PCB Fabrication Process

This process for fabricating a PCB is referred to as the “Print & Etch” method. So named because a pattern of the circuit is ‘printed’ onto a laminated copper substrate, then a chemical ‘etchant’ selectively removes Cu from areas of the printed image. This is a ‘subtractive’ method since material is removed. Alternatively, there is another common method called ‘pattern plating’ where Cu is selectively plated onto a substrate. The pattern plating the process for making PCBs is an ‘additive’ process.

Combinations of additive and subtractive processes using photolithography (image transfer) are the basis for the manufacture of all PCBs and nearly all the electronics circuits and devices you’ll ever see or use. Let’s describe the process for fabricating a PCB using the print & etch technique. This will also likely be demonstrated by the instructor in lab.

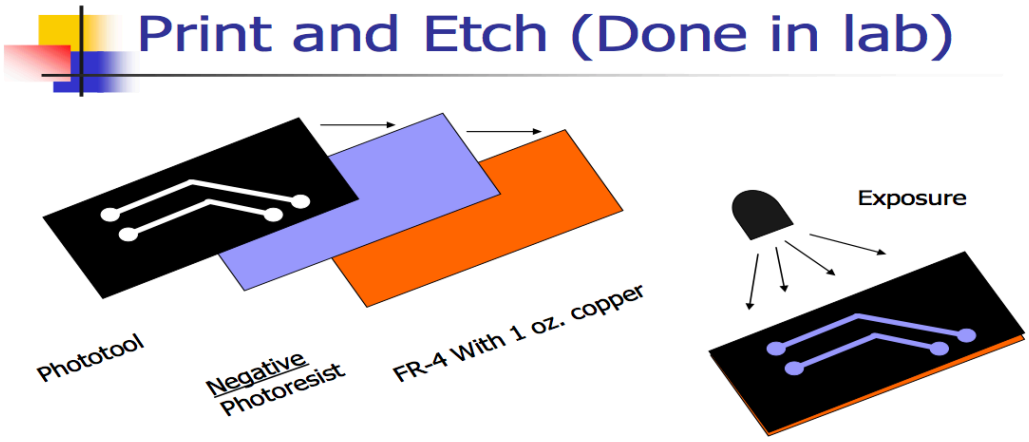
First, a raw stock single-sided board (SSB) or a raw stock double-sided board (DSB) is cleaned with water and a scrub pad. If a board is excessively dirty, a mild detergent such as dish soap can be used. Once a board has been cleaned, it should be handled by the board edges or using gloves to avoid getting finger oils or dirt on the copper.

Next the board is dried in an oven for at least several minutes. The cleaning and drying of the board prepares it for application and good adhesion of photo-resist. Photo-resist is a material that is sensitive to light energy. When exposed to a light source, such as UV light, the photo-resist changes chemically. There are two types of photo-resist: negative and positive. Negative photo-resist becomes hard when exposed to an energy source, positive photo-resist becomes soft. The PCB fabrication process uses negative photo-resist. The IC fabrication process uses positive photo-resist.

In addition, there are dry photo-resist and wet photo-resist materials. Dry photo-resist is a relatively thick solid film material while wet photo-resist is a liquid. Dry photo-resist is used in PCB fabrication and wet photo-resist is used in IC (integrated circuit) fabrication as will be discussed in lecture.

Dry photo-resist film is applied to the copper surface of the board with a laminator. A laminator is a machine which uses high heat and pressure to adhere the photo-resist to the copper.

After lamination, a photo-tool is placed adjacent the applied photo-resist. A photo-tool is a negative of a circuit trace pattern most often generated by a CAD (Computer Aided Design) program such as Dip Trace. The transparent areas of the photo-tool correspond to the eventual circuit traces. With the photo-tool held adjacent to the photo-resist, UV light is applied to the assembly as shown pictorially below.



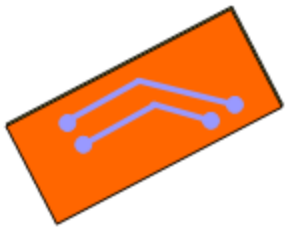
In our lab, the UV light is applied for 90 seconds - enough time for the exposed photo-resist (photo-resist underneath transparent areas of photo-tool) to become hard, but not too much time. If the UV energy were applied for too long, seepage of UV light through the edges of the transparent areas would occur and this cause larger width traces than desired. Larger width copper traces can lead to shorts which result in electrical malfunction of the PCB circuit.

After exposure to the UV light source, the photo-tool is removed. As long as the transparent areas of the photo-tool are kept clean (no dark spots) and the dark areas of the photo-tool are not scratched (no clear spots), a photo-tool can be used over and over again.

Now the board with exposed photo-resist is put through three wet chemical processes: Developing, Etching and Stripping. During the wet chemical processes eye protection must be worn.

The board is first placed in a tank that sprays a developer solution on to it. The purpose of the developer is to prepare the board for etching by removing the unexposed photo-resist (i.e., photo-resist that was underneath the dark areas of the photo-tool). In our lab, the board is developed for 60 seconds. Sixty seconds is enough time for the unexposed photo-resist to be removed, but not too much time. If the board is developed for too long, hardened (exposed) photo-resist will be removed causing reduced-width or missing traces. Missing traces are called opens which result in electrical malfunction of the PCB circuit.

Next the board is rinsed in water to remove excess developer solution. Below is a computer drawing of what a board looks like after developing. The orange represents bare copper and the blue represents exposed (hardened) photo-resist. The copper underneath the hardened photo-resist become the desired circuit trace regions.



After rinsing, the board is placed in a tank that sprays an etchant solution (acid) on to it. The acid dissolves the bare copper thorough a chemical reaction called oxidation-reduction or “Redox”. When the acid makes contact with the bare copper, the oxygen anions in the acid strip electrons from the copper atoms producing cupric oxide or copper rust. This chemical reaction, Redox, is the same chemical reaction that turns copper statues blue due to acid rain. The dissolution of copper reduces the concentration of the acid in the tank and over time contributes to the acid becoming weaker. A chart is kept near the etchant tank to record the time required to etch a board completely. When the etchant solution is fresh, it takes only two minutes to etch a typical board. When required etch times increase, additional time in the etchant is allowed – until times approach five to six minutes - then the etchant solution is replaced.

Ammonium persulphate, $(NH_4)_2S_2O_8$ is the acid used in the IME156 lab. This acid is not strong enough to burn skin, but it is a strong enough acid to eat through some fabrics. Plastic aprons are available to protect clothing.

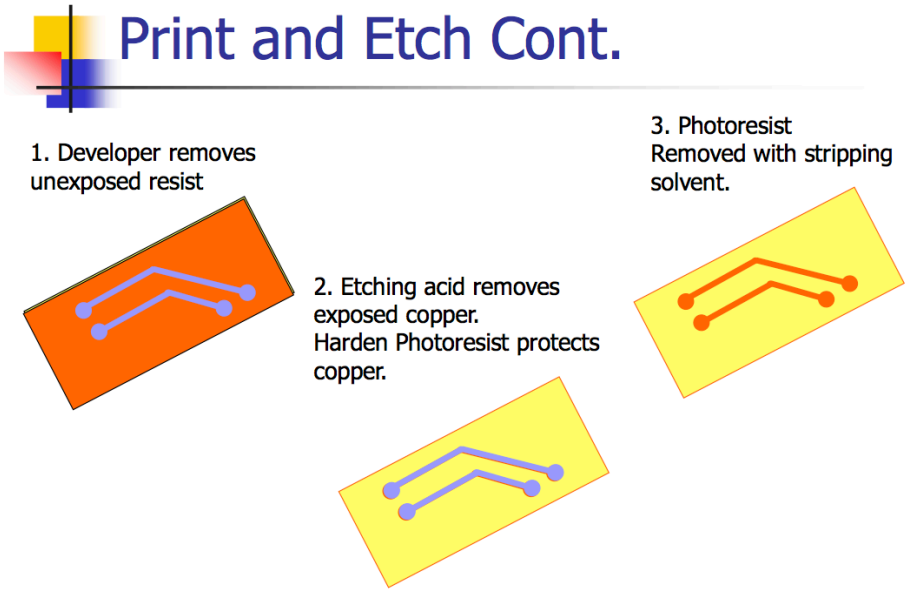
It is important to etch only long enough to remove the bare copper. If the board is etched for too long (over-etched), hardened photo-resist along with the copper along the trace edges will be removed resulting in reduced-width or missing traces. Missing traces are called opens which result in electrical malfunction of the circuit. To avoid over-etching, an iterative process was used to determine the optimum etch time.

Next the board is rinsed in water. Below is a computer drawing of what a board looks like after etching. The yellow represents board substrate (fiberglass) and the blue represent hardened photo-resist. The copper underneath the hardened photo-resist are the desired circuit traces.

After again rinsing with water to remove excess etchant, the board is placed is a tray of stripping solution. Stripping solution is water with dissolved potassium hydroxide (KOH), a component in a household cleaner like “Comet”. The purpose of the stripper is to remove the hardened photoresist from the copper traces. Unlike the developer or etchant where time is a critical process variable, there is less concern with the stripping solution timing. The board can be left in the stripper for an hour or so without damage, but being mildly caustic, discoloration occurs after longer exposures to stripper solution. After 10 to 15 minutes, the photo-resist is soft enough to scrub away easily with a scrub pad. After 30 to 40 minutes, the photo-resist will be removed unassisted.

Next the board is rinsed with water a final time. Below is a computer drawing of what a board looks like after stripping. The yellow represents board substrate (fiberglass/epoxy composite) and the orange represents the desired PCB traces.

A summary of the chemical portion of the Print & Etch process for circuit fabrication is shown below.



Study Questions:

1. Order the following chemical steps of print & etch chronologically: **etch, develop, clean & dry, strip.**
2. Before photo-resist is laminated to the copper side of a board, how is the PCB prepared?
3. True / False Finger prints on copper does not affect photo-resist application.
4. The type of photo-resist that becomes hard when exposed to UV light.
5. Material sensitive to light energy.
6. True / False Wet photo-resist is used in PCB fabrication.
7. A laminator uses _____ to adhere photo-resist to copper.
8. When chronologically is a photo-tool placed adjacent to photo-resist?
9. What is another name for a negative of a circuit pattern generated by Dip Trace?
10. True / False The transparent areas of a photo-tool correspond to the eventual traces.
11. Which of the following will cause larger width traces than desired?
12. Which of the following will cause smaller width traces than desired?
13. True / False A photo-tool is used only once and then discarded.
14. During the chemical portion of PCB fabrication what safety rule must be obeyed?
15. The purpose of the _____ process is to prepare the board for etching by removing the unexposed photo-resist.
16. Missing traces are called _____ and cause electrical malfunction.
17. The etchant solution dissolves the bare copper thorough a chemical reaction called:
18. The acid used in the IME156 PCB fabrication lab room is:
19. True / False The etchant used in the IME156 lab is a strong acid that can burn skin.
20. The chemical equivalent to a household cleaner.
21. How long is a board left in the stripper solution?