Electrochemistry: DIY Silver Plated Jewelry

Where do we use electroplating?

Figure 1: X-ray showing locations of medical implants. Figure adapted from https://www.health.harvard.edu/blog/how-long-will-my-hip-or-knee-replacement-last-2018071914272 (accessed April 3, 2019)

Medical Implants

In the US, orthopedic implants are used in around 1 million joint replacement surgeries every year. Overall, the medical implant market, including the fastest growing orthopedic implant market, is expected to grow to $116 billion US dollars by 2022. Common metals that are used for electroplating are gold, silver, copper, tin, nickel, and platinum. There are several metals used to manufacture medical implants such as stainless steel, titanium, magnesium, etc. Titanium is the most common base metal used in medical implants because of its strength to weight ratio. Since the 1900s, stainless steel was commonly used. Titanium, on the other hand, has the same strength but weighing almost half as much as stainless steel. Therefore, titanium is used for knee joint implants. To prevent its corrosion, nickel and platinum together are often used for plating the implant made of titanium. However, nickel causes some allergic reactions to some people; therefore, it is usually used as a ductile undercoat before platinum is plated because nickel is highly resistant to corrosion.

Although titanium is widely used in orthopedic implants, medical manufacturing researchers are currently researching on the use of magnesium alloy. Their goal is to used magnesium alloy on bone enhancement surgeries of fractured bones. Magnesium alloy, like titanium, has good strength to weight ratio. However, magnesium is biodegradable which takes away the need for the additional surgery to remove the implant after it has served its function. Magnesium is an essential metal in many metabolic processes. With chloride ions which are present in physiological saline that contains 0.9% NaCl, magnesium alloy is degraded in vivo. Mg^{2+} with chloride ions will form a hydroxyl complex as the following reaction: $Mg^{2+} + H_2O + 2OH^- + 2Cl^- \rightarrow 2Mg(OH)Cl{\cdot}H_2O$

Then, this hydroxyl complex will break through the protective layer of the implant which causes the chloride ion to penetrate into the layer, creating cracks in the outer layer. The contact between the surface and an electrolyte-containing medium leads to higher initial corrosion rate. This involves a release of hydrogen and the alkalization of the environment as the following:

Oxidation: $Mg \rightarrow Mg^{2+} + 2e^-$
Reduction: $2H_2O + 2e^- \rightarrow 2OH^- + H_2\uparrow$
Overall: $Mg + 2H_2O \rightleftharpoons Mg^{2+} + 2OH^- + H_2\uparrow$

Mg^{2+} is a cation corrosion product from magnesium alloy implants. Excessive amounts of Mg^{2+} cations are easily excreted through urine. Although its biodegradability is beneficial to us, magnesium is difficult to plate with other metals. These metals are used for primary structures, so they usually need a coating with another metal to integrate more completely with biological tissues and bones.

Typically, medical devices and implants are coated with a metal using a process called electroplating. Plating a metal provides better electric conductivity, thermal conductivity, sanitation, corrosion resistance, and biocompatibility. The most common metal used for electroplating is gold. Gold is extremely biocompatible and an excellent corrosion resistor. This also provides a superior electrical conductivity which makes the electroplating process valuable for electrical connectors in some medical devices.

Jewelry

Another example where electroplating is used is in the enhancement of jewelry. Electroplating can increase jewelry's value and wear-ability. Therefore, it is very common to find jewelry that is coated with silver and white gold. As seen in electroplating on medical devices, there are benefits of electroplating on jewelry such as making it more attractive, difficult to corrode, and less likely to cause allergic reactions. However, silver turns into black eventually depending on the pH of our skin. These coatings through electroplating are only about 0.0002 inches think. By creating metallic bonding between two metals, the piece of jewelry can have a new coating. This technique has been used since the 1840s for commercial purposes and it is still used by a lot of manufacturing companies and bench jewelers with their own workshops.

Experiment

You are a bench jeweler who needs to electroplate silver for your customer who is allergic to copper jewelry that was passed down in her family to be worn in her wedding. The customer would like to keep her family's tradition. Design an experiment by which you can electroplate silver onto a piece of copper jewelry. Consider which materials to use and come up with an appropriate procedure to conduct this experiment.

Post-Experiment Questions

PART 1: Questions

1. Why are we not using silver cyanide to electroplate silver?
2. Does oxidation take place in this experiment? How do you know?
3. Does reduction take place in this experiment? How do you know?
4. What is the overall reaction of this electrolytic cell to plate silver?
5. Where is the positive terminal of the battery connected? Why?
6. Draw a fully labeled diagram of this electrolytic cell. Include: electrodes, a direction of electron flow, an anode, a cathode, half-cell reactions, and a battery.

PART 2: Assume the following conditions.

- Your jewelry is made of copper.
- The two electrodes are separated in different beakers each containing a 0.001M nitrate solution of the electrode material.
- The two beakers are connected through a salt bridge.
- The wires are connected to a voltmeter instead of a battery source.

PART 2: Questions

1. What would happen to the cell if you make these assumptions? Why do we need a salt bridge?
2. What is this cell? Draw a fully labeled diagram of this cell. Include: electrodes, a direction of electron flow, an anode, a cathode, half-cell reactions, a salt bridge and a voltmeter.
3. Write half-cell reactions and the overall reaction. Then, calculate the cell potential.
4. Write this cell using a shorthand cell notation.

References

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