# Design and Validation of an Electrochemical Cell for the Surface Characterization of Biomedical Alloys

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## Abstract

It is essential to develop a rigorous method for evaluating the biocompatibility of a given biomedical alloy. As such, an electrochemical cell has been designed in which biocompatibility can be evaluated through characterization of the surface oxide layer. Two electrical characterization methods, electrochemical impedance spectroscopy (EIS) and step polarization impedance spectroscopy (SPIS) will be utilized independently and also compared. A formal comparison of these methods has not previously been reported.

## Background

- Biocompatibility: critical for successful integration of a medical device
- Most biomedical alloys generate an oxide layer spontaneously
- Biocompatibility: directly related to oxide layer
- Oxide structure: chemistry, thickness, and semi-conducting properties
- Structure: influenced by electrochemical potential (voltage)
- Upon implantation, an electrical potential is setup across the material interface (Fig. 1)

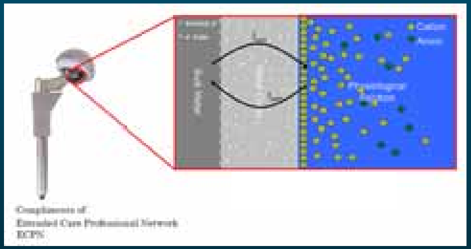


**Fig. 1:** Electrical Potential Setup Across Alloy Interface

- **An electrochemical cell is a tool that can be used to characterize the oxide layer.**
- Electrochemical Impedance Spectroscopy (EIS) is used to study the effect of potential on the oxide

## Materials and Methods

### Material Preparation

- Samples cut to size using EXTEC Labcut Model 250 saw
- Standard sanding and polishing techniques utilized [3]
- Samples electropolished and etched to observe microstructure (Fig. 2) [3]

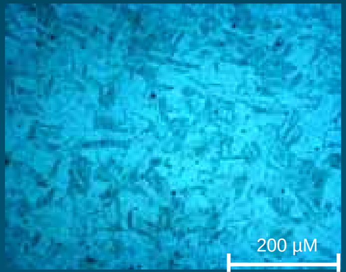


**Fig. 2:** Microstructure of 316 LVM

### Design Considerations

- To most accurately represent the physiological environment, an electrochemical cell should include:
  - Mixing capability
  - Temperature control
  - Known sample parameters
  - Physiologically representative solution
  - Regulation of oxygen content in solution
  - Appropriate sample interface
  - Signal noise reduction apparatus

### Electrochemical Cell Design

- Mixing accomplished using a laboratory mixer (Cole-Parmer).
  - Adjustable mixing speed
  - Model stagnant conditions (decreased circulation)
- Temperature controlled using tissue culture incubator
  - Simulate room or physiological temperatures
- Phosphate-buffered saline at pH 7.4 (Sigma) used as physiologically representative solution
- Nitrogen gas option to bubble into solution (eliminates oxygen presence)
- Sample-air interface eliminated
- Faraday cage constructed to reduce electro-magnetic interference

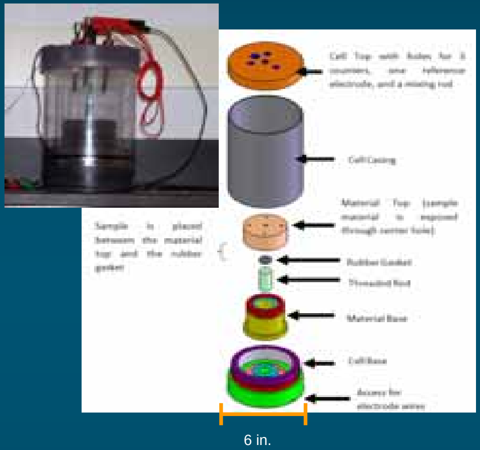


**Fig. 3**: Electrochemical Cell

## Results

- **E**lectrochemical cell validated using Gamry Framework included with the Gamry Series G 300 potentiostat [4]
- Data collected was compared to literature and modeled using the Randle's Model (Fig. 4-6) [4]

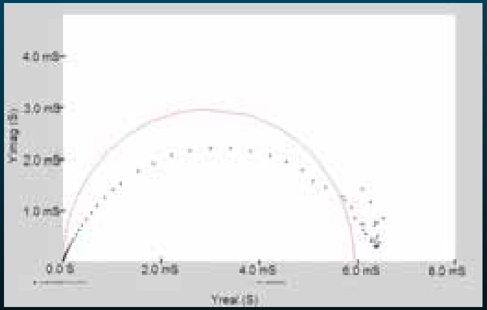


**Fig. 4**: Nyquist Plot (from 316 LVM)

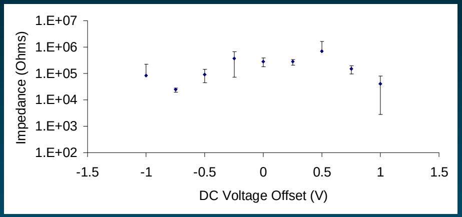


**Fig. 5:** Oxide Impedance

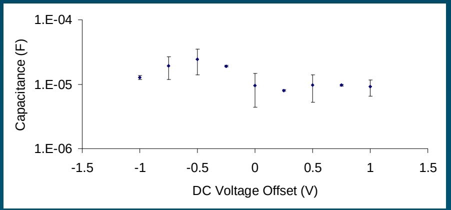


**Fig. 6:** Oxide Capacitance

## Conclusion

The designed electrochemical cell incorporates the features required for accurately modeling the physiological environment. This is important for studying the oxide layer which is directly related to the biocompatibility of an alloy. Using the electrochemical cell, the comparison of EIS and Step-Polarization Impedance Spectroscopy (SPIS) can be made. This comparison is as yet unreported in the literature.

## References

[1] J.L. Gilbert, "Step-polarization impedance spectroscopy of implant alloys in physiologic solutions," *J Bio Mat Res*, vol 40, pp. 233-243, 1998

[2] Extended Care Professional Network. "Product News: Smith and Nephew Launches Modular Hip System."

[3] ASM Handbook. Volume 9. Metallography and Microstructures.

[4] Joyce, KE and Turner, RC. Western New England College Senior Project Report. 2008.

## Acknowledgements

This work was supported by a grant from the American Society for Quality (ASQ) Biomedical Division. The authors would like to acknowledge Mr. Peter Bennett, Mr. Mike McCarthy, and Dr. Mary Vollaro for their help with the project.