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Anodising Titanium Teachers' Notes: Exploring the relationship between light scattering and colour through anodising.

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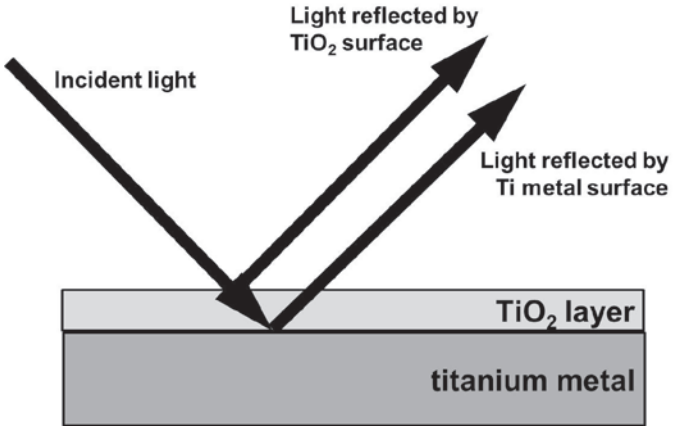
Anodising Titanium Teachers Notes

Background Chemistry

Anodising is the electrochemical process used to thicken the protective oxide layer found on several metals. Aluminium is the most common metal treated in this way, but others, including titanium can also be anodised.

The titanium is used as the anode of an electrochemical circuit. Oxygen from the acidic electrolyte is produced at the anode and this can react with the metal to thicken the metal oxide layer. The higher the voltage, the thicker the oxide layer can become.

The colour produced is an example of 'structural' colouration: rather than molecular pigmentation, the colour comes from *light scattering* through the oxide layer. Some light is bounced off the surface of the titanium dioxide layer. Other light travels through the oxide layer and bounces off the metal surface under it. If the light reflected by the oxide layer is **in phase** with that reflected by the metal there will be constructive interference and therefore the anodised titanium strip will appear coloured. Destructive interference will result in no colouration.



What colour appears is dependent on the thickness of the TiO_2 layer. At a given thickness, certain wavelengths with interfere constructively whilst others will interfere destructively, and so particular voltages (and therefore TiO_2 thicknesses) are associated with particular colours.

A whole range of colours is possible with very high voltages, however for safety reasons this experiment is limited to a range of up to 30 V.

A layer with thickness *d* will appear the same colour as a layer with a thickness of *2d*.

A natural layer of titanium oxide forms on the metal in ambient conditions but much thicker layers can be achieved electrochemically. The different colours produced are often used in art, jewellery and dental implants.

Relevance to solar energy

Nanocrystalline titanium dioxide (TiO_2) is used in dye-sensitised solar cells (DSSCs) where it acts as the semiconductor on one of the electrodes. Titanium dioxide in this form is white and does not absorb visible light so light-absorbing coloured dyes are bonded to it to enable their use in solar cells.

Thin TiO_2 films are added to some types of solar cells (e.g. DSSCs) to act as 'light scattering layers' in order to increase light harvesting and improve efficiencies.

During the experimental

It is possible to create coloured stripes on just one piece of titanium. Put the titanium into the acid all the way in when using the lowest voltage set-up (i.e. one battery). Raise the titanium out of the acid about half a centimetre and adjust the set-up to give a higher voltage. Repeat and you should get stripes of increasing thickness of titanium oxide as you go down the titanium, giving different coloured stripes.

Variations and Extensions

- Try using different electrolytes and comparing which produce the best effects – e.g. compare fizzy drinks (cola, lemonade etc), or try vinegar. The electrolyte must contain oxygen.
- Experiment with submersion times to see if this affects the colour.
- Clean the titanium with metal polish (e.g. Brasso), wash with soapy water, then rinse with acetone then ethanol before anodising. Does this affect the results? Titanium metal will become oxidised slightly when exposed to air, so cleaning it before anodising may produce more uniform and reproducible results.

Links to the curriculum

- Light scattering
- Electricity and circuits
- Anodising
- Oxidation and reduction
- Electrochemcial cells

Safety

Below is some general safety information for the chemicals used in this experiment. See appropriate Hazcards for more details.

Phosphoric Acid (H_3PO_4)

- Emergency Harmful if swallowed: call for medical aid. Wash off skin with plenty of soap and water. Flush out eye with plenty of water for at least 5 minutes and call for medical help.
- Protection Wear safety glasses and work in well-ventilated area.
- Disposal Small quantities of dilute phosphoric acid can be washed down the sink.

Anodising Titanium Experiment – RISK ASSESSMENT

Hazard	Likelihood and Seriousness of Injury	Control measures	Assessment of remaining risk
Use of scissors	Possible, serious injury unlikely.	Explain risk of cuts. Care needed.	Low
Use of chemicals	Possible, serious injury unlikely	Safety glasses must be worn at all times. Careful handling. See additional risk assessment form.	Low