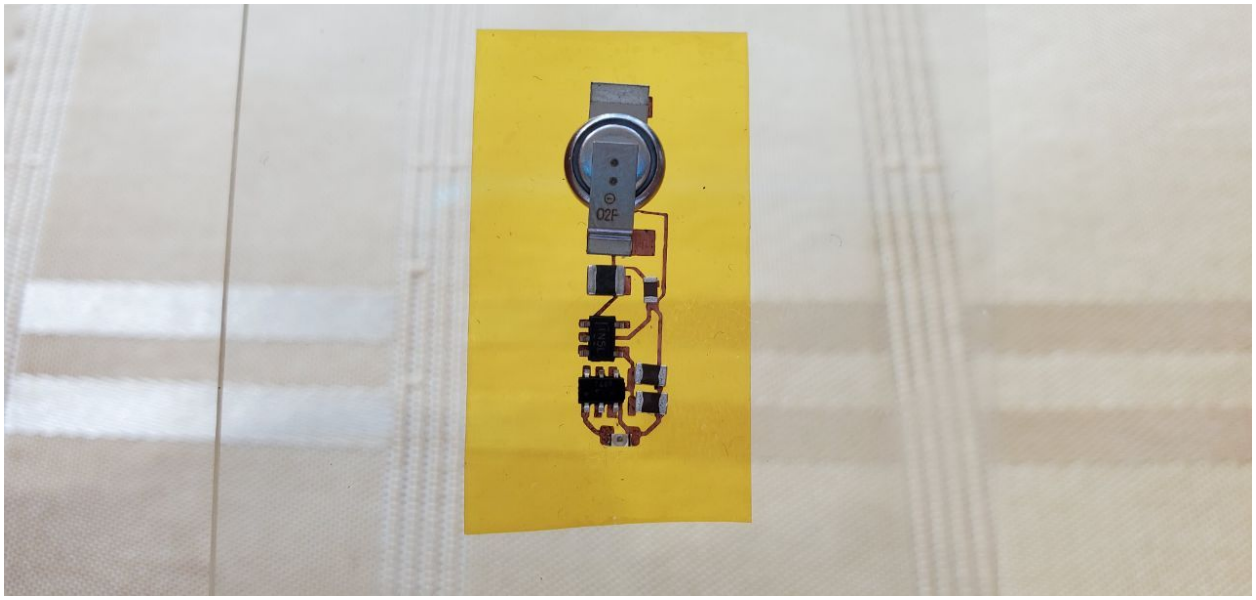
Binomica Labs

Binomica Bytes #1

DIY Flexible PCB Fabrication

V1.0



Aim of the Experiment

You'll learn how to easily make your own flexible PCB's for prototyping and learning using a minimal set of tools and resources.

Materials

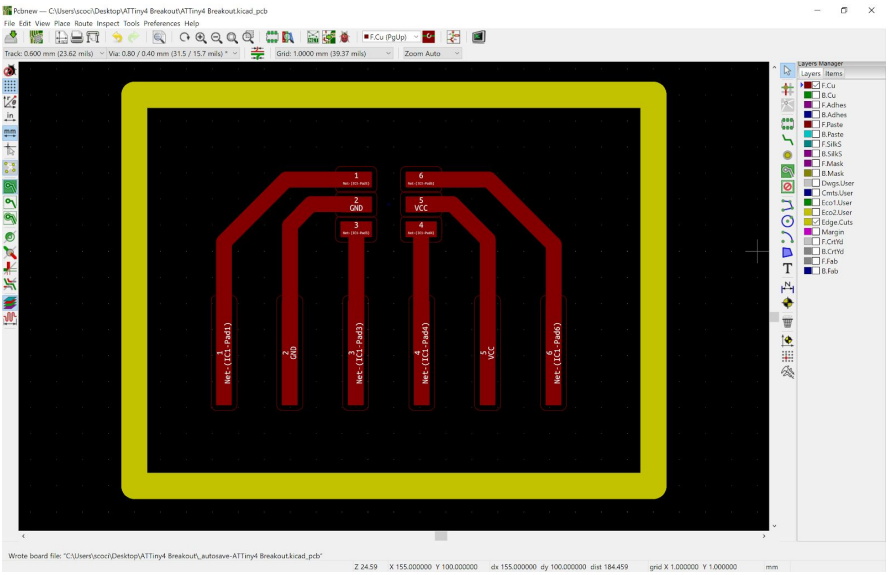
- Copper Foil (0.05mm thick)
- Kapton Tape (50mm wide)
- Photoresist Film
- Wright's Copper Cream
- Scotch Tape or equivalent
- Printer paper (any thickness but thinner is better)
- Hydrogen Peroxide 3%
- Hydrochloric Acid 37% (working on a vinegar method, updates soon)
- Sodium Carbonate (washing soda)
- Tap Water
- Scissors

Equipment

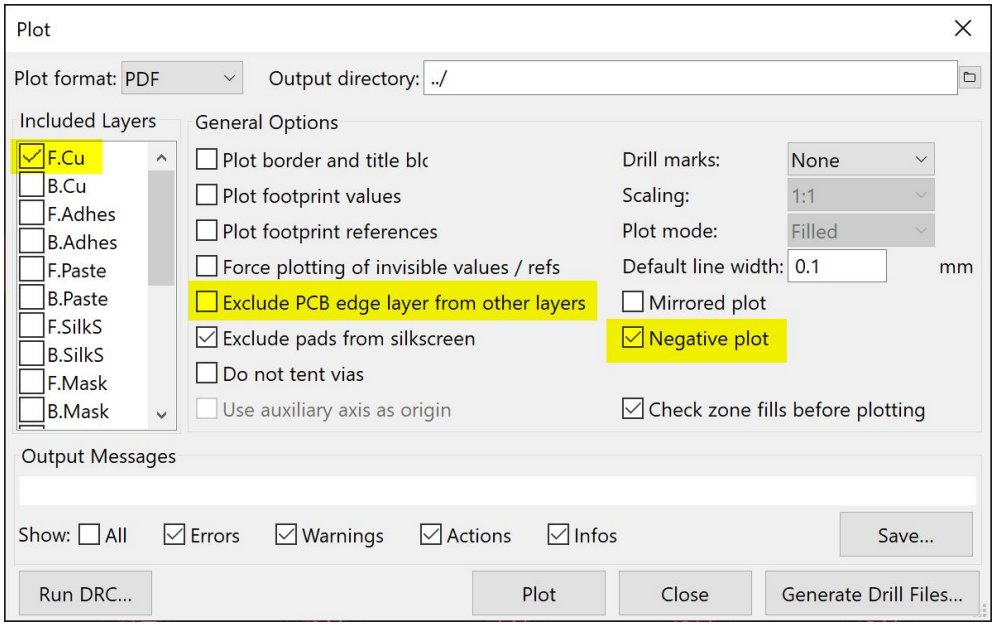
- Laser Printer (I use an old Brother but anything that uses toner will suffice)
- Laminator (semi-optional, works without but YMMV in terms of bonding)
- Light Source (I use a white LED light panel about 6" from source but you'll have to experiment to determine exposure time). Natural sunlight also works, just expose until it no longer darkens in color.

Instructions

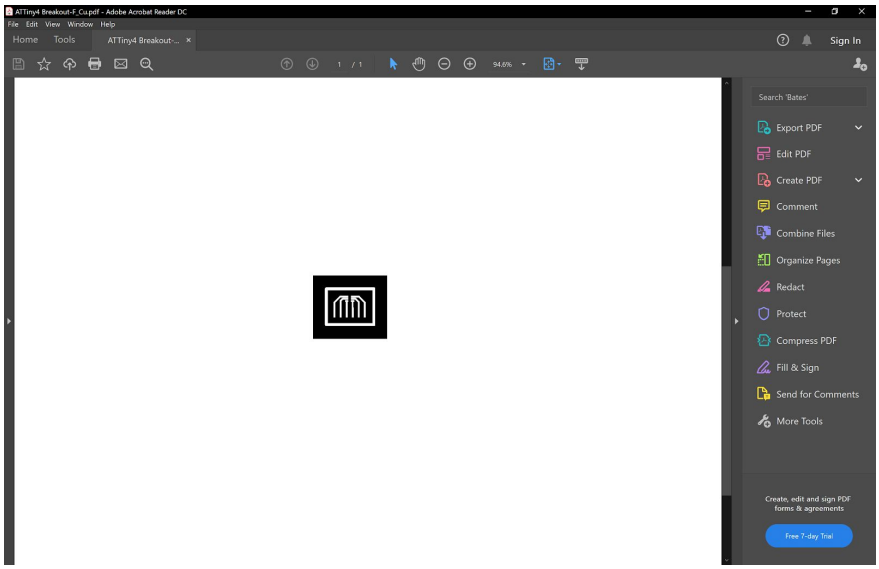
1. Design your PCB using whatever tool you prefer. I use KiCAD, there's an awesome course on Udemy which offers education on using KiCAD. Link here. I added a 1mm thick Edge Cut trace (yellow) to act as a kind of copper frame for the floppy kapton circuit which will fold once etched.



2. Plot the resulting PCB design to PDF using your EDA's export function. Here's my settings using KiCAD, note the highlighted regions.

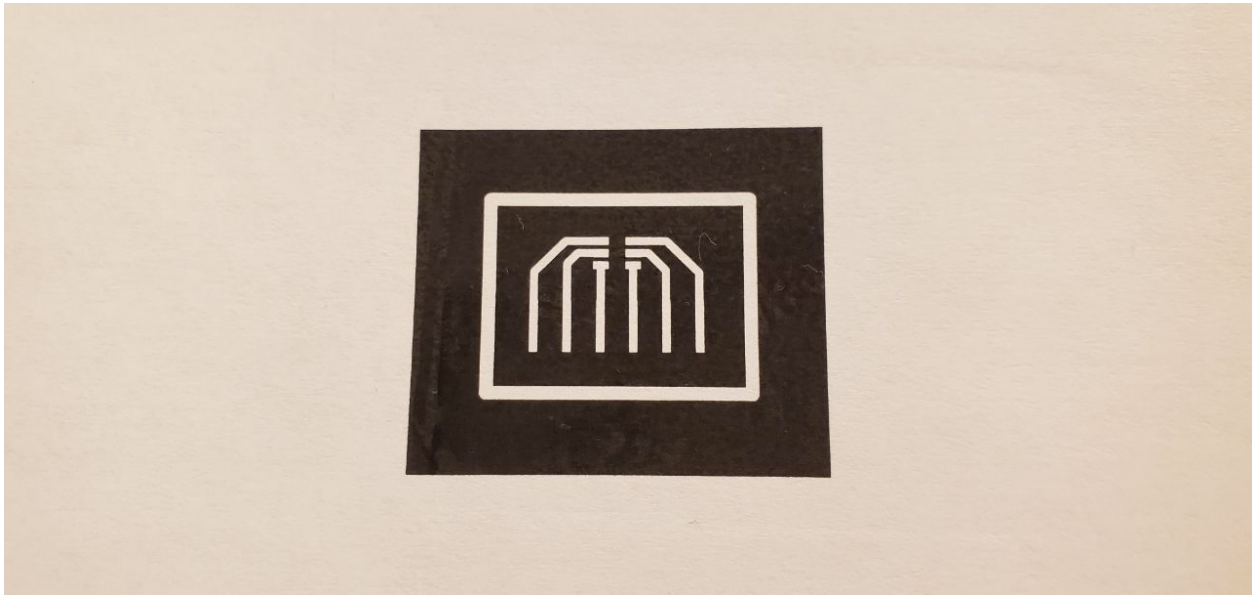


3. Check the resulting PDF for any errors or overlap, if you have a high enough resolution screen you can set the PDF zoom to 100% and measure or align parts directly to the screen to see if the sizing is correct. Note to be careful as screens can scratch.



4. On a sheet of paper in your printer's feed tray, make a mark to indicate the top of the paper closest to you. This will help align the paper once your copper is secured to it and avoid misprinting the toner circuit mask later.

5. Print the PDF and triple check no traces are touching where they ought not to. If your printer's resolution is too low, opt for larger traces. I find it good practice to always route the largest traces within reason to avoid any erosion caused by the etching process.



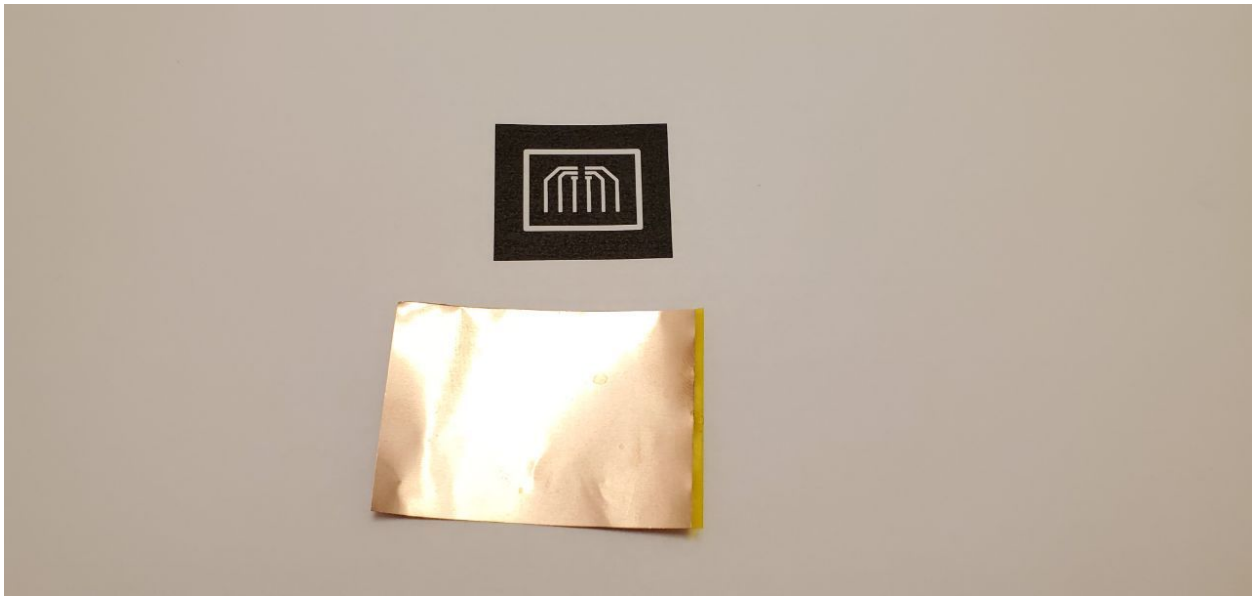
6. Wipe a sheet of copper with the copper cream to remove any trace of tarnish, this is important to ensure good adherence of tape to the foil. Rinse off and wipe dry. Once clean, avoid touching the surface with your bare hands as oils from your hands will oxidize the surface and tarnish the foil.

7. Lay down a strip of kapton tape neatly over the top of your copper sheet. Align the tape such that it is as straight as possible and no air bubbles are formed. IF you do spot air bubbles, peel off the tape and try again. It takes practice but your tape MUST be bubble-free.

8. Cut out tape-widths of your copper-kapton sandwich and store them for later use, avoid touching the bare copper surface if possible.

9. Cut out a small piece of the copper-kapton foil a bit larger than your intended print. This leaves room for printer error or miscutting. An excess of 5mm on either side is ample. Align the copper such that it's

in the middle of the printed PCB design, this step is crucial for getting a clean printed mask within the copper boundaries.



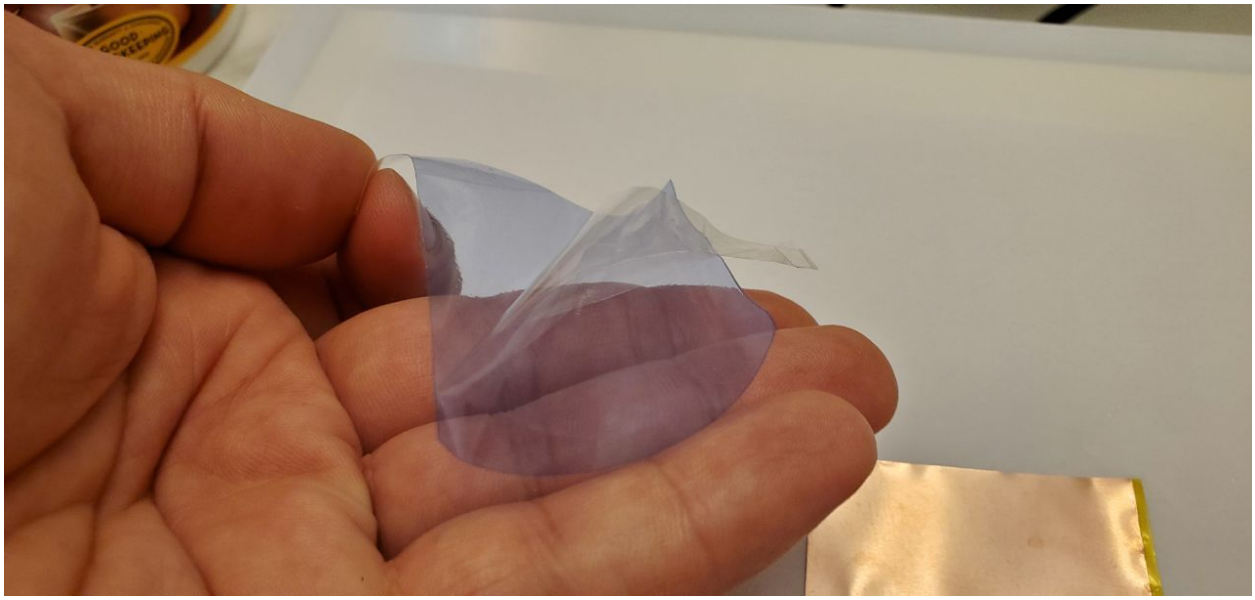
10. Tape down the corners of the copper so it does not move from the center of the PCB area. Do not tape too far into the copper foil or you'll block the adhesion of the photoresist to the intended area.

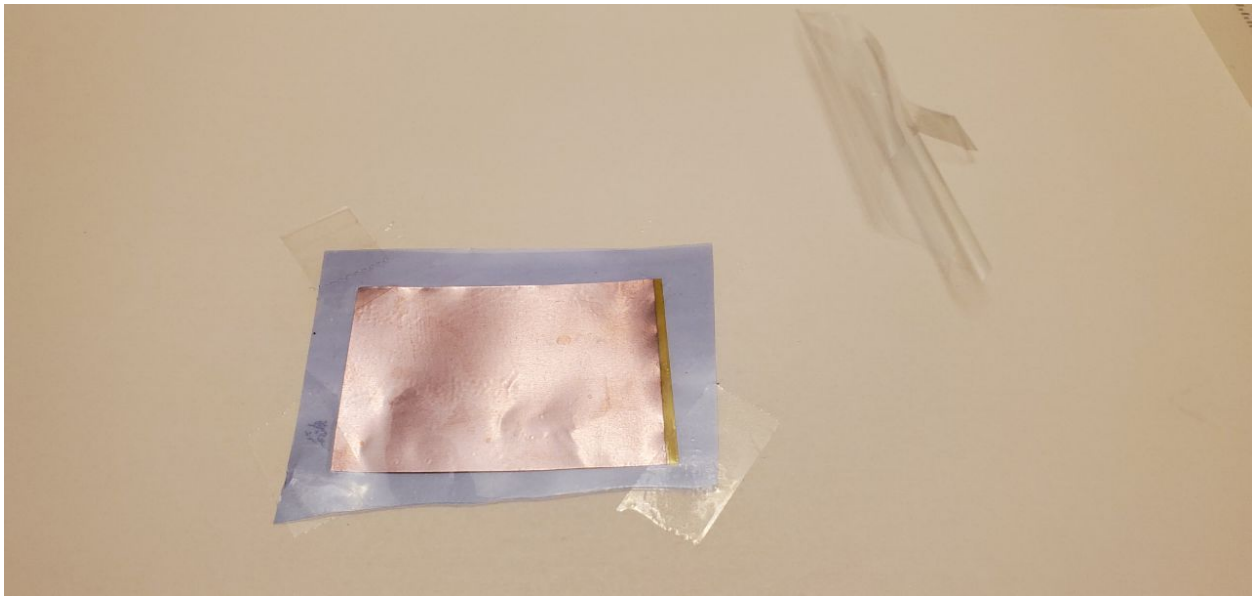
11. Cut out a piece of photoresist film a bit larger than your copper foil and place it over the cut copper foil to check sizing.

12. Make two tape tab strips by folding a small portion of each strip of tape (1" or so) onto itself creating a little pull tab. This is gonna be important for the next steps.

13. To one of the corners of the cut photoresist sheet, apply a tape tab strip at a 45 degree angle to the corner on either side. Line up the tabs such that the folded over parts of both strips line up. Firmly press the tape tabs together to tightly seal around the corner of the photoresist.

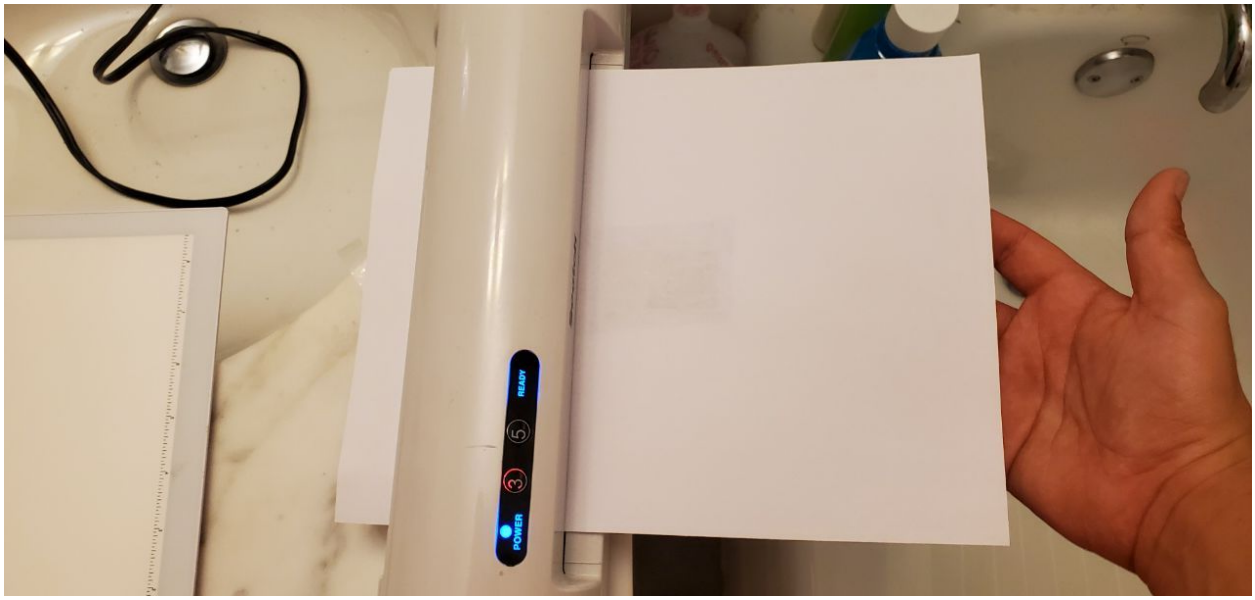
14. Carefully peel apart the two tape tab strips. The protective layer of the photoresist film (clear) will peel away on with one tab and the actual photoresist (purple-blue) will follow the other tab. Discard the protective layer sheet and apply the photoresist to your copper sheet. Do not press down until everything is lined up and then begin to press down gently using a paper towel or toilet paper square starting from a corner and working your way to each edge. Avoid forming bubbles at all costs, if you do form it and it is in a spot the circuit will be printed onto, it would be wise to peel off the photoresist and try again. This is a very critical step and the quality of the photoresist's adherence will make or break your etched circuit. Take your time with it and practice.





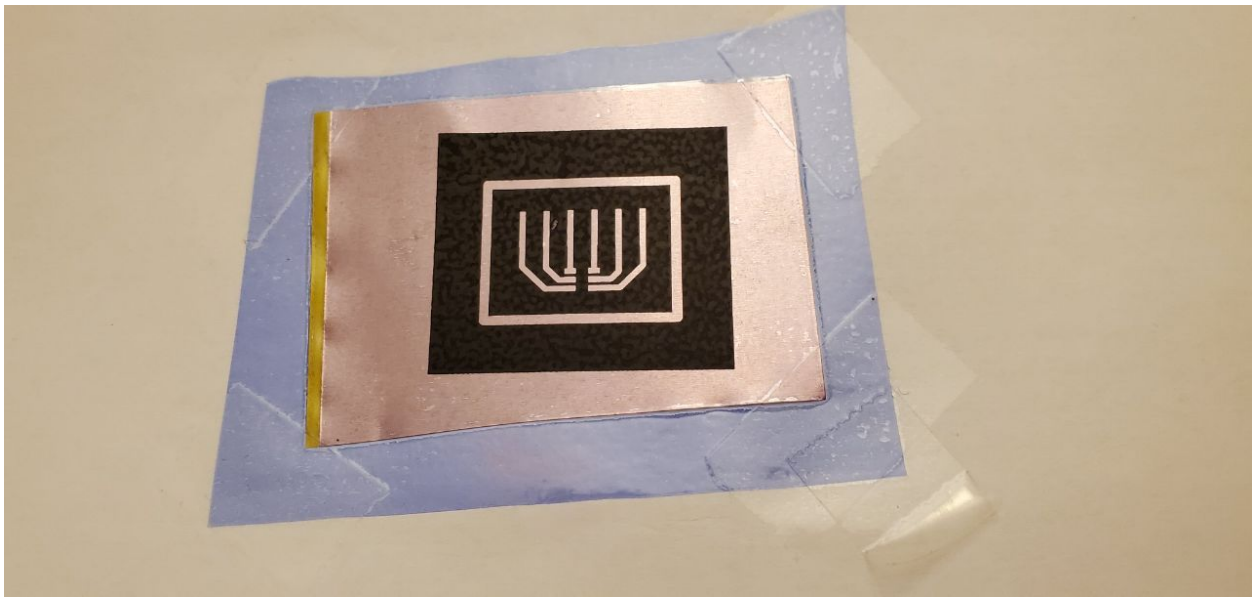
15. Heat up your laminator and when ready, set it to the tightest setting (3 mil on my laminator). Place a sheet of paper over your photoresist-laden copper foil and feed it through your laminator. Do not pull or tug on the sheet and try to keep it level at all times to

avoid warping or bends in the copper.

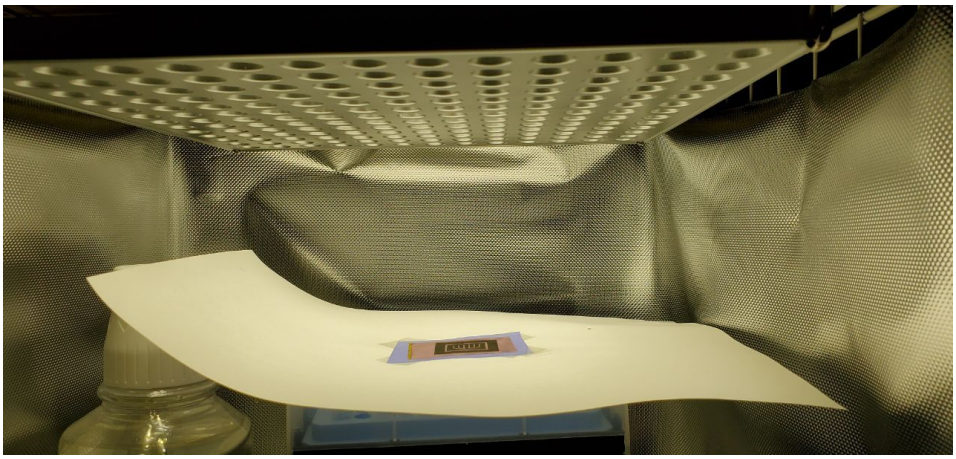


16. Once laminated, you're ready to print! Place your copper-kapton-photoresist-paper sheet into your laser printer, aligning the initial mark to the same position. In your printer settings, ensure it's at the highest DPI possible (mine is 1200) and no toner-saving settings are in effect. This will ensure a jet black finish. Click print and fingers crossed!

17. Inspect your print for any flaws in the circuit artwork. Fill in any scratches or inconsistencies with a sharpie or, ideally a black paint marker. Don't worry if it's not completely dark, the difference between the light and dark areas within the exposure window will suffice.

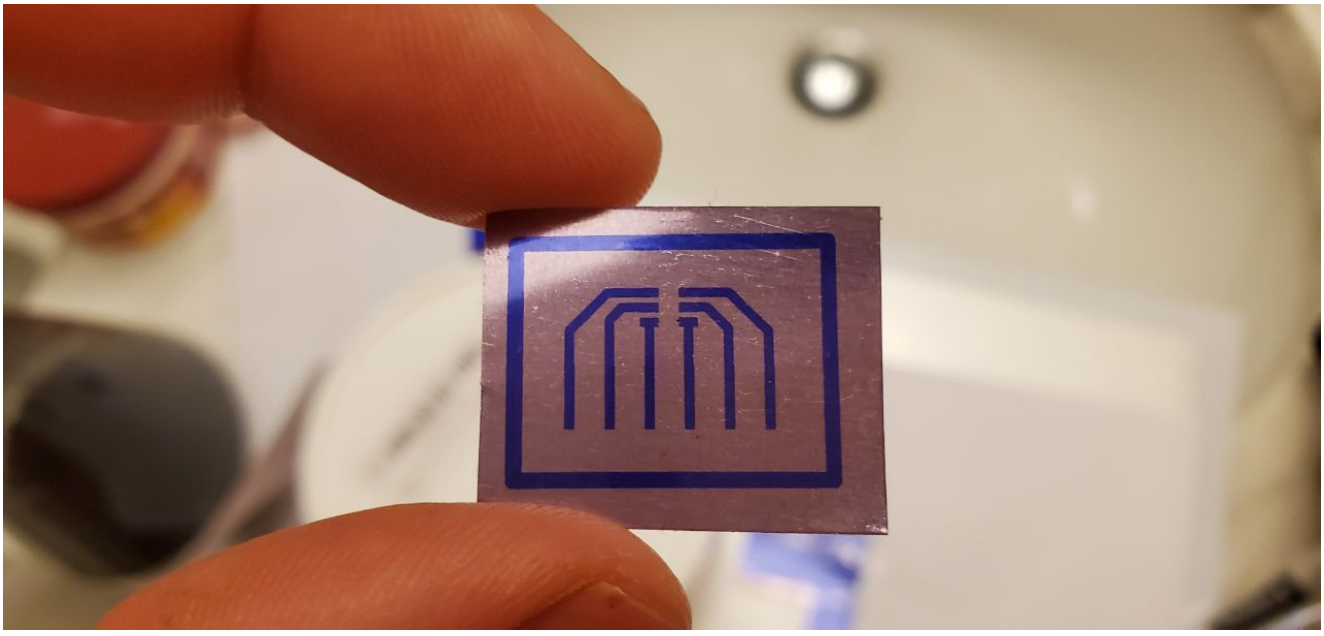


18. If all looks good, place your masked copper under a bright lightsource until the photoresist color turns into a dark ultramarine. You'll know when it's ready as the color is very saturated. Use a spare bit of photoresist on the side ahead of time to determine the best exposure. A very stark color difference between exposed and unexposed photoresist is important; any underexposure will lead to the mask dissolving during the next steps.

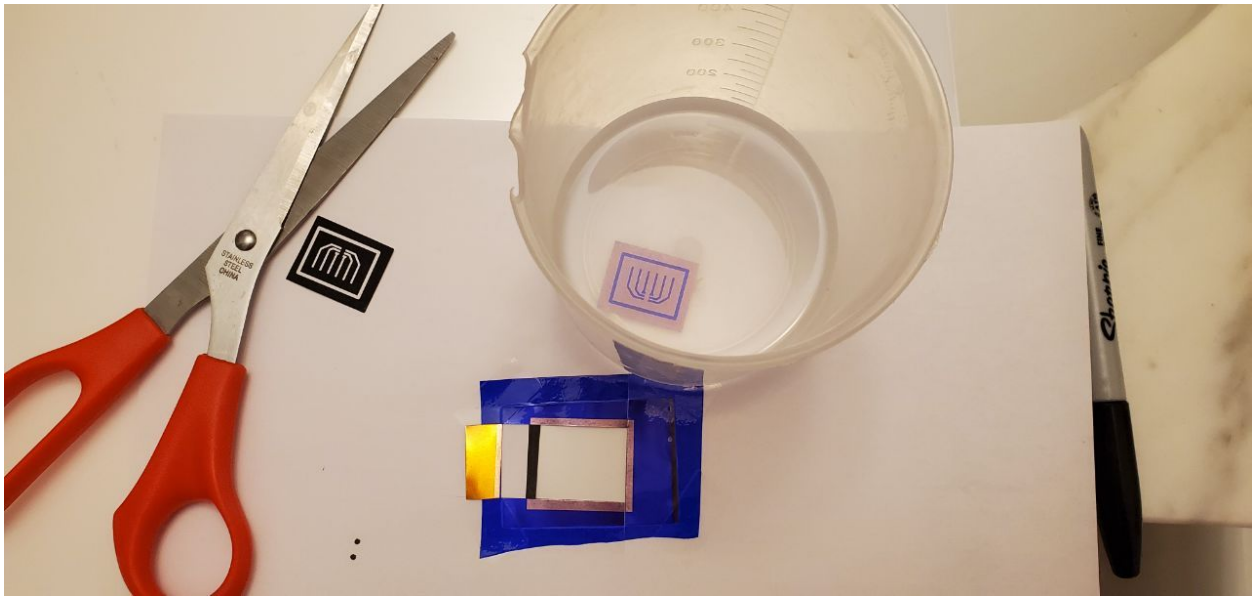


19. Once the exposure is complete, peel off the photoresist film using the remaining tape tab strip and examine the resulting copper surface. The masked regions should be a pale translucent blue-purple and the exposed photoresist should be very dark ultramarine.

20. Cut out the copper using scissors. Cut just a bit larger than the perimeter of the 1mm edge cut outline. Ensure you do not touch the surface of the copper with bare hands.

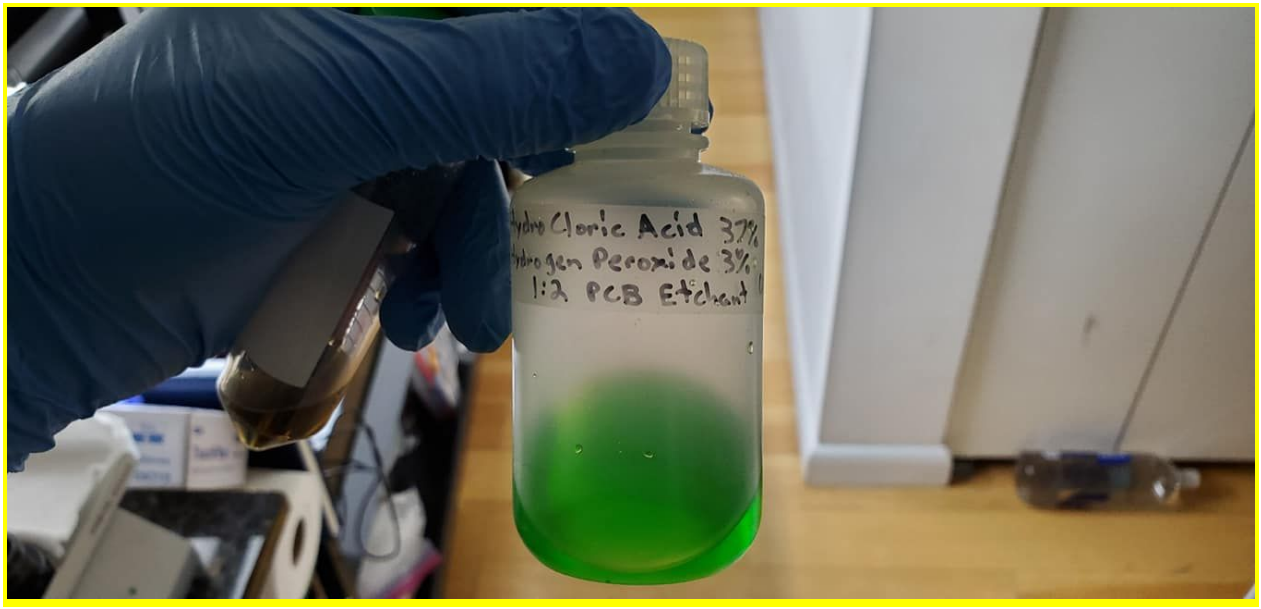


21. Place the cut copper into a small beaker of sodium carbonate (30g/L), for this run I used 100mL of tap water + 3 grams of washing soda. Stir occasionally and remove once the unexposed photoresist dissolves completely leaving behind the darker exposed mask and a raw copper background. You'll know it's done if you gently rub your **GLOVED** fingers over the artwork and no slimy sensation is felt. Rinse the copper with tap water and pat dry.

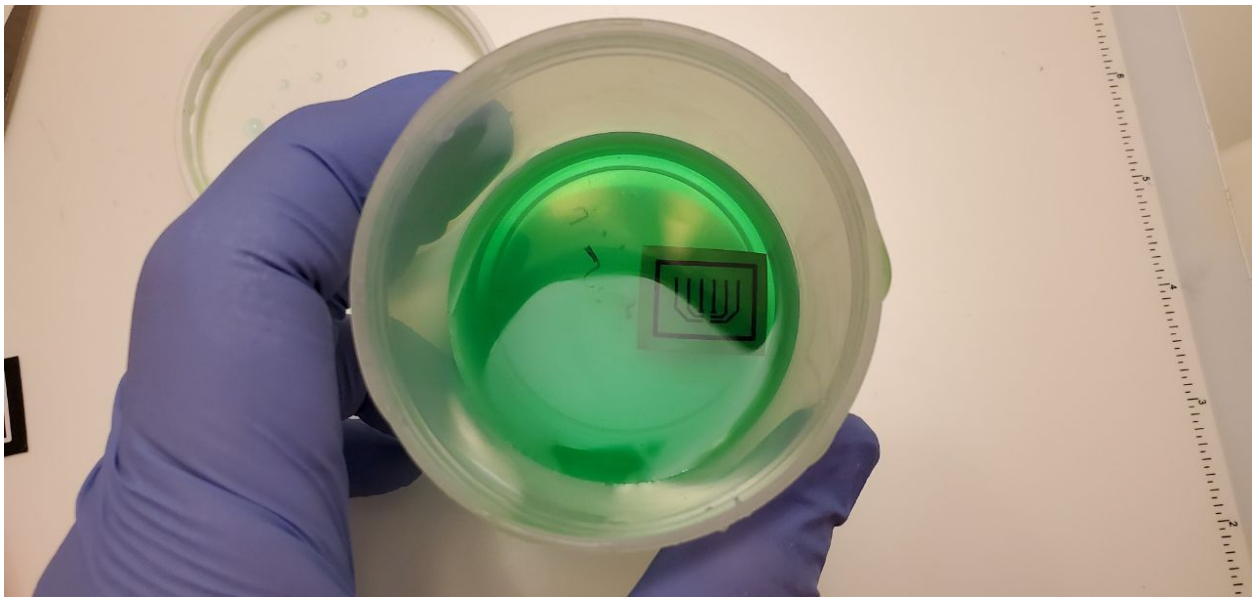


22. Prepare your etchant of choice. I prefer a 1:2 solution of Hydrochloric Acid 37% to Hydrogen Peroxide 3% but you can use

traditional PCB etching solutions like Ferric Chloride or Ammonium Persulfate. If you decide to make your own HCL + H2O2 etchant, you MUST WEAR PROPER PPE ESPECIALLY GOGGLES!!! I make no more than 50mL of said solution as it is regenerable by adding more H2O2 when the solution turns brown. To make the solution, chill a small beaker of H2O2 on ice until cold. Then, in a well ventilated area wearing all the appropriate PPE for acid handling, add the HCL to the H2O2 SLOWLY using no more than 1mL at a time. Thermal runaway from this reaction can produce copious amounts of chlorine gas and is extremely dangerous if mishandled. You've been warned. Once you mix all of the solution, your etchant is ready. It will appear as a clear liquid so please properly label the container and keep it in a safe place. Over time, your etchant will appear emerald green as more and more copper gets dissolved into solution. This is normal and can indicate the "health" of the etchant. If brown, add more H2O2. If blue-ish, add more HCL. As you regenerate the solution, the volume will grow so plan accordingly and work with the smallest volumes possible. Once you amass too much etchant, dispose of the etchant according to local, state, and national laws in accordance with your country's waste management regulations. The solution contains acidic cupric ions which are toxic to the environment so DO NOT FLUSH DOWN TOILET OR POUR INTO DRAIN!!!



23. Place your masked copper into a small glass, polypropylene or polyethylene container and add just enough etchant to cover the PCB 3 to 4 times over. Stir occasionally and monitor the etching process, ensuring that you pull the circuit out when all the background copper has been etched from the tape. You CAN overetch so do not let it sit too long. Depending on the freshness of your etchant, it may take 5 minutes to about one hour. Experimenting is important so practice patience and note the changes.



24. Once etching is finished, remove the circuit from the acid etchant using tweezers and gloved hands, rinse off the tape circuit with tap water. Inspect the final circuit for proper etching.

25. If the circuit passes inspection, prepare a solution of saturated sodium carbonate (300g/L) and soak the circuit in this solution until the dark ultramarine exposed photoresist peels off the etched copper. This can take some time but try not to brush or rub the resist off as it may damage the fragile copper traces. The photoresist should peel off by itself as it's less dense than water and will float away.

26. Inspect the finished circuit for poor etching, residual photoresist, etc. Check traces with a multimeter in continuity mode to check for shorts. If everything checks out, you now can make PCB's at home that are flexible and cheap. Enjoy!

Tips and Tricks

If you want a more rigid circuit, be sure to use a ground plane fill in your design if space permits. Adding thermal reliefs help with soldering if the circuit is large and your soldering iron is not up to snuff when it comes to heating larger ground plane's worth of copper.

Tinning the entire board could help with placing the components and soldering them but will make the circuit rigid, consider tinning once you know the shape your circuit will bend onto or into.

You MAY have some luck skipping the laminator entirely but I've had hit or miss results in terms of the photoresist binding properly to the copper.

If you can't purchase the copper cream cleaning agent, you can make your own using lemon juice, baking soda, and citric acid. Look up home remedies for polishing copper on YouTube for clever hacks using readily available supplies.

Your circuit's "board" will be sticky since it's technically the adhesive side of the kapton tape. Sprinkling some silica powder onto the circuit board can neutralize the sticky surface without oxidizing or interacting with the copper metal.

Consider encapsulating your circuit in a resin or epoxy for protection and waterproofing, in case your circuit will be submerged or in harsh environs. Note the traces are bare copper thus will tarnish with time. The patina is not harmful to the circuit unless you see a green or blue oxide layer. IF you do see this, clean with copper cream, rinse with 99% isopropyl alcohol or a dedicated electronics cleaning product. Dry completely before energizing the circuit.

You can find larger sheets of kapton or "polyamide" film if you desire and also if you're feeling lazy, you could always purchase the finished product as the name brand Pyralux but a 6" by 4.5" sheet is about $16 which I find extravagant to say the least.

You can find larger rolls of copper sheet if you hunt around online and, of course, prices of items linked will be far cheaper on AliExpress of Ali Baba if you don't mind waiting 2 weeks. Just note 0.05mm or thinner is ideal.