Factors affecting the anodizing of an aluminum metal

Anodizing is a process for producing decorative and protective films on articles made from aluminum and its alloys. It is essentially a process where a thick film of aluminum oxide is built up on the surface of the aluminum through the use of a direct current electrical supply. In the majority of anodizing plants in New Zealand it is carried out in an electrolyte bath containing sulfuric acid with aluminum sheet cathodes and the work to be anodized attached to the anode (Figure 1).

When the current is flowing in the cell the following sequence of events is believed to occur. Sulfuric acid begins to decompose, the hydrogen ions moving to the cathode where they are reduced to hydrogen gas:

$2H^+ + 2e^-$ â†’ $H_2(g)$ (1)

Simultaneously, negatively charged anions, i. e. hydroxide, sulphate and maybe oxide ions move to the anode. The electrical charge in the circuit causes positively charged aluminum ions (Al^{3+}) to be generated in the anode and in turn move toward the cathode. At the anode surface they react with the oxide/hydroxide ions to form aluminum oxide (in the case of the hydroxide ion, hydrogen ions are released into the solution).

There are two types of ions involved in any Electrolyte. The reactions take place and Anions and Cations are formed and transferred to the opposite ends of an Electrolyte. Anions are positively charged ions and Cations are negatively charged ions in an electrolyte.

In chemistry, an electrolyte is any substance containing free ions that make the substance electrically conductive. The most typical electrolyte is an ionic solution, but molten electrolytes and solid electrolytes are also possible. Ion is a particle which is electrically charged either positive or negative; an atom or molecule or group that has lost or gained one or more electrons.

An ion is an atom or molecule where the total number of electrons is not equal to the total number of protons, giving it a net positive or negative charge. An anode is an electrode through which electric current flows into a polarized electrical device. A cathode is an electrode through which electric current flows out of a polarized electrical device.

Anodizing is a method of electrolytic passing to increase the thickness of the natural oxide layer of the surface of various metal parts. This process is called “ anodizing” because the part which to be treated forms an anode electrode of the electrical circuit. Anodizing mainly increases corrosion resistance and provides better bond for paint primers and glues than bare metal. Anodizing is even used to prevent galling of threaded components and to make dielectric films for electrolytic capacitors. Anodic films are most commonly applied to protect aluminum alloys, although processes also exist for titanium, zinc, magnesium, niobium, and tantalum. This process is not a useful treatment for iron or carbon steel because these metals exfoliate when oxidized; i. e. the iron oxide, flakes off, constantly exposing the underlying metal to corrosion.

Anodizing changes the texture of surface and also changes the crystal structure of the metal near the surface. Thick coatings are normally porous, so a sealing process is often needed to achieve corrosion resistance. Anodized aluminum surfaces, for example, are harder than aluminum but have low to moderate wear resistance that can be improved with increasing thickness or by applying suitable sealing substances.

Equations of the anode reactions

Al â†’ Al3+ + 3e- (2)

2Al3+ + 3O2- â†’ Al2O3 (3)

2Al3+ + 3OH- â†’ Al2O3 + 3H+ (4)

For which the overall process is:

2Al + 3H2O â†’ Al2O3 + 6H+ + 6e- (5)

The sulfate ions also play some part as the oxide coating contains 12 – 15% sulfate ions. It is suggested that the sulfate ions facilitate the movement of hydrogen ions reducing the cell voltages required.

THE DEVELOPMENT OF THE ALUMINIUM OXIDE LAYER

Fresh aluminum reacts readily with oxygen to produce aluminum oxide. Once formed the oxide remains firmly bonded to the surface forming an impenetrable layer. Consequently, further reaction ceases. The film is very thin (0. 01m), and despite its tenacity it can be removed by abrasion and chemical corrosion. In such instances the aluminum is subject to wear or the surface will mark or become pitted at the site of corrosion.

Anodizing produces much thicker coatings (12 – 25 m) which, if properly sealed, can extend the life of the surface appreciably. Recent research in

New Zealand has shown that pitting of the surface can be reduced by up to 90% with a 12 m coating, and by up to 93% with a 25 m coating.

In the initial stages (i. e. first 60 s) of anodizing the oxide layer formed is dense and of even consistency. It provides the greatest resistance to wear and corrosion and consequently is called the barrier layer. The growth of this layer ceases when the high electrical resistance of the oxide reduces the potential of the applied voltage in the electrolytic cell. The depth of the coating at this stage is about 0. 08m. Subsequent growth is very slow and competes with the acid reaction:

Al2O3 + 6H+ _ 2Al3+(aq) + 3H2O

which releases Al3+ ions into the solution. Note that the H+ can be at high concentration near the oxide layer due to one of the anode reactions above. See equation (5).

At low applied voltages only the barrier layer forms. However, the gradual production of Al3+ ions tends to smooth out the underlying metal surface and give a brightening effect to the article. Objects such as wheel trims and bumper bars are general treated in this way. At higher voltages the growth of the layer continues beyond the barrier layer. Unlike the initial barrier layer this secondary layer, although constitutionally the same, has an open pore-like structure; a consequence of the competing anodizing and acid solution processes. Electron photomicrographs reveal the structure of these anodized surfaces to be as shown in Figure 2.

The conditions required to produce coatings vary according to the concentration and nature of the electrolyte, the voltage – current density applied, the alloy being anodized and the temperature of the bath. In the majority of electrolytic plants articles are anodized at a potential of 15 – 20 V and a current density around 1. 6 A d-1 m-2; the electrolyte is 3. 5 mol L-1 sulfuric acid maintained at temperatures between 20 and 23oC. Under these conditions the quality of the coating is satisfactory for most applications. At higher electrolyte concentrations and temperatures, and at lower voltages or current densities, the acid solution process occurs earlier in the development producing thin, open oxide coatings. Conversely, hard dense coatings are produced at low temperatures and high current densities. The conditions established in each plant are determined by the type of application.

PRE-TREATMENT

Step 1 – Cleaning

Correct and adequate cleaning of the aluminum object prior to anodizing is essential if the finished work is to have a uniform and attractive appearance. When aluminum arrives from the rolling, casting or extrusion mills it may be soiled following ways:

- Carbonaceous deposits from the surface of forgings and die castings
- Traces of oil-based lubricants
- Traces of polishing compounds or sanding grits
- Oxide films from heat treatment

Cleaning these ‘ soils’ from the surface may prove difficult, especially if the requirements of the work do not allow etching of the surface. Most cleaning solutions used in New Zealand operations are detergent based. In addition to the detergent, a wetting agent and a complexion compound may be used. The complexion compound frequently used is sodium polyphosphate – a component of many soap formulations – which prevents ions, such as Fe3+, adhering to the surface of the work. If etching is not a problem, sodium hydroxide or sodium carbonates (Na_2CO_3 / $NaHCO_3$) may be added to increase the effectiveness of the solution.

Step 2 – Etching

Etching is most often achieved by the use of a warm, 10 % (2. 5 mol L-1) sodium hydroxide solution. It gives the surface of the metal a light grey satin finish (through diffuse reflection of the incident light). The vast majority of work is pretreated in this way. In theory the reactions occurring in the etching solution are:

The etching reaction:

2Al + 2NaOH + 2H2O â†’ 2NaAlO2 + 4H2 (7)

Dissolution of the aluminates:

NaAlO2 + H2O â†’ NaOH + Al (OH)3 (8)

Dehydration of the solid hydroxide:

2Al(OH)3 â†’ Al2O3 + 3H2O

The rate of etching is dependent on the concentration of the sodium hydroxide solution, the temperature and the concentration of aluminum ions which are released into the solution. When high concentrations of aluminum ions are present the solution loses its effectiveness. Presence of other ions, some of which may be a component in the alloy, can also interfere in the process, causing blemishes to appear on the surface of the work.

The problem of ion contamination is overcome by employing etching solutions which suppress the action of the Al3+ and other metal ions released. The compositions of these solutions are the propriety of the companies that develop them, but generally contain sequestering agents which complex metal ions. Such solutions do not have an infinite capacity to do this but, due to the ‘ carryover’ of solution by the etched work and periodic replacement by fresh etch solution, the etching batch is maintained in an effective condition (Figure 3).

Foaming agents are also a constituent of the etching solution; their action is to reduce the pungent mists/fumes that result from the vigorous reactions that occur. It is important to note that the appearance of the end result is determined at this stage. Work which is poorly etched will reveal scratches or blemishes no matter how well it is anodized or colored.

POST TREATMENT

After cleaning and anodizing the work is colored and sealed. As all anodized work is sealed, sealing will be considered first, although if coloring is to be done it is carried out prior to sealing.

Sealing

Sealing is the process in which the pores at the surface of the oxide layer are closed off. It is affected by placing the anodized object in boiling water for a

15 – 20 minute period. During that time the water reacts with the aluminum oxide to produce the mineral Boehmite – Al2O3. H2O or AlO. OH:

Al2O3 + H2O â†’ 2AlO. OH

Boehmite is a hard, transparent material with a greater volume than the aluminum oxide. As it forms it closes off the openings of the pores.

As would be expected, the durability of the anodized surface, especially in regard to chemical corrosion, is greatly influenced by the effectiveness of the sealing. If the duration of the sealing is too short the pores, although constricted, remain open for corrosion agents to be in

close proximity to the aluminum surface. Corrosion studies have shown that anodized aluminum which has been sealed for 15 minutes or more has greatly increased resistance to pitting by chemical corrosion agents such as H+ and Cl-.

Colouring

Colouring involves the absorption of a coloured dye into the pores of the oxide coating which becomes fixed after the sealing process has been completed. Dyestuffs which can bond to the oxide or metal ions in the anodized layer have better colour properties than those that do not.

Electrolytic colouring is the most important method of colouring anodised aluminum today. It produces attractive finishes of very great colour and heat fastness and is easy to perform. The anodized work is dipped in a tank containing coloured ions of other metals.

Under the influence of alternating current the colouring agents deposit rapidly at the very base of the pores and the take is even over the entire surface. Unlike the process of dye absorption, electrolytic colouring is easy to control and gives uniformity of colour from one run to the next. The success of this technique is evident in the widespread use of bronze colored aluminum in joinery and house fittings. Approximately 66% of all bronze tinted aluminum is coloured by this technique.

To a much lesser extent coloured inorganic compounds can be used to colour the work. Ammonium ferric oxalate is a very common compound used to impart a goldy colour to the metal. Other colours can be impacted by treating the absorbed ferric ammonium oxalate with other compounds: for example, potassium ferrocyanide solution will react with the ferrioxalate compound to produce a blue colour. The technique used is to dip the work firstly in a solution of the ammonium ferrioxalate followed by dipping the work in the potassium ferrocyanide solution. This double dipping technique can be used with other compounds to produce a variety of colours: e. g. copper sulfate followed by ammonium sulfide gives green, and lead nitrate followed by potassium chromate gives yellow.

Experiment on Anodizing of aluminum

Method

Before the demonstration

Line the inside of the sides of the 1 dm3 beaker with a double thickness of aluminum foil. Fill the beaker with sulfuric acid. This should be at about 25 C – adjust the temperature if necessary. Set up the electrical circuit shown in the figure. Make up the dye solution according to the instructions supplied (i. e. dissolve the contents of the tin in about 600 cm3 of water) and add a few cm3 of glacial ethanoic acid.

The demonstration

De-grease the aluminum strip by rubbing with a tissue soaked in propanone and then dip the strip into a beaker full of propanone for short time and allowing drying. From now on, hold the aluminum by the top few cm only.

Dip the bottom half of the aluminum strips into the sodium hydroxide solution in a beaker. Leave it until it begins to effervesce, indicating that the surface layer of oxide has been removed. (This will take about one minute.) Now remove the strip and dip the cleaned portion of it into the nitric acid for a few seconds to neutralize the alkali. Then rinse away the acid with water. Clamp the strip so that the lower, cleaned, section is immersed in the sulfuric acid electrolyte and is in the centre of the cylinder of aluminum foil which forms the cathode. It must not touch the cathode.

Complete the circuit with crocodile clips making the aluminum strip positive and the foil negative. Now adjust the power pack and rheostat so that current flows which give a current density of 10 -20 mA cm-2 of anode area immersed. For example if the anode has an area of 3 cm x 3 cm immersed, the area will be 3 x 3 x 2 cm2 = 18 cm2 so the current should be between 180 and 360 mA (0. 18 and 0. 36 A).

Leave to electrolyze for about 30 minutes, keeping an eye on the current and adjusting the rheostat if necessary to keep its value constant. (The current may tend to drop as the oxide layer thickens.)

When the electrolysis is complete, switch off the power and remove the aluminum strip. Rinse the strip in water. It will not look very different at this stage. Now dip the strip into about 200 cm3 of the dye solution in a beaker. Make sure that some of the non-anodized part of the strip is immersed as well as the treated section.

Leave for about 15 minutes – longer immersion will produce a deeper colour. Some of those who trialed this demonstration left the strip in the dye overnight. Rinse to remove any dye which has not been absorbed. Dye will only be absorbed by the anodized section, which will turn a deep cherry red. If desired, seal the dye by immersing the dyed strip for a few minutes in water that is already boiling. This will make the colour less prone to rubbing off, but will wash out some of it. Many teachers may prefer to omit this procedure.

Visual tips

Large demonstration meters will be easy to see. Long connecting leads are useful to prevent the electrolysis tank becoming lost in a maze of wires.

Teaching tips

It would be wise to prepare something to fill in the half hour of electrolysis time and the 15 minutes dyeing time. The class could be asked to calculate the expected increase in mass of the anode or to discuss the chemical reactions involved. Have a selection of anodised objects such as saucepan lids available for the class to look at. The demonstration (No. 18) of the reactivity of aluminium without its normal oxide layer could be shown. Some teachers may prefer to anodise some aluminium before the lesson to have some pieces ready to show the class.

Theory

Untreated aluminium has a layer of oxide about 10-8 m thick. This explains its apparent lack of reactivity. Anodising, invented in 1923, is used commercially to thicken this layer to 10-5 m to improve the metal’s corrosion resistance.

The relevant equations are:

Cleaning:

Al2O3(s) + 2OH-(aq) + 3H2O(l) â†’€ 2Al(OH)4-(aq)

Once the oxide is removed:

2Al(s) + 2OH-(aq) + 6H2O(l) â†’2Al(OH)4

– + 3H2(g)

Electrolysis at the anode:

2Al(s) + 3H2O(l) â†’Al2O3(s) + 6H+(aq) + 6e-

Electrolysis at the cathode:

6H+ (aq) + 6e- â†’3H2(g)

Electrolysis overall:

2Al(s) + 3H2O(l) â†’Al2O3(s) + 3H2(g)

The oxide coating develops a positive charge by the reaction:

Al2O3(s) + H2O(l) â†’Al2O3H+(s) + OH-(aq).

Thus it attracts dyes that contain coloured anions. These are absorbed in oxide layer which have pores, where they are trapped by heating the oxide to form an Al2O3. H2O seal.

Extensions

There are a great many variables in this experiment such as: electrolysis time, voltage, current density, concentration of electrolyte, temperature of electrolyte, temperature of dyebath and type of dye. Investigations of some of these could form interesting projects. It is possible to measure the gain in mass of the anode by rinsing the aluminium strip with propanone and weighing it immediately before and immediately after electrolysis.

The Different of Anodizing And Electroplating

Electroplating is a technique to plate some metal or non metal with metal using electric current. While anodizing is plate metal like aluminum by inserting some substance under the oxidized layer of aluminum by using of electric current force. The function and the effect of both process may the same, like have color surface so that can use as decorative purposes.

Not all metal can use anodizing process but only certain metal can use this method to make endure to corrosion effect. Aluminum metal can be treated by anodizing because after electric current process make the aluminium have oxidized layer on the surface and this layer can have wide pore so that other chemicals like dye or prevented agent to be impregnated to enter this oxidized layer. After certain substance enter into this oxidized layer then by certain method the pore can be closed by further process. Actually by using just electric current will create anodized layer, but the problem this layer have no colour and look bad, to make this more interesting then on anodizing process using colour agent and inserted below the anodized layer.

Electroplating is directly plate other metal into certain metal with the goal to make more interesting or make more endure to corrosion or from other outside effect. Like on hard chrome plating on screw driver, can make this surface hard and not easy to break if not plate by hard chrome. By nickel plating on other metal will make the surface is endure from reaction effect because nickel more noble than the metal below the nickel surface. Nickel plating usually use in canning process, or use in decorative accessories. Electroplating rely on the plate stick strong, more strong certain plating metal stick to the base metal is better.

Electroplating

Electroplating is plating to certain metal with other metal that is usually more durable from corrosion or stronger than original metal. The process itself use of electrochemical by which metal is deposited on the origin metal through the chemical bath.

Usually using electrode pole that is connected to the negative and the other to the positive pole. Electrode on the negative pole is called as anode and electrode that connected to positive charge is called as cathode. Metal on the solution form will turn to positive ion and on the electrochemical process this ion will attract to negative electrode or to anode and will plate anode. So metal that will be plated is placed on the anode position.

Electroplating is done in a plating bath which is usually a non-metallic tank like plastic or glass. The tank is filled by metal solution, which the metal kind will plate the anode. The anode is substrate to be plated which is connected to the negative terminal of the power supply.

As we apply current, positive metal ions from the solution move towards anode with negative charge and deposit on anode. As a replenishment of these deposit ions, the metal from cathode will dissolve and goes into the solution and make the ionic potential balance.

In the case using of noble metal like gold as cathode it is not sacrificial, but it is made out of materials which do not dissolve in an electrolyte such as titanium.

Electrochemical Theory:

Actually electroplating is based on the Faraday’s Laws that state as follows:

The weight of a substance formed at an electrode is proportional to the amount of current passed through the cell. The weights of different substances produced at an electrode by the same amount of current are proportional to their equivalent weights.

Corresponding mass in an oxidation-reduction reaction is = molar weight of the compound / algebraic change in oxidation number of the atom that is oxidized or reduced.

$2 FeCl_2 + Cl_2$ â†’ $2 FeCl_3$

Fe valence is change on the reaction from +2 to +3. However on the reaction will:

Mn + FeSO4 â†’ Fe + MnSO4

Chrome Plating

Chrome plating is a part of coating technology that use of electroplating process. Electroplating process itself can use many kind of metal like chrom, copper, nickel, silver or gold. The process of all metal is similar, that is use of DC electric current and using of metal solution. But the differences of all the process generally on the solution uses, concentration uses, current flow, temperature limitation, plating time and many other limitation that difference of each metal coating.

Chromium plating is also different among the result purposes from the current flow, chromium concentration and other chemical additive that is use on each of chromium plating kind. The chromium plating such as hard chrome, dull chrom, black chrome and bright chrome. Every result goal needs different parameter uses that must be followed in order to get the result as the process goal. So chromium plating process needs strict control on the bath concentration, equipment precision and on the method uses. Any small substance contain on chromium bath can result a different kind of product.

Anodizing aluminum

This is an experiment showing interesting application of electrolysis. The oxide layer on aluminum foil is made thicker by anodizing which improves the metal’s corrosion resistance. In the process, the thickened oxide surface coating is coloured by using dyes.

Lesson organization

This works well as a class demonstration, but there are several tasks to complete in preparation. The anodising process itself takes about 30-40 minutes, with nothing particularly dramatic happening, so you will need to plan other activities to fill the time.

At the start of the experiment, show the students the effervescence due to the hydrogen evolved from the cylindrical aluminum cathode. A flexi camera connected to a projector could be used here.

During the anodizing phase, the theory could be explained with an emphasis on the applications of the process. A collection of anodized objects such as saucepan lids or sports equipment could be available to look at.

A well-disciplined and organised class might be able to carry out this process for themselves (in twos or threes), but it is strongly recommended that the treatment with sodium hydroxide solution (Corrosive) – prior to the electrolysis – is carried out under strict supervision.

Apparatus and chemicals

Eye protection, Low-voltage DC power pack, adjustable up to 10 volts, Connecting leads and 4 crocodile clips Paper clips, plastic Test-tube holder, wooden, Paper tissues Strip of wood, 15 cm long Ruler (30 cm), Beaker (1 dm3), Beakers (250 cm3), 3Aluminum foil, approximately 40 cm x 15 cm, Congo Red dye (Toxic) Ethanol (Highly flammable, Harmful) Sulfuric acid approximately 2 mol dm-3 (Corrosive), 1 dm3, Sodium hydroxide, approximately 1. 5 mol dm-3 (Corrosive), 250 cm3. Propanone (acetone) (Highly flammable, Irritant)

Technical notes

Congo Red dye (Toxic). Refer to CLEAPSS Hazcard 32. Ethanol (Highly flammable, Harmful). Refer to CLEAPSS Hazcard 40 (2007: 40A) Sulfuric acid approximately 2 mol dm-3 (Corrosive). Refer to CLEAPSS Hazcard 98 (2007: 98A Sodium hydroxide, approximately 1. 5 mol dm-3 (Corrosive). Refer to CLEAPSS Hazcard 91. Propanone (acetone) (Highly flammable, Irritant).

1 Reasonably thick aluminium foil should be used, but, if unavailable, ordinary kitchen foil works quite well.

2 Propanone is needed to degrease the aluminium foil and it is worth keeping a bottle specifically for this purpose. The used propanone can be poured back into the bottle and kept for future use. This reduces waste disposal requirements.

3 The solid Congo Red dye needs to be made up into solution. Use 0. 5 g of dye, 50 cm3 of ethanol and 50 cm3 of water and warm to dissolve. Dylon cold fabric dye (Camilla A 16) also gives good results. Red fountain-pen ink can be used as an alternative but does not give such good results.

4 Instead of a power pack, a battery or series of batteries could be used.

Procedure

HEALTH & SAFETY: Eye protection must be worn.

Before the demonstration

a) Cut two pieces of aluminum foil, one 10 cm x 3 cm (the anode), the other about 30-35 cm x 12 cm (the cathode). Ensure that when the foil is folded into a cylinder it fits inside the beaker as shown below.

Anodising aluminium

b) Work in a fume cupboard and ensure that there are no flames close by. Work on a clean surface. Degrease the two pieces of foil by rubbing well with a paper tissue soaked in propanone and then dip the strips into a beaker of propanone for a few seconds.

c) Remove the strips of aluminum from the propanone and allow drying. From this point on, only hold the aluminum foils at the top edges.

d) Arrange the larger piece of aluminum into a cylinder. Fix it in position with plastic paper clips and then place inside the large beaker as shown in the diagram.

e) Set up the strip of wood on the beaker and use Bluetak to attach two crocodile clips, one at the edge and one in the centre. Attach the outer clip to the aluminum cylinder. This is the cathode.

f) Pour some of the cold sodium hydroxide solution (Corrosive) into a 250 cm3 beaker. Hold the smaller piece of aluminum foil with a wooden test-tube holder, and dip it into the sodium hydroxide solution. After a short while, hydrogen gas will be given off rapidly. Remove the strip after a few seconds of fizzing, and wash it in a stream of cold running water.

g) Attach the aluminum strip to the central crocodile clip ensuring that it is arranged vertically (see diagram). This central strip (the anode) must not touch the aluminum cylinder.

h) Carefully fill the beaker with the sulfuric acid from a measuring cylinder up to a level about 1 cm below the top of the aluminum cylinder.

SAFETY: Remember that hydrogen (Highly flammable) will be evolved during the electrolysis. Keep all naked flames well away from the experiment (e. g. when heating the dye solution).

Demonstration

a) Connect up the circuit and use a voltage of 5-10 volt. Electrolysis is occurring when bubbling can be seen at the cathode (hydrogen). Pass a current for about 20 minutes, or longer, if time permits.

b) While the electrolysis is running, heat the dye solution in a beaker to about 70°C. An electric hotplate is preferable to a Bunsen burner. An additional beaker of boiling water will also be needed.

c) Remove the central aluminum strip (the anode) and place it in the hot dye solution. Stir and leave for about 10-15 minutes.

d) Transfer the aluminum anode to a beaker of boiling water and leave for another 10 minutes. This seals the dye onto the anodized surface of the aluminum and makes the aluminum oxide layer less porous.

e) The upper non-anodized portion of the strip should be the original metallic grey colour whilst the rest should be coloured red. The aluminum strip can be dried in paper tissue and passed round the class. It should not be possible to rub off the dye off the surface.

Teaching notes

The demonstration itself

The instructions may seem very detailed, but experience shows that success depends on getting the conditions just right. You should try out the experiment before carrying it out as a demonstration. It would be useful to have some sample strips of anodized aluminium to pass round.

The voltage will drop during the experiment, since the anode is becoming increasingly coated with aluminium oxide. If a rheostat and voltmeter are used, the readings can be constantly monitored and adjustments made to keep the voltage approximately constant.

A longer immersion in the dye will produce a strip with a deeper red colour. Leaving the strip in the dye overnight produces the best results.

If time is short, omit the dye-sealing stage in boiling water.

If there is time, a piece of the cathode could also be immersed in the dye. It will be found that the dye is not taken up by the metal in the same way.

This is a good experiment to show students towards the end of their study of electrolysis.

Chemistry points

When a piece of aluminum is exposed to the air, it rapidly becomes coated with a protective surface layer of aluminum oxide.

Heating the aluminum in air can make the oxide layer thicker, but anodising is much more effective.

The oxide layer can be made to absorb dyes. This is useful in a range of everyday goods, such as kettles, window frames and some sports equipment, all of which need to be able to withstand extreme physical conditions.

Untreated aluminium has an oxide layer about 10-8 m thick. This explains aluminium’s apparent lack of reactivity in the laboratory. Anodising thickens this layer to about 10-5 m and dramatically improves the metal’s corrosion resistance.

Oxygen is often evolved at the anode during the electrolysis of aqueous solutions. Aluminium is a reactive metal. The oxygen formed reacts immediately with the aluminium. It forms a solid oxide coating on the surface of the metal electrode.

Theory for more able students

For students working at a higher ability level, some or all of the following equations and explanations could be introduced:

The cleaning process with NaOH:

(1) Al2O3(s) + 2NaOH(aq) + 3H2O(l) â†’ 2NaAl