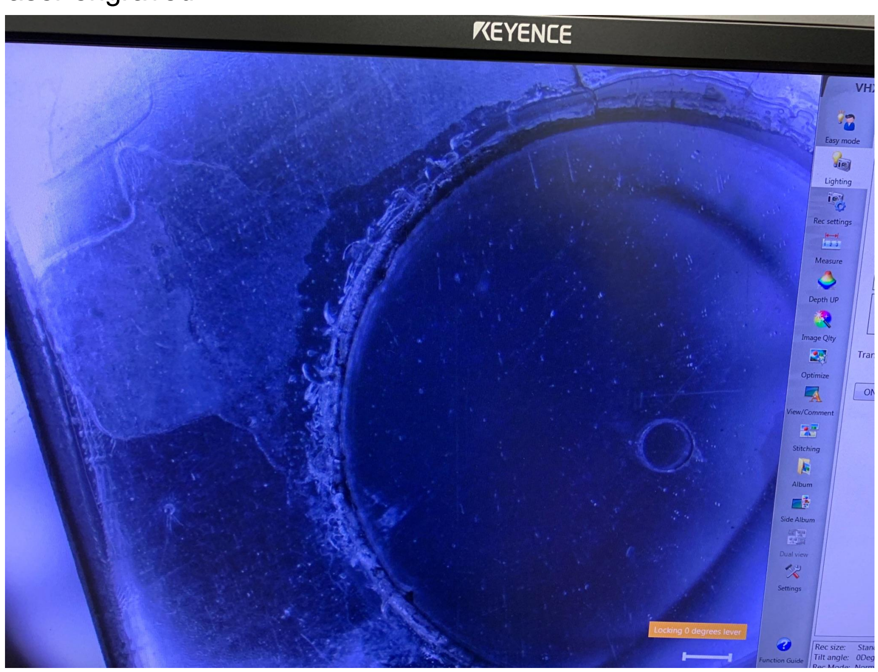
Andrew J Furst
6/30/21
CNSI uFL
COC testing Documentation

1. **Laser cut plaques into 25 mm x 25 mm squares for bonding testing using laser cutter**
    a. Trotec recipe:
        i. Single pass
            1. Power: 100%
            2. Velocity: 1.6%
            3. Passes: 1
        ii. Multi pass
            1. Power: 20%
            2. Velocity: 1%
            3. Passes: 3
    b. **Notes**: Because COC has such a low Tg and melting point even with multiple passes it is apparent that there is some melting of the plastic. This causes rounded edges along the cut line as well as slag built up on the back side of the cut. Slag must be cleaned off cut edge before bonding or the COC plaques will not contact each other fully.
    c. **Notes**: laser cutting the sample (and heat polishing the edge) will cause bad crazing of the COC if exposed to Cyclohexane. This means that the COC placed on the filter paper must be saw cut or sanded after laser cutting. (damn)
        i. This really sucks because the COC exposed to cyclohexane sometimes has small bubbles or pitting which result in bad optical (and also likely X-ray//UV) properties. The hope was that if the midplate were exposed rather than the plaque on both sides the pitting would not interfere with the channel. This means the plaque with channels can not be laser cut or laser engraved.



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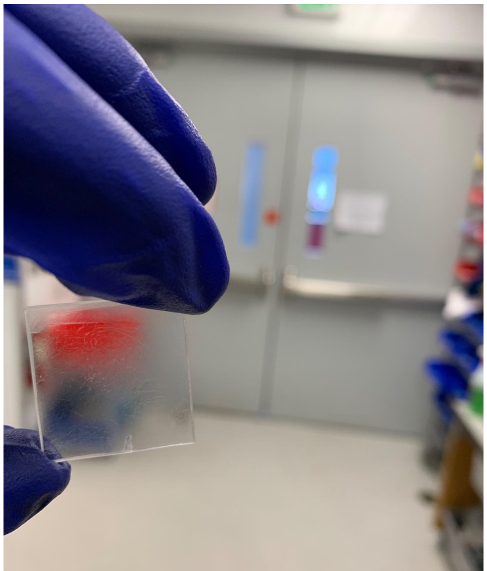
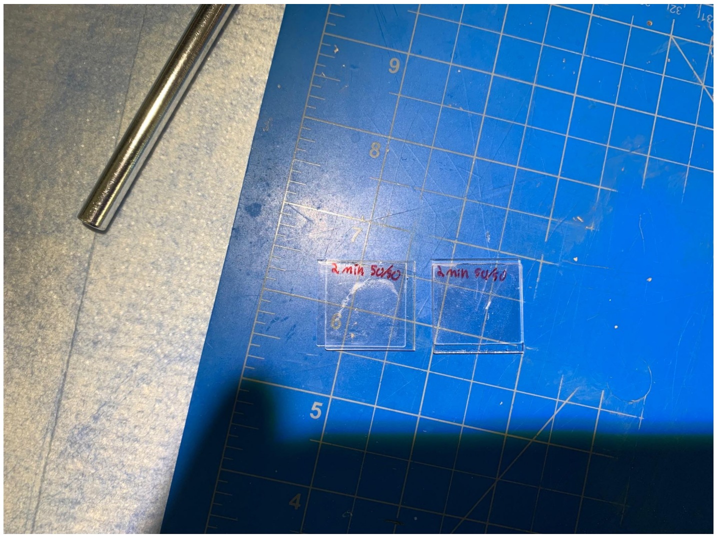
2. **Test cyclohexane solvent bonding (qualitative)**
    i. Solvent bonding is preferable for biocompatibility as thermal bonding can cause protein degradation and cause bio molecules to denature. This is only if proteins/enzymes have been immobilized on the COC surface prier to bonding
    b. Clean sample with IPA, blowing dry with clean compressed air
    c. Place 3 layers of filter paper in petri dish and soak with solvent solution comprised of 35% volume cyclohexane in acetone
    d. Place 1 COC plaques on filter paper for one minute
    e. Rinse /clean with acetone to remove remaining cyclohexane
    f. Blow with compressed air until tacky
    g. Place tacky surface to clean COC plaque, compress with 20 pounds of force for 30 seconds
        i. https://drive.google.com/file/d/1CpGYvevx6I1w3BuR4o9n3zWYC2n-L19H/view?usp=sharing
    h. **Notes:** In my limited testing 35% volume cyclohexane in acetone is suitable for solvent bonding and making microfluidic chips. As mentioned above the plaque placed in cyclohexane can not be laser cut as it results in bad crazing. Only one plaque needs to be placed in cyclohexane (it will bond to just a clean COC plaque), however it would be interesting to test both exposed to see if it results in a stronger bond. The bond appears to be rather strong, however it is difficult to get a clean and consistent bond. I had best results placing it in the press with a thick piece of PDMS between one of the press plates and the COC sandwich. The PDMS allows for even pressure to be applied across the entire surface of the COC, which results in a more consistent bond. A consistent bond is also more optically transparent. Using too high of a cyclohexane to acetone ratio results in bubbles and pitting of the COC exposed, resulting in bad optical transparency. I would like to test using two large glass plates in the press, with a piece of PDMS between the glass and the plates to allow the glass plates to remain parallel. Picture left is coc after exposure to cyclohexane picture right is uneven bonding and some bubbles from bad pressure and too much cyclohexane.
3. **Test vapor solvent bonding (qualitative)**





a. Clean sample with IPA, blowing dry with clean compressed air
b. Heat cyclohexane to 70 degrees C in beaker with lid to vaporize
c. Expose COC for 40 seconds by taping to inside of lid and placing over beaker
d. Remove COC from beaker and place exposed surfaces together
    i. https://drive.google.com/file/d/1RNl_sDVKeL97chR8YE-RiwSSs7-Iiwqb/view?usp=sharing
e. **Notes**: we don't want to do this unless we have to because solvent fumes are not very fun if you like keeping your eyebrows or lungs.

4. **Test UV exposure w/ hot press bonding (below Tg) (qualitative)**
    i. https://drive.google.com/file/d/1b3hWbKefK8_1f9zWZOC45EO9ry0T9b6q/view?usp=sharing

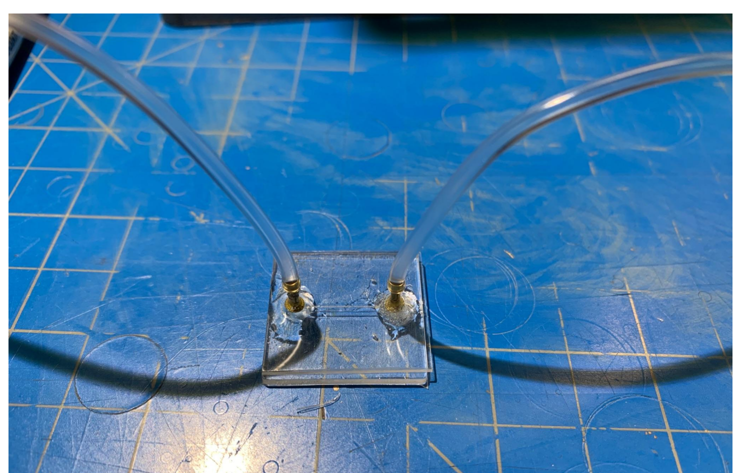
    b. Clean sample with IPA, blowing dry with clean compressed air
    c. Expose COC to UV/ozone 185 and 254 nm light for 10 min
    d. At hot press heat to 60-80 degrees C and compress exposed surfaces together at 30 PSI for between 5 and 10 min
        i. Higher press temp results in higher strength bond
    e. **Notes**: I wonder if this paper is a joke, because I was unable to get even the tiniest bond at 100*c and a lot more pressure then they were using. Maybe I just don't know what I'm doing. Need I include a picture?
5. **Test high pressure hot press bonding (below Tg) (qualitative)**
    a. Clean sample with IPA, blowing dry with clean compressed air
    b. Expose COC to UV/ozone 185 and 254 nm light for 10 min
    c. At hot press heat to 100 degrees C and compress exposed surfaces together at 30 PSI
        i. https://drive.google.com/file/d/1V5a8Lyr9CjVVh2Mt90Dp_7dTeKBhuIRi/view?usp=sharing
    d. **Notes**: yeah that's a no…..

6. **Mini luer lock bonding test**
    a. Use double sided tape or epoxy to bond mini luer lock to COC film
7. **Cavity pressure test of 3 layer COC sandwich (Quantitative)**
    a. Cut ⅜" hole in center of 25 mm square COC plaque
    b. Punch 1/16" hold in COC plaque
    c. Bond plaque with ⅜" hole to uncut 25 mm square and plaque with 1/16" hole
    d. Bond mini luer lock to top plaque with 1/16" hole
    e. Pressure test until she pop
        i. See if any solvent or deformation obstructs or enters ⅜" hole
    f. **Notes**: It holds pressure! I'm not sure how much yet, but I was able to fully compress a 10ml syringe and it springs back to its original position.
8. **Test laser engraved channel of 2 layer COC sandwich**
    a. Identify recipe for laser engraving channels

   b. Test high power engrave vs taking multiple passes

9. Test 3 layer channel COC sandwich
   a. Cut all the way through center COC plaque and sandwich it between two other COC plaques similar to how the pressure test was done
   b. Bond luer lock fittings and test microfluidic device
   c.

10. Test 2 layer embossed COC sandwich
   a. Create master mold from aluminium
   b. Polish master mold
   c. Create embossing recipe by varying temp and pressure in hot press
   d. Start at 120 degrees C and 15 PSI for one hour
   e. Cool below Tg while pressed before removing
   f. Might be worth trying with a high temp epoxy mold as it would allow different types of channels to be cast rather then machined for the master mold
   g. Embossing was attempted with 2mm thick COC to a depth of 100 micron
      i. https://drive.google.com/file/d/1dStsa-kn3KF9FMLvT6DQWT5tgP6QgVx-/view?usp=sharing
   h. Notes: Okay, so I won't lie, I desperately wanted to try COC molding using COC resin, so I did that instead. It was my day off anyways! But I had reasonable success molding the raw COC pellets using an aluminum mold. The problem is bubbles, and the COC is still so viscous as 210 C that when the pellets mold tougher they enevidably form bubbles in the goo before it's even molded. I found that I had good success overfilling the mold and letting the press squeeze out all the bubbles. The gauge on the press reaches its max before the "dies" (ha) can contact each other, so there is quite a bit of "flashing" (lol by flashing i mean 300 micron of flashing for 10 mm out from the edge of the mold). The "die" (using this term very loosely) was not polished and the plate it was contacting was raw extruded aluminium plate and I found that the COC takes on the texture of the "die" as well as the plate. This means the COC itself would need to be polished however I believe if the "die" was polished and a glass plate was used that the COC goo would solidify optically transparent and require very little post processing. That being said the COC transparency wasn't that bad with the haphazard attempts I did, and I was able to create a simple channel microfluidic device and push some water back and forth between syringes.



11. **Test 2 layer direct machined COC sandwich**
    a. Mount COC to flat aluminium plate using super glue and painters tape
    b. Machine channel into COC using large endmill
    c. Machine channel into COC using small endmill
    d. Compare surface finish
    e. Bond similar to 3 layer COC but only two layers
12. **Test COC solvent vapor polishing**
    a. Use cyclohexane to polish
    b. Heat to 25 degrees C
    c. Expose for 4 min
13. **Test COC mechanical polishing**
    a. .3mm wool polishing tool depress distance
    b. Use CNC or manual mill to polish channel so as to not induce more deformation then necessary
14. **Test COC flame polishing**
    a. Could not find any documentation on flame polishing COC's
    b. Plan is to cut a plaque with a saw and hold it to a bunsen burner to see if it flame polishes the edge
15. **Test Flexdym bonded to COC**
    a. Flexdym bonds to Glass
    b. No heat
        i. .7-.9 bar (10-13 PSI) for 3 min at 70 degrees C
    c. Oven
        i. 95 degrees C for 60 min
16. **Test fixture jig for holding COC to PDMS**
17. **Test bonding COC to PDMS**
18.

Important information:
- COC used is TOPAS 8007S-04
- Tg is 78 degrees C
- Mechanical polishing introduces less distortion
- Solvent polishing should result in a slightly better surface finish
- What about post processing irradiated with UV light (2 J/cm2 at 254 nm) to increase the bond strength

TO DO:
1. Test NOA for bonding fittings
2. Ask rohm about COC recipe for heat bonding
3. Contact flexdym on size/samples available and if it can be laser cut
4. Test embossing mold

5. Test polishing
6.
7.