



A Process of Chemically Etching Circuit Boards

Application Note

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Abstract:

In this application note, a step by step process of chemical etching will be presented. In addition to the process of chemical etching, the pros and cons of various chemical options, substrate selection, and equipment choice will be discussed in the appendix section.

Introduction:

Chemical etching is a process of printed circuit board (PCB) manufacturing that provides many advantages over mechanical methods. Most importantly, chemical etching is a very low cost procedure that requires only a few inexpensive chemicals and very little equipment. The inexpensive setup of chemical etching also makes it a very accessible means for hobbyists and professionals alike to develop their own PCBs.

In chemical etching, a “mask” is created by inverting the colors of the PCB design such that the parts of the board that are desired to be etched are transparent, and the remainder is black. The mask is then illuminated with UV light onto a copper substrate such that the desired PCB design is etched onto the substrate, as shown in Figure 1. Chemical Etching can provide varying degrees of maximum resolution depending on the quality of the equipment and chemicals used. For the equipment used in this application note, a maximum resolution of $\sim 150\mu\text{m}$ was achievable. While chemical etching does provide a high resolution, accuracy can be an issue due to a number of errors that may occur, such as miss-alignment with the mask and substrate, over etching, or under exposure.

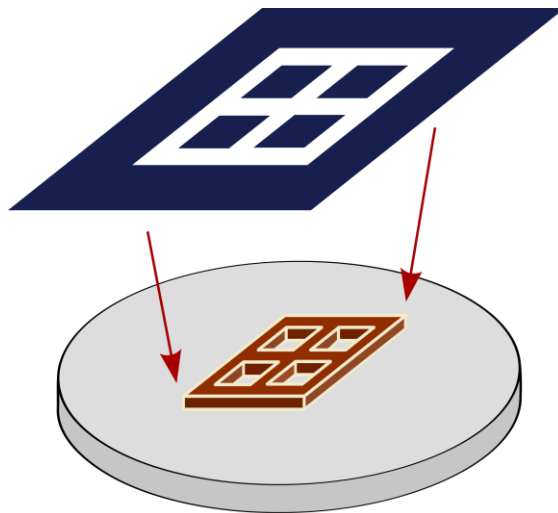


Figure 1 - Mask Being Transferred to Substrate.

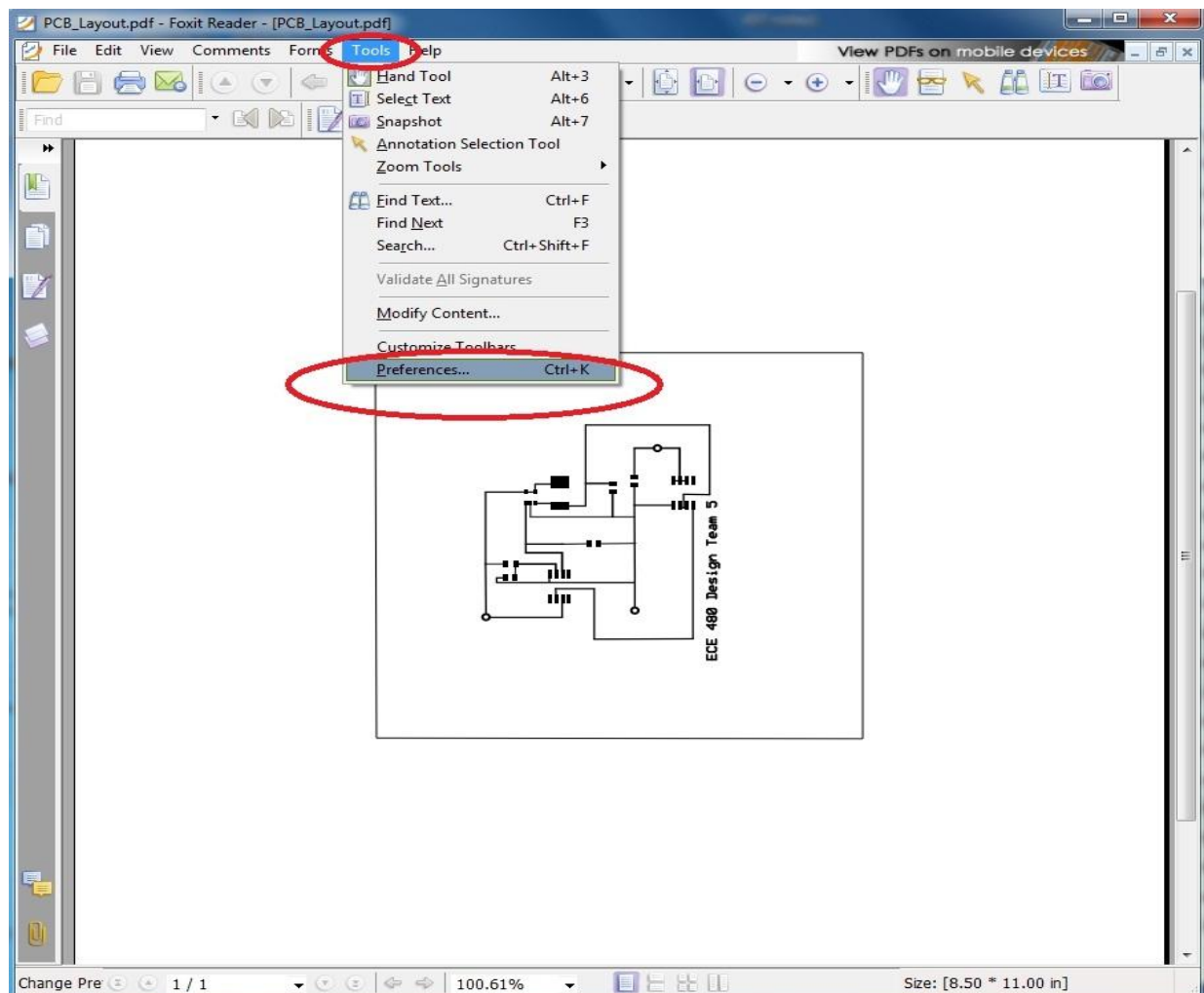
Chemical Safety:

Before following this application note, or even thinking about setting up a chemical etching system to manufacture PCBs at a hobbyist or professional level, make sure to read the proper materials safety data sheets (MSDS) associated with each of the chemicals involved. The chemicals used in the etching of PCBs tend to be very toxic, and need to be handled and disposed of properly. It is fundamentally wrong to pour toxic chemicals down the drain, outside, on someone else's property, or dispose of them in anyway other than in accordance with the proper MSDS.

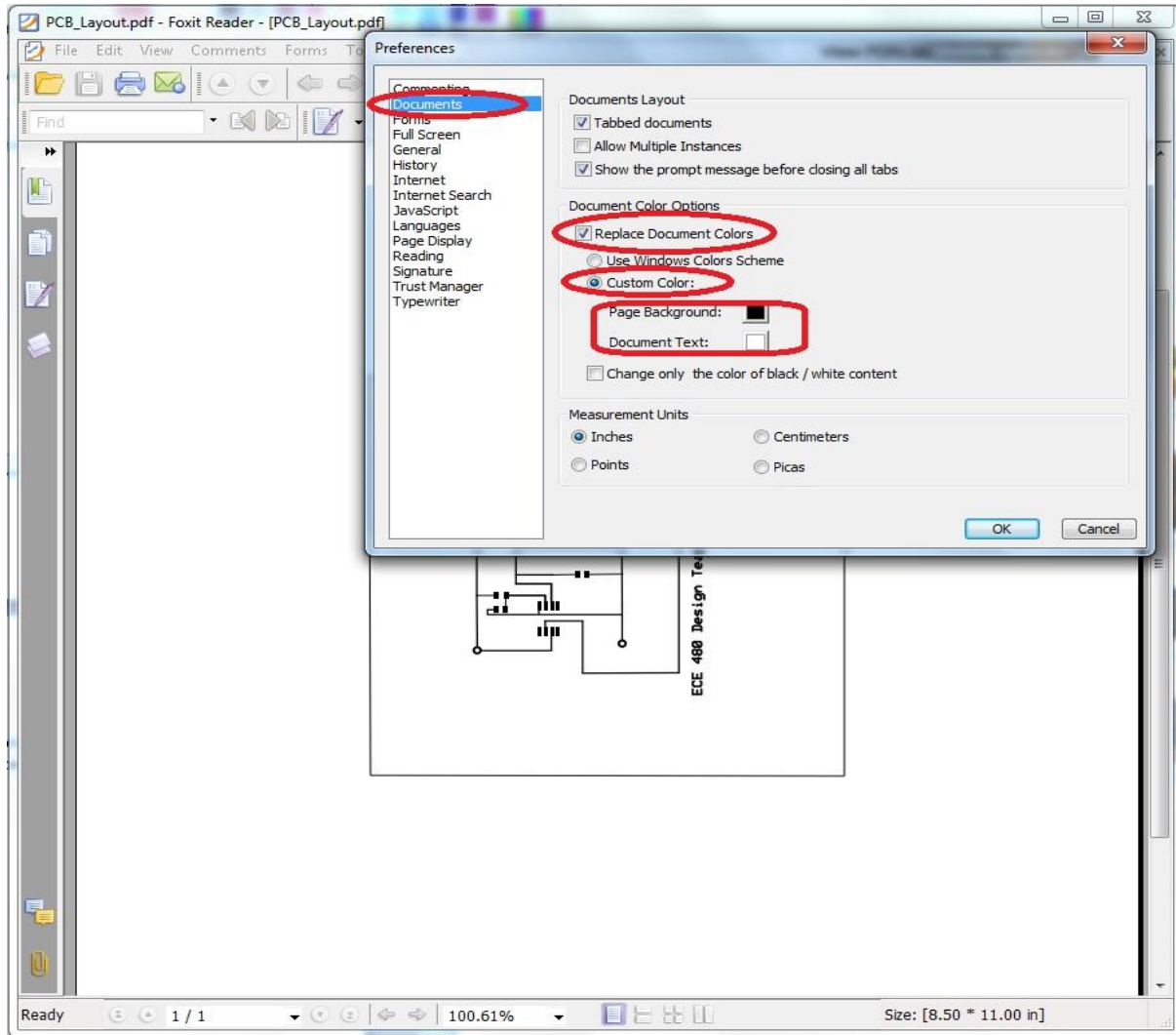
Chemical Etching Process:

- **Preparation:**

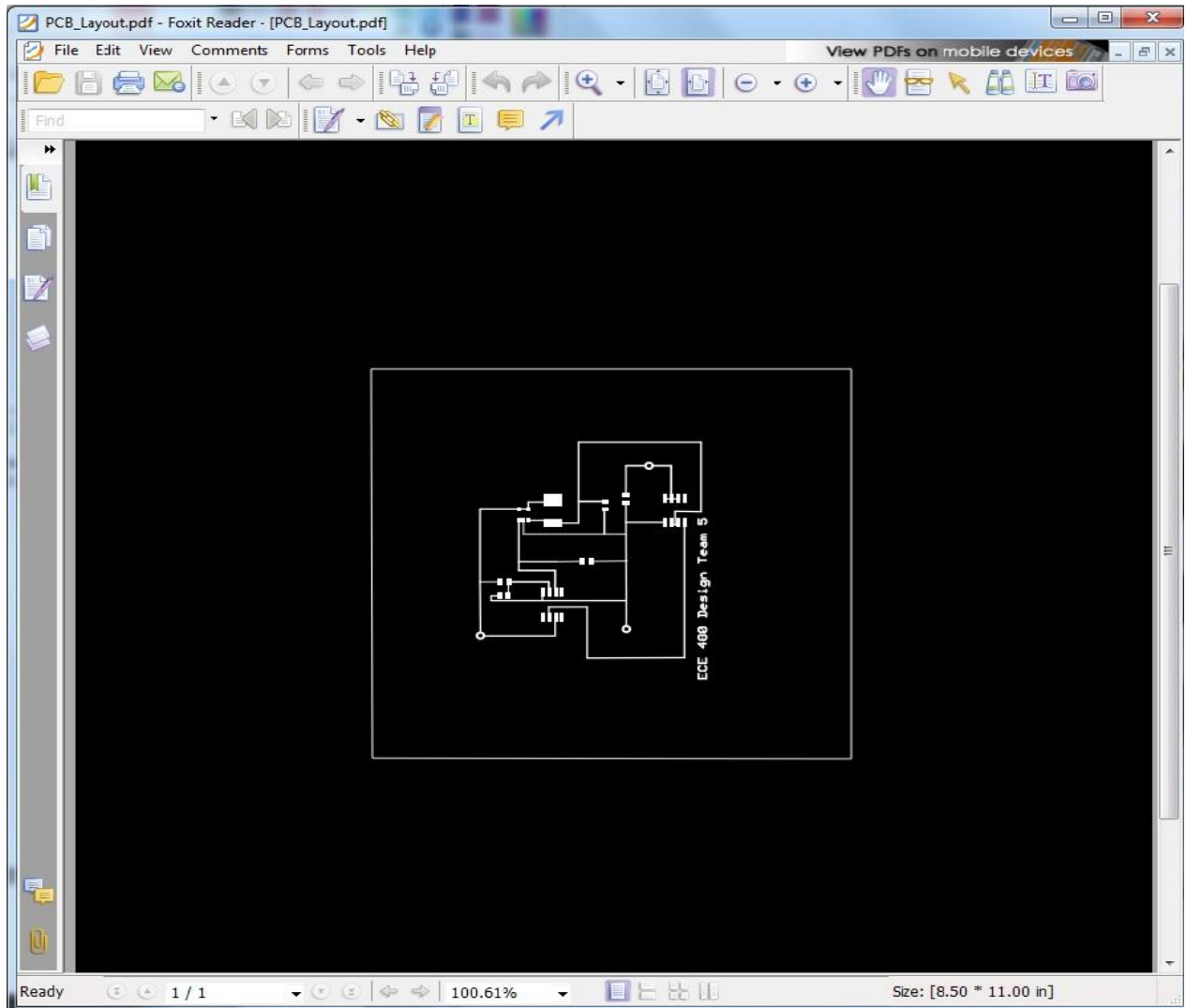
The first step in the chemical etching process is creating a proper mask. This can be accomplished by saving the PCB design as a .pdf file format, which most PCB editors allow. Once saved as a .pdf file, the design can be opened in pdf editors such as *Foxit Reader*^[1]. Once the file is opened in *Foxit Reader*, select: *Tools > Preferences...*



Once in the preferences tab, select: *Documents > Replace Document Colors > Custom Color > change the Page Background to black > change the Document Text to white.*

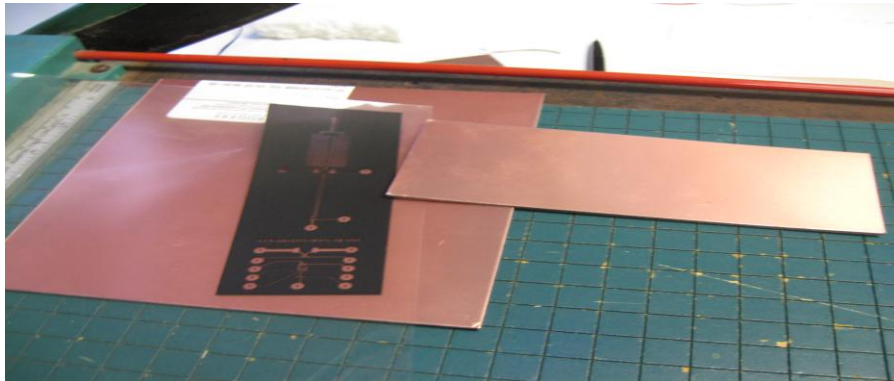


Finally, once the color options are set correctly, select OK to save the changes. The background color should be inverted black, and the traces and part layouts should be white. This will then be printed onto transparency paper, where the white will become transparent.

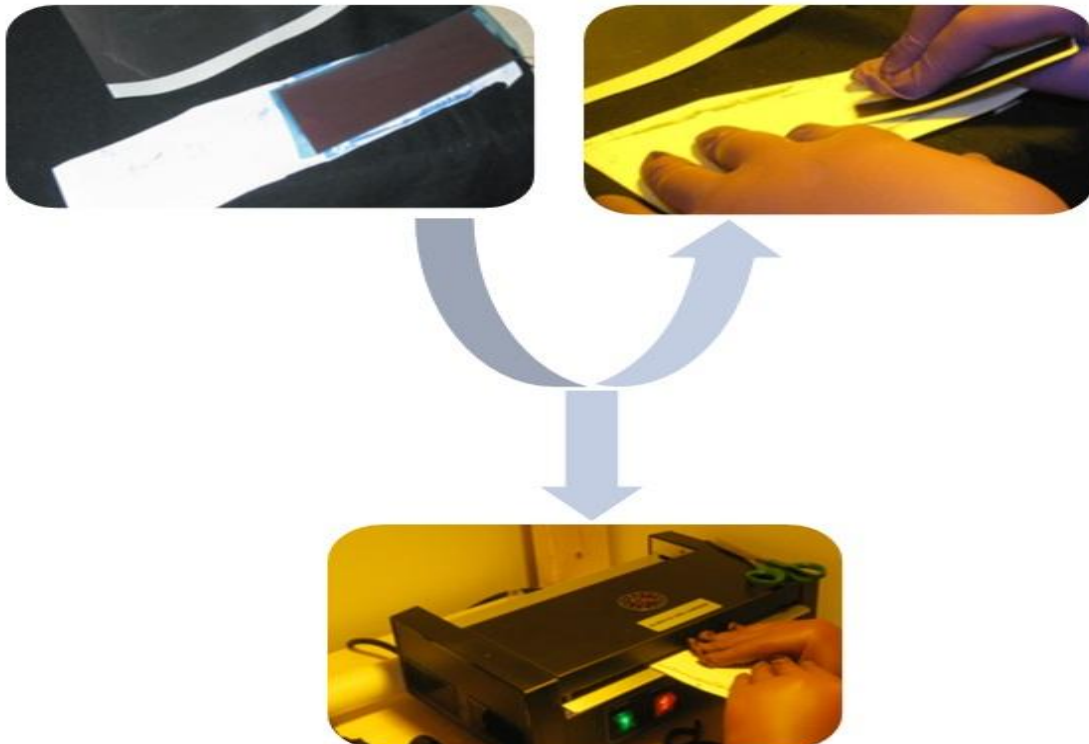


- **Lamination:**

Once the mask has been prepared, the substrate is cut to the proper length.



Next, the plastic protection layer needs to be peeled from each layer of the substrate that is desired to be etched. Afterwards, a thin layer of negative dry film resist is placed onto the substrate, peeling the side of the resist which will be placed onto the side of the substrate which will be etched. After the layer of resist is placed on the substrate, air bubbles may appear between the surface of the substrate and the resist. Pressure must be placed on the film to eliminate the air bubbles so that the film is uniformly distributed onto the substrate for proper etching. This can be done with a student I.D. or credit card. Once the air bubbles have been properly removed from between the resist and substrate, the substrate and laminate are to be placed into a laminator, once for each side, to secure the resist on the substrate. Once laminated, the other side of the resist must be peeled off of the substrate.



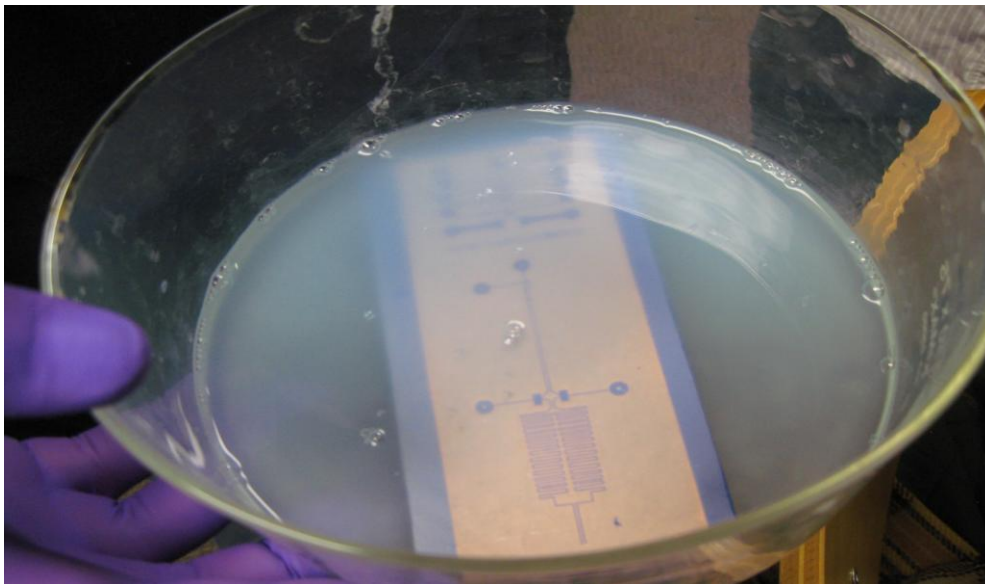
- **Exposure:**

Once the substrate is properly laminated with resist, the board must now be layered with the mask and exposed to UV light. Correctly place the mask into the UV exposure frame, and then place the laminated substrate on top of the mask. Make sure the mask is correctly oriented, and that the substrate is covering the entire mask. Exposure time varies depending on the type of exposure frame; however, the exposure used to develop the boards in this application takes roughly 10 seconds.

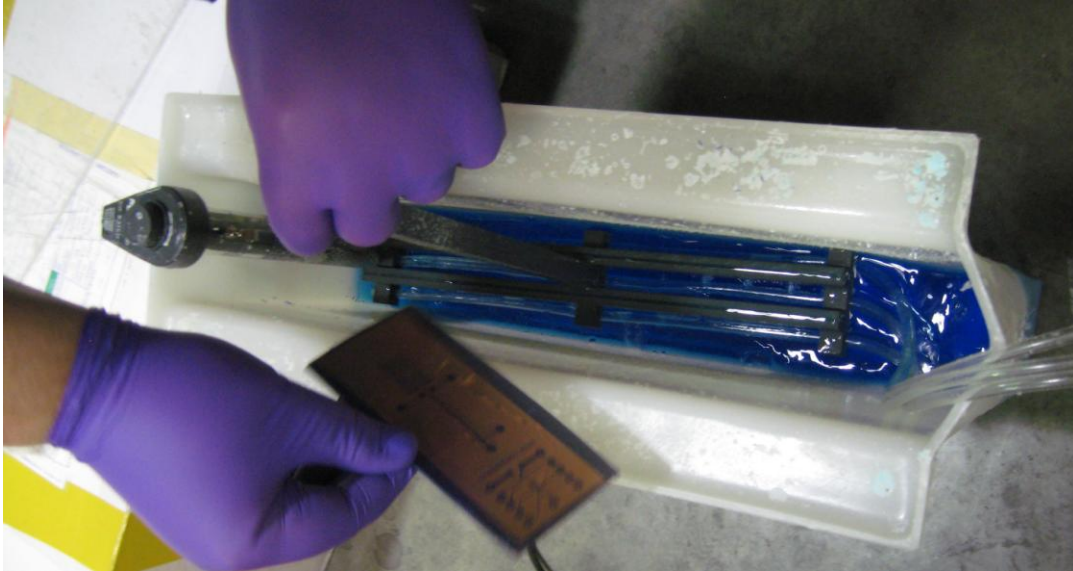


- **Etching:**

After the substrate has been exposed to UV, the board needs to be immediately placed into a developer solution while being careful not to expose the board to any light. A solution of 10:1 water and negative developer is used as the solution which removes any excess exposed resist and prepares the board for etching.



Once the excess resist has been cleaned off the board, the substrate is ready for etching. The etching solution used for this application note is sodium persulfate, although there are other options available. The board is to be submerged into a tank of etching solution, which is circulated through the tank by a water pump. This etchant will completely remove copper from the substrate, except for where there is resist still on the board. This leaves copper only where traces and parts are meant to be inserted.



- **Final Steps:**

Once the board has been etched, a solution of acetone is wiped onto the substrate. This solution removes the resist from the substrate, revealing the copper below. The copper is then rubbed with Metal Polish to remove any excess resist and polish the copper. This finishes the fabrication of the PCB.



Conclusion:

In conclusion, a process of chemical etching PCBs has been presented. This method is low in cost, fast, and easily repeatable. The final results of this method are shown to be well crafted and useable. More information on the specifics of the chemicals and equipment involved is presented in the appendix section.

Appendix:

- **Chemicals**

A number of different etching chemicals are available, providing advantages and disadvantages with each option. Sodium persulfate was the etchant used in this application note, primarily due to its less toxic nature. Another benefit of sodium persulfate is that the solution will turn blue as the board is etched, allowing careful monitoring of the etching. Ferric chloride is another chemical option for etching, and is one of the most commonly used. This is primarily due to its relatively low cost. However, ferric chloride is very toxic and environmentally unsafe, which is why it was not chosen for this application note. Ammonium persulfate is also used as a chemical solution for etching. However, Ammonium can be very expensive, and hard to control. Various acids such as acid cupric chloride and hydrochloric acid may also be used as etchants. Acids such as these make for an extremely powerful etchant, reducing etching time. However, these acids are extremely toxic and cannot be inhaled or touched, making them very difficult to use.

The developer used to strip any excess metal from the substrate before etching is negative developer, which can be found from MG Chemicals [2]. This developer is normally paired with a negative dry film resist, also found from MG Chemicals [3]. The MSDS's for all of these chemicals can be found at the MSDS solution center [4].

- **Equipment**

The UV exposure in this application note was achieved through use of a Kempro BTX 200A Ultra Violet Exposure Frame. The time used for exposure in this application note was three clicks on the timer embedded in the Kempro exposure frame, or roughly 10 second. Any laminator can be used to laminate the boards, and are widely available. The tank used in etching can also be chosen from any widely available, and the corresponding pump is generally the same as used in a fish tank.

- **Substrate**

Substrate selection is primarily determined by the operating frequency of the circuit to be fabricated. In this application note, only DC signals were used, allowing essentially any substrate to be used. However, if higher frequency applications such as RF or antenna manufacturing are desired, substrates with low $\tan\delta$ losses such as the RT/duroid substrates from Rogers Corporation [5] are needed.

References:

[1] *Foxit Reader Software.*

<http://www.foxitsoftware.com/pdf/reader/>

[2] Negative Dry Film Resist, MG Chemicals.

<http://www.mgchemicals.com/products/4170.html>

[3] Negative Developer, MG Chemicals.

<http://www.mgchemicals.com/products/416dfr.html>

[4] MSDS solution center.

<http://www.msds.com/>

[5] RT/duroid High Frequency Substrates, Rogers Corporation.

<http://www.rogerscorp.com/acm/producttypes/2/Rogers-High-Frequency-Laminates.aspx>