Electrical Etching

Purpose

Etching is a process of surface treatment performed on objects using chemical etchants, mechanical polishing, or electrochemical electrolysis. This process enhances aesthetics and adds value to the product. The application of etching is diverse, ranging from corporate logos to artistic designs, from traditional metalworking to high-tech semiconductor fabrication.

Equation:

Anode (Positive Electrode, Metal to be etched):

$Fe\ (s) \rightarrow Fe^{3+}(aq) + 3e^-$

Cathode (Negative Electrode, Saltwater in etching pen):

$2H_2O\ (l) + 2e^- \rightarrow H_2\ (g) + 2\ OH^-(aq)$

Principle:

Electrochemical etching involves the application of direct current to facilitate oxidation-reduction reactions.

Oxidation	Reduction
Early Concept Chemical reaction involving oxygen	Chemical reaction involving hydrogen
Oxidation number increases	Oxidation number decreases
Loss of electrons	Gain of electrons

** Oxidation and reduction necessarily occur simultaneously and can take place at the same location.

1.Anode (red, oxidation reaction): As the metal loses electrons, the surface gradually undergoes etching (the metal surface appears slightly concave with hollowed areas), and the etching depth becomes more pronounced with longer current application.

Cathode (black, reduction reaction): Hydrogen gas is produced in small quantities as electrons are gained (electrolyte is saturated saltwater).

In this experiment, the metal surface to be etched is connected to the positive terminal (red alligator clip) of the power source, while the etching pen (metal forceps + cotton) is connected to the negative terminal (black alligator clip) of the power source. The cotton tip of the etching pen is soaked in saturated saltwater solution.

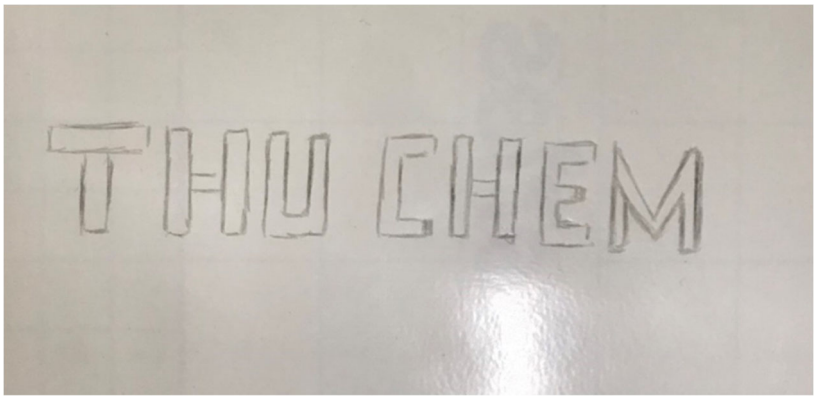
2. The electrolyte used in this experiment is saturated saltwater: The concentration of saltwater directly affects the etching time (higher concentration results in shorter etching time). Saltwater is convenient to obtain, non-toxic, and easy to recycle. If vinegar is used as the electrolyte, the reduction potential of hydrogen ions is higher than that of water molecules, resulting in a reduced voltage requirement and shorter reaction time. However, vinegar has a pungent odor, so it is recommended to operate in a fume hood. Generally, acids, bases, and salts can all serve as electrolytes for this experiment.

3.The greater the metal activity, the lower the voltage required for etching, making the electrochemical etching reaction easier to perform. The order of metal activity is: Zn > Fe > Ni > Cu, with Zn being the most active and requiring the lowest voltage for etching, while Cu is the least active and requires the highest voltage. If stainless steel (containing nickel and iron) is etched, and the etching pen is connected to the negative terminal (black wire), the front end of the cotton swab turns yellow-green. This is because nickel metal oxidation reaction occurs in the hollow areas of stainless steel, producing a yellow-green nickel chloride ion complex ([NiCl4]2-), and iron metal undergoes oxidation reaction, producing iron ions, forming brown-yellow ferric chloride (FeCl3).

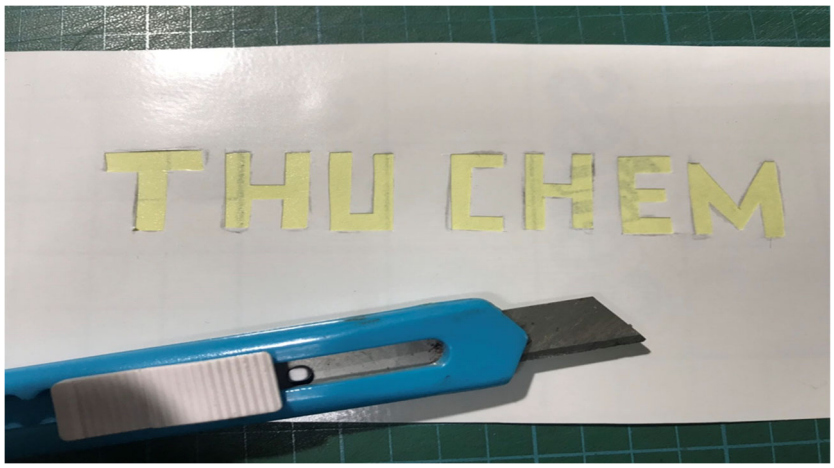
4.The direct current source used for electrochemical etching in this experiment is: USB power bank (5V) or mobile phone charging device, along with a USB charging cable. To use the USB charging cable, peel off the outer insulation to expose the red and black wires, where red is the positive terminal and black is the negative terminal.

Procedure

1. Take a 6 × 4 cm sticker to depict your favorite pattern or letter



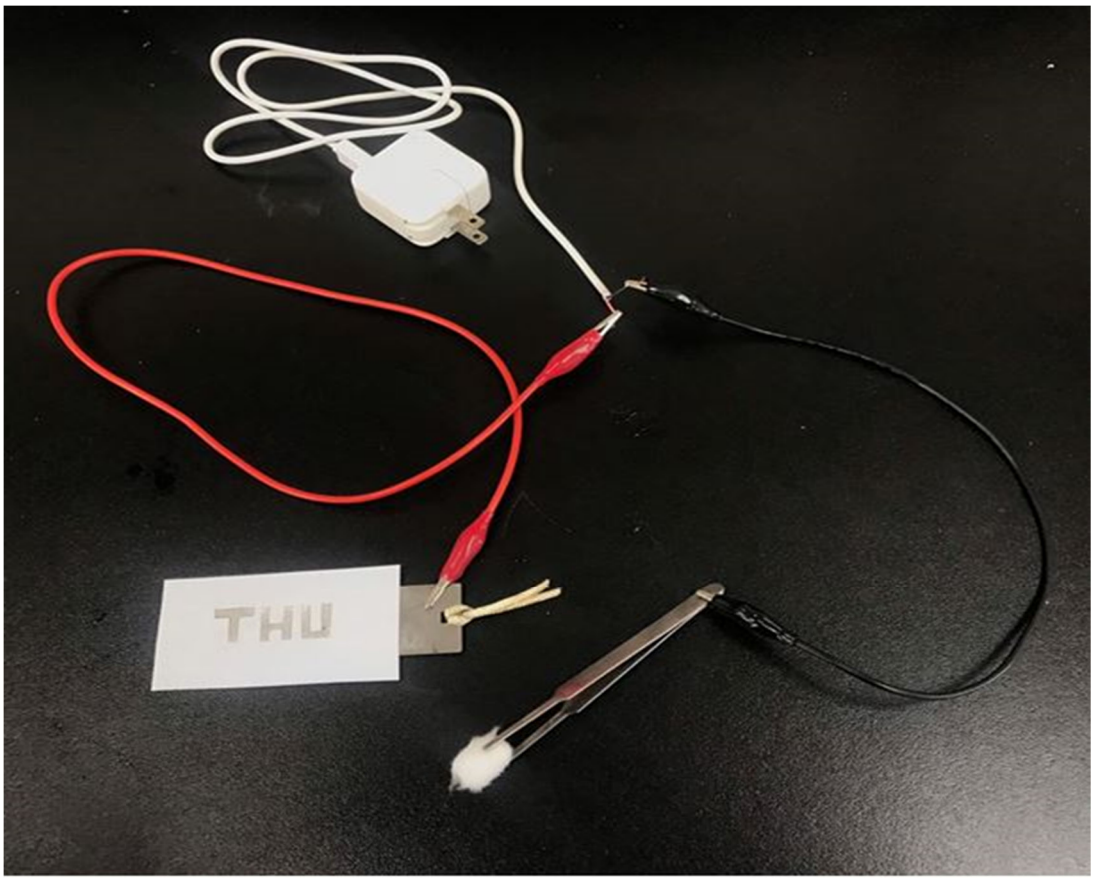
2. Use a knife to carve out the pattern and leave the sticker empty pattern



3. Peel off the sticker and stick it on the metal

4. Clip the red wire on the metal, it is anode (+)

5. Clamp the black wire with metal tweezers, is cathode (-)



6. Dip the cotton in a small amount of salt water and clamp it with metal tweezers

7. Connect USB powered , hold the cotton with metal tweezers and gently press the empty pattern on the metal (start electro-etching)

8. In about 15 minutes, the pattern will etching on the metal