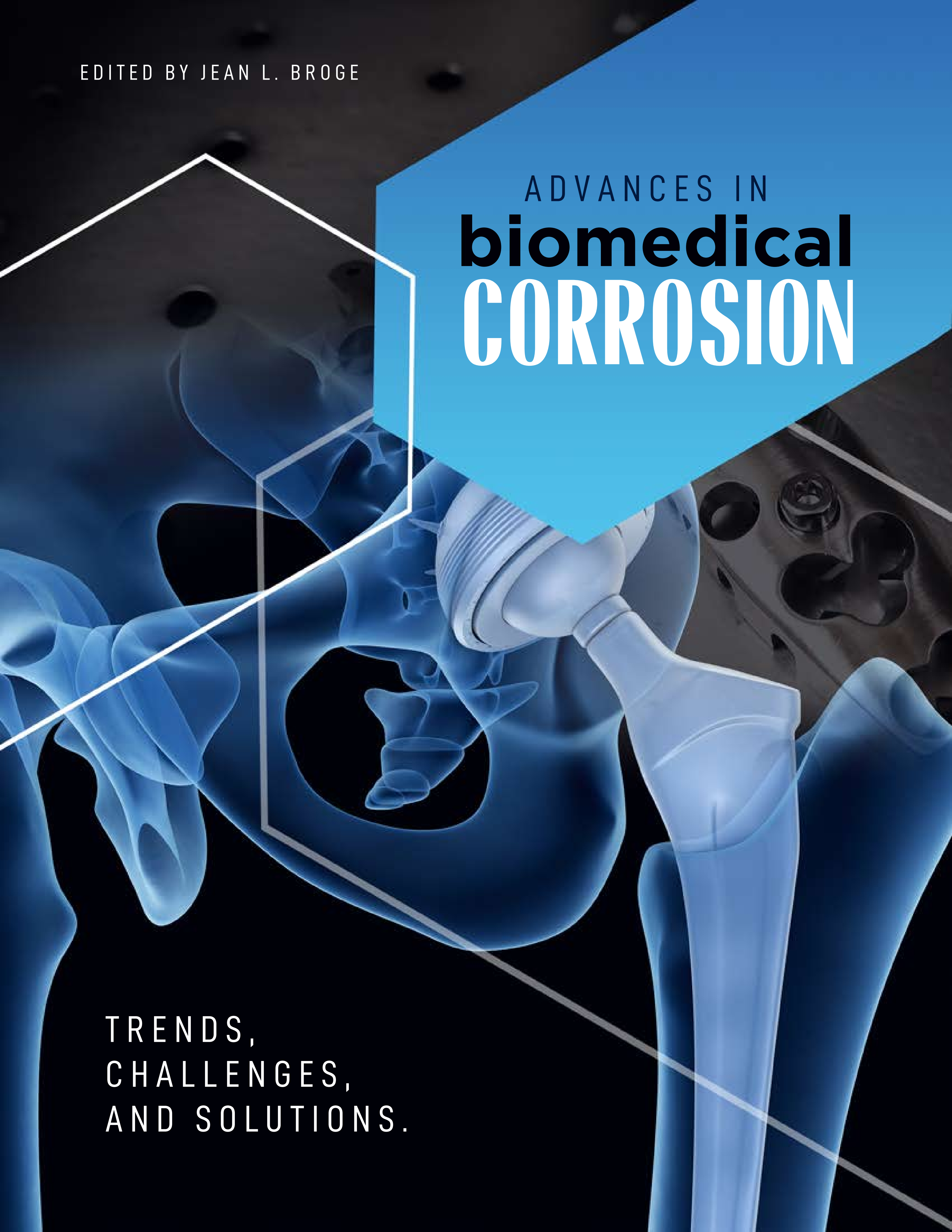

EDITED BY JEAN L. BROGE

ADVANCES IN biomedical CORROSION

TRENDS, CHALLENGES, AND SOLUTIONS.

Advances in Biomedical Corrosion:

Trends, Challenges, and Solutions

Edited by Jean L. Broge

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Crevice Corrosion of Biomedical Alloys: A Novel Method of Assessing the Effects of Bone Cement and its Chemistry (Technical Paper C2012-01510) 1

Studies to date have identified that the introduction of antibiotics into PMMA bone cement can affect the crevice corrosion initiation and propagation mechanisms of commonly used biomaterials. In this study, five commercially available poly(methyl methacrylate), or PMMA, bone cements were evaluated to investigate the effects of antibiotics on the severity of crevice corrosion. Bone cements with varying chemistry were also tested.

M. Bryant, X. Hua, R. Farrar, K. Brummitt, R. Freeman, and A. Neville, "Crevice Corrosion of Biomedical Alloys: A Novel Method of Assessing the Effects of Bone Cement and its Chemistry," CORROSION 2012, Technical Paper C2012-0001510 (Houston, TX: NACE International, 2012).

Flow-Assisted Corrosion Effects On Nitinol For Biomedical Applications (Technical Paper C2012-01591) 17

Nitinol as a biomedical alloy has become an ideal material for use as self-expanding stents, grafts, and other support systems due to its excellent superelasticity, biocompatibility, and corrosion resistance. In this study researchers looked at the flow-assisted corrosion effects of fluid flow on Nitinol material.

E. Trillo, J. Dante, and C. Popelar, "Flow Assisted Corrosion Effects On Nitinol For Biomedical Applications," CORROSSION 2012, Technical Paper C2012-01591 (Houston, TX: NACE International, 2012).

Electrochemical Evaluation of Titanium-Boron Alloys for Potential Biomedical Applications (Technical Paper C2016-07842)... 29

The leading material used for structural implants is Ti-6Al-4V (Ti64) because of its excellent corrosion resistance, biocompatibility, and mechanical properties of this alloy. Recent developments have shown that the addition of boron to Ti64 improves mechanical properties such as yield strength and hardness. In this paper, further progress on the corrosion study of these alloys is reported in the context of physiologically relevant media.

K. McCann, T. Voorhees, G. Margoosian, J. Miguel, and V. Ravi, “Electrochemical Evaluation of Titanium-Boron Alloys for Potential Biomedical Applications, CORROSION 2016, Technical Paper C2016-07842 (Houston, TX: NACE International, 2016).

Bio-Functional High-Performance Coatings of Titanium and Magnesium Alloy for Biomedical Applications (Technical Paper C2017-09271)... 41

Researchers present the challenge of understanding the correlation of corrosion behavior between different scales (human body scale and laboratory scale). The study uses in vitro and in vivo methods to establish this correlation and highlights the significance of identifying and applying corrosion methods for biomaterials used in various applications.

A. Eliezer and C. Gasqueres, “Bio-Functional High-Performance Coatings of Titanium and Magnesium Alloy for Biomedical Applications, CORROSION 2017, Technical Paper C2017-09271 (Houston, TX: NACE International, 2017).

Controlling the Degradation Profile of Mg Biomedical Devices by Alloy Design and Thermomechanical Processing (Technical Paper C2017-09395) 49

Magnesium (Mg) alloys are gaining interest for biodegradable medical implant devices due to a good combination of mechanical properties and biocompatibility. Nevertheless, the fast degradation rates of Mg and its biocompatible alloys in the aggressive physiological environment impose limitations on their clinical applications.

S. LeBeau, R. Decker, C. Sfeir, and B. Collins, “Controlling the Degradation Profile of Mg Biomedical Devices by Alloy Design and Thermomechanical Processing,” CORROSION 2017, Technical Paper C2017-09395 (Houston, TX: NACE International, 2017).

Electrochemical Studies of Titanium-Based Alloys in Physiological Solutions (Technical Paper C2017-09537) 65

An important mode of failure with modern structure biological implant alloys—e.g., UNS R56400 (Ti-6Al-4V; Ti64)—is aseptic loosening. In this paper, researchers quantitatively compare the corrosion behavior of Ti64 with and without boron addition in various physiological solutions.

S. McCarthy, K. Robles, J. Medina, L. Nguyen, R. Rodriguez, J. Fly, and V.A. Ravi, “Electrochemical Studies of Titanium-Based Alloys in Physiological Solutions,” CORROSION 2017, Technical Paper C2017-09537, (Houston, TX: NACE International, 2017).

Graphene-Based Nanomaterials for Biomedical Coatings (Technical Paper C2017-09584) 73

The use of graphene-based nanomaterials is well-known in the electronics industry, but not so much in the biomedical and bio-implant field. This study highlights work done on utilizing highly oxidized graphene oxide (GO) coatings and dispersions as anti-microbial and protective barriers for preventing biocorrosion and biofilm growth.

R.C. Advincula, “Graphene-Based Nanomaterials for Biomedical Coatings,” COROSION 2017, Technical Paper C2017-09584, (Houston, TX: NACE International, 2017).

Electrochemical Testing of Additive Manufactured Ti6Al4V and NiTi Materials in a Biological Fluid Environment (Technical Paper C2021-16540) 81

The use of additive manufacturing (AM) has seen a marked increase in the biomedical arena for hip and knee replacements, especially for older populations. The AM method is particularly attractive in the biomedical industry as it allows for patient specific designs in the case of unusual anatomy. AM is also well suited to manufacture highly complex parts and has the benefit of rapid prototyping and rapid manufacturing. However, as the increase in fabrication and use of these components have increased, there are still some underlying corrosion issues that have yet to be fully understood.

E. Trillo and C. Popelar, “Electrochemical Testing of Additive Manufactured Ti6Al4V and NiTi Materials in a Biological Fluid Environment,” CORROSION 2021, Technical Paper C2021-16540 (Houston, TX: AMPP, 2021).

Corrosion Behavior Assessment and Comparison of UNS S31603 Stainless Steel, Nickel-Titanium Shape Memory Alloy, and Al2Cr5Cu5Fe53Ni35 High-Entropy Alloy in Biomedical Environments (Technical Paper C2023-19413) 95

A simulated bio-fluid electrolyte was used to study the chemical- and temperature-controlled parameters that the alloys experienced when they were exposed to corrosion conditions. Electrochemical testing, such as EIS and LPR tests, was performed to observe the response of the material under a range of conditions.

O. Esmacher, D. Narayanan, and M. Paredes, and H. Castaneda, “Corrosion Behavior Assessment and Comparison of UNS S31603 Stainless Steel, Nickel-Titanium Shape Memory Alloy, and Al2Cr5Cu5Fe53Ni35 High-Entropy Alloy in Biomedical Environments,” CORROSION 2023, Technical Paper C2023-19413 (Houston, TX: AMPP, 2023).

Development of New Grades of Titanium-Based Metal Glasses for Dental Applications (Technical Paper C2023-19522)..107

Nowadays, titanium-based alloys are commonly used in biomedical applications as, for example, materials for dental implants or hip replacements. Their good corrosion resistance, biocompatibility and high mechanical properties for a relative weight make them good candidates. However, improvements in the design of these alloys for biomedical applications need to be made.

B. Ter-Ovanessian, “Development of New Grades of Titanium-Based Metal Glasses for Dental Applications, CORROSION 2023, Technical Paper C2023-19522 (Houston, TX: AMPP, 2023).

From the Editor

Advances in Biomedical Corrosion: Trends, Challenges, and Solutions presents over a decade's worth of groundbreaking research focused on the intricate interplay between corrosion and biomedical materials. Spanning materials development and manufacturing processes, this compilation is a comprehensive exploration of the connection between corrosion and the biomedical field.

While the array of biomedical materials spans metals, alloys, ceramics, and polymers — each with its unique susceptibility and behaviors towards corrosion — this compilation focuses on metals and alloys.

For those seeking either an introduction or a deeper understanding of biomedical corrosion, it is also referred to as biomedical materials corrosion or biocorrosion. Whatever the preferred terminology, it encapsulates the gradual degradation or deterioration of materials used in biomedical applications due to interactions within biological environments. Corrosion within medical devices and implants is clearly a critical concern due to its potential to induce detrimental effects, including implant malfunction, tissue impairment, and systemic health complications.

The main factors influencing corrosion in biomedical applications are the specific biological environment, material composition, design, and the presence of mechanical forces or stresses. Below are some key points focused on biomedical corrosion:

Varieties of Corrosion: Biomedical materials span distinct corrosion pathways, spanning uniform corrosion, localized instances like pitting and crevice corrosion, galvanic corrosion, and the intricate realm of stress corrosion cracking.

Biological Environment: In the human body, biomedical materials are exposed to a complex environment containing various chemical species, electrolytes, enzymes, proteins, and cells. The pH, temperature, and presence of corrosive substances can vary depending on the location of the implant or medical device.

Metallic Implants: Metals and alloys used in orthopedic implants (e.g., stainless steel, titanium alloys, cobalt-chromium alloys) are susceptible to corrosion due to the aggressive nature of physiological fluids, leading to ion release and implant deterioration.

Corrosion of Dental Materials: Dental implants and restorative materials are also susceptible to corrosion in the oral environment, which contains saliva, acids, and several types of bacteria.

Protective Measures: To mitigate biomedical corrosion, researchers and manufacturers employ various protective measures, such as using corrosion-resistant materials, surface coatings (e.g., titanium oxide coatings on titanium implants), and biocompatible materials that promote tissue integration.

Biodegradable Materials: In some cases, biomedical materials are intentionally designed to be biodegradable, gradually degrading in the body as new tissue forms, reducing the need for removal surgeries.

Testing and Standards: Biomedical materials undergo extensive testing to assess their corrosion resistance and biocompatibility before approval for clinical use. Several international standards and guidelines exist to ensure the safety and performance of these materials.

Long-term Effects: Long-term corrosion of biomedical materials can result in the release of metal ions into the body, potentially causing local inflammation, allergic reactions, or systemic health issues

Suffice to say, all the above are covered within these pages.

It should be understood as well that regular monitoring of implanted materials is essential to detect any signs of corrosion-related issues and ensure patient safety.