

Hydrolytic Degradation of Electrospun Polycaprolactone and Polyglycolide Copolymer Blends

Amy S. Chung^{1,5}, Ho Seong Hwang¹, Patricia Zuk³, David R. McAllister^{2,3,5}, Benjamin M. Wu^{1,2,4},
 University of California at Los Angeles, ¹Department of Bioengineering, ²Department of Orthopedic Surgery,
³Department of Surgery, ⁴Department of Materials Science and Engineering, Los Angeles, CA 90095
⁵Department of Surgery, Greater Los Angeles Veteran Administration Medical Center, Los Angeles, CA 90073

Statement of Purpose: Though electrospun fibrous constructs have emerged as popular tissue engineering scaffolds, characterization of their degradative behaviors has been nearly absent. Electrospun fibrous constructs were engineered from a blend of polycaprolactone (PCL) and Monocryl[®], a triblock copolymer of polyglycolic acid (PGA) and PCL (PGA-PCL-PGA). The aliphatic penta-alkyl chains of PCL slow down the hydrolytic degradation to up to 3 years while PGA degrades within 2 to 4 weeks *in vivo*¹. The effects of increased hydrophilic triblock polymer in the PCL:PGA-PCL-PGA blend were examined over time under hydrolytic degradation. Hydrolytic degradative behaviors of electrospun PCL and PGA-PCL-PGA copolymer blends, as exhibited by mass and molecular weight loss, changes in mechanical properties, crystallinity, morphology and activation energy of degradation were investigated.

Methods: Polymer mixtures of varying PCL to Monocryl[®] ratios were dissolved in 1,1,1,3,3,3-hexafluoro-2-propanol (HFP) to produce solutions with viscosity ~1250cP. Electrospinning was carried out as previously described² using PCL/Monocryl solutions charged with 25kV delivered at 2.5 ml/h with an 18-gauge

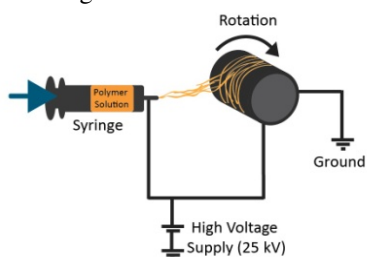


Figure 1. Electrospinning setup

blunt-ended needle to a rotating mandrel (3450rpm), as depicted in Figure 1 below. For material degradation analysis, electrospun fibrous constructs were incubated in PBS 1X (pH 7.4) at 25, 37, and 45°C for up to

42 days. Mass loss, morphological changes, storage modulus reduction, molecular weight loss, crystallinity, and activation energy were investigated. Morphological changes (pore structure, fiber diameter, fiber angles) were examined with a scanning electron microscope with a variable pressure (SEM, Nova 230, FEI). Storage modulus and crystallinity were measured with a dynamic mechanical analyzer (DMA 800, Perkin-Elmer) while molecular weight of the polymers were monitored with gel permeation chromatography (GPC, Waters).

Results: With increased PGA-PCL-PGA triblock copolymer content in the PCL:PGA-PCL-PGA blend led to increased hydrolytic degradation, as exhibited by increased mass and molecular weight loss, as shown in Figure 2a. The corresponding decrease in hydrophobic PCL content led to faster hydrolytic degradation rate, as reflected by enhanced decrease in mass, molecular weight, and modulus loss at 25°C, 37°C, and 45°C. The activation energy for hydrolytic degradation for 15:85

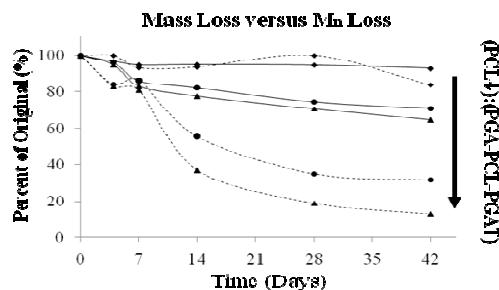


Figure 2. Loss of mass and molecular weight over time for select blends of PCL:Monocryl electrospun sheets at 37 °C. Mass loss (solid lines) and number average molecular weight loss (dashed lines) and (long dashes) for:100:0 (PCL only) (◆), 25:75 (●) and 15:85 (▲) electrospun copolymer blends. Error bars were omitted for clarity.

PCL:Monocryl[®] was approximately half that of 85:15 PCL:Monocryl[®]. Fiber morphology and crystallinity analysis revealed initial surface erosion followed by the formation and reorganization of crystalline lamellar stacks and bulk degradation at 37°C, as shown in Figure 2. The amorphous components were initially lost, as indicated by the increase in crystallinity for PCL:PGA-PCL-PGA blends.

Conclusions: Hydrolytic degradative behaviors of electrospun PCL and PGA-PCL-PGA copolymer blends and the effects of increased hydrophilic triblock copolymer were investigated. For triblock copolymer containing mats, much of the mass loss in the earlier stages of degradation were due to the loss of the relatively amorphous triblock into solution on the fiber surface, as revealed by fiber diameter reduction for select fiber populations and simultaneous increase in crystallinity. Morphological analysis and molecular weight loss at the later stages of hydrolytic degradation revealed bulk degradation along with the formation of intrafiber lamellar stacks from cleavage induced recrystallization, as depicted in Figure 3.

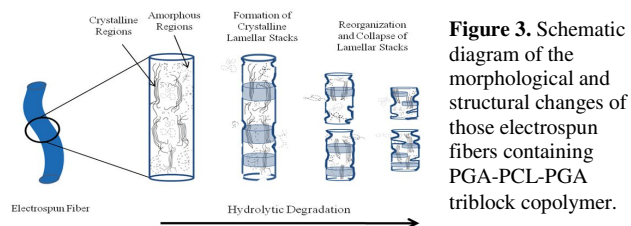


Figure 3. Schematic diagram of the morphological and structural changes of those electrospun fibers containing PGA-PCL-PGA triblock copolymer.

Thus we highlight the dynamic and interrelated mechanisms of hydrolytic degradation, unique to the electrospun PCL and PGA-PCL-PGA copolymer blends due to the fibrous mats' distinct architecture that embodies high specific surface to volume and interfiber porous ultrastructures.

References: 1. Smith et al. J Eng Fibers and Fabrics. 2007: 2:41-46. 2. Heydarkhan-Hagvall, S. Biomaterials. 2008; 29:2907-2914. **Acknowledgements:** Veterans Administration BLR&D Merit, I01 BX000126-01, VA Rehabilitation RR&D