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Undergraduate Seminar | Biological Engineering

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Undergraduate Seminar:

Controlled Micro- and Nanostructured Biomaterials through Photopolymerization

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Abstract:

Photopolymerization has taken an increasing prominent role as a tool in providing unique properties for a wide array of advanced materials. The inherent spatial and temporal control allow great ability to tailor processing conditions and change ultimate properties. This talk will focus on two projects, including work from two Utah State alumni, in which photopolymerization enables directed structure both on the micron and nanometer size scale for unique functionality.

Photopolymerization has also enabled research to improve nerve regrowth and guidance to improve neural prostheses such as cochlear implants. We have used the spatial and temporal control inherent to photopolymerization methodology to fabricate micropatterned methacrylate polymers that direct nerve cell growth based on substrate topographical cues. Micropatterned substrates are formed in a rapid, single-step reaction by selectively blocking light with photomasks. The resultant pattern is a continuous series of parallel ridges and grooves at regular intervals and of various amplitudes that can be used for cellular contact guidance studies. Micro-feature depth is controlled and reproducibly generated from the nanometer to micron level by shutting the light source at different time steps during the reaction. Regenerative growth of inner ear nerve cells orients to the direction of the micro-pattern and is strongly dependent on feature size and slope. Substrate stiffness is modified by varying the cross-link density of the final material by either increasing the amount of cross-linker in the prepolymer formulation or by increasing the size of the spacer unit between cross-links. Spiral ganglion neurites were observed to align more strongly as substrate rigidity increased. The ultimate goal of the research is to develop materials that predictably orient regenerative nerve cell growth and improve neural prosthetic stimulatory specificity and, thus, improve patient outcomes.

The second topic will focus on generating nanostructure in organic polymers through photocuring in self-assembling lyotropic liquid crystals (LLC) as polymerization templates to direct polymer morphology. The water- and oil-soluble domains inherent in the liquid crystal phase serve as a platform to segregate monomers into ordered geometries based on polarity. The rapid polymerization kinetics of photopolymerization are then utilized to trap and thereby template the LLC structure. Many useful property relationships are observed in the resulting nanostructured polymer systems such as concurrent increases in mechanical strength and swelling as well as increased solute release rates that are not observed in traditional polymer systems. This unique combination is particularly useful for tissue engineering platforms when enhanced transport and mechanical stability are needed including for materials in retinal regeneration. Additionally, the structure has a profound impact on stimuli-responsive properties of poly(N-isopropylacrylamide) with a two-fold increase in equilibrium water content and over two orders of magnitude decrease in deswelling time without compromising the strength of the material. These templated materials show a favorable increase in polymer properties and polymerization kinetics for systems photopolymerized in LLC phases useful in a wide-variety of applications ranging from drug delivery and tissue scaffolds to water purification.