Chemical solution for etching printed circuit boards

This chapter is based on several sources. The main contribution is made by this [article](https://radiokot.ru/lab/hardwork/62/) by Murlock

General safety rules:

* Use plastic or glass containers only!
* All leftover solutions are toxic due to high concentrations of copper in it!
* Use personal protection equipment: goggles for eyes, gloves for hands

If recipe mentions sodium chloride and you decided t use kitchen salt: make sure to use non-iodized

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# Ferric chloride

This compound is available as 2 products:

* Anhydrous:
* Hexahydrate:

Overall reaction:

The “half-reactions” are:

The electromotive difference of potential is 0.771 – 0.117 = 0.434 V, but it becomes lower with accumulation or reaction products in solution. Used solution etches slower than fresh one.

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| --- | --- |
| Pros. | Cons. |
| * relatively fast * one component solution * not critically depends on concentration of solution * not critically depends on temperature od solution * can be used several times | * etching speed is decreasing over the process * leave spots (marks) on skin and fabric, and those marks are hard to get rid of * easy storage of prepared solution (needs to be in sealed container, optimally, with addition of hydrochloric acid) |

RadioShack PCB etchant (according to [MSDS](https://asrc.gc.cuny.edu/content/uploads/sites/4/media/member-resources/chemicals/material-safety-data-sheets/PCB-Etchant-MSDS.pdf)) is an aqueous solution, containing:

* 30-60% of Ferric chloride
* 0.1-1% of hydrochloric acid

The acid is added to prevent formation of precipitates. Alternatively, for general rule, consider solution, containing:

* 28-40% of ferric chloride
* <5% (typically 1.5-2%) of hydrochloric acid

# Copper sulfate with sodium chloride

Copper sulfate is used against fungus infections of trees and is available on market as pentahydrate under names: “blue-stone”, “blue-vitriol”, “milestone bluegrass”

The overall reaction is:

However, this is considered to be a set-by-step reaction:

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| Pros. | Cons. |
| * Available components | * Copper sulfate is toxic * Needs heating for fast reaction * Slow etching process |

At the contact with fabric may leave blue marks, which should be removable with vinegar.

Recipe:

* 100 ml of copper sulfate powder (yes, ml, not g)
* 200 ml of sodium chloride
* 500 ml of boiling water

Use only warm. The reaction rate drops significantly with cooling down!

# Persulfates

This a group of compounds, available on the market:

* Ammonium Persulfate:
* Sodium Persulfate:
* Potassium Persulfate:

Regardless of the used chemical, the reaction idea is the same, only difference is concentration of prepared solution for etching.

Overall reaction:

Where can be replaced by or , depending on the reagent used.

The electrochemical description of process is:

The electromotive difference of potential 1.77 – 0.337 = 1.43 V.

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| Pros. | Cons. |
| * One component solution * Fast etching | * If contacted with skin / fabric, behaves as aggressive bleach * Needs heating for reaction * Highest possible speed is not achievable * Uses high concentrations since about of half mass of reagent is ballast sulfate |

Recipe:

* 200 g per L of ammonium persulfate[[1]](#footnote-1) (additionally, can be added 10 ml of sulfuric acid with density of 1.4 g/L)

# Hydrogen peroxide with acids

Criteria for acid:

* Non oxidized by hydrogen peroxide
* Soluble salts with copper[[2]](#footnote-2) (under given circumstances[[3]](#footnote-3))

## Hydrogen peroxide with hydrochloric[[4]](#footnote-4) acid

The overall reaction is:

Half-reactions are:

The electromotive difference of potential 1.77 – 0.337 = 1.43 V. It seems to be the same as in case of persulfates, but it is achievable in mixture this time. The reason is that hydrogen is already in solution at the maximum concentration.

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| Pros. | Cons. |
| * Very high etching speed * No dirty marks on contact * No need to heat us the solution | * Normally, use of strong acids results in holes in clothes )) |

Recipe:

* Pour 200 ml of 35% hydrochloric acid to container
* Add 30 ml of 30% hydrogen peroxide[[5]](#footnote-5) or 300 ml of 3% hydrogen peroxide
* Add water[[6]](#footnote-6) up to final volume of 1 L:
  + 770 ml if used 30%
  + 500 ml if used 3%

For smaller quantities:

* Mix 20 ml of 37% hydrochloric acid with 80 ml of water
* Mix 30 ml of 36% hydrogen peroxide with 30 ml of water
* Put the PBC into diluted acid and add (in portions) the diluted hydrogen peroxide until the visual beginning of etching!

## Hydrogen peroxide with citric acid

Recipe:

* Pour into the vessel 100 ml of 3% hydrogen peroxide solution[[7]](#footnote-7)
* Add and dissolve 30 g of citric acid
* Add and dissolve 5 g of sodium chloride[[8]](#footnote-8) (can be more)

Approximated amount of etched copper: 100 squared cm with thickness of 35 micrometers.

Heat up to 20-25 Centigrade for better performance. Max use temperature: 35 Centigrade.

Not higher! At higher temperatures hydrogen peroxide is able to oxidize citric acid

Not for storage! Prepare fresh solution before use!

## Hydrogen peroxide with sulfuric acid

Recipe:

* Pour 100 ml of 3% hydrogen peroxide into container
* Add 100 ml of electrolyte for automotive lead batteries
* Add 10 g of sodium chloride

Use of 3% hydrogen peroxide is terrible since it is diluted during preparation process. Beter would be:

* Pour 100 ml of electrolyte for automotive lead batteries
* Add 10 ml of 30% hydrogen peroxide
* Add 5 g of sodium chloride

Alternatively:

* 25 g of automotive electrolyte with density of 1.23 g/ml
* 100 ml of 5% hydrogen peroxide
* 5 g of sodium chloride.

# Carbamide peroxide[[9]](#footnote-9) with acids

Carbamide peroxide is a chemical, used as solid storage of hydrogen peroxide for disinfection applications. The chemical reaction should be the same as in cased of hydrogen peroxide with acids.

Carbamide peroxide with sulfuric acid

Recipe:

* Add 100 ml of electrolyte for automotive lead batteries
* Add 9 g of carbamide peroxide[[10]](#footnote-10)
* Add 5 g of sodium chloride

# Percarbonate[[11]](#footnote-11) with acids

Recipe:

* Dilute 100 ml of lead acid electrolyte (solution of sulfuric acid) with 100 ml of water
* Dissolve in obtained solution 50 – 100 g of sodium chloride
* Add <15 g of persol[[12]](#footnote-12)

Don’t add all persol at once, there is a lot of bubbling due to chemical decomposition of carbonate)

The solution has yellow-green color, and can be used until turns almost black.

# Questionable compositions

In this part I collected a few recipes, which can be used, but have some controversial moments in preparation and/or use.

## Hydrogen peroxide with acetic acid

While the acetic acid is relatively easier to get via vinegar or vinegar essence. The ease of use and preparation is questionable. Especially due to a strong smell of acetic acid. However, one recipe can be found:

* Pour 100 ml of 3% Hydrogen peroxide into e vessel
* Add 15 ml of vinegar essence
* Add 5 g of sodium chloride

This is smelly! To my opinion the preparation needs to be recalculated for every case since:

* Vinegar (as a solution of acetic acid) has various concentration depending on country it is manufactured
* Vinegar essence is also a general name for aqueous solutions of acetic acid in concentration range between 30 and 80%

Another problem is copper acetate precipitation on the surface of etching board. It leads to inconsistent etching process. Also, use of vinegar with 3% hydrogen peroxide leads to dilution of hydrogen peroxide as main etching agent! Ideally is to have 5-10% of acetic acid in the final etching solution!

Another recipe:

* Pour 100 ml of 9% vinegar to container
* Add 100 ml of 3% hydrogen peroxide
* Add 5 g of sodium chloride

# Afterword

Despite the fact, that here are some “home-brew” recipes, the same components are present and used within industrial etchants. The major difference is the presence of additional chemicals for additional purposes such as: ability to recover copper from etching solution and reuse of that, more even etching speed distribution across the surface, storage stability improvement, precipitation prevention, etc.

For example, here is the recipe suggested in patent [EP0164757A2](https://patentimages.storage.googleapis.com/93/42/d1/012dce5fe0cc04/EP0164757A2.pdf):

* 100 ml/L of 35% Hydrogen peroxide
* 100 ml/l of concentrated sulfuric acid
* 100 ml/L of 50% aqueous solution of amino-trymethylphosphoric acid
* 50 ml/L phosphoric acid
* 1.5 ml/L of phenol sulphonic acid

Another example is composition form soviet patent 1239371 dated 1979 (recommended use temperature is 40-45 centigrade):

* 350 g/L of ammonium persulphate
* 55 g/L of sulfosalicylic[[13]](#footnote-13) acid
* 0.5 g/L potassium permanganate
* 3 g/L of glycerol

1. https://www.youtube.com/watch?v=4wTEe3RB7p0 [↑](#footnote-ref-1)
2. This is why phosphoric acid can’t be used here [↑](#footnote-ref-2)
3. Acetate is badly soluble, but acetic acid still can be used [↑](#footnote-ref-3)
4. Hydrochloric acid is also known as muriatic acid and is sold as 35% solution [↑](#footnote-ref-4)
5. Can be found as chemical solution to clean water pools [↑](#footnote-ref-5)
6. Not a tap water! [↑](#footnote-ref-6)
7. Can be found in pharmacy, normally used as topical disinfection solution [↑](#footnote-ref-7)
8. Sodium chloride – kitchen salt. 5 g is approx. 1 tea spoon. [↑](#footnote-ref-8)
9. Also known as: “Hydrogen peroxide - urea”, hyperol, artizone, UHP, urea hydrogen peroxide. In Russian-speaking countries is known under name “гидроперит”. In fact, it is a compound (clathrate) formed of carbamide and hydrogen peroxide with a chemical composition , having of ~35.4% of hydrogen peroxide by mass when dissolved in water. [↑](#footnote-ref-9)
10. Normally sold as 1.5 g or 0.75 g tablets [↑](#footnote-ref-10)
11. Sometimes abbreviated as SPC, contains 32.5% of hydrogen peroxide by mass. Chemical composition is . Widely used as eco-friendly bleaches [↑](#footnote-ref-11)
12. Persol (персоль) is a chemical bleach or cleaning agent containing > 30% of sodium persulfate, > 30% sodium carbonate and rest for the fragnance. [↑](#footnote-ref-12)
13. Also knows as 5-Sulfosalicylic acid [↑](#footnote-ref-13)