Degradation Of Polymeric Materials For Multi-use And Re-use

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The Problem

Why do we care?

- As we look into long term space travel we can't sustain the current magnitude of waste output
- Routinely discarded waste may in fact be a reusable source
- Potential Solutions:
  - Mandated limits on consumption and consumed materials
    - Limited standards of living
    - Reduced product efficiency
  - Get creative
    - Maximize the efficiency of waste management through the recycling and repurposing of materials
    - Encourages innovation and competition

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Biomaterials in Tissue Engineering

- Biomaterials in tissue engineering have a variety of applications from bone to muscle to skin
  - Biodegradable meshes for hernia and cardiac repair
  - Biodegradable scaffolds for bone growth and repair
  - Biodegradable synthetic skin analogues for burn injuries
- It is crucial to characterize the appropriate mechanical parameters of these meshes, to support regeneration without impeding native tissue function
- In cardiac applications, for example, a prolonged degradation period and high mechanical strength could restrict ventricular filling

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Objectives

- Develop and characterize a variety of methods to repurpose and customize the mechanical properties of pre-manufactured polymer meshes for multi-purpose use on Earth and in space
- Our work is designed to elucidate these material characteristics of meshes to aid in handling, engraftment, and biodegradation

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Methods

- Two polymeric meshes were explored:
  1. Polycarbonate and polylactide co-polymer
  2. Polyglactin 910
- Three methods of degradation:
  1. Hydrolytic degradation (pH 7.4, 37°C)
  2. Ethylene oxide chemical degradation
  3. Ultraviolet photolytic degradation (254nm, 15mW)
- Tensile testing
  - To extract the stiffness and maximum tensile strength over the course of degradation

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Hydrolytic Degradation

- Simulates in-vitro degradation
  - pH 7.4, 37°C
- Seven day degradation intervals

Photolytic Degradation

- Ultraviolet light degradation
  - 254 nm, 15 mW
- 12 hour exposure periods

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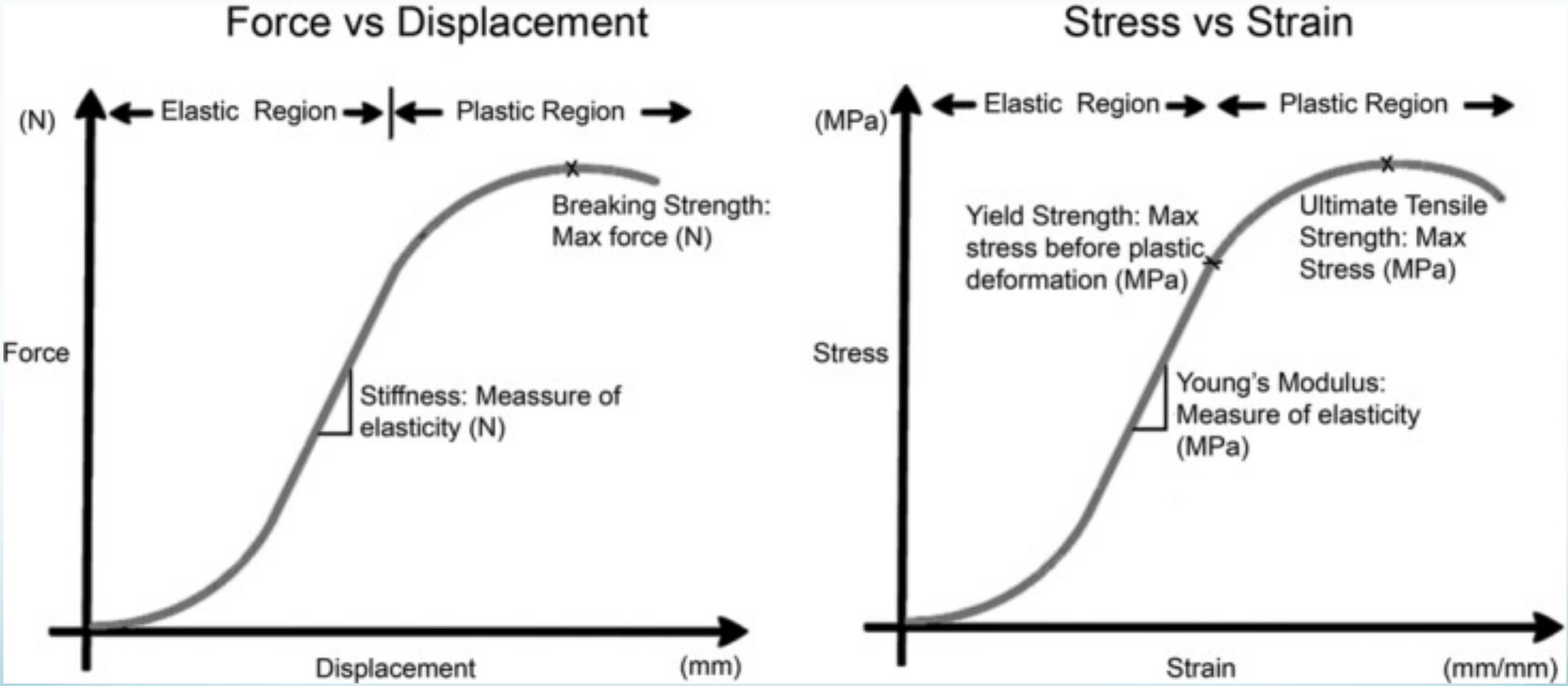
Chemical Degradation

- Ethylene oxide sterilization
  - 12 hour exposures
- Three stages:
  - Pre-conditioning
    - Temperature and humidity controlled to stimulate microorganism growth
  - Sterilizer
    - EtO gas injection
  - De-gasser
    - Remove lingering EtO particles

Tensile Testing

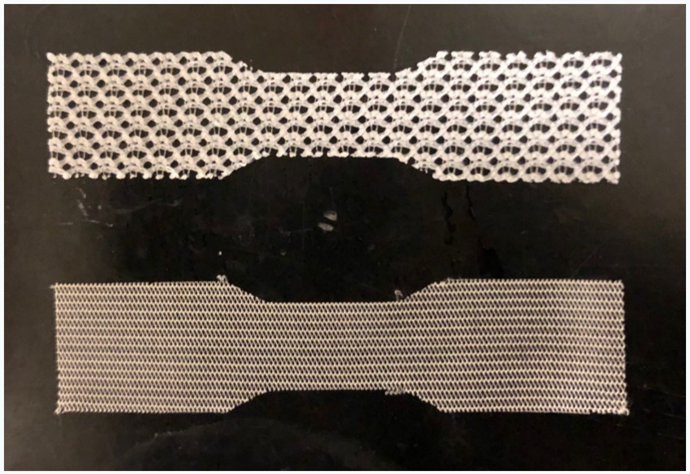
- Young's Modulus (Elastic Modulus)
  - Describes the tendency of an object to deform along an axis when opposing forces are applied along that axis
  - Stress(F/A) / Strain(mm/mm)
  - The more elastic a material, the lower its elastic modulus
- Stiffness
  - Describes the rigidity of an object, the extent to which it resists deformation to an applied force
  - Force(N) / Displacement(mm)
- Maximum Tensile Strength
  - The maximum force(N) a material can withstand while being stretched before breaking

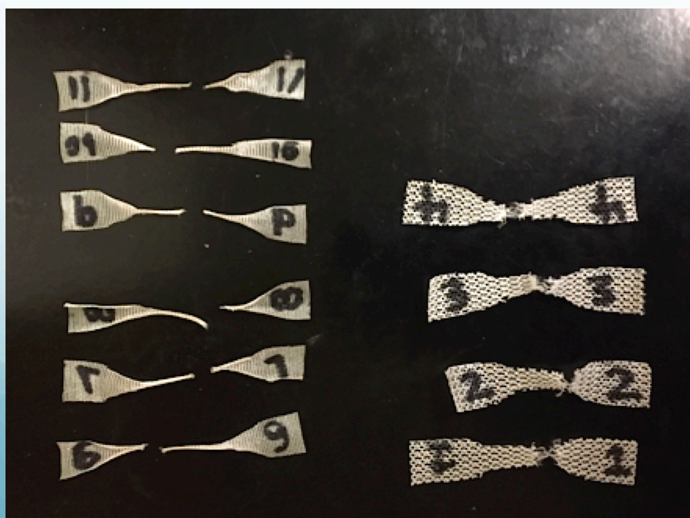
Tensile Testing

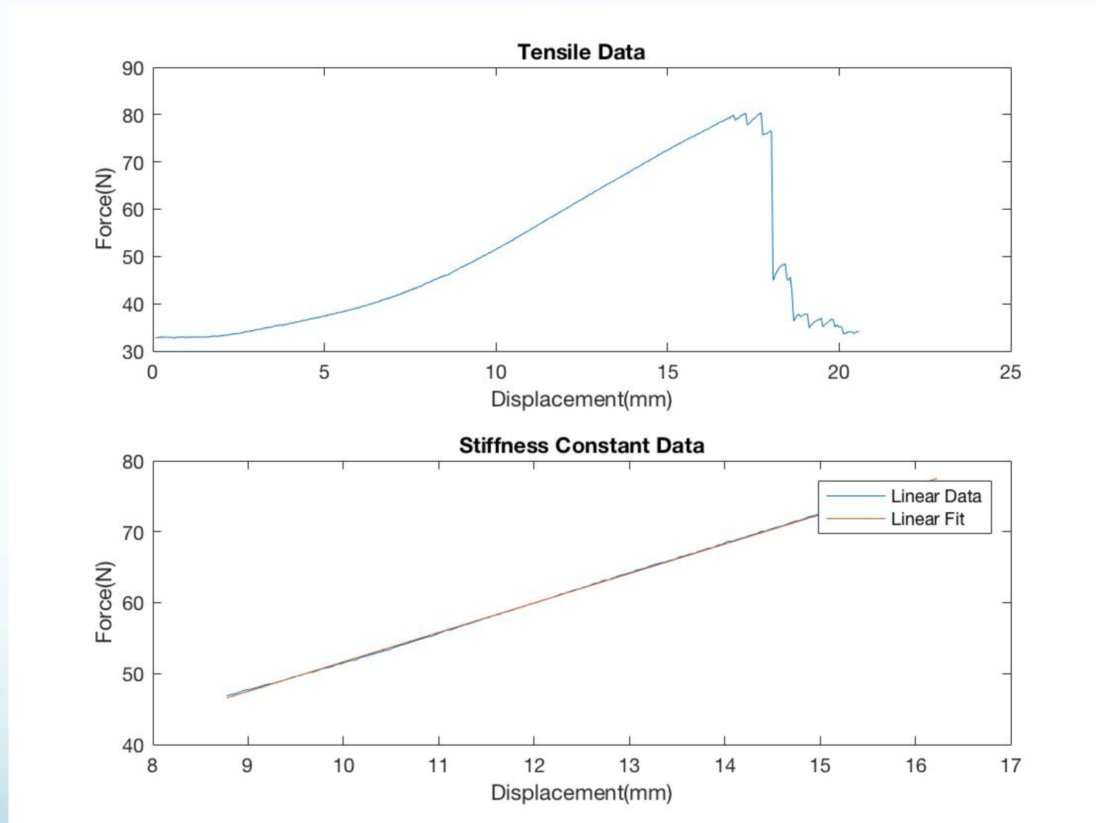


Kueckelhaus, Maximilian & Philip, Justin & Kamel, Rami & A Canseco, Jose & Hackl, Florian & Kiwanuka, Elizabeth & J Kim, Mi & Wilkie, Ryan & Caterson, Edward & Junker, Johan & Eriksson, Elof. (2014). Sustained Release of Amnion-Derived Cellular Cytokine Solution Facilitates Achilles Tendon Healing in Rats. Eplasty. 14. e29.

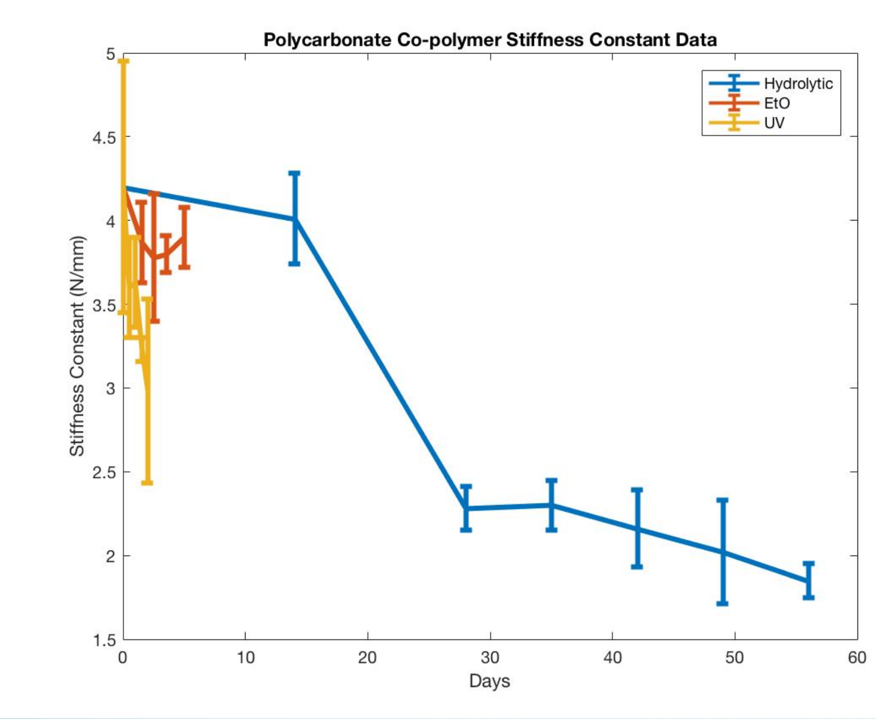
Tensile Testing

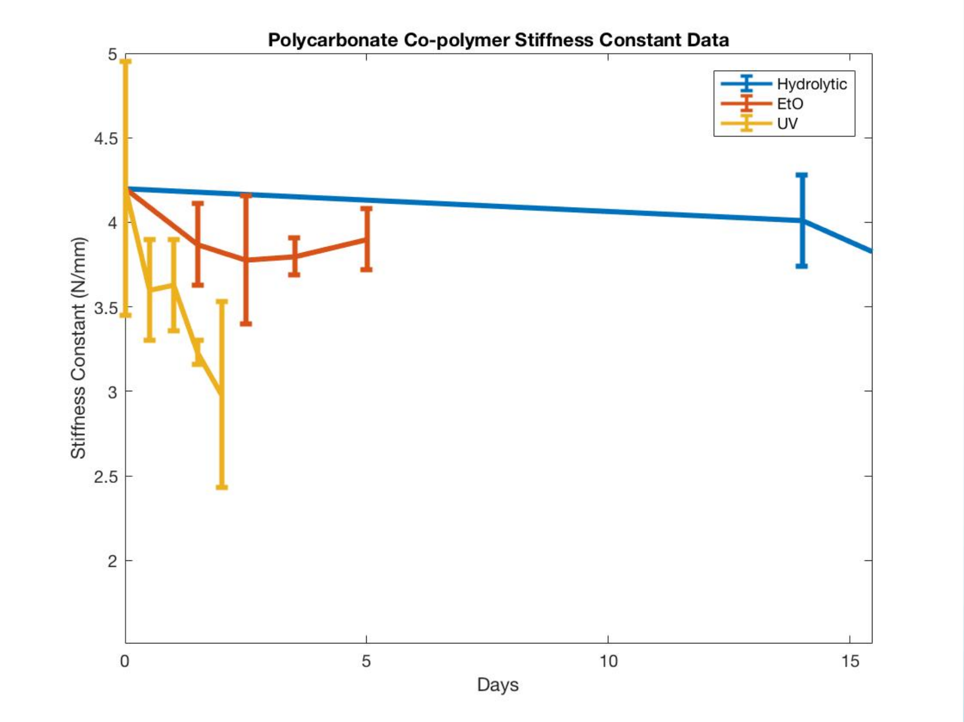




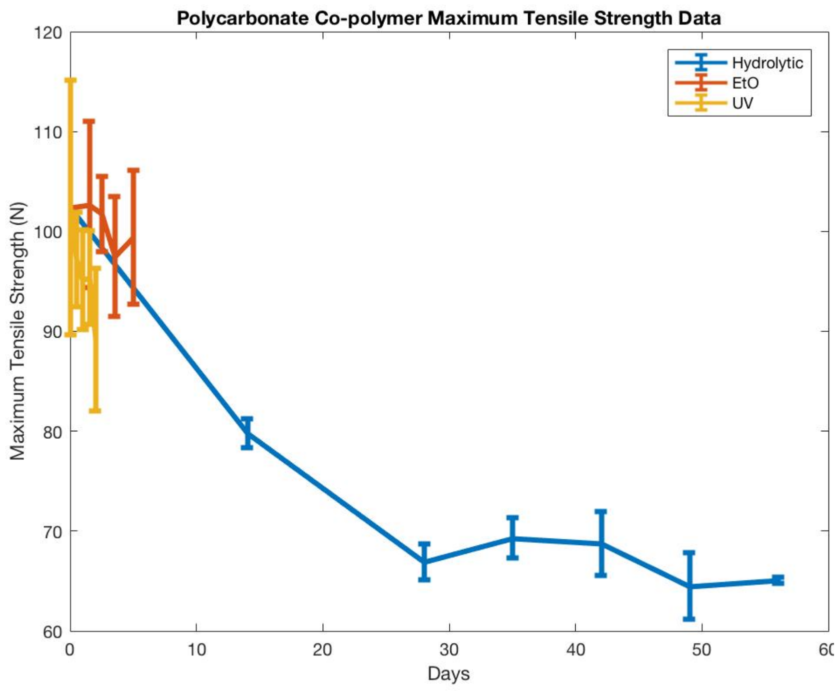


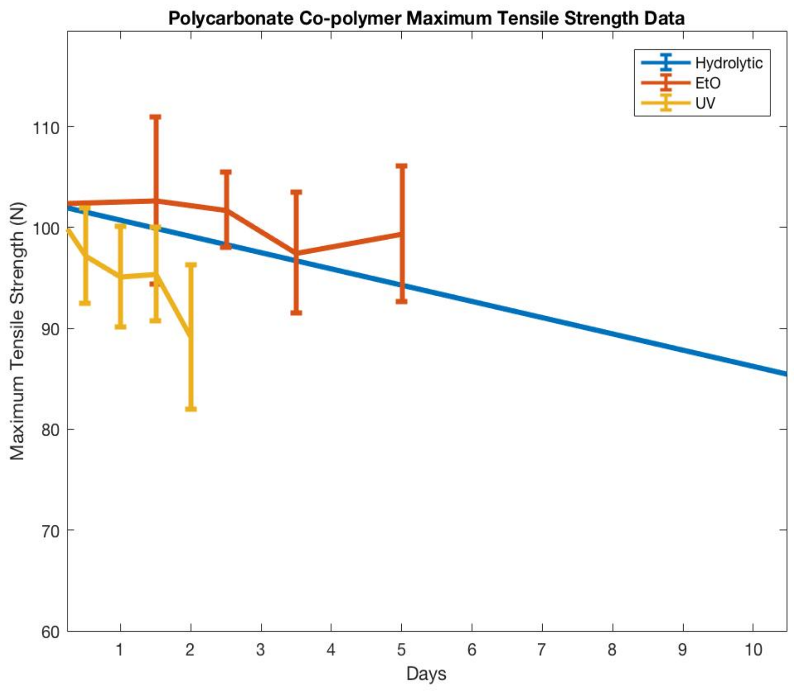
Polycarbonate Co-polymer Stiffness Constant Data



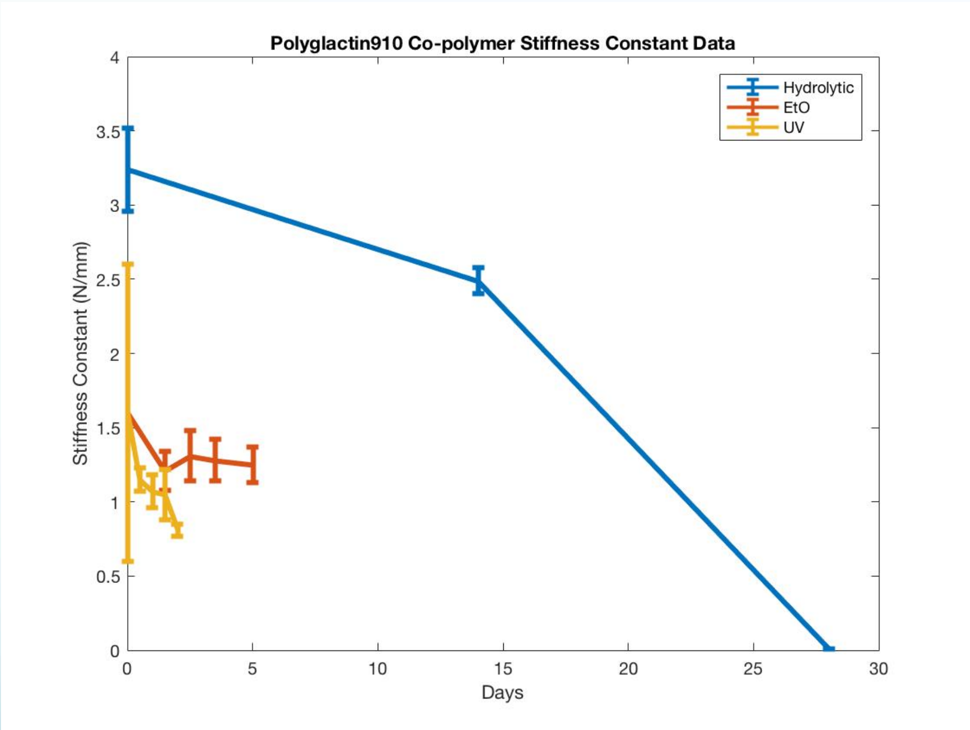


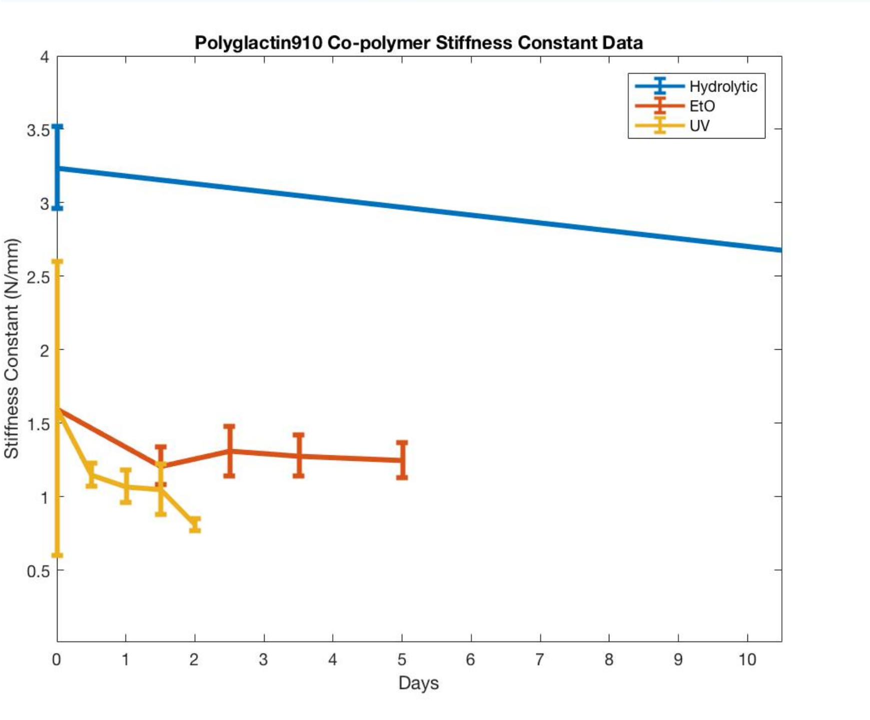
Polycarbonate Co-polymer Maximum Tensile Strength Data



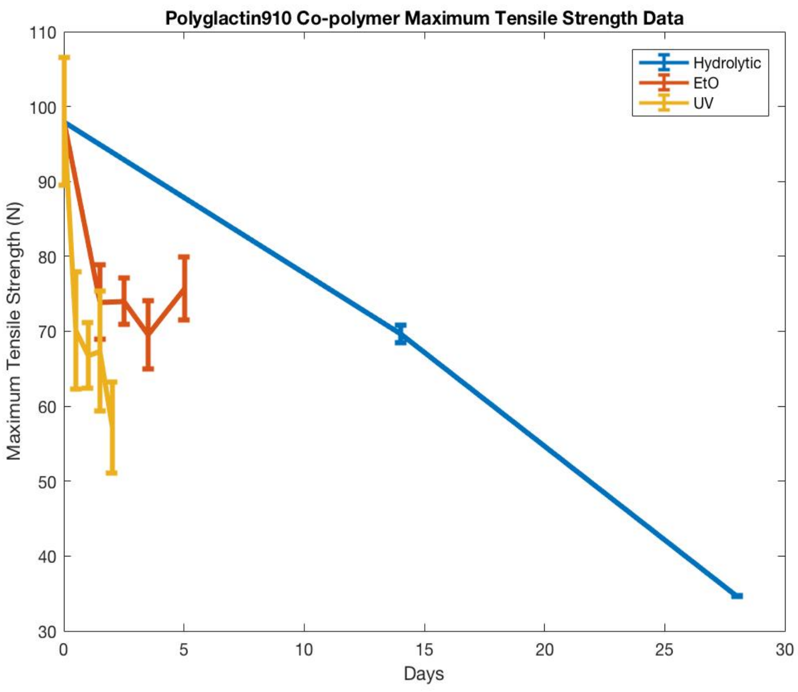


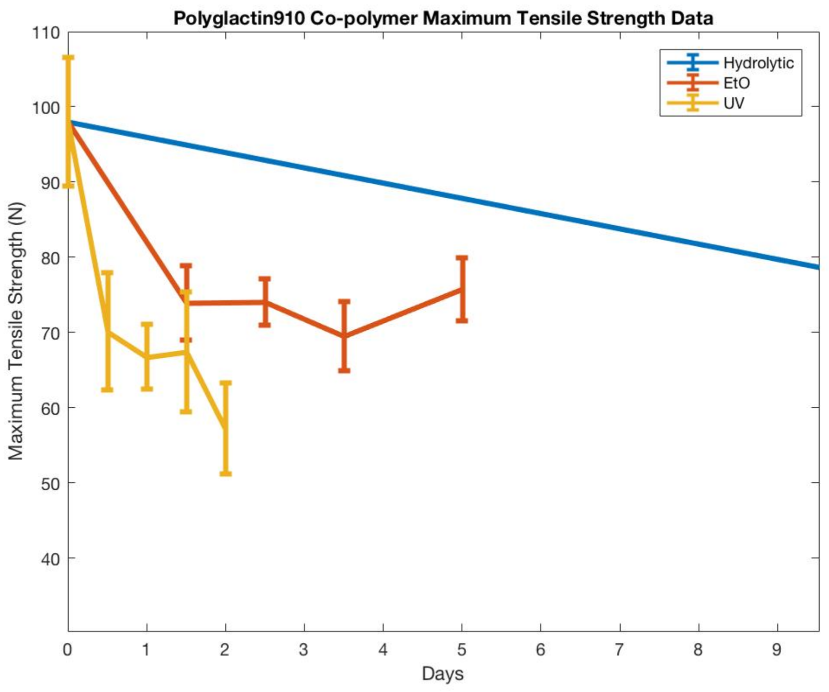
Polyglactin910 Co-polymer Stiffness Constant Data





Polyglactin910 Co-polymer Maximum Tensile Strength Data





Conclusions

- UV degradation is most effective
- EtO degradation is least effective

Future Works:

- Analyze the effects of combined degradation methods
  - Ex: UV and Hydrolytic Degradation of implanted biomaterials in space
- Establish a model of polymer degradation to extrapolate potential material properties given a material and environment

The Big Picture

What does this mean for polymers in space?

- EtO degradation and hydrolytic degradation are feasible in space but must be conducted in controlled environments such as metal encasings to limit simultaneous UV degradation
  - Aluminum can absorb approximately half the radiation it is exposed to
- Light in the range of 200-300 nm is strongly absorbed in the stratosphere by ozone
- Transmission of radiation of wavelengths below 290 nm is negligible below 10 km
- Effects of photolytic degradation will play an important role in long term space travel
  - Negative: difficult to maintain material stability/integrity
  - Positive: for re-purposable materials this means that no extra effort needs to be put into degradation

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Thank You

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