ndc

We are Nitinol.™

Galvanic Corrosion Behaviour of Passivated Nitinol

Venugopalan, Trepanier, Pelton

Society for Biomaterials - 6th World Biomaterials Congress Transactions 2000
p. 1124

2000

Galvanic Corrosion Behavior of Passivated Nitinol

Ramakrishna Venugopalan[1], Christine Trepanier[2], Alan R. Pelton[2]
[1]Department of Biomedical Engineering, University of Alabama at Birmingham, Birmingham, AL 35294-4440
[2]Cordis Corporation - Nitinol Devices and Components, 47533 Westinghouse Drive, Fremont, CA 94539

Introduction: Nickel-titanium (NiTi) is now used in a wide variety of biomedical applications ranging from minimally invasive devices such as stents to metallic rods used in orthopedics. The unique combination of mechanical and surface properties of NiTi (shape memory, superelasticity and biocompatibility) is the reason for its success and increased popularity as a biomaterial. While several studies have been published on the individual corrosion behavior of NiTi very few studies have demonstrated the galvanic corrosion behavior of NiTi with other implant alloys.

Aim: The objective of this study was to investigate the galvanic corrosion behavior of NiTi coupled to other implant alloys.

Materials and Methods: Disc samples of Nitinol (NiTi), platinum (Pt), platinum-iridium alloy (IR), Will-Ceram® gold-palladium alloy (WC), 316L stainless steel (SS), tantalum (Ta) and grade II titanium (Ti) were processed per ASTM F86 standards for implant alloys. Tests were conducted on 3 samples per group in de-aerated Hanks salt solution at 37°C in a setup standardized per ASTM G5. The cathode to anode ratio was 1:1. The results were analyzed using Duncan's multiple range grouping at a 95% confidence level.

Mixed Potential Theory Predictions: Cyclic polarization curves for each material were overlaid with an averaged NiTi alloy curve. The intersection of the cathodic portion of one curve and the anodic portion of the other curve was determined graphically. The y-axis intercept was the predicted E_{couple} and the x-axis intercept was the I_{couple} for that combination.

Direct Coupling Experiments: NiTi samples were galvanically coupled to other materials using a Model 273A Potentiostat/Galvanostat modified to perform as a zero-resistance ammeter (EG&G, Princeton Applied Research, Oak Ridge, TN) and the current flow measured over a period of 12 h. The asymptotic steady state value of the current flow at t =12 h is presented in this abstract.

Results and Discussion: Consolidated results are presented in Table 1. The galvanic coupling of NiTi to (a) Pt and IR samples will result in E_{couple} potentials in the middle of the passive region of the NiTi alloy, (b) WC and SS will result in E_{couple} potentials in the beginning of the passive region of the NiTi alloy, and (c) Ta will result in E_{couple} potentials similar to the corrosion potential of the NiTi alloy. The predicted increase in the NiTi corrosion rate when coupled to Pt, IR and WC was greater than when coupled to Ta. The Tafel regions of NiTi and Ti were too close to each other to conduct tangential extrapolation using mixed-potential theory. However, the proximity of the Tafel regions may indicate that the galvanic influence when NiTi is coupled to Ti may be negligible. The predicted increase in the NiTi corrosion rate when coupled to SS was not conclusive due to significant standard deviation in the calculated results.

Table 1: Mixed-potential theory predictions and direct coupling results. Values are presented in arithmetic mean (standard deviation) format. Superscript letters in a column represent groupings at a 95% confidence level.

Cathode-Anode	Mixed-Potential Theory Prediction		Direct Coupling Experiments
	E_{couple} mV vs SCE	I_{couple} $^{nA}/_{cm^2}$	I_{cc} at t=12 h $^{nA}/_{cm^2}$
Pt-NiTi	126 (22)[a]	277 (9)	836 (74)[a]
IR-NiTi	40 (27)[b]	256 (3)	780 (302)[a]
WC-NiTi	-137 (3)[c]	285 (2)	608 (34)[a]
SS-NiTi	-218 (76)[d]	176 (111)	35 (5)[b]
Ta-NiTi	-406 (27)[e]	9 (6)	12 (17)[b]
Ti-NiTi	*	*	22 (17)[b]

Individual NiTi corrosion rate = 9 (5) $^{nA}/_{cm^2}$

During direct coupling experiments the largest I_{cc} measurements were obtained for the noble alloys (Pt, IR, WC) galvanically coupled to NiTi alloy. The smallest I_{cc} values were obtained for SS, Ti and Ta galvanically coupled to NiTi alloy. Also, the I_{cc} values for the (Pt, IR, WC)/NiTi alloy combinations were an order of magnitude greater than the I_{cc} values for the (SS, Ti, Ta)/NiTi alloy combinations.

Conclusions: Good rank order agreement was obtained between the predicted results from mixed-potential theory calculations and the results from direct coupling experiments. The galvanic coupling to the noble alloys increases the corrosion rate of the NiTi alloy by two orders of magnitude, while coupling to the base-metal alloys results in a corrosion rate in the same order of magnitude as the uncoupled NiTi alloy. The increased coupled current density measurements obtained in this study were not of sufficient magnitude to breakdown the passivated NiTi surface layer due to galvanic action alone.

These results are valid only for a cathode to anode ratio of 1:1. In general, increasing the surface area of the cathode will make the combination more susceptible to galvanic corrosion phenomena.