Titanium Anodizing

In a galvanic or voltaic electrochemical cell, the spontaneous reaction occurs and electrons flow from the **anode (oxidation)** to the **cathode (reduction).** In an electrolytic cell, a non-spontaneous reaction occurs using energy supplied by an external source. Electrons are forced from the external circuit at cathode to produce the reduction. The **cathode** is the **negative electrode** and is the **black** connection on the power supply. Electrons are drawn into the external circuit at the anode to produce the oxidation. The **anode** is the **positive electrode** and is the **red connection** on the power supply.

Some metals form an oxide coating on the surface the metal as the metal is electrolytically oxidized. Since this oxidation takes place at the anode, the process is called anodizing. Aluminum metal is commonly anodized.

$$2\ Al_{(s)} + 3\ H_2O_{(l)} \rightarrow Al_2O_{3\,(s)} + 6\ H^{+1}{}_{(aq)} + 6\ e^-$$

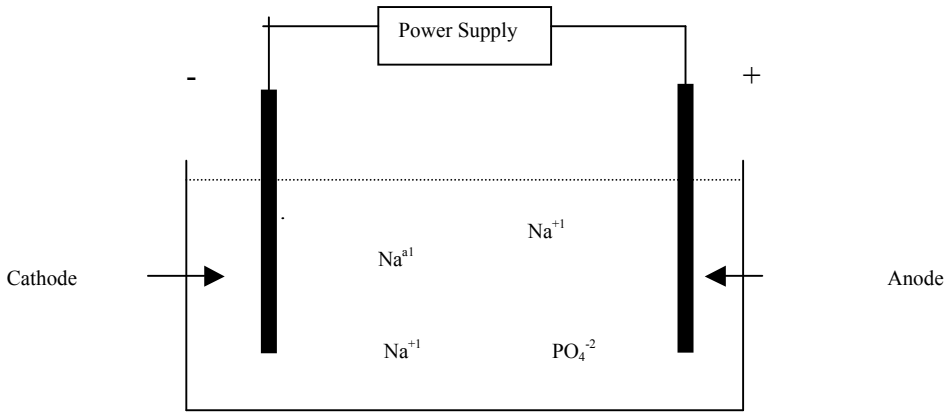
The layer of aluminum oxide bonds tightly to the metal and can be used to bond different dyes to the surface. Many types of sports equipment and furniture have a durable colored surface of dyed anodized aluminum.

Titanium metal can be oxidized (anodized) by the following reaction.

$$Ti_{(s)} + 2\ H_2O_{(l)} \rightarrow TiO_{2\,(s)} + 4\ H^{+1}{}_{(aq)} + 4\ e^-$$

The oxide coating on the titanium, however, acts as a diffraction grating and separates white light into its colors so that no dyeing is necessary. The color of the surface depends on the thickness of the oxide layer on the surface, which is control by the voltage used during the anodizing process.

A typical electrolytic cell is used.



A stainless steel cathode is used in the cell. Water is reduced at the cathode.

$$2\ H_2O_{(l)} + 2\ e^- \rightarrow H_{2\,(g)} + 2\ OH^{-1}{}_{(aq)}$$

The hydrogen gas escapes from the solution and the OH^{-1} ions enter the solution. The OH^{-1} ions react with the H^{+1} ions produced at the anode to form water.

Questions:

1. Which color lead should be attached to the cathode?
2. Which color lead should be attached to the anode?
3. Write an overall balanced equation for the reaction occurring the electrolysis.

Sodium phosphate, Na_3PO_4, is added to the solution as the electrolyte so the solution is electrical conducting.

In this experiment, you will design and anodize a pair of earrings.

Procedure:

Safety glasses must be worn during this experiment.

1. Cut the titanium wire to the desired length. Shape with a pair of pliers. Decide the color pattern you want to create on the wire.

2. Connect anodizer unit to the step up transformer. Attach the red and black leads to the anodizer.

3. Place about 80mL of 5% Na_3PO_4 solution into a 100mL beaker.

4. Bend a small piece of stainless steel so that it will hang over the edge of the beaker into the solution.

5. Attach the black lead from the anodizer to the stainless steel electrode.

6. Use a pair of tweezers to hold the wire. Dip the wire in the multi-etch solution for a couple of minutes. The multi-etch roughens the surface of the titanium so the oxide coating adheres better. Remove the wire and rinse the wire with water. Avoid handling the wire with your fingers to keep from getting oil from your skin on the wire.

7. Attach the red lead from the anodizer to the titanium wire.

8. The voltage determines the color that is formed. The following dial setting on the anodizer give the correspond color.

9. You can start at the highest setting to be used and work your way down as you dip more of the metal into the solution. A lower setting will not anodize over a higher setting

color. You can protect areas with tape to prevent them from being anodized at a particular setting.

10. Set the anodizer to the highest setting to be used. Dip the part of the wire to be anodized at that setting into the solution for about 15-30sec. **Be careful not to let the pin touch the cathode at anytime during the plating process.** Remove the wire from the solution.

11. Set the anodizer to the next setting to be used. Dip the part of the wire to be anodized at that setting into the solution for about 15-30sec. Remove the wire from the solution.

12. Set the anodizer to the final setting to be used. Dip the part of the wire to be anodized at that setting into the solution for about 15-30sec. Remove the wire from the solution.

13. Rinse the wire with water and dry the wire.

14. Turn off anodizer.

15. Follow your instructor's directions about coating the wire with a clear acrylic spray. Attach the earring hangers.

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Setup Sheet

6 100mL beakers labeled 5% Na_3PO_4
6 Anodizing units
6 Step-up transformers
6 Pairs of wire leads (one black and one red) with alligator clips at both ends
6 Tweezers (metal)
6 100mL plastic beakers labeled Multi-etch.
6 100mL beakers labeled Rinse water
6 Wash bottles

1 liter 5% Na_3PO_4
Pliers
Titanium wire
Multi-etch solution
Acrylic spray

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Instructor's Notes

1. The balanced equation is obtained by

$$Ti_{(s)} + 2\,H_2O_{(l)} \rightarrow TiO_{2\,(s)} + 4\,H^{+1}{}_{(aq)} + 4\,e^-$$

$$2\,[\;2\,H_2O_{(l)} + 2\,e^- \rightarrow H_{2\,(g)} + 2\,OH^{-1}{}_{(aq)}\;]$$

so the electrons gained and lost are equal.

$$Ti_{(s)} + 6\,H_2O_{(l)} \rightarrow TiO_{2\,(s)} + 2\,H_{2\,(g)} \quad 4\,H^{+1}{}_{(aq)} + 4\,OH^{-1}{}_{(aq)}$$

$$Ti_{(s)} + 6\,H_2O_{(l)} \rightarrow TiO_{2\,(s)} + 2\,H_{2\,(g)} \quad 4\,H_2O_{(l)}$$

Final Eqn: $Ti_{(s)} + 2\,H_2O_{(l)} \rightarrow TiO_{2\,(s)} + 2\,H_{2\,(g)}$

2. Earrings are usually shaped first then anodized. This is also true with rings. While the wire can be shaped after anodizing, care must be taken to protect the anodized surface and not scratch it. A piece of cloth can be used.

3. Plastic containers should be used for the multi-etch since it may attack glass.