

**RELIEF ELECTRO-ETCHING  
FOR CHAMPLEVÉ ENAMELLING**

- by -

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## Introduction

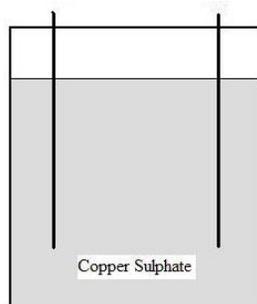
In the Guild of Enamellers Journal, (Spring 2000), Dorothy Cockrell described how to build an electric etching kit and to prepare small pieces of copper or silver for etching using a weak solution of acid. It is a relatively safe and clean method of producing items for Champlévé enamelling.

At that time, I was relief etching copper using the more conventional Ferric Chloride solution. Relief etching is the eating away of large areas of metal as opposed to line etching which results from scribing through a pre-applied resist. Ferric Chloride is not a very agreeable chemical and the etching process creates bubbles and deposits and the solution must be carefully disposed of when exhausted. A development that alleviates the unpleasantness of Ferric Chloride is Edinburgh Etch. This involves adding citric acid to the solution and this speeds up the process, dissolves the sediment, creates less bubbles and the solution has a longer life.

Despite this improvement to the mordant, I was keen to try electro-etching as it uses less aggressive chemicals and it should give a more controllable etch. Starting with Dorothy's work, I have gradually progressed with this technique. In doing so, I have relied heavily on the work of Cedric Green, (see References), who has explained and identified the benefits of using copper sulphate solution as the electrolyte and the use of new resists. He places considerable emphasis on the benefits of using non-toxic chemicals for etching copper and other metals. Although his work is aimed primarily at the printmaker, much is of direct application to Champlévé enamelling.

So I have set down these notes of my own experiences with electro-etching copper. My work is not definitive and there are many other techniques for electro-etching copper. Others embarking down this road may, nevertheless, find the information helpful.

## Principles of Electro-Etching



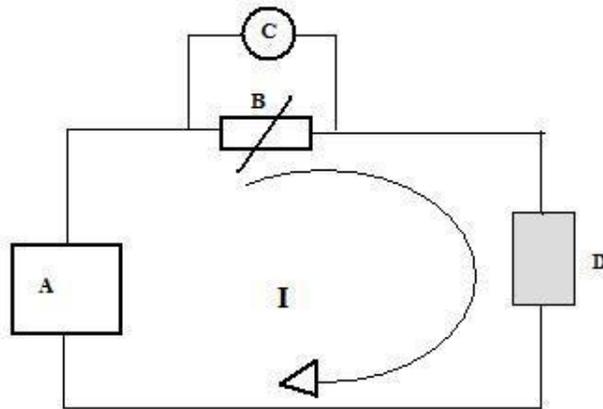
**Figure 1. The Electrolytic Cell**

Figure 1 shows two copper plates immersed in an electrolyte (in this example a solution of copper sulphate). The positive or anode plate is the piece to be etched and the negative or cathode is a copper plate or strip. When connected to an external direct current (DC) supply, current will flow through the electrolyte. The positive copper ions of the copper sulphate solution are attracted to the cathode, where they are deposited, and the negative sulphate ions are attracted to the anode where they combine with the exposed copper surface to form copper sulphate.

The advantages of using copper sulphate are that the concentration of the solution remains constant and in theory there are no deposits or bubbles. Thus, having made up the solution, it can be used repeatedly with no reduction in effectiveness. The current is switched off when the copper has been etched to the desired depth.

The law governing the process is due to Faraday who determined that the mass of metal liberated at the anode is proportional to its chemical equivalent weight and the total amount of electricity passed. This law is used later to calculate etching times for a range of metal areas exposed to the electrolyte.

### A DC Power Supply for Etching



**Figure 2. The Basic Circuit**

Dorothy Cockrell's article described how to make a 12V DC power unit, (A). This will deliver up to about 0.3A, depending on the electrical resistance of the cell, (D). A ballast resistor, (B), was included in series with the output, (33Ω, 10W), to ensure that the current did not exceed the safe rating of the power unit. To start with, I found an old battery charger that was capable of delivering up to 5A at 12V, and so I used this, again with a ballast resistor. I purchased four 10Ω, 10W resistors for this purpose so that, by connecting them all in series, (40Ω), or all in parallel, (2.5Ω), or in other combinations, I could adjust the current, (I) to suit the size of piece to be etched.

The resistance presented by the electrolytic cell itself will vary according to the size of the metal plates, their separation and the nature and concentration of the electrolyte. As a rough guide,

values range from about  $20\Omega$  for small pieces to  $1\Omega$  or less for a large plaque. It is desirable to be able to measure the current flowing, and I did this by connecting a multi-range voltmeter, (C), across the ballast resistor and then using Ohm's Law to work out the current.

Although the above arrangement worked quite well, the setting of the current level with the ballast resistors was tedious. I subsequently purchased a commercial DC power unit with a maximum rating of 6A and that was controllable from 3 – 15V. The unit comes with a built-in ammeter. So, by adjusting the output voltage control knob, the current can be set to any desired level. When working at the lowest voltage setting of 3V, I found that the external ballast resistors were still useful when I wanted to reduce the current still further. I also found the built-in ammeter rather small and so I purchased a larger instrument that would allow me to set the current level more precisely and easily. Details are listed in the Appendix.

### **The Anode and Cathode Assemblies**

The anode, being the item to be etched and subsequently enamelled, needs an electrical connection to be made to its back. There are many ways of achieving this and my preferred method, (see Figure 3), is to cut out a strip from a sheet of 0.5mm thick copper, and to form a circular pad bend at right angles near one end. The other end is soldered to four twisted strands of varnished or enameled copper wire, (each about 0.4mm diameter). The wires are sufficiently flexible not to constrain the position of the anode in the electrolyte. Then the whole of the strip, apart from the pad, is covered in a sandwich of Fablon plastic.



**Figure 3. Back Plate Connector**

The pad of this back plate connector is abraded and also the centre of the back surface of the anode to ensure good electrical contact. The plate is then secured to the anode with a small covering piece of Gaffa tape. The connector can be re-used repeatedly on other samples.

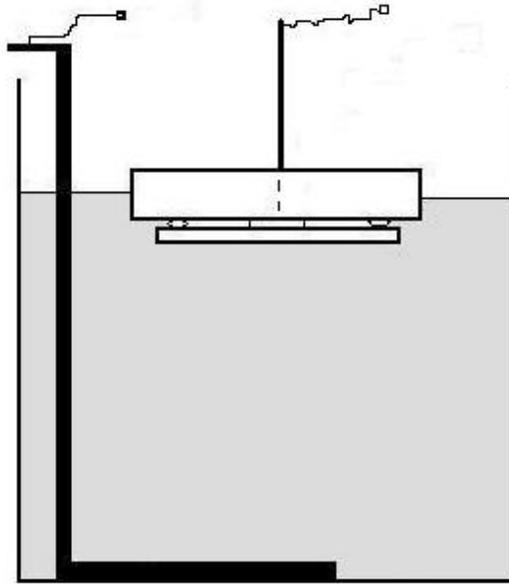
My cathode arrangement is shown in Figure 4. Again this is cut out of 0.5mm thick copper sheet to form a circular pad with a strip at right angles. The vertical height of the latter is around 150mm and it is sealed in a Fablon sandwich. The underside of the pad is also covered in Fablon so that the electrical current is directed only through the upper face of the pad. Again twisted strands of copper wire are soldered at the top for connection to the negative terminal of the DC supply. The cathode can be used repeatedly and the pad will gradually thicken as copper is deposited on its upper surface when current flows through the cell.



**Figure 4. The Cathode**

Figure 5 shows the anode and cathode mounted in a horizontal configuration. I prefer this horizontal arrangement as it ensures the plates are parallel at all times, (so that the current entering the anode plate is as uniform as possible), and any slight impurities released during etching can float away under gravity. The tank can be glass or plastic, rectangular or round depending on what is available to accommodate the assembly. More details about protecting the back of the anode and applying the design to be etched on the front face are described later.

The anode, with its back plate, is secured to a polystyrene raft using blobs of silicone rubber adhesive at the four corners, the back plate vertical strip being first threaded through a central hole in the raft. To ensure the copper anode floats in the liquid, the thickness of the raft has to be at least nine times as thick as the copper, if it is the same surface area.



**Figure 5. The Assembly**

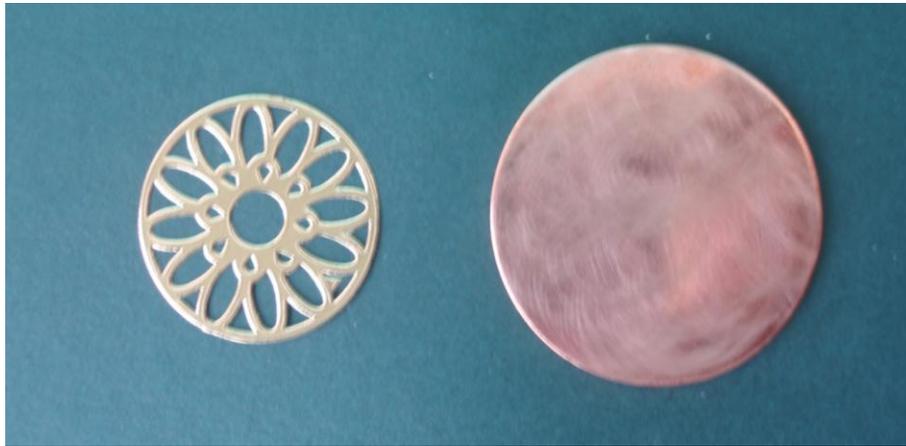
After removing the anode assembly from the liquid after etching, a sharp knife is used to slice through the adhesive so as to separate the anode from the raft. Any remaining adhesive can then be peeled off both items. The raft can then be re-used. Cedric Green suggests that the anode and cathode be about 50mm apart and so sufficient solution is poured into the tank to achieve this separation. It is a good idea to have a reasonable volume of solution, not less than say 500ml, to ensure any heat generated due to the passage of the current is more readily dissipated. Excessive temperature places a greater stress on any protective resist.

Of course there are other ways of mounting the electrodes and Dorothy Cockrell has outlined a method with them placed vertically in the tank.

### **Samples for Electro-Etching**

Although there are many ways of creating a design on copper for it to be etched, to investigate the basic electro-etching process I used a peel-off stencil applied to a circular piece of copper, 45mm diameter and 0.9mm thick.

Since the stencil is adhesive, it is clearly an attraction to stick it directly on the copper surface and to allow etching to take place in the exposed areas. However, even if it is warmed and burnished to promote maximum adhesion, I found that the electrolyte leached to some extent at the stencil edges and those parts of the copper were partly etched and made narrower as a consequence. So a protective resist needs to be applied to the copper first and this is now described. Further protection is needed at the outer edge and on the reverse of the copper. The stencil and copper sample are shown in Figure 6.



**Figure 6. Stencil and Copper Blank**

### **A Resist for Electro-Etching Copper**

When using either acid or ferric chloride for etching, I used a suspension of bitumen in solvent, (Rhind's Stopping Out Varnish), for covering those areas to be protected. This had proved satisfactory and I continued to use it when I started electro-etching with the copper sulphate solution. However, I found I had to be very diligent with the application of the bitumen as pitting occurred on a number of my samples. The information provided by Cedric Green casts doubts on soft resists for electro-etching because there can be considerable heat produced at the copper surface when current flows and the resist can soften and the protected edges become ragged. My electro-etched samples all seemed to suffer in this way, and so I tried a number of different hard resists.

Among these is an acrylic resist that has been developed by Edinburgh Printmakers It is commercially available as Lascaux Hard Resist in 500ml containers. It proved to be excellent in every respect, provided the application instructions are carefully followed. It is worth downloading the technical data sheet which contains detailed directions for applying and then removing the resist.

In essence, the surface of the plate should first be lightly abraded to help the resist to adhere to it. Then, the surface of the copper should be made completely grease free by scrubbing it well with a household degreaser using a clean cloth or felt pad and then checking that water sheds completely. A short dip in acid will ensure any traces of alkali are removed. After washing again and drying, the resist is applied using a brush. I found it desirable to apply two thin coats, allowing each coat to dry before application. Particular care is need at the outer edge of the copper piece as any deficiency in the coat will result in the edge being eaten away rapidly. The resist, when still liquid, is water soluble so brushes can be cleaned with warm soapy water.

Having attached the back connection using a small piece of Gaffa tape, it is important to also then cover the back overall with the resist as it is susceptible to being electro-etched.

## **Creating the Image on the Copper**

Having applied the Lascaux hard resist, the stencil is then laid on top and lightly pressed down. Using a sharp scalpel, the resist is scraped away in the parts to be etched. The waxy resist allows these broad open areas to be exposed without creating a ragged edge. Any deficiencies can, however, be touched up if necessary. Finger marks on the exposed copper will inhibit etching and household dishwashing liquid should be used to remove any grease so formed. The stencil is now pulled carefully off the waxy resist for use again on other pieces.

## **An Alternative to Using Resist**

There is no doubt that time and considerable care is needed in applying a hard resist in order to ensure that the etching takes place only where it is wanted. At a 2007 GOE Conference tutorial, Penny Gildea outlined an alternative approach that is quicker and well suited to relief etching. This method uses clear sticky back plastic as marketed by Fablon. It comes in conveniently sized rolls.

The top surface of copper is lightly abraded and degreased as before, although acetone alone seems to be adequate for good adherence. A piece of the Fablon is cut out of the sheet so that it overlaps the copper by about 5 mm and the sticky transparent film is parted from the backing sheet and laid over the copper. This backing sheet is slid temporarily underneath the copper sample to prevent the Fablon from adhering to the working surface.

A small rounded burnishing tool is then used to press the film down excluding any small pockets of air. The stencil is laid on top as before and now the scalpel is used to go round the edges of each section of the stencil to enable the Fablon elements to be lifted out. It is prudent to use the burnisher again in case any of the remaining Fablon has lifted slightly.

Having done this, and avoided making finger marks on the now exposed copper, another piece of Fablon of equal size to that on the top face is applied to the reverse and a sandwich is formed by squeezing the two plastic films to each other. A slit will have to be cut in the second film before applying it to the reverse side of the copper to enable the rectangular strip of the back connector to be fed through it first. The vulnerable outer edge of the copper is sealed very effectively with this method. The stencil should again be lifted off carefully.

Of course, another alternative is to use the Lascaux resist for the design and up to near the outer edge, and then to deploy the Fablon sandwich technique to give robust protection to the edge and reverse. Dorothy Cockrell mentions this in her article using Gaffa tape as protection. However, the latter does have some interaction with the electrolyte and it is a much less attractive material than the plastic. For these reasons, I prefer to use Fablon.

## Electro-Etching the Copper Sample with Copper Sulphate Electrolyte



**Figure 7. The Set-Up for Electro-Etching**

Figure 7 shows the general arrangement with the power pack and large ammeter to the right, and the cell with the cathode in the middle of the picture. Just to the left is the anode sample attached to the polystyrene raft. To the left again are the ballast power resistors for use at very low current levels, and behind is a 500gm tub of copper sulphate and the 500ml of Lascaux resist.

A saturated solution of copper sulphate crystals, ( $\text{CuSO}_4$ ), is 250gm/litre of water. I made up a 1:3 solution by dissolving 42gm in 500ml of distilled water. It is sensible to use plastic gloves, as the solution can dry the skin and leave a long-lasting blue tinge under finger nails.

I made several test samples using the stencil shown in Figure 6, with both the Lascaux resist and the Fablon method, and they were all etched individually.

Remembering that the test piece is connected to the positive terminal, the power pack is switched on with the voltage control at a minimum. Where there is no control of the voltage ie if using a battery charger, the current will be determined by the cell resistance and the rate of etching will be indeterminate. With the power pack, the current level can be set to any desired level. To start with, I set the current to 1.0A.

Over the first five minutes or so, the current fell away to almost half its initial value and then it recovered slightly. At this point, I deemed it is sensible to switch off and examine the sample to check the integrity of the resist or Fablon. If penetrated, both will show a dark spot or spots, and repairs are needed. A convenient and quick repair can be accomplished by a dab of nail varnish applied over the spot. It will dry in minutes.

The areas being etched had a brown film on their surface, and I lightly brushed this off back into the electrolyte. Switching on again, the current was back at 1.0A, but falling away again albeit to a lesser extent. So every ten minutes, I removed the piece and brushed it. At each stage, the current became more stable and eventually the current remained at 1.0A with only minor variations. With this level of current density, if there is no removal of the brown film, the final etched surface had the appearance of crumpled tissue paper. This effect is observed with conventional etching and it can be an effective surface profile for the subsequent laying of the enamels as it provides multiple reflections.

There is clearly an initial settling-in phenomenon when using copper sulphate electrolyte. I repeated the tests on other samples using 0.5A current setting and also 0.25A. The settling-in process was much faster and at the 0.25A level, it was virtually absent. I still used the brushing technique but only at thirty minute intervals and the final surfaces were quite smooth. I have used these results, relating to the effect of different current densities, in the next section to provide some guidelines when etching different areas of copper.

The electrical resistance of the cell using my copper discs was of the order of 12 ohms when conditions had stabilized. So, at the 1A level, the heating is 12W and this caused the temperature of the electrolyte to rise from 18<sup>0</sup>C to 33<sup>0</sup>C. This is well within acceptable levels and, in principle, the current could be further raised. However, etching times can then become very short and it is easy to over-etch. I found that a reasonably deep etch of 0.4mm could be achieved at the 1A setting within one hour.

As regards differences between the use of the Lascaux hard resist and the Fablon, both showed slight evidence of lift at the etched edges but no measurable etching underneath. Hence, I regard both methods as being suitable. Where there are very large open areas to be etched, the scraping away of the Lascaux resist is tedious and the use of a lifting solution would speed it up. This is described in the Lascaux technical notes.

To remove the Lascaux resist after etching, I immersed the samples in neat household ammonia. This not only softened the resist so it could be peeled off, but it created a clean copper etched surface that could be further brightened using a soft brass brush and plenty of liquid detergent. Figure 8 shows an electro-etched sample. The undercutting was minimal.



**Figure 8. Copper Sample Electro-Etched**

### **Etching Current and Time to Etch**

When etching a piece of copper using acid or ferric chloride, the time to etch to a given depth is governed primarily by the strength of the etchant and the length of time of immersion, although the temperature and agitation of the solution does also affect the rate of etch. Small pieces may etch somewhat quicker than large pieces if the volume of solution is inadequate and it becomes exhausted.

With electro-etching, it is the magnitude of current flowing through the cell and again the time that are the factors that determine the depth of etch of a particular area of exposed copper. Of course, without voltage control or the use of ballast resistors, one has to simply connect up the cell and switch on and hope that the current that flows will produce a satisfactory etch in a reasonable time. The current may be so low that etching proceeds at an inordinately slow rate. Conversely the current may be so high as to etch the metal to an excessive depth before one realizes it and it may also degrade the resist, resulting in imperfect etching. What I needed were guidelines that not only tell the user what level of current is appropriate for a given size of piece to be etched, but also for how long to apply the current to achieve a given depth of etch. Based on Faraday's Law, I have devised a formula to assist in this process, and this is set down below:

$$D = K \times T \times I / A_c \quad (1)$$

Where D = depth of etch, mm, K is a constant, T = time of etching, mins, I = current, amps and  $A_c$  = the area of copper being etched,  $\text{mm}^2$ .

The value of K depends only on the metal forming the anode, in this case, copper. It is independent of the electrolyte and its strength, spacing of electrodes etc.

### **The Current Density**

$I/A_c$  in equation (1) is the current density, or the amount of current passing through each square mm of exposed copper. It is this quantity that determines how fast the etch proceeds. Thus, for a given current I, a large area will etch more slowly than a small area. If  $I/A_c$  is too high, the resist may break down and the etched area be uneven with pits and bumps, although as mentioned earlier some may find this of benefit in reflecting light through enamel. On the other hand, setting  $I/A_c$  too low will result in tediously long etching times. In a range of tests, I have used values for  $I/A_c$  ranging from 0.001 up to 0.004. From this, I have concluded that a sensible value for  $I/A_c$  is around 0.002. What this means in practice is that one has to first estimate  $A_c$ , the total area that is exposed to the electrolyte. When the area to be etched is composed of circles, triangles or rectangles, this is easy to calculate, but when the shapes are more complex, it is better to make a tracing of them and to fit them side by side into a calculable geometric shape. Typical values for  $A_c$  will range from 50 mm<sup>2</sup> for a small item to 5000 mm<sup>2</sup> or greater for a copper plaque.

When using the stencil as described here, the negative parts of the stencil remain on the backing sheet and they can be lifted off and assembled tightly together but not overlapping. Figure 9 shows the process for the stencil portrayed in Figure 6.



**Figure 9. Determining the Area  $A_c$**

Then the value for current, I, is obtained by multiplying the calculated area by 0.002. Taking the stencil sample above,  $A_c$  is 254 mm<sup>2</sup> and so a sensible current is 0.5A.

It must be emphasized the formula is applicable to relief etching of relatively large areas of exposed copper and it is clear that the method cannot be easily applied to the etching of lines.

## Time to Etch

To determine the total etching time  $T$  using equation (1), the constant  $K$  has now to be determined. I did this by etching a number of different copper samples and for each test noting the value of  $I$ ,  $A_c$ , and  $T$ . Then, having removed the resist, the depth of etch,  $D$ , was measured using a vernier depth gauge. The depth does vary somewhat across a sample and so an average value was taken. Applying these measured values in the equation,  $K$  can then be found for each sample. It varied from about 1.6 to 1.8. So with an average value of 1.7, the equation now becomes:-

$$D = 1.7 \times T \times 0.002 \quad (2)$$

It is now possible to complete the exercise by constructing a table giving the etching current and time to etch for different areas being etched. The etching times have been suitably rounded.

Depth D - mm		0.2	0.3	0.4	0.5
$A_c - \text{mm}^2$	I - Amps	Time to etch - mins			
50	0.1	60	90	120	150
100	0.2	60	90	120	150
150	0.3	60	90	120	150
200	0.4	60	90	120	150
300	0.6	60	90	120	150
500	1.0	60	90	120	150
1000	2.0	60	90	120	150
2000	4.0	60	90	120	150
4000	5.0	95	145	190	240
6000	5.0	145	215	290	360

Note: values in table are for  $I/A_c = 0.002$  except for  $A_c = 4000$  and  $6000 \text{ mm}^2$  where the current has been limited to 5A. For higher values of  $I/A_c$ , eg 0.004, reduce the above etching times proportionately.

**Table 1 Guide to the Current and Time for Relief Etching Copper**

## **An Alternative Electrolyte**

In the literature are references to many solutions that can electro-etch copper and other metals. Among these are salt solution and even Coca Cola. However, the copper sulphate electrolyte has the major advantage of not creating by-products and of retaining its potency almost indefinitely.

It is perhaps only the settling-in phenomenon that prompted me to think about electrolytes other than copper sulphate. Knowing that a weak nitric acid solution will also etch copper and in the process create copper nitrate, I decided to purchase a 500gm drum of the latter ( $\text{Cu}(\text{NO}_3)_2$ ) and to make up a solution of this for trial. It has the same irritant characteristic as the copper sulphate, so gloves are again recommended. A saturated solution is 1380gm/litre and in view of its much greater solubility, I used a 1:4 solution by dissolving 172gm in 500ml of distilled water. Because of the cell chemistry described at the outset, a copper nitrate solution should also last indefinitely. Allowing for postage, the copper nitrate crystals cost about the same as copper sulphate.

I used the same set-up as outlined in the earlier trials and the same stencil design and copper disc. Although, from Table 1, the current setting should be around 0.5A (for the  $A_c$  of  $254\text{mm}^2$ ), I set the current at 1.0A as before because I wanted to see if the current fell away in a similar manner. In fact, the current remained totally steady from the outset and did not alter over the whole period of etching. I did note the presence again of a brown film, and the final etched surface could have the appearance of crumpled tissue paper as before. Thus, if desired, the surface can be brushed from time to time to give a more uniform appearance to the etched surface. It was also noted that the cell resistance was only 2.5 ohms as compared to the 12 ohms for the copper sulphate electrolyte. Thus, the heating effect is insignificant.

Based on the above findings, I concluded that copper nitrate is a superior electrolyte for relief etching of copper and I have used it ever since.

## **Uniformity of Etch**

It is well known that the depth of an electro-etch is not uniform and the edges of a piece etch faster than more central regions. The values of depth  $D$  given in Table 1 are thus average values. Some indication of the variation is by reference to Figure 8. Here the “petals” around the edge have been etched to a depth of around 0.5mm, (as measured using the vernier depth gauge), but the central disc to a depth of just 0.4mm. For some enamelling projects, this difference might be of little consequence. However, it is quite feasible to wash the piece thoroughly and remove the brown deposit, so that fresh resist can be applied to stop-off all but the central region. In the above example the central area is  $44\text{mm}^2$ , and so by reference to Table 1, it can be deduced that an etch current of 0.1A will etch it another 0.1mm in about 30 minutes. This is what I achieved in this example.

To illustrate the non-uniform etching in more detail, I marked out, on another copper disc, three discrete areas, (a long rectangle, a smaller rectangle and a circle), and I prepared the disc for etching as previously described. Details were:-

Total of the three areas  $A_c = 278\text{mm}^2$ ,  $I/A_c = 0.002$ ,  $I = 0.55\text{A}$ , etching time for nominal depth  $D$  of  $0.5\text{mm} = 150$  mins. ( $2\frac{1}{2}$  hours).

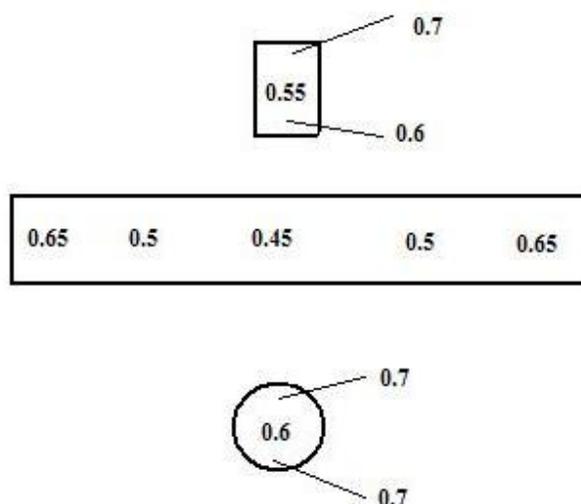
To try and ensure that the current streamlines entered the copper disc anode as uniformly as possible, I made a hollow cylinder from a sheet of  $0.5\text{mm}$  thick polypropylene so that it encircled the disc and raft assembly and, when sitting on the cathode, it stood proud of the upper surface of the electrolyte. After the  $2\frac{1}{2}$  hour etch, the result is shown in Figure 10.



**Figure 10. Test to Show variation in Depth of Etch**

All the three areas exhibit characteristic convex surfaces with edges biting deeper than the middle. The effectiveness of the plastic cylinder in creating a more uniform current flow pattern is not proven from this one example. However, it should counteract one tendency ie for the current to concentrate at the outer edges which could result from having a cathode area much larger than the anode, (as in this case), and/or the use of a very large diameter container of electrolyte.

The depth of etch in these three areas was measured using the vernier depth gauge and the results are shown in Figure 11.



**Figure 11. Depth of Etch in mm for Sample shown in Fig. 10**

If electro-etching has a disadvantage, it is in producing this non-uniformity of etch. Perhaps one solution for the enameller, apart from selected stopping-off and re-etching, is to ensure that a minimum acceptable etch has been reached everywhere on the piece. The deeper parts can then be laid with a flux enamel to produce a flat surface for subsequent layers of coloured enamels.

### **Relief Electro-Etching of Silver**

For those interested in applying and extending the techniques described here to the etching of silver, I offer a few suggestions. My own experience to date is, however, limited to just one test and so what follows is very preliminary. Firstly, because silver is slightly more dense than copper, the raft used to float the silver anode should be some eleven times as thick as the silver.

As for a suitable electrolyte, the logical choice would appear to be silver nitrate ( $\text{AgNO}_3$ ). It is very soluble in water, (2220gm/litre), and only slightly affected by light. However, even if making up a 1:20 solution, it will cost over £70 for 500ml. A cheaper alternative is dilute nitric acid and this will eventually convert into silver nitrate as etching takes place. A 500ml solution of 1:20 nitric acid ( $\text{HNO}_3$ ) can be made by measuring out 25ml of concentrated acid and pouring it gently into 475ml of distilled water. Gas will be released at the cathode when etching, but the bubbles should not inhibit etching at the anode. The life of the solution will be determined by experience in its extended use.

### **Time to Etch**

It should be possible to use the results in Table 2 to deduce etching times for silver. Referring back to Faraday's Law, that the mass of metal liberated at the anode is proportional to its chemical equivalent weight and the total amount of electricity passed, I compared the chemical

equivalent weight of silver with copper to determine a new value for the constant K. The chemical equivalent weight,  $W_e$  is the atomic weight divided by the valency. For the two metals the values of  $W_e$  are:- Silver =  $107.9/1 = 107.9$ , Copper =  $63.5/2 = 31.75$

Thus the mass of silver liberated is  $107.9/31.75 = 3.4$  times as much as copper for the same amount of electricity passed. The depth of etch is related to the volume of material released and the weight ratio of 3.4 needs to be converted to volume ratio using the density relationship. The density of silver =  $10518 \text{ kg/m}^3$  and density of copper is  $8930 \text{ kg/m}^3$ . So the volume or depth of silver etched is  $3.4 \times 8930/10518 = 2.89$  times that for copper. Hence the value of constant  $K_{\text{silver}}$  is  $2.89 \times K_{\text{copper}}$  and we have already established the latter value as around 1.7. Thus  $K_{\text{silver}} = 4.9$ .

This result suggests that the etching times for silver are nearly three times shorter than for copper or alternatively the current may be reduced to a third for the same duration of etch. I was intrigued to see if this is actually the case, and so I used a somewhat different transfer on a 45mm diameter sterling silver disc and electro-etched it in the 1:20 nitric acid. I deployed a plastic cylinder again to help define the current streamlines and I reduced the current density,  $(I/A_c)$ , to 0.001 in view of the anticipated faster rate of etching with silver.



**Figure 12A. Piece ready for Etching**



**Figure 12B. Area  $A_c$  (not to scale)**

The test piece was coated with Lacaux resist and the transfer applied. Figure 12A shows the piece with the resist scraped away but the stencil still in place. Figure 12B is the negative parts of the transfer laid closely together to form a triangle whose area could be calculated –  $740\text{mm}^2$ . The current level was thus set at 0.74A and the time of etch was 97 minutes. I used a copper cathode as before and cleaned it thoroughly to ensure the silver was depositing on it.

The depth of etch, (D), varied from 0.6 mm at the extreme edges to 0.4 right in the centre and this is consistent with the findings on copper. The etched result is shown in Figure 13.



**Figure 13. Sterling Silver Piece Electro-etched in Dilute Nitric Acid**

Taking a mean value and applying it to equation 1, the value of  $K_{\text{silver}}$  came out at 4.7. This experimentally derived value is close to the theoretical value of 4.9, and although more tests on other sized samples should be undertaken, I have constructed a Table similar to that for copper but using a K factor of 4.9. The result is shown below.

Depth D - mm		0.2	0.3	0.4	0.5
$A_c - \text{mm}^2$	I - Amps	Time to etch - mins			
50	0.05	40	60	80	100
100	0.1	40	60	80	100
150	0.15	40	60	80	100
200	0.2	40	60	80	100
300	0.3	40	60	80	100
500	0.5	40	60	80	100
1000	1.0	40	60	80	100
2000	2.0	40	60	80	100
4000	4.0	40	60	80	100

Note: values in table are for  $I/A_c = 0.001$ . For higher values of  $I/A_c$ , eg 0.002, reduce the above etching times proportionately.

**Table 2 Guide to the Current and Time for Relief Etching Silver**

## Conclusions

Relief etching of copper for Champlevé enamelling can be readily achieved using electro-etching equipment. The chemicals are relatively non-toxic and long lasting. Copper Nitrate is a particularly effective electrolyte. By determining the area to be etched, it is possible to specify the etching current and time to etch for different depths of etch. Edges etch more deeply than central areas and they may need to be stopped off if uniformity is required. Two effective resists are Lascaux Hard Resist and Fablon plastic. Small repairs can be made using nail varnish. An initial test on silver using dilute nitric acid indicates the electro-etching method is effective for this metal also.

## References:

1. Build your own Electric Etching Kit, D. Cockrell, Guild of Enamellers Journal, Spring 2000.
2. Green Prints, Cedric Green, [www.greenart.info](http://www.greenart.info)
3. Lascaux Resist, [www.lascaux.ch/english](http://www.lascaux.ch/english)
4. Etching techniques, [www.edinburgh-printmakers.co.uk](http://www.edinburgh-printmakers.co.uk).

## Appendix List of Suppliers

Intaglio Printmaker (Lascaux Hard Resist)  
Tel. 020 7928 2633 Fax 020 7928 2711  
Website [www.intaglioprintmaker.co.uk](http://www.intaglioprintmaker.co.uk)

T N Lawrence and Son Ltd (etching products and chemicals)  
Tel. and Fax. 0845 644 3232 Website [www.lawrence.co.uk](http://www.lawrence.co.uk)

Rapid Electronics Ltd (DC power supplies for electro-etching, ammeter, terminals etc)  
Tel. 01206 835516 Fax 01206 751188  
Website [www.rapidonline.com](http://www.rapidonline.com)

L.P. Chemicals Ltd (copper nitrate, copper sulphate)  
[www.labpackchemicals.co.uk](http://www.labpackchemicals.co.uk)

Scientific Wire Company (enamelled copper wire)  
Tel. 020 8505 0002 Fax 020 8559 114  
[www.wires.co.uk](http://www.wires.co.uk)

Maplin Electronics (heavy duty resistors)  
Tel. 0870 429 6000 Fax 0870 429 6001  
Website [www.maplin.co.uk](http://www.maplin.co.uk)