Biologically Active Bioabsorbable Fibers for Biomedical Uses
C.C. Chu (Cornell), leader; Joseph E. Spruiell (Univ. of Tennessee)

We are developing an innovative new class of synthetic bioabsorbable fibers that would be biologically active for a wide range of biomedical applications. These new bioabsorbable fibers will be made from a new type of pseudo-polyamino acids, poly(ester-amide)s (PEA). PEA fibers will be cheaper to make and yet would have far better biodegradation and biological properties than current commercially available synthetic bioabsorbable fibers. These new PEA fibers could meet the increasing demands of better and more efficient health care needs as well as more environmentally friendly consumer and agricultural textiles.

When we began, there was no fiber spinning history for PEAs, so we established melt-spinning parameters and structure-property relationships for a series of saturated (SPEA) PEA polymers and unsaturated (UPEA) [2nd and 3rd generation PEA, respectively] with improved spinning and fiber properties [see chemical structures below; details in 2004 and 2005 NTC Annual Reports].

Structure of SPEA: PEA 4-Phe-4 Polyester Amide

![Structure diagram]

UPEA with Unsaturated Double Bond (circled) in Diol

Biocompatibility of PEA Fibers in Mammals.

We initiated a preliminary in vivo study to determine the biocompatibility of PEA fibers in mammals (rats), so that their applications in medicine could be warranted. Monocryl® suture fibers were implanted in a rat’s gluteal musculature area. Commercial Monocryl® synthetic absorbable monofilament sutures (from Ethicon) were implanted in the same region of the same rat as the control for determining the merit of the new PEA fibers. The duration of study ranged over 7, 14, 28 and 42 days and there were at least 7 animals per period for statistical purposes. At the end of each time period, fibers/sutures were retrieved and stained for standard histopathological evaluation [modified Sewell Tissue Score System].

PEA fibers showed a significant reduction in tissue reaction (in terms of size of inflammatory zone and type and number of inflamed cells) with all durations of post-implantation, particularly at 28 and 42 days. PES also showed significantly less tissue response than Monocryl® control suture fibers over all time periods [see images below]. On the other hand, Monocryl® showed a marked increase in tissue reaction with time, particularly at 42 days.

Enzymatic In vitro Biodegradation of PEA Fibers

Our goal is to determine what effect enzymes might have on the in vitro hydrolytic degradation of 2nd and 3rd generation functional PEA polymers. We chose α-chymotrypsin as the model enzyme for this study. While PEA fibers retained their mass and form after 2 days immersion in a phosphate-buffered saline (PBS) control solution, no trace of PEA fibers was found following 2 days immersion in α-chymotrypsin enzyme during the same period. This indicates that PEA fibers, in general, are very susceptible to α-chymotrypsin-induced biodegradation. Unlike commercial absorbable sutures that lack enzymatic sensitivity, the high enzymatic sensitivity of PEA fibers may provide a unique filament PEA fiber strands were implanted in a rat’s gluteal musculature area. Commercial Monocryl® synthetic absorbable monofilament sutures (from Ethicon) were implanted in the same region of the same rat as the control for determining the merit of the new PEA fibers. The duration of study ranged over 7, 14, 28 and 42 days and there were at least 7 animals per period for statistical purposes. At the end of each time period, fibers/sutures were retrieved and stained for standard histopathological evaluation [modified Sewell Tissue Score System].

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Histologic microscopic images of PEA Fiber (left) vs. Monocryl® Suture Control (right) retrieved from rats after 7, 14, 28 and 42 days post-implantation.
tool to manage their biodegradation property in vivo. Commercial sutures do not have this tool available.

PEA fibers also retained their strength longer and significantly better in pure aqueous buffer (PBS) medium than some commercial absorbable suture fibers. Such good retention of PEA strength over 35 days period should prove to be a major advantage in actual clinical uses because wounds could heal over a longer time. This is of particular importance for patients, like diabetics, who have delayed wound healing.

New Derivatives of PEA Polymers

We designed and synthesized modifications of 2nd and 3rd generation PEA polymers for better fiber spinnability. 20/80 wt% PEA/PEG-DA Hydrogel

We made four types of hydrogel derivatives based on the functionality of the built-in C=C bonds on the PEA backbones from 3rd generation PEA and poly(ethylene glycol) diacrylate (PEG-DA) precursors [see sample in photo above]. These polymers had increased hydrophobicity, crosslinking density (denser network) and mechanical strength (higher compressive modulus), but reduced $Q_{eq}$. The hydrogel mechanical and swelling properties are consistent with the interior morphology of the hydrogels [see SEM images below]. The hybrid hydrogel (20/80 wt% PEA/PEG-DA) displayed a much tighter, denser interior morphology with smaller pores than 100% pure PEG-DA hydrogel, hence PEA-based hybrid hydrogels had higher compressive modulus and lower $Q_{eq}$.

We also accomplished the following:

- determined melt-spinning conditions (draw ratio, etc.) for improved crystallinity, orientation and mechanical properties for PEA 4-Phe-4 fibers.
- explored solution spinning PEA 4-Phe-4.
- developed techniques to electrospin PEA raw polymers into 3-D porous network scaffolds for potential tissue engineering uses and conducted a preliminary cell culture study to determine the feasibility of these fibrous mats to support cell proliferation and viability.
- improved crystallinity, melting and glass transition temperatures and mechanical properties for 4th generation PEA to improve rigidity, modulus and strength in fibers.

The 4th generation is still not the optimal PEA, so we continue to look for additional means to improve the overall PEA fiber properties.

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Industry Interactions: 2 [Boston Scientific, MediVas]
Non-NTC Academic Interactions: 1 [Univ.. of Tennessee].

Project Web Address:
http://www.ntcresearch.org/projectapp/?project=F04-NS17

For Further Information:

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Joseph E. Spruiell, a Professor in Materials Science & Engineering at Univ. of Tennessee, joined the faculty after earning both a B.S. in chemical engineering (1958) and a Ph. D. there in metallurgical engineering in 1963. Joe's research interests include polymer structure-property-processing interrelationships, fiber science and technology, melt spinning, polymer film technology, process modeling, polymer morphology and crystallization, carbon fiber processing and structure.

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