Why is corrosion control important in your field?

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Most of us in America know of someone that has had or has a metal implant in their body; I have a metal screw myself. Unfortunately, these implants only last a few years to 20 years at best. The need for longer lasting implants and prosthetics becomes evident when one sees the growing demand for these devices and the costs and strain involved in replacing them once they fail. What are the factors that limit the service life of prosthetic implants? One of the primary obstacles in achieving longevity in implants is their eventual corrosion.

"Corrosion is the destructive result of chemical or electrochemical reaction between a metal or a metal alloy and its environment."[1] In the case of prosthetic implants, such as total joint replacements, the interaction between the metal alloy and the body's electrolytic environment leads to the corrosion of the implant: general and pitting corrosion mechanisms reduce the size and integrity of the implant and release metallic debris. Furthermore, the corrosion particles trigger an inflammatory reaction that activates bone erosion by osteoclasts. Loss of bone mass around the implant leads to the loosening of the device, which can cause failure and possibly fatal accidents, and thus requires surgical revision. How can we stop corrosion to prevent failure?

Corrosion is inevitable, but engineering novel materials with higher corrosion resistance could lead to more durable prosthetics; this type of corrosion-control design is invaluable for engineering advancement. As Dr. Ravi's Corrosion Research team at Cal Poly Pomona, we are studying the corrosion behavior of novel titanium alloys that could potentially replace standard alloys being used in the biomedical field. Our alloys of interest are commercially pure titanium and Ti-6Al-4V containing low concentrations of boron additions. Adding boron to titanium alloys has already been proven to give them superior mechanical properties relative to the base alloys. Our goal is to evaluate the corrosion resistance of these boron-containing titanium alloys in biologically relevant aqueous media to see if they could be suitable for biomedical applications.

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[1] Jones, D. A., *Principles and Prevention of Corrosion* (2nd Edition) (1996). Upper Saddle River, NJ: Prentice Hall, Inc.

Our research consists of characterizing alloy response to aqueous corrosion tests in biologically relevant, chloride-based media: 0.9 wt% NaCl (saline), Ringer's, and Hank's solution. Given the tendency of titanium alloys to primarily exhibit pitting corrosion in chloride solutions, our experiments are focused on evaluating the rate and mechanism of pitting corrosion. Experiments consist of linear and cyclic polarization scans on samples using a three-electrode flat cell and a potentiostat. Cyclic polarization scans are used to evaluate the pitting potential of each sample across a broad overpotential range. Linear polarization scans are then conducted at the pitting potential of each sample for varying exposure times. Pit morphologies are examined using scanning electron and atomic force microscopy. Pit depth, size, and areal density will be reported as a function of boron content.

Results to date indicate that Ti-6Al-4V samples containing boron additions have pitting potentials well above the resting potentials measured in animal models (sheep) and form fewer pits per unit area than the base alloy for a range of exposure times in 1.0 wt% NaCl solutions at their respective pitting potentials (see Figure 1). Ongoing research is currently underway on a number of Ti-6Al-4V alloys containing various amounts of boron in the 0-1.0 wt% range as well as titanium-boron alloys with 0.02 to 0.4 wt% B. We anticipate that our corrosion study results will help evaluate whether boron-containing titanium alloys are suitable for advanced biomedical applications.

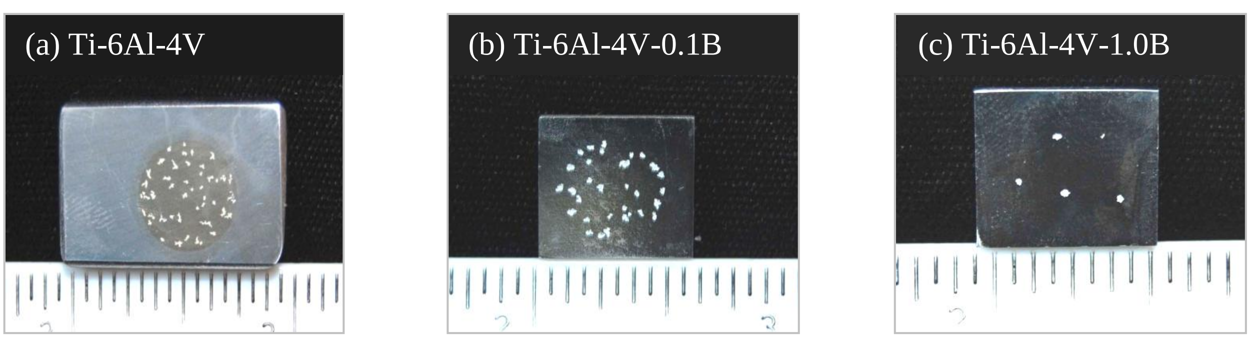

Figure 1: Pit development in Ti-6Al-4V with and without boron after 120 seconds of linear polarization scan in 1.0 wt% NaCl at respective pitting potentials (a) 6.5, (b) 6.0, and (c) 5.3 V. Notice how pit density decreases with increasing boron content.