Simulating Corrosion in a Crevice of Commercial Pure Titanium

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Abstract

Implant devices are assistive devices surgically placed in the human body to restore the functionality of organs and tissues. Metallic implants are often used for load bearing applications including the hip and knee joints. To allow maximum flexibility during surgery for surgeons to pick and choose different combinations of parts (say, head, neck and stem, in the case of total hip replacement), implant modularity becomes a common practice.

Modular metallic implants consist of not only different parts but different alloys also. While implant modularity indeed provides great flexibility to achieve, to some extent, personalized fits for patients, different parts coming together will create small gaps (or crevices) between parts and pose galvanic potential differences. In the past decades or so, more and more evidence emerges from the clinical retrieved implants that corrosion in the crevices of these modular implants is one major contributing factor leading the failure of these modular implants.

Crevice corrosion has been studied for many years both experimentally and computationally, though the true cause for modular implant failure remains elusive. A close look at modeling of corrosion quickly reveals a common practice - the setting of either a known corrosion current or a known corrosion over-potential. While the argument could be made that either piece of information is necessary in order to study the corrosive behavior, it would be more relevant and useful if the spontaneous corrosion potential and corrosion current can be predicted based on the modeling of the entire process including the electrochemical reactions, electrostatics, and mass transport, among others.

This study uses COMSOL Multiphysics® software to investigate the problem of corrosive process occurring a crevice in commercially pure Titanium in a spontaneous manner, meaning that without setting a known corrosion potential or corrosion current. In a spontaneous process, all the paired half-cell reactions which are often governed by the available surface areas, the surrounding conditions including oxygen and pH, and efficacy of mass transport, among others, will dictate the local corrosion potential and current. So in the model all these factors are considered and the resulting thermodynamically determined corrosive potential and current are predicted.