Building a Rainbow

by Daniel B. Allred

The electrodeposition of materials on surfaces is a nanoscale phenomenon that proceeds within a thin boundary layer near the surface of an electrode. If said material has a uniform thickness less than a few wavelengths of the incoming light, and is sufficiently transparent, then the classic "thin film interference" effect becomes apparent, as described in the "Enginearring" article.

The electrodeposition of cuprous oxide is such an example. Cuprous oxide is normally a semi-lustrous ruby red color in the bulk, due to its absorption edge near the blue; but thin cuprous oxide films are semitransparent up to almost a micron. Electroplating from a Stareck bath (U.S. Patent #2081121, 1937) results in very uniform films and can be performed either potentiostatically or galvanostatically.

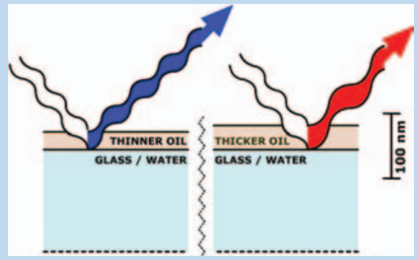
The challenge with developing an instructor's kit is that the deposition of cuprous oxide must be performed within a small overpotential window, otherwise pure copper co-deposits. However, most classrooms will not be equipped with our beloved potentiostats and the goal was to keep all functional components exposed, i.e., no black boxes.

To use a simple power supply, a standard 1.5 V "D" cell can be used, but the voltage needs to dropped to about 0.5 V reducing across the negative terminal to the solution. With a potentiostat, we typically just use a reference electrode and type the number in, and an internal feedback loop keeps the potential there. In a galvanostat, one merely selects the current, but with a battery there is nothing to dial in. Thus, we grab a variety of resistors and since the electrolyte has a characteristic current density at a proper working voltage, the correct resistor can be calculated, about 30 kW for a 1 cm^2 elect rode. However, masking alterations may require a suite of resistors. Mask size variations will make each student's results unique.

The first attempted demonstration of this kit was performed with one fatal flaw: no masking of electrodes. Thus, the electrodes were too large. Using Ohm's law, given a fixed voltage and a fixed resistance, the current is then fixed. Therefore, the total current is shared over a much larger area and the deposition proceeded extremely slowly and the only "thin film" color observed was blue (the first one visible). It wasn't a total loss though, everyone learned how to use a voltmeter very well: they poked probes all over the place, on desks, chairs, metal stools, themselves… Fun is good. For more information about National Nanotechnology Network (NNIN) and to download the instructional kit, visit www.nnin.org and select the "K-12 Teachers" button. At the time of this writing, much of this site is new and materials may not yet be available.

Teachers' Guide

The instructor must have a clear sense of the science involved and also be provided with detailed instructions for preparing the necessary materials from commercially available suppliers.



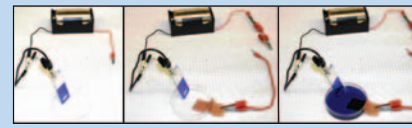
This specific kit describes the thin film interference phenomenon.

It illustrates how a simple battery can demonstrate electrodeposition.

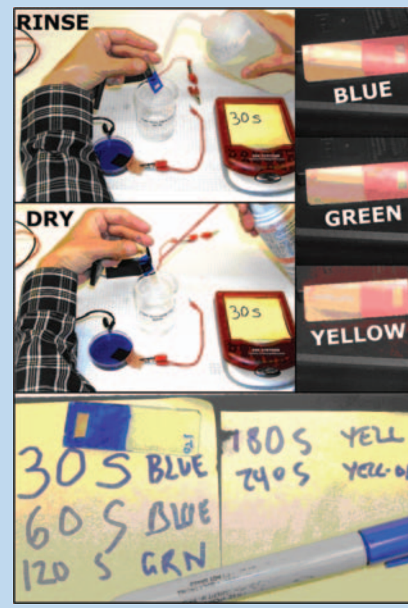
It then prepares the instructor for building a "kit." Each component of the kit is detailed from how to crimp a wire to how to prepare the electrolyte.

Students' Guide

The students are first asked to ponder some questions. Simple questions can be thought-provoking: Why are there 7 colors in a rainbow? With the light off, does the color still exist? If an object were smaller than the light, can it still have color?



Then the students set up their own cell…



… and run experiments. The "Science for Success" program allows students to visit our labs to try the kits out and even get access to privileged equipment.

A new electron microscope helmsman.

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