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1-25-08

Provost Fellowship Progress Report

My first semester as a graduate student in the Department of Biomedical Engineering at IIT has proven to be an exciting, challenging and rewarding experience. Working under the guidance of my advisor, Dr. Georgia Papavasiliou, I have taken the first steps in my path to earning my degree. These include the completion of several courses as well as the initial steps in developing my research project. I have also had the opportunity to become a mentor for fellow students and teachers as well as participate in nationally organized conferences, all of which will be useful in the years to come.

My primary research project involves the development of experimental and computational techniques that can be used to fabricate poly (ethylene glycol) diacrylate (PEG-DA) hydrogels with controlled physical and biological properties for directing cell function. PEG-DA hydrogels have been widely investigated for tissue engineering due to the fact that they are biocompatible and can be formed under physiological conditions. One means of fabricating these materials is via free-radical polymerization in the presence of a photoinitiator sensitive to light. This technique is useful because it allows for the manipulation of the kinetics of gel formation, which in turn provides a means of controlling the spatial and temporal properties of the resultant hydrogel. More importantly, PEG-DA hydrogels are resistant to protein and cell adhesion and can be used for selective incorporation of covalently bound biological signaling molecules that possess key functionalities of the natural extracellular matrix. While this approach has been primarily investigated by researchers studying cell-biomaterial interactions, there are numerous biophysical properties of the matrix that can influence cell behavior. For example, in their natural environment, cells respond to and migrate along protein gradients contained within the extracellular matrix. Therefore, the ability to replicate these natural characteristics within a synthetic system should allow for directed migration.

PEG-DA gel formation is a kinetically controlled process in which hydrogel properties can be controlled through a variety of polymerization parameters and conditions. However, little is known regarding the effect of these conditions on the incorporation of biological signals (cell adhesion and degradation sites) as well as physical properties (crosslink density) of the scaffold. My solution to this problem involves manipulating the kinetics of hydrogel formation to control the spatial and temporal properties of PEG-DA hydrogels using computational and experimental techniques. These studies will likely have a broad impact on the design of these materials for multiple areas of tissue engineering and provide physical insight on the key parameters that can be used to fine-tune the biophysical cues required to optimize cell-biomaterial interactions.

The preliminary studies I have performed can be divided into the following areas: (1) characterization of gel properties under varying polymerization conditions; (2) fabrication of bioactive hydrogel scaffolds that promote cell adhesion and migration; and (3) quantification of cell adhesion peptides incorporated into hydrogels. With regards to characterization, I have determined the effect of the composition of the pre-gel solution on the swelling properties of the resultant hydrogel. I have also begun to explore experimental techniques for inducing gradients of properties within PEG-DA hydrogels. Ultimately, I will use these findings to develop a computational model capable of tracking the incorporation of biological signals as well as gel crosslink density as a function of time. This model will be a useful guide for optimizing properties that can be used to direct cell behavior.

In addition to studying the effect of kinetic parameters on hydrogel properties, I have also performed preliminary adhesion studies to determine the conditions necessary for different cell types to adhere to the surface of PEG-DA gels. To date, I have been successful in demonstrating that fibroblasts adhere specifically onto PEG-DA hydrogels functionalized with adhesion peptide sequences and that they are able to migrate across the hydrogel surface. Current efforts are directed towards modifying these hydrogels to support endothelial cell adhesion, proliferation and migration by experimental variation of the biological parameters.

The third aspect of my current research is directed at quantifying the incorporation of biological molecules into hydrogels. Numerous studies have been performed in which the investigators propose a hypothetical concentration of incorporated ligands. However, these studies have not focused on quantifying the degree of peptide incorporation. In doing so, I hope to obtain significant insight on the effect of polymerization conditions and how they can be used to control the level of incorporation of biological signaling molecules. My experimental approach will involve the use of radiolabelling to tag the protein and track its location within the gel. These results will also be used to verify the computational model with experimental data.

In addition to my research, I have also had the opportunity to become a mentor for both fellow students and public school teachers. In the latter case, I have become involved in the IIT Public School Initiative (IIT-PSI) in which middle school teachers from Chicago public schools are brought into the lab and given hands on experience in designing and conducting scientific experiments. I have also had the opportunity to mentor several undergraduate and NSF REU students as they have performed their own independent research projects. Lastly, I have been able to work with other IIT students as a TA for my advisor's classes.

Outside of my research, I have completed several graduate courses that will be helpful not only in the years to come but in passing my qualifying exam that I will take at the end of the current semester. I have also had the opportunity to travel to Los Angeles for the annual 2007 Biomedical Engineering Society (BMES) conference at which I was able to meet other prominent researchers in the field of hydrogels, many of whom have published the articles that I have been reading related to my research. Additionally, I was also a co-author on a poster presentation presented in the REU section of the 2007 BMES meeting entitled "Poly (ethylene glycol) Hydrogel Crosslink Density Gradients Through Interfacial Photopolymerization."

During the next few months, I plan on submitting abstracts to other tissue engineering consortiums with the hope that I will be able to attend conferences and present my experimental results. I will also be taking additional classes to prepare me for my qualifying exam and continuing with my research. Overall, my first semester as a graduate student has been a rewarding journey and I am looking forward to the challenges and opportunities that the remaining years of my graduate career will hold.