

Technology in the School: Alternative Approaches I

The second of three short papers on technology in school, this article will examine an important family of metalforming techniques, seldom, if at all, represented in school work. Some of these might be described as unusual or even exotic, but in pursuing the alternative approaches theme I shall attempt to indicate how they might be brought into school at a minimal cost.

It would be impossible in such a short space to discuss all the techniques in depth, and what follows makes no apology for appearing somewhat superficial and emphasising practical rather than theoretical considerations. The literature on all that follows is enormous, and if any of this work is to be developed, it is an easy matter to consult standard texts and obtain advice from suppliers and manufacturers.¹

Electroplating

For a technique whose origins date back to the early nineteenth century and one which has long been of such commercial importance, it seems surprising that electroplating (and associated processes) should have been so neglected in school and college work. An obvious explanation is the highly toxic nature of the chemicals required for many useful plating solutions. One can safely assume that the commonly employed cyanide compounds are quite out of the question in schools. However, if certain limitations are accepted, other solutions can be used to good effect. One of these is considered below, but it is obvious, nevertheless, that great caution has to be exercised.

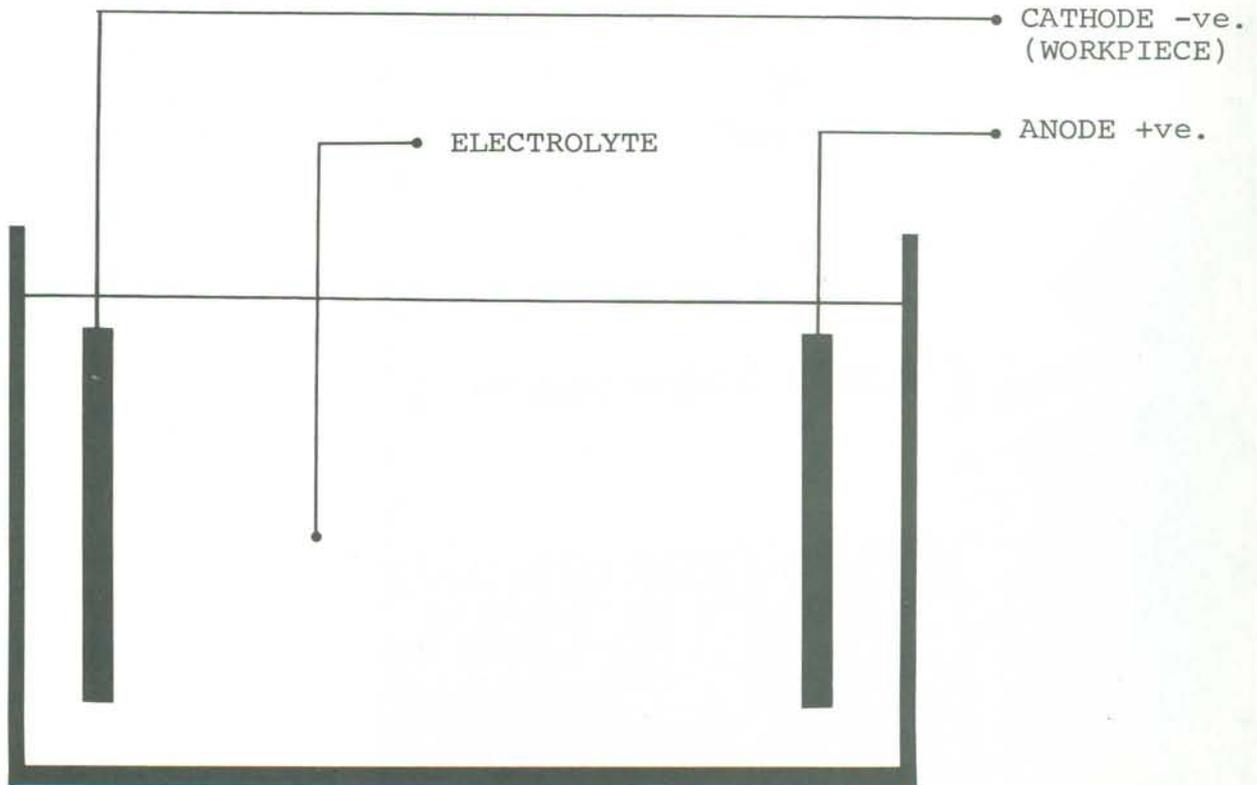
Electroplating involves the deposition of metal by electrochemical action in a bath containing an electrolyte — a solution consisting in its most basic form of dissolved salts of the metal to be deposited. Figure 1 shows the circuit for a simple electroplating bath; when current flows in the circuit completed by the partially conductive electrolyte, metal will go into solution from the anode (a mass of the metal to be plated out) and eventually deposit out on the cathode (the object to be plated). The electrolyte around the anode will tend to become locally enriched and around the cathode locally depleted; and for this reason — together with the fact that gas is liberated at both anode and cathode — the solution would normally be agitated.

An electrolyte for copper plating can be made up in the following proportions:

Copper sulphate	220 grams/litre (of water)
Alum	12 grams/litre
Sulphuric acid (pure)	
Sp. gravity 1.84	26 grams/litre.

(The usual safety precautions should be observed in making up such a solution — i.e., acid is added

Figure 1:
Circuit for a simple
electroplating bath.



slowly to the water – and warning signs should be displayed). SEE SAFETY NOTES.²

In making up and using this bath, the following points should be noted:

1. The bath can be operated within a wide range of room temperatures and, contrary to the normal textbook insistence on distilled water, tapwater can be used – remembering, though, that mineral content will differ from area to area.
2. A medium size battery within the voltage range 1.5 to 4.5 volts can be used to power the bath – e.g. HP2 size cells, singly or in series multiples. No instrumentation is strictly necessary for the small and uncomplicated work envisaged here.
3. Ferrous metals cannot be plated with this particular bath but the following can be: copper, brass, lead, certain fusible alloys.
4. A pure copper anode is desirable, but not strictly necessary. Commercial copper sheet proves adequate.
5. Although it is desirable to chemically clean the surface to be plated, mechanical cleaning with metal polish – providing all traces of polish and dirt are scrupulously removed – will give good results.
6. After a period of use the bath may acquire a dirty surface film which tends to wrap itself around the work as this is lowered into the electrolyte. Before use, therefore, the surface should be 'wiped' with (e.g.) the edge of a piece of paper and the film lifted off.

A stout glass or other suitable container should be found to hold the electrolyte. In a commercial operation, both the form and positioning of the anode(s) can be important, but here a single copper sheet bent over and hooked to the top edge of the container will suffice. (As a very rough guide, allow at least 8 square inches of contact area/litre of electrolyte). The workpiece (cathode) may be held in the bath with a pair of brass tongs wired to the negative side of the battery, but this naturally entails altering the place of contact with the tong jaws periodically to avoid masking small areas of the work. In the absence of stirring equipment, such an arrangement can be agitated during plating.

Apart from its usefulness for demonstrating the process, some interesting work is possible even given the limits of this particular bath. For example, dry transferes such as 'Letraset' are relatively unaffected by the electrolyte and can be used for stopping out. If a small piece of brass sheet is stopped out in this way and copper plated, a sharp definition copper/brass contrast appears when the transferes are removed. It is not without interest that this type of effect is produced commercially in connection, for example, with the manufacture of nameplates.

Electroforming

The thickness of the electrodeposited film on the cathode depends on a number of factors, but in time the anode should eventually disappear and the equivalent weight of metal appear on the cathode. The deliberate growth of thick metal shells

by protracted plating has long been an important means of forming metal objects, and the technique is applied, for example, to the making of printing plates, art metalwork (e.g., the Prince of Wales' crown), and generally in the mass manufacture of components.

Fusible alloys are commonly used for moulds (and subsequently melted away from the electrodeposited shell) but providing that a mould surface can be rendered conductive, non-conducting materials such as rubber or wax may be used. One traditional surface treatment involves the application of powdered graphite, and in spite of more recent advances – e.g. silver base paints, spluttering techniques – this method remains both cheap and effective, and can easily be adapted for school work.

The process normally begins with a pattern (or object to be reproduced) from which the mould is made – and subsequently prepared for plating. For school work, an easier alternative is to plate over a wax reproduction of the pattern, providing that one can accept the loss of surface definition as the shell grows in thickness.

A proven method for thus producing small objects is as follows:

1. Model the object to be electroformed in 'Plasticine'.
2. Take a mould from it by applying several layers of latex rubber, or any suitable cold setting mould material. (For demonstrations, these two stages can be avoided by using commercially produced moulds – e.g., for chess pieces).
3. Melt a quantity of paraffin wax and stir in powdered graphite until the mixture remains just liquid enough to pour at a temperature which will not injure the mould.
4. Pour the graphite loaded wax into the mould, but before setting takes place introduce a conductor rod (e.g., a 2" wood screw) into the wax at the open end of the mould so that when solidification has taken place it can be used to suspend the wax model in the electrolyte and afford a connection to the current source.
5. Holding the wax model by the conductor rod, dust the surface with powdered graphite and polish with a soft brush until uniformly shiny. (It should be noted that the success of the initial plating depends on the amount of time invested in this operation).
6. Using the plating bath described, immerse the model and agitate during plating. After about 15 seconds, remove the model and inspect the surface; if any part remains unplated, dry in a forced draught and repolish those areas with graphite. After blowing away excess powder, begin plating – and inspect again to determine whether the process needs repeating.

Depending upon conditions, a shell of some 0.1 mm can be built up within 15 minutes. A self-supporting one will obviously take longer, but since wax and graphite are relatively cheap, there seems little point in attempting to recover

them by melting unless it is important to end up with a hollow object. A very thin film of copper supported by the wax model can be finished and polished by any conventional means.

Because the quantity of metal deposited is proportional to the current passed, it is worth considering a low-voltage power supply for this type of work rather than expensive batteries. It must be stressed, however, that only proven commercial equipment should be used and that any supply unit should be electrically isolated (preferably removed) from the area of the bath to avoid possible dangers from fluid spillage. SEE SAFETY NOTES.²

Electrochemical Machining (E.C.M.)

In any electroplating operation, unless an inert anode is employed and the solution simply replenished with fresh salts, the anode will be sacrificed as the cathode grows in size. If attention is now focussed on the anode disappearing rather than the cathode growing, it becomes obvious that a means exists for deliberately removing metal. If, for instance, a pattern of small square holes is required in a thin gauge copper sheet, electrochemical removal offers a potentially distortion-free method. The material to be retained is stopped out and both sides and then exposed in a suitable bath as the anode. Depletion occurs only at the exposed surface, and these areas eventually disappear leaving only the desired stopped-out part of the anode. In principle, this is the process applied commercially in the production of pierced foils such as those destined for electric shaver heads.

In recent years, the same principle has been exploited to shape hard alloy steels with great control and precision, and purpose-built machines are available to perform electrochemically a wide range of operations which would otherwise be virtually impossible by conventional mechanical means. A workable arrangement for demonstrating the stripping of steel in this way involves nothing more than the simple bath already outlined with a brine solution as the electrolyte into which the steel workpiece is immersed as the anode. The iron does not plate out on the cathode (which serves only as a conductor to the electrolyte) but combines with the electrolyte, which must eventually be replaced.

(This work should only be carried out on a *small scale and in a suitable place* since the operation of the bath gives rise to toxic fumes. The spent solution should be safely disposed of). SEE SAFETY NOTES.²

It is possible at little further expense to arrange a more specific 'machining' process by pumping the brine electrolyte through a microbore tube against the anode workpiece, and thus confining the electrolyte action locally to the small area at the end of the tube (Figure 2). Such a drilling operation can be remarkably rapid and effective on a material such as high speed steel.

The practical requirements for a simple E.C.M. drill are a short length of microbore tube, either found or manufactured (e.g., brass rod turned down and drilled out to give 0.5mm/1mm diameter bore); a standard car windscreen washer pump; a length of P.V.C. tubing; and found or manufactured fittings to join the P.V.C. tubing to the side of the bath and the microbore tube.

Figure 2 shows the complete layout, with the electrolyte being drained from the bottom of the bath to be recycled. The anode and cathode connections can be made respectively with a large crocodile clip on the workpiece and a lead soldered to the microbore tube. The same power supply can be used to operate the motor and the bath if the voltage is more or less correct and a relatively high current (e.g. 5 amps) can be drawn from it. Holding the microbore tube as close as possible to the workpiece requires a steady hand, and a mechanical arrangement capable of providing a slow and precise feed is really necessary if the device is to be used for anything more than a simple demonstration.

Photofabrication

Reference has already been made to stopping-out techniques both in relation to depositing metal and removing it. An ever widening range of commercial operations now make use of photosensitive emulsions to facilitate the production of etch-resist images on metal surfaces.

In essence, the process involves applying a photosensitive emulsion to the metal surface; exposing it to ultraviolet light through a mask bearing the image (opaque against transparent) to be formed as etch-resistant; and then 'developing' the emulsion. In the case of a positive photo-resist emulsion, an opaque area on the mask will result in the emulsion remaining on the metal surface as an etch-resist film after exposure and development; where U.V. impinges on the emulsion through the transparent areas of the mask, the reaction causes it to be subsequently dissolved in the developer.

The mask is normally produced photographically from a large piece of original artwork. Since this can be dramatically reduced (and multiplied) by photographic means, and since the fidelity of image transfer to the photo-resist emulsion surface is typically very high, the advantages of the technique begin to become apparent. Among other applications the technique is used in the preparation of printed circuits, finely detailed components for model making, and currently in the production of silicon chip circuitry.

The process can be successfully demonstrated in school providing that a safe U.V. source is available – or one is prepared to depend on bright sunlight. Small U.V. boxes for this work are commercially available, but a low voltage fluorescent unit can be made up for under £10 (see suppliers). SEE SAFETY NOTES.²

Photosensitive emulsions can be purchased in the form of bottled liquids and aerosols, or materials

can be obtained already photosensitized. To buy the emulsion as a liquid is usually expensive (large minimum quantities) and can be potentially hazardous as some of the chemicals involved are highly toxic. Emulsions, even in aerosol form, can also be extremely difficult to apply in an even film.

Only the use of photosensitized boards of the type used for making printed circuits will be considered in what follows. This avoids potential hazards and virtually guarantees a successful result. It also limits the range of possible work, but apart from manufacture of printed circuits it is possible to create a vast range of decorative images and forms by partially or fully etching away the copper foil and shaping the board itself. Recent work here by David Prest and some of our students demonstrates that sophisticated pieces of jewellery can be made in this way.

A number of routes exist from the inception of an idea to the finished product, but only two will be dealt with here. Detailed instructions relating to the use of particular boards can easily be obtained from manufacturers, and the following description will therefore be confined to one of general procedure.

The most straightforward technique begins with the making of a mask directly onto thin acetate sheet of the type used for O.H.P. work. This can be done, for example, by stopping out areas with a suitable ink or by applying dry transfers such as 'Letraset'. When the mask is complete, the light proof backing film is peeled off the circuit board

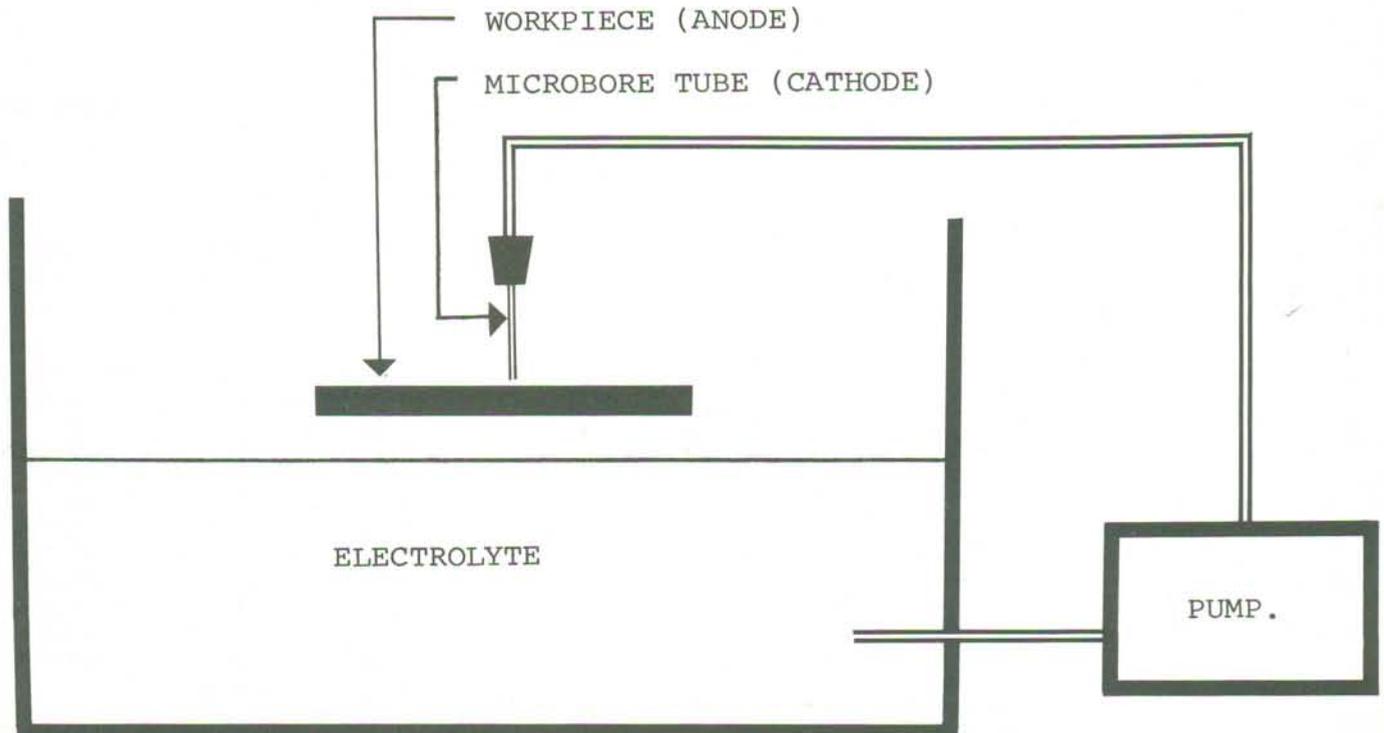
and the photosensitized surface exposed to U.V. through the mask — typically for a period of four minutes. The board is then developed (usually a weak caustic soda solution) leaving the etch-resist image as required. Finally, the copper foil surface can be conventionally etched in ferric chloride, etched electrolytically in the copper bath, or even plated heavily — if continuity permits — to build up the image in low relief.

An alternative technique, and one closer to commercial reality, involves drawing up the artwork on a relatively large scale on plain paper and photographing it to produce a 35mm size negative which becomes the mask. If a camera and simple developing facilities are available, 36 such masks can be made in a single batch. The film required is Kodalith 2556. Purchased in 100 ft. rolls, it works out at less than 1p per frame (see suppliers).

Anodising

Of all the techniques examined so far, anodising is probably one which many schools have already attempted — and with varying degrees of success. Since a good deal has been written specifically with school work in mind, there would seem little point in reiterating it here. It might be worth concluding, though, with a brief look at the anodising technique used for colouring metals such as titanium, now frequently employed for jewellery work. As a matter of fact this metal remains prohibitively expensive, but industrial offcuts can be almost worthless, and some firms are only too happy to supply sample pieces.

*Figure 2:
Electrochemical drill.
Electrolyte is pumped
from the bath and
ejected under pressure
from the microbore
tube. The microbore
tube is wired to the
negative side of a low
voltage supply and the
workpiece connected
to the positive side.*



In principle, titanium anodising is identical to the method employed for aluminium. The item to be treated is put into a suitable bath as the anode, and when current is passed oxygen is liberated which combines with the surface metal to form a tenacious oxide film. But here the similarity ends. In the case of titanium, vivid colours arise out of the oxide film itself as a result of thin film interference, unlike aluminium which has to be subsequently dyed. Also, the power supply requirements and electrolytes are quite different.

To obtain the full colour range, a variable voltage supply up to 100 volts is necessary. This is clearly out of the question in school, but an interesting range of colours is still possible if one thinks in terms of an upper limit of 20 volts. This is within the range of some low voltage power supplies and can be achieved alternatively by using a number of 9 volt batteries (e.g., PP9) in series. The thickness of the oxide film, and therefore the colour, is effectively determined by the voltage, and this can be varied by altering the number of batteries or by switching a suitable power supply.

A number of electrolytes are suitable for this work but – strange as it may seem – fresh ‘Lucozade’ is appropriate, and must surely be the safest one can start with. Colouring a surface can be carried out by simple immersion combined, possibly, with stopping out. It is also possible to ‘paint’ on the colour by connecting the metal ferrule of a camel hair brush to the negative side of the low voltage supply, dipping the brush in electrolyte, and working it very slowly over the surface.

The intrinsic fascination of some of the techniques considered above and their relevance to modern manufacturing methods are surely two good reasons for thinking that they have a place in the ever widening spectrum of CDT work. Nothing suggested here requires anything more than a very modest capital outlay, and our experience certainly suggests that an amount of interest can be generated out of all proportion to the actual costs involved.

Acknowledgement

I would like to thank Mr. Gordon McGowan for drawing our attention to the subject of titanium colouring.

Notes

1. The current *Canning Handbook on Electroplating* is an excellent reference source, but concerned largely with industrial practices. A useful little book is Warburton, L. (1975) *Electroplating for the Amateur*, MAP Technical Publications.
2. As a matter of good practice, no chemical should be regarded as harmless or even relatively so. Where a plating bath is involved, all precautions must be taken to ensure its safe use; i.e., ventilation should be adequate (or a fume cupboard used), protective clothing, including approved goggles, must be worn, and electrical supplies should be safe and safely positioned. U.V. radiation can be harmful, and any source should be properly shielded before use. Where doubt exists with regard to the safety of a particular electrolyte, process or piece of equipment, expert advice should be sought.

Suppliers

Canning Limited,
Greenhill Crescent,
Holywell Estate,
Watford.

Suppliers of plating equipment, solutions, etc.
Will supply very useful technical literature on request.

Kodak Limited,
P.O. Box 114,
246 High Holborn,
London, WC1V 7EA.

Suppliers of photographic and photo-resist materials
Will supply technical information on request.

Process Supplies (London) Limited,
19 Mount Pleasant,
London, WC1.

Suppliers of Kodalith 2556 film – approximately
£8 per 100 ft.

G.F. Milward Electronic Components Limited,
369 Alum Rock Road,
Birmingham, B8 3DR.

Suppliers of aerosol photo-resist emulsion (‘Fotolak’) photo-resist coated circuit boards, Ferric chloride crystals.

R.S. Components Limited,
P.O. Box 427,
13-17 Epworth Street,
London, EC2P 2HA.

Main suppliers of electrical/electronics goods.
Stock items include photo-etch materials and U.V. light boxes.

Downswood Products Limited,
Park Lane,
Knebworth,
Herts., SG3 6PJ.

General laboratory suppliers: chemicals and chemical apparatus.

Radio Service Co.,
Newport Street (Off Lisle Street),
London, WC2.

General electrical suppliers. Low voltage U.V. light kits are currently available for approx. £10.

IMPORTANT NOTE:

IN THE LAST ISSUE OF THIS JOURNAL, THE FIRST ARTICLE IN THIS SERIES EXAMINED THE IDEA OF USING DISPOSABLE SYRINGES FOR HYDRAULICS DEMONSTRATIONS, MODELLING AND PROTOTYPE WORK. SINCE THE POSSIBILITY OF ABUSE, HOWEVER REMOTE, MIGHT BE THOUGHT TO EXIST IT IS URGED THAT ANY SYRINGES USED IN THIS WAY SHOULD REMAIN THE PROPERTY OF THE SCHOOL AND THAT A STRICT SYSTEM OF ACCOUNTING SHOULD BE ADOPTED.