Oct 29, 2022

Microfluidic Digital Logic Chip Assembly

Erik Werner[1], Elliot Hui [University Of California[1]
[1]University of California, Irvine

dx.doi.org/10.17504/protocols.io.8efhtbn

Erik Werner
University of California, Irvine

ABSTRACT

This protocol describes how to reversibly bond layers of poly(methyl methacrylate) (**PMMA**) and polydimethylsiloxane (**PDMS**) using thermo-compresison bonding. Usually, two layers of PMMA are sandwiched around a center layer of PDMS. While compressed, all materials are heated to the softening temperature of the PMMA. They are then allowed to slowly cool to room temperature before removing from compression. The result should produce a bubble-free lamination between both PMMA-PDMS interfaces without melting the PMMA or significantly distorting micro-scale features. The times and temperatures in the SOP may be adjusted to accommodate different thicknesses or types of materials where a similar lamination-effect is desired.

DOI

dx.doi.org/10.17504/protocols.io.8efhtbn

EXTERNAL LINK

https://doi.org/10.3390/mi13101784

PROTOCOL CITATION

Erik Werner, Elliot Hui [University Of California 2022. Microfluidic Digital Logic Chip Assembly. **protocols.io** https://dx.doi.org/10.17504/protocols.io.8efhtbn

MANUSCRIPT CITATION please remember to cite the following publication along with this protocol

Werner EM, Lam BX, Hui EE, Phase-Optimized Peristaltic Pumping by Integrated Microfluidic Logic. Micromachines 13(10). doi: 10.3390/mi13101784

KEYWORDS

microfluidic, fabrication, assembly

CREATED

Oct 18, 2019

LAST MODIFIED

Oct 29, 2022

PROTOCOL INTEGER ID

28839

GUIDELINES

To ensure success:

1. The PMMA layers should be thicker than the middle PDMS layer (or at least substantially thicker than the thickest air pocket between the layers)
2. The thicker material (PMMA in this case) must have a lower softening temperature
3. The PMMA must be allowed to heat uniformly (see note)
4. The device must remain compressed until it is cooled completely (see note)
5. Uniform pressure should be applied to both sides of the device
6. Holes and pockets in the PMMA should be greater than 100 um

Note: Minimum hold times for heating and cooling will vary depending on the type of oven used. For a standard lab without forced air circulation, use 2 hours for 3mm of material thickness, and add 1 hour per additional mm. See the attached guidelines from plexiglass for more information.

Fabrication-Guidlines-Plexiglas-Annealing.pdf

MATERIALS TEXT

MATERIALS

Scotch™ Magic Tape **Staples Catalog #14172**

41mm Binder Clips **Contributed by users Catalog #B079CV2S77**

Corning® microscope slides plain 75 × 50 mm **Contributed by users Catalog #CLS294775X50-72EA**

BISCO HT-6240 Liquid Silicone Rubber Sheeting (40 Durometer) **Contributed by users**

Cole-Parmer® Micro-90 Cleaning Solution **Cole Parmer Catalog #VV-99999-14**

3 x 4 inches 2Mil Clear Reclosable Zip Lock Bags **Contributed by users Catalog #B01A09SKNY**

18-8 Stainless Steel Taper Pin Pin Number 7/0 0.063 Large End Diameter 3/4 L **Contributed by users Catalog #90681A002**

Materials:
Device:
1x device to bond (usually a 45 mm x 70 mm chip made of [1.5 mm PMMA, 250 um PDMS, 1.5 mm PMMA])

Consumables:
2x 75 mm x 100mm pieces 250 um silicone (HT6240) sandwiched between PET (mylar)
3M Scotch Magic Tape

Reusable:
4x 50mm x 75 mm glass microscope slides
4x medium sized (41mm) binder clips
4x taper pins
Fine Tweezers
Scissors
1x Oven capable of 110 C
1x Thermometer

SAFETY WARNINGS

PMMA can release harmful concentrations of vapors and monomers if heated above 176ºC (350ºF). Always work in a well-ventilated area and exhaust fumes to the outdoors.

Citation: Erik Werner, Elliot Hui [University Of California Microfluidic Digital Logic Chip Assembly https://dx.doi.org/10.17504/protocols.io.8efhtbn

PMMA is combustible. Observe all relevant safety precautions for flammable materials.

Clean

1 Rinse all parts to be assembled under a stream of DI water to remove charred material or debris from machining.

2 Insert each component of the Microfluidic device into a 3" x 4" zip loc bag.

If some parts only have features on one side, two pieces may be combined in the same bag. Face the non-patterned surfaces toward each other.

3 Prepare a solution of ~1% Microsoap in DI water and fill each bag about half way

Liquid dish soap can be substituted for Microsoap

4 Sonicate the bags for 20 minutes

Sonicator
Branson **B2510**

5 Remove the parts from each bag, rinse thoroughly with DI water, and dry with compressed nitrogen. Transfer to a Petri dish to keep clean from dust.

Assemble

6 In a clean work environment, insert four tapered dowel pins into a PMMA piece of the device. Let this side be the "bottom" layer. Ensure the small end of the pin faces the side with the device features that will be bonded.

Either piece of PMMA can be the bottom layer. It helps to pick whichever piece has more critical alignment requirements with features in the PDMS.

Laminar Flow Hood
Benchtop workstation
Envirco **TT4830**

Citation: Erik Werner, Elliot Hui [University Of California Microfluidic Digital Logic Chip Assembly https://dx.doi.org/10.17504/protocols.io.8efhtbn

7 Orient the chip so the features face up and inspect the surface of the device to ensure it is free from dust and debris. Remove dust with compressed air or lightly touching with Scotch MagicTape.

Angle the device to reflect light off the surface to help identify debris.

Other brands of tape may be used, but may leave adhesive residue on the PMMA device surface. Scotch magic tape seems to work best, but it can also leave residue if it is firmly pressed onto the surface of the device. For best results, roll the tape back onto itself to form a "wheel" and lightly blot the PMMA.

Stereoscopic Microscope
Microscope
Olympus **SZ40**

8 Orient the PDMS membrane over the prepared PMMA layer, and peel away the PET layer protecting the side that contacts the PMMA.

9 Clean the exposed PDMS with MagicTape

The MagicTape will not leave residue on PDMS as easily as with PMMA. Press into the PDMS and clean thoroughly, as PDMS is a dust magnet.

10 Using the tapered dowel pins, lower the PDMS onto the PMMA chip. When the material get close, press in the middle of the PDMS to start the adhesion process, then allow the materials to adhere from the middle outwards.

11 If any bubbles remain under the PDMS, inspect for dust. Bubbles may be a result of the PDMS wrinkling over the PMMA or a spot of dust. Where there is dust, peel back the PDMS and blot with MagicTape to remove.

12 Remove one of the taper pins and crease the PDMS/PET at that corner. Peel off the top layer of PET.

It helps to peel the PET parallel to the device to create a large difference in the circumference of the PET/PDMS as the materials bend. This facilitates an easier release of the PET from the PDMS.

If the PDMS wrinkles, distorts, or comes of the PMMA while peeling the second PET layer, use the tapered dowel pins to lower the PDMS onto the PMMA again and realign features as necessary.

Citation: Erik Werner, Elliot Hui [University Of California Microfluidic Digital Logic Chip Assembly https://dx.doi.org/10.17504/protocols.io.8efhtbn

13 Clean the exposed PDMS with MagicTape

During this step, it helps to secure at least two points of the membrane with a clean, gloved finger to prevent the PDMS from lifting off the first PMMA layer during cleaning.

14 Inspect clean the top layer of PMMA using compressed air and MagicTape

15 Reinsert the taper pins into the bottom PMMA /PDMS

16 Lower the top layer, feature side down, over the taper pins onto the lower PMMA layer and PDMS.

17 When the materials are close, press firmly from the center outwards to adhere all layers together.

18 Remove the taper pins

19 Inspect the device to ensure features are aligned and there are no large air pockets. Small air pockets will smooth and disappear with annealing, wrinkles in the PDMS membrane will not.

Compress

20 Clean the outside of the device with compressed air and MagicTape

This step is mostly cosmetic. Dust or residue on the outside of the device may leave an imprint during the annealing process.

21 Prepare two more pieces of PET/PDMS/PET "bumper" slightly larger than the size of the device (at least 30mm extra length and width)

These pieces will be placed on the outside of the chip to help evenly distribute the pressure during compression. They will be removed after annealing.

22 Crease one corner and peel away one layer of the PET from one of the bumpers

Peel the PET away parallel again to create a sharp angle and facilitate the release of the two materials without wrinkles

Citation: Erik Werner, Elliot Hui [University Of California Microfluidic Digital Logic Chip Assembly https://dx.doi.org/10.17504/protocols.io.8efhtbn

23 Place the completed chip onto the exposed PDMS

24 Peel one layer off PET from the other PET/PDMS/PET bumper and repeat for the other side of the chip

25 Trim away any excess PDMS/PET bumper material

A few mm of material sticking out is fine

26 Sandwich the entire chip and bumpers between glass slides, ensuring the that entire device is between both slides. Parts that are not covered will not be compressed.

Other rigid materials, like aluminum plates or larger pieces of glass, may also be used to compress the device.

From top to bottom, the product should be: Glass, PET, PDMS, PMMA, PDMS, PMMA, PDMS, PET, Glass

27 Clamp with binder clips on all four sides.

Anneal

28 Transfer to an oven, setting the device vertically in the middle of the oven.

29 Heat to 110ºC and maintain temperature for long enough to heat the entire device thoroughly.

Time will vary depending on the oven. For a 3mm heat for at least 2 hours. It is better to let it heat longer than necessary than not long enough. If lamination results are not satisfactory, bake again and increase the time in the oven by 1 hour increments. If results are still not satisfactory, increase the temperature by 1ºC increments.

30 Set the oven to room temperature and allow to cool completely (preferably over night).

31 Remove the binder clips, class slides, and peel away the outer PET/PDMS bumpers. The device is now ready to use.

Citation: Erik Werner, Elliot Hui [University Of California Microfluidic Digital Logic Chip Assembly https://dx.doi.org/10.17504/protocols.io.8efhtbn

If the device will not be used immediately, the outer PET - PDMS bumpers may be left in place to protect the device from dust ingress.

Citation: Erik Werner, Elliot Hui [University Of California Microfluidic Digital Logic Chip Assembly https://dx.doi.org/10.17504/protocols.io.8efhtbn