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Strategies for Improving Oxygen Transport and Mechanical Strength in Alginate-Based Hydrogels

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Joseph C. White, *University of Massachusetts - Amherst*

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First Advisor
Surita R. Bhatia,

Second Advisor
Susan C. Roberts

Third Advisor
David A. Hoagland

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Abstract
Hydrogels have attracted significant interest over the past several decades due to their outstanding versatility as biomaterials. Alginate-based hydrogels are among the most popular studied due to their low cost, biocompatibility, and tunable physical properties. However, as with all hydrogels, persistent oxygen solubility and poor mechanical strength

limits their utility for creating macroscopic devices for biomedical use. This thesis presents two strategies for improving oxygen transport and mechanical properties of alginate-based hydrogel. The former involves incorporating perfluorocarbons, hydrophobic compounds with very high oxygen solubility, into the formulation. The perfluorocarbons are stabilized by nonionic surfactants, Pluronics®, and the emulsion is entrapped within the alginate hydrogel during the crosslinking process. The latter utilizes the thermoreversible gelation of concentrated Pluronics®. High concentrations of Pluronics® infiltrate alginate hydrogel networks, and then gelation is induced by raising the temperature above the lower gelation temperature (LGT). The impact on overall mechanical properties and transport of biological molecules is evaluated to gain insight on whether either strategy affects the potential for these materials as biomedical devices.

The results show that oxygen transport is enhanced by the addition of perfluorocarbon emulsion to alginate hydrogel formulation, but at a cost—integral to designing efficacious biomedical devices. Due to the presence of hydrophobic domains within the aqueous alginate gel, the transport of hydrophobic molecules and proteins are hindered. Moreover, mechanical integrity is decreased by the presence of the dispersed perfluorocarbons which decreases the crosslink density of alginate. Understanding the trade-off between maximizing oxygen transport and maintaining both mechanical integrity and proper transport of biologically relevant nutrients and therapeutic molecules is crucial and must be utilized effectively when designing materials for tissue engineering and drug delivery applications.

Enhancing mechanical strength of alginate-based hydrogels is possible by incorporating a Pluronic® gel structure to the hydrogel network by quadrupling the fracture strength. Results show that the composite material exhibit plastic deformation due to the sliding of ordered Pluronic® micelles at conditions above the LGT. However, transient transport of hydrophilic molecules is most likely impacted by the swelling dynamics and controlled by the transition from gel back to sol of the Pluronic® phase within the alginate scaffold, which happens relatively fast. The prospect of utilizing these materials for applications like artificial cartilage or grafts for bone defects is promising with further optimization.

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