## Performance of Optim<sup>TM</sup> Insulation in an Accelerated In Vitro Model of Environmental Stress Cracking

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Statement of Purpose: Cardiac leads have traditionally employed either silicone or poly(ether urethane) (PEU) materials as insulation. Silicone is extremely biostable, but has moderate mechanical properties. PEU has excellent mechanical properties, but may be susceptible to oxidative degradation, including environmental stress cracking (ESC) and metal ion oxidation (MIO) under some circumstances. Optim<sup>TM</sup> insulation (OPT) was designed to combine the biostability of silicone with the mechanical properties of polyurethane by replacing most of the susceptible polyether soft segment with biostable poly(dimethylsiloxane). Well-established accelerated in vitro models of MIO exist and are extensively used by both academia and industry to predict the in vivo performance of these materials. On the other hand, accelerated in vitro models of ESC have not been optimized and are not highly utilized. The purpose of the current study was to study the performance of OPT compared to 80A and 55D Pellethane® PEU controls in an optimized accelerated in vitro model of ESC.

Methods: The performance of Optim<sup>TM</sup> insulation (AorTech International, Rogers, MN) was compared to that of Pellethane<sup>®</sup> 80A (P80A) and 55D (P55D) (Lubrizol, Wicklifee, OH) in this study. The accelerated in vitro model utilized was an optimized version of the model reported by Zhao, et. al. The sample configurations were based on a coaxial cardiac lead body, consisting of inner and outer coils of MP35N, a silicone tubing inner insulation, and an outer tubing insulation of the test material. Outer insulations were not annealed. The samples were bent into a "U" shape inside of a 15 mm diameter glass vial in order to induce wrinkling in the outer insulation. Samples were exposed to a 7 day pretreatment at 37 °C in human plasma, followed by 72 days of exposure at 37 °C to a solution of 0.9% NaCl, 20% H<sub>2</sub>O<sub>2</sub>, and 0.1M CoCl<sub>2</sub>. After 72 days of exposure to the oxidative solution, the tubing insulations were inspected using an optical microscope at 20X and scanning electron microscope (SEM) at 20-200X. Semiquantitative degradation scores between 1-6 were assigned during visual and SEM inspection (1 = no)degradation, 6 = insulation breach). The surface chemistry of the samples was investigated using attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR). The phase morphology of the samples was evaluated using small angle x-ray scattering (SAXS).

**Results:** Average SEM scores were  $6.0 \pm 0.0$  for P80A,  $4.6 \pm 0.6$  for P55D, and  $3.4 \pm 0.5$  for Optim<sup>TM</sup> insulation. OPT had significantly lower scores than P80A and P55D. P80A samples demonstrated a white frosted outer surface accompanied by significant surface cracks consistent with ESC. All P80A samples also demonstrated breaches. P55D samples exhibited significant surface cracks consistent with ESC. Some OPT samples demonstrated shallow localized cracking on the outer tubing surfaces consistent with minor surface oxidation or ESC.

Representative SEM images of the outer tubing surfaces of each material are shown in Figure 1. FTIR-ATR spectral changes for the outer tubing surfaces of P80A were consistent with significant surface oxidation and minor hydrolysis of the urethane linkage. Spectral changes for P55D were consistent with significant surface oxidation and increased phase separation. Spectral changes for OPT were consistent with minor surface oxidation and increased phase separation. SAXS results indicated that the mean inter-domain spacing increased for all materials after aging at 37 °C for 72 days in saline, consistent with increased phase separation. For P55D and OPT samples aged in plasma followed by oxidative solution, the mean inter-domain spacing was similar to that from samples aged in saline, and consistent between samples, indicating that any oxidative degradation did not significantly impact the morphology of these polymers. SAXS results for P80A varied significantly between samples. Some P80A samples had mean inter-domain spacing similar to samples aged in saline, while other samples exhibited an overall decrease in scattering intensity. This indicates that oxidative degradation may have significantly impacted the phase morphology of some P80A samples.



**Figure 1.** 200X magnification SEM images of typical a) P80A, b) P55D, and c) Optim<sup>TM</sup> insulation after aging for 72 days in the *in vitro* model.

**Conclusions:** This accelerated *in vitro* model successfully produced degradation consistent with ESC observed on clinical explants of cardiac leads. Optim<sup>TM</sup> insulation performed significantly better than P80A and P55D in this model, exhibiting only minor cosmetic signs of ESC. **References:** Zhao QH. Journal of Biomedical Materials Research. 1993;27:379-389.