An Evaluation of Polymer for the Encapsulation of Mechanically Loaded *In Vivo* Sensors

by

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ABSTRACT

Wireless implantable electronic medical devices have the ability to treat, augment, or diagnose many conditions in a way not previously obtainable without external equipment. However, the implementation of these wireless devices has seen a significant number of failures with a disproportionate amount of these incidents stemming from a breakdown in the polymeric insulation and encapsulation used to protect the vital electronics. Therefore, the purpose of this research was to assess the capability of commercially available polymers as well as a novel polymer, epoxidized linseed oil (ELO), to act as *in vivo* electronic encapsulants.

Commercially available polymers were investigated to determine which, if any, suited the needs of an *in vivo* electronics encapsulant based on published material, mechanical, and biocompatibility data. Materials whose published properties met the criteria for good encapsulants were obtained and put through a battery of preliminary experiments to determine their processing and manufacturing characteristics. Materials that had sufficiently facile manufacturing characteristics were then tested for compressive mechanical, long-term moisture absorption, and moisture permeability properties.

Several commercially available polymers were identified that had low moisture absorption as well as a biocompatibility certification. Based on the materials that had the best combination of handling properties as well as published moisture absorption data, two polypropylenes, three epoxies, and a silicone were obtained for further testing. In addition, a novel polymer formulated from ELO was developed. Following initial characterization of the materials only one epoxy and ELO were found to be manageable encapsulant candidates.

When tested in compression epoxy showed ductile behavior with a modulus of elasticity of 1815 MPa. The ELO, however, exhibited highly nonlinear brittle behavior and a modulus of elasticity of 720 MPa. After 24 hours of saline immersion, moisture absorption samples of the epoxy had gained a mean 0.31% (std 0.01%) mass, whereas the ELO absorbed 0.79% (std 0.03%) in mass. Permeability tests were useful only in characterizing the testing apparatus. Two ELO samples were tested and had permeabilities of 2.47e-6 $g \bullet h^{-1} \bullet m^{-1} \bullet Pa^{-1}$ and 1.20e-6 $g \bullet h^{-1} \bullet m^{-1} \bullet Pa^{-1}$.

Manufacturing capabilities were the main contributor to failure of materials as encapulants for in vivo electronics. Although ELO was predicted to perform well as an encapsulant, it was observed to have high moisture absorption and brittle mechanical properties. These two results preclude this material from use as encapsulation. Epoxy showed good mechanical properties, but performed poorly in moisture absorption relative to published data on thermoplastic materials. In further testing it should be considered in combination with other material with better moisture barrier properties.