

## FURTHER NOTES ON ELECTRO-ETCHING COPPER

Some time after I wrote a report on electro-etching in 2009, I had to retire from enamelling. However, I have been responding to questions and comments from a number of people interested in electro-etching copper. In particular I have exchanged much useful information with friends in America. I thought it might be useful to share those experiences, and to summarise what was contained in my earlier report. For people who electro-etch infrequently, some of the refinements and equipment mentioned here are perhaps considered unnecessary and simpler equipment and readily available liquid electrolytes have been found adequate. So I must emphasize that these notes are directed at those who wish to electro-etch copper fairly regularly, perhaps for Champlevé enamelling. It relates to the etching of fairly large areas to depths of up to say 0.5mm to accommodate enamel flux followed by transparent enamels.

Firstly, the electrolyte that conducts the flow of electricity from the cathode to the anode. The electro-chemical action removes copper from those parts of the copper anode not protected by resist. There are many liquids that will etch in this way such as nitric acid and a number of salts. Most of them are eventually converted, lose their effectiveness and will need replacing. All electrolytes have a resistance ( $R$ ) to the flow of electricity ( $I$ ), and heat will be produced, ( $I^2R$ ). It is desirable to use an electrolyte which does not have a high resistance to the flow of current as the heat produced may degrade the resist that is used. Further the voltage needed to drive the current through the electrolyte, ( $IR$ ), may be too high for the battery or power pack used. An electrolyte with low resistance and which maintains its effectiveness indefinitely is copper nitrate,  $Cu(NO_3)_2$ . It is not quite so easy to obtain as copper sulphate, but in my opinion its performance is unequalled. Having discovered its advantages, I was not aware that it had been considered before for electro-etching copper. Since then, others have also used it successfully. Like copper sulphate, the electro-chemical action does not change the chemistry of the copper nitrate and it remains pure, and there are no deposits that need to be filtered out. Hence the solution can be used again and again.

When making up a solution from copper nitrate crystals, the lowest resistance of electrolyte is not achieved by using a saturated solution i.e. one that contains the maximum weight that can be dissolved in a given volume of water (1380 gm/litre). The lowest electrical resistance is obtained by dissolving just 275gm in 1 litre of distilled or de-ionised water. This is a 1:5 solution. For most purposes, 500 ml of this made up solution is more than enough, so a purchase of a 500gm tub of copper nitrate could be shared by three people each having 500ml. This will enable them to electro-etch large samples almost indefinitely. Although the solution is not aggressive like nitric acid, it is still poisonous, and gloves should be worn to avoid staining the fingers.

The advantage of the low electrical resistance of a copper nitrate solution means etching large areas, say  $5\text{cm}^2$  and above, can be accomplished without the solution overheating or needing a high voltage from the D.C. power source. Etching times are also modest i.e. a couple of hours at most. As a matter of interest, a 1:5 solution of copper nitrate has an electrical resistivity about  $1/4$  of that of a 1:3 solution of copper sulphate.

Now having made up the electrolyte and completed the connections, if one simply switches on the D.C. supply from a fixed voltage source such as a battery or rectifier power pack, the current that flows might be so low as to require a very long etch time, or be so high as to etch very quickly. The former outcome is tedious and the resist could be affected by the long immersion time. Equally, the latter might overheat the solution, again causing problems with the resist and the etch can be rough and uneven. Having said that, many people manage to produce acceptable results with this switch on and fingers crossed method.

However, in my earlier report, I set down how to determine the current value, (I amps), that will etch effectively a given size of sample, ( $A\text{ cm}^2$ ). Large pieces need a higher current than small pieces if the etching time, (T minutes), is to be kept as low as is considered reasonable. I am aware that this alternative approach, which is based on the scientific work of Michael Faraday, might seem over complicated and difficult to apply in practice. I am probably guilty in this respect, and so I have simplified the calculation, but still using the basic laws of Faraday. The result is as follows.

The area,  $A\text{ cm}^2$ , is the total area exposed to the electrolyte, and its estimation is the key to what follows. Tedious though it may be to determine, my report shows a convenient way of doing this. That is the tricky bit over. Typical values will range from  $0.5\text{ cm}^2$  for a small item to  $10\text{ cm}^2$  or greater for a plaque. Then the current I amps is simply given by dividing this etching area by 5 ( $A/5$  amps). So, if the area A is, for example,  $7\text{ cm}^2$ , then the current should be set at  $7/5$  i.e. 1.4 amp.

Setting the current to this calculated value, as described above, requires a D.C. power supply whose voltage can be adjusted and which has an ammeter to display the current flowing. Many units are available from electronic suppliers. When using copper nitrate as the electrolyte, once the current is set at switch on, it remains very stable and the need for further adjustment is rarely necessary.

Finally, it is desirable to have some idea how long to etch for, (t minutes), and then to switch the current off. This of course depends on what depth of etch, (d mm), one is aiming for. The answer to this question is to multiply d mm by 300 and this then is the time in minutes. So, if you want to etch to a depth of 0.4mm, multiply by 300 to obtain the answer - 120 minutes, (2 hours). Note that you must have set the current level at the calculated value,  $A/5$  amps. In practice it is sensible to etch for say just

ten minutes to start with and then switch off to check etching has started and the resist is free of pinholes. Any deficiencies can then be rectified at this early stage.

A summary of my procedure for electro-etching copper samples for subsequent enamelling is best illustrated by the following diagram.

