm displacement from center of source optic
  - Long dimension of phantom reduced from 71mm to 69mm, making molding stubs 2.5mm instead of 1.5mm
  - Modified M8 screw holes to remove need for printing supports



#### 11-9-2021 (SV)

Cast flow phantom mold #2 in Mold Star 30

- Recipe:
  - 380 g total of Mold Star 30 (50:50 weight ratio)
- Methods:
  - Re-glued previously used acrylic container
  - Tacked down 3D printed part to bottom of mold with 2 small dots of super glue.
  - Coated entire inside of mold and 3D printed part with very thin sprayed layer of universal mold release spray, and let it dry for about 30 minutes
  - Mixed silicone moderately fast for 4-5 minutes.
  - Vacuum degassed - material expanded to ~3x volume before collapsing
  - Cast and let cure at ambient temperature for 6 hours - box had a small leak, but this didn't affect the quality of the mold
  - Broke walls apart with fine blade to access mold - some joints were very strong and one acrylic piece broke
  - Mold is good - small defects around holes, otherwise perfect surface finish.
  - De-molding took considerable force, M8 hole in base of master was helpful

#### 11-10-2021 (SV)

Cast flow phantom #2 in Crystal Clear 200 polyurethane

- Recipe:
  - 150 g of polyurethane - 144.8 mL @ 1.036 g/mL
    - 79 g of A

- 71 g of B
  - 1.124 g of powder mix
    - 7.76 g/L TiO<sub>2</sub>
    - 0.0602 g/L carbon black
- Methods:
  - Coated sst rods with universal mold release
  - Inserted rods into silicone mold #2
  - Lightly sprayed inside of mold with more universal mold release
  - Preheated silicone mold in oven at 100 C. Used black oven at ~4.5.
  - Mixed dry powders with ~10 mL of part B
  - Added more part B for total part B mass of 71 g
  - Placed mixture in sonication bath for 30 minutes
  - Mixed in part A, stirred gently for 2 min
  - Poured into mold fresh out of the oven
    - Temp 72 F, RH 43%
- Results:
  - Perfection 🙌
  - Silicone demolded fairly easily (easier than mold from 3D print), with no damage to mold.
  - Most SST rods demolded easily with undersize drill rod pushing them through
    - Some required moderate pressure on arbor press to get them loose
  - Material is uniform, with the exception of some small specks of dust, mainly on the sides.



11-12-2021 (SV)

Post-processed flow phantom #2

- Methods:

- Cut off flashing around where SST rods used to be with a razor
- Sanded faces with channel openings in them
- Reamed flow channels to 0.134" x 6mm deep
- Heated phantom to 60 C to expand holes

- Inserted SST tubing stubs at correct angles. Some holes needed additional clean-up with the reamer, and some tubes needed additional sanding to clean up chamfer on OD.
- Results:
  - Some leaking, hard to tell if it's at the phantom to SST transition or the SST to silicone tubing transition, but it may be at both.
  - Concentration of TiO<sub>2</sub> is way too high at 7.3 g/L - should be closer to 1

### 11-22-2021 (SV)

Cast Static phantom to test scatterer concentration (no absorber). Using concentration of 1 g/L.

- Recipe:
  - 155.4 g of polyurethane - 150 mL @ 1.036 g/mL
    - 81.8 g of A
    - 73.6 g of B
  - TiO<sub>2</sub>:
    - 1.0 g/L ==> 0.15 g TiO<sub>2</sub>
- Methods:
  - Lightly sprayed inside of mold with universal mold release
  - Preheated silicone mold in oven at 100 C. Used black oven at ~4.5.
  - Mixed TiO<sub>2</sub> with ~10 mL of part B
  - Added more part B for total part B mass of 73.6 g
  - Placed mixture in sonication bath for 30 minutes
  - Mixed in part A, stirred gently for 2 min
  - Poured into mold fresh out of the oven and acrylic cuvette for scatterometer
    - Temp ? F, RH ?%

### 12-1-2021 (SV)

Cast Static phantom to test scatterer concentration (no absorber).

- Recipe:
  - 155.4 g of polyurethane - 150 mL @ 1.036 g/mL
    - 81.8 g of A
    - 73.6 g of B
  - TiO<sub>2</sub>:
    - 3.76 g/L ==> 0.56 g TiO<sub>2</sub>
- Methods:
  - Lightly sprayed inside of mold with universal mold release
  - Preheated silicone mold in oven at 100 C. Used black oven at ~4.5.
  - Mixed TiO<sub>2</sub> with ~10 mL of part B
    - Forgot to shake part B before dispensing
  - Added more part B for total part B mass of 73.6 g
  - Placed mixture in sonication bath for 30 minutes

- Mixed in part A, stirred gently for 2 min
- Vacuum degassed - mixture bubbled violently and did not stop for 5 minutes
- Did not attempt to pour into mold because material was already solidifying

### 12-2-2021 (SV)

Cast Static phantom to test scatterer concentration (no absorber).

- Recipe:
  - 155.4 g of polyurethane - 150 mL @ 1.036 g/mL
    - 81.8 g of A
    - 73.6 g of B
  - TiO<sub>2</sub>:
    - 3.76 g/L ==> 0.56 g TiO<sub>2</sub>
- Methods:
  - Lightly sprayed inside of mold with universal mold release
  - Preheated silicone mold in oven at 100 C. Used black oven at ~4.5.
  - Mixed TiO<sub>2</sub> with ~10 mL of part B
    - Forgot to shake part B before dispensing
  - Added more part B for total part B mass of 73.6 g
  - Placed mixture in sonication bath for 30 minutes
  - Mixed in part A, stirred gently for 2 min
  - Vacuum degassed - mixture bubbled violently and did not stop for 5 minutes
  - Poured into mold fresh out of the oven and acrylic cuvette for scatterometer
    - Temp 73 F, RH 47%
- Results:
  - Success

### 12-6-2021 (BH)

Cast static phantom to test scatterer concentration (no absorber).

- Recipe:
  - 155.4 g of polyurethane - 150 mL @ 1.036 g/mL
    - 81.8 g of A
    - 73.6 g of B
  - TiO<sub>2</sub>:
    - 4.78 g/L ==> 0.717 g TiO<sub>2</sub>
- Methods:
  - Lightly sprayed inside of mold with universal mold release
  - Preheated silicone mold in oven at 100 C. Used black oven at ~4.5
  - Weighed out 0.717 g of TiO<sub>2</sub> into 400 mL polypropylene container
  - Shook up part B container for 1-2 minutes
  - Mixed TiO<sub>2</sub> with ~30 mL of part B using acrylic stir stick
  - Added more part B for total part B mass of 73.6 g
  - Placed mixture in sonication bath for 30 minutes
  - Shook up part A container for 1-2 minutes

- Mixed in part A, stirred gently (so as to not introduce bubbles) for 2 min
- Vacuum degassed - only <1mm diameter bubbles formed after 5 minutes
- Poured into mold fresh out of the oven
  - Tried to pour slowly enough such that the rod holder features didn't have any air bubbles trap
  - Initially overpoured to form lip, but ultimately was too thin at the time and started to spit over the edges
  - Gooey by 13 minutes after adding part A
  - Temp 73 F, RH 45%
- Results:
  -

### 12-9-2021 (BH)

Cast static phantom to test scatterer concentration (with absorber).

- Recipe:
  - Made new stock of TiO<sub>2</sub> & carbon black
    - 9.60 g TiO<sub>2</sub>
    - 0.056 g carbon black
  - 455.4 185 g of polyurethane - 450 179 mL @ 1.036 g/mL
    - 81.8 95 g of A
    - 73.6 90 g of B
    - 3.9 g/L ==> 0.698 g TiO<sub>2</sub>
    - 0.023 g/L ==> 0.00405 g carbon black
- Methods:
  - Same as 12-2-2021 but used different TiO<sub>2</sub> concentration and included carbon black
- Results:
  - mu\_eff matches those of the INO phantoms (~0.13) but intensity values are about 6 times lower

### 12-14-2021 (BH)

Cast static phantom to test scatterer concentration (with absorber).

- Recipe:
  - Made new stock of TiO<sub>2</sub> & carbon black
    - 1.000 g TiO<sub>2</sub>
    - 0.055 g carbon black
  - 155.4 g of polyurethane 150 mL @ 1.036 g/mL
    - 82 g of A
    - 73.6 g of B
    - 0.158 g of TiO<sub>2</sub>/CB mixture
      - 1.0 g/L TiO<sub>2</sub>
      - 0.056 g/L carbon black
- Methods:

- Same as 12-2-2021 but used different TiO<sub>2</sub> concentration and included carbon black
- Results:
  - Too attenuating for third channel,  $\mu_{eff}$  higher than INO

### 12-15-2021 (BH)

Cast static phantom to test scatterer concentration (with absorber).

- Recipe:
  - Made new stock of TiO<sub>2</sub> & carbon black
    - 2.000 g TiO<sub>2</sub>
    - 0.056 g carbon black
  - 156 g of polyurethane 150 mL @ 1.036 g/mL
    - 82 g of A
    - 74 g of B
    - 0.158 g of TiO<sub>2</sub>/CB mixture
      - 1.0 g/L TiO<sub>2</sub>
      - 0.028 g/L carbon black
- Methods:
  - Same as 12-2-2021 but used different TiO<sub>2</sub> concentration and included carbon black
- Results:
  - Looks visually very similar to the 12-14-2021 phantom despite half the carbon black
  - $\mu_{eff}$  still higher than INO but intensity half of INO at third camera

### 12-16-2021 (BH)

Cast static phantom to test scatterer concentration (with absorber).

- Recipe:
  - Made new stock of TiO<sub>2</sub> & carbon black
    - 10.000 g TiO<sub>2</sub>
    - 0.140 g carbon black
  - 155.4 g of polyurethane 150 mL @ 1.036 g/mL
    - 82 g of A
    - 73.6 g of B
    - 0.158 g of TiO<sub>2</sub>/CB mixture
      - 1.0 g/L TiO<sub>2</sub>
      - 0.014 g/L carbon black
- Methods:
  - Same as 12-2-2021 but used different TiO<sub>2</sub> concentration and included carbon black
- Results:
  - Too much light, too low  $\mu_{eff}$

### 12-17-2021 (BH)

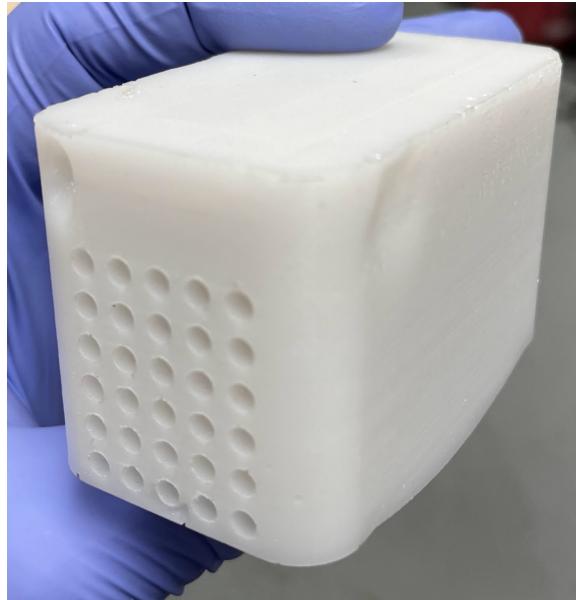
Cast static phantom to test scatterer concentration (with absorber).

- Recipe:
  - Made new stock of TiO<sub>2</sub> & carbon black
    - 10.000 g TiO<sub>2</sub>
    - 0.200 g carbon black
  - 155.4 g of polyurethane 150 mL @ 1.036 g/mL
    - 82 g of A
    - 73.6 g of B
    - 0.158 g of TiO<sub>2</sub>/CB mixture
      - 1.0 g/L TiO<sub>2</sub>
      - 0.020 g/L carbon black
- Methods:
  - Same as 12-2-2021 but used different TiO<sub>2</sub> concentration and included carbon black
- Results:
  - Matched mu\_eff & 3rd camera intensity of INO phantom

### 12-20-2021 (BH)

Cast flow phantom to test if static scatterer/absorption concentration work for flow phantom

- Recipe:
  - Used TiO<sub>2</sub>/C.B. stock from 12-17-2021
  - 155.4 g of polyurethane 150 mL @ 1.036 g/mL
    - 84.4 g of A
    - 75.9 g of B
    - 0.163 g of TiO<sub>2</sub>/CB mixture
      - 1.0 g/L TiO<sub>2</sub>
      - 0.020 g/L carbon black
- Methods:
  - Same as 11-10-2021 but used different TiO<sub>2</sub> & carbon black concentrations
  - Tried vacuuming the mold after pouring up to height to cover all rods, this was a BAD IDEA as it seemed like the hot metal of the rods catalyzed the curing of polyurethane and instead of a small amount of bubbles small coming up to the surface like happens with the mixing cup, foamy solid chunks of partially cured polyurethane started floating to the top edges (despite the polyurethane in the cup being extremely liquid still). Suggest to just pour semi-rapidly in one shot after vacuuming the mixing cup.



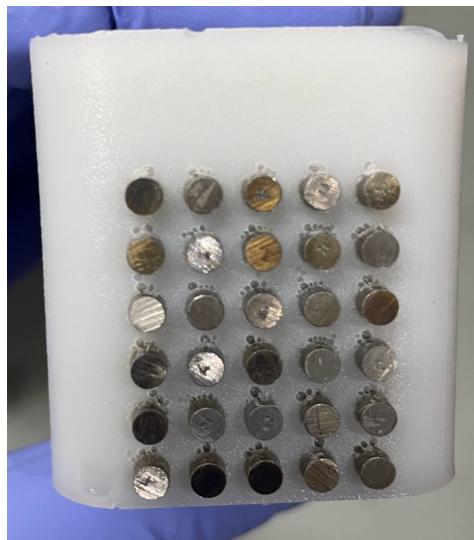
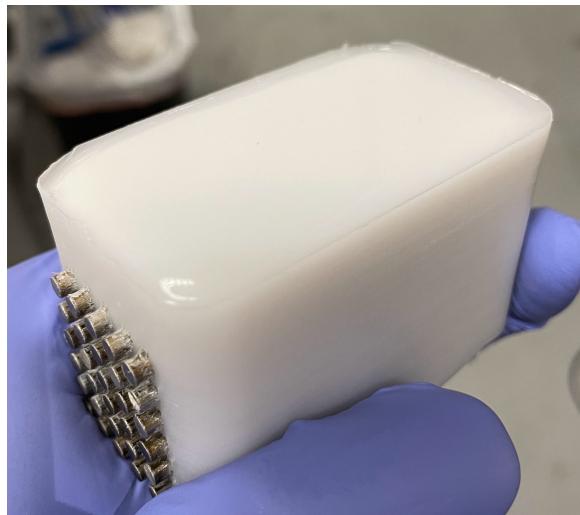
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- Results:
  - Lots of small to medium sized bubbles over entire phantom but mostly at top
  - All features seemed to cast well otherwise
  - Machined connecting channels on each end on 12-21-2021
  - Sealed end places with Loctite AA 349 (softer than Loctite 4310), worked okay but inside of windows didn't cure as well as the test run
  - Tried using Loctite Super Glue - Ultra Gel to glue pipe ends into phantom. Seemed to hold them in place but the extra glue at the top didn't cure well. Repeated with Loctite 4311 (high viscosity version of 4310) and this worked just as well for sealing but looked a lot nicer and cleaner.

#### 12-21-2021 (BH)

Recast flow phantom to avoid bubbles that occurred last time

- Recipe:
  - Used TiO<sub>2</sub>/C.B. stock from 12-17-2021
  - 155.4 g of polyurethane 150 mL @ 1.036 g/mL
    - 81.8 g of A
    - 73.6 g of B
    - 0.158 g of TiO<sub>2</sub>/CB mixture
      - 1.0 g/L TiO<sub>2</sub>
      - 0.020 g/L carbon black
- Methods:
  - Same as 12-20-2021 but heated up mold to 60C instead of 100C and did not vacuum the mold after pouring it. Also a BAD IDEA, the lower temperature caused shrinking in the corners. However, there were also lots of bubbles that formed on the sides around the stainless steel rods. Seemingly, best option is to

try sticking with 100C and pouring as quickly as possible after mixing and vacuuming mixing cup.



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- Cut 32.2mm x 21.2mm (into laser cutter, producing final 30mm x 20.5mm)  $\frac{1}{8}$ " clear acrylic end plates
- Sanded faces with 120 grit sandpaper prior to gluing
- Used squeeze bottle with XXXX guage dispensing needles for Loctite 4311 dispensing onto face ends and tubes



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- Results:
  - Loctite glue 4311 worked better for sealing ends than the AA 349, clearer and harder (lower viscosity didn't make much of a difference)

