Effect of Melt-blowing Processing on Shape-Memory Polyurethane Microfiber Fabrics

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Statement of Purpose: Shape-memory fabrics (SMF) have many potential biomedical applications, especially in wound healing and soft-tissue repair. A SMF may act as a mechanically active scaffold and apply tensile forces to adjacent tissue as it contracts *in vivo*. The SMF would serve as a distraction histiogenesis device to close gaps in tendons and nerves. The purpose of this study is to determine the processing-structure-property relationships of melt-blown SMF and initial *in vitro* biocompatibility.

Methods: A biomedical grade polyurethane resin was melt-blown directly into a non-woven fabric web using the 6" melt blowing line at the University of Tennessee Nonwoven Research Lab. Air pressure was varied from 10 to 30 psi, and collector speed was varied from 0.3 to 2.0 m/min to form the fabric. Fabric density was measured following ASTM D3776. Fiber diameter was measured by using scanning electron microscopy (SEM) (FEI Quantra 450 FEG) and Image J. Tensile testing followed ASTM D5035, where the fabric was pulled at 300 mm/min using an Instron 5567 (n=3) to determine mechanical properties. Select fabrics were strained at 70ºC, 90ºC, or 110ºC, cooled to ambient, then immersed in saline at 37°C to determine amount of shape-recovery over 2 weeks. Human mesenchymal stem cells (hMSC) (ScienCell) were seeded onto 15 mm fabric discs at 150,000 cells/disc. Materials included samples produced at 10 and 30 psi. hMSCs were cultured on samples for 14 days in MSC media (ScienCell), changing media every 3-4 days. Cell viability was assessed using LIVE/DEAD staining (Invitrogen) at 1, 3, and 7 days (n=4). Total collagen content was assessed using Sirius Red assay (Chondrex) at 7 and 14 days (n=5).

Results: Fabric density increased from 108 to 792 g/m^2 and thickness increased from 0.4 to 2.0 mm as collector speed decreased from 2.0 to 0.3 m/min (Figure 1). SEM revealed a random microfiber structure (Figure 2) and fiber diameter increased from 4.9±3.2 to 15.1±8.2 µm as air pressure decreased to 10 psi. Tensile modulus increased from 1.41±0.20 to 6.74±0.29 MPa as air pressure increased. Maximum stress increased from 2.15±0.68 to 4.84±1.65 MPa as collector speed decreased. Failure strain increased from 62±12 to 200±18% as air pressure decreased. Over 2 weeks, fabric shape-recovery ranged from 38.5% to 83.9% as programming temperature decreased. Qualitative assessment of cell viability shows cell attachment directly to microfibers at 1, 3, and 7 days, with cells appearing to proliferate with time (Figure 3). Total collagen content was 15.55±8.36 µg/ml on 10 psi samples and 7.25±2.60 µg/ml on 30 psi samples at 7 days, and 66.9±24.16 µg/ml on 10 psi samples and 66.15±21.73µg/ml on 30 psi samples at 14 days. **Conclusions:** This study produced SMFs with a range of structures and mechanical properties, while displaying favorable biocompatibility. The melt-blowing allows for the production of a web similar to electrospinning, but the process is solvent free and high-throughput. By altering the air pressure and collector speed, SMFs were produced with a wide range of fabric densities and fiber diameters. As the collector belt speed decreases, more fabric is collected in a specific time period, which increases the fabric density. As air pressure is increased, fibers are forced through the die with greater force, which increases the draw of the fiber and decreases the diameter. Mechanical testing showed fabrics that were highly ductile. The modulus increased as the air pressure increased due to the decrease in the fiber diameter and higher number of entanglements. Conversely, failure strain increased as the air pressure decreased due to increase in fiber diameter and less number of entanglements. The *in vitro* studies showed cell attachment directly to the microfibers and deposition of collagen, which both indicate fabric cellular compatibility. Future studies will study the shape-recovery behavior under varying bias loads, effect of shape-recovery strain rates on cellular behavior, and elongation of various soft-tissues.

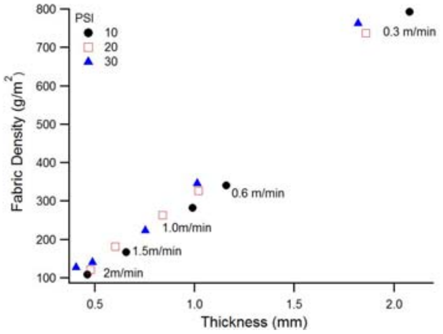

Figure 1. Fabric density and thickness for varying process speeds during meltblowing.

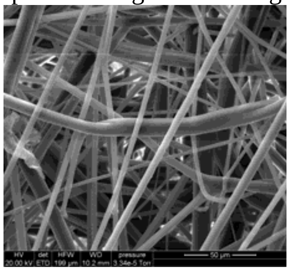

Figure 2. SEM of 20 psi microfiber fabric.

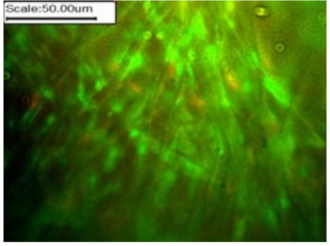

Figure 3. LIVE/DEAD stain at 3 day. (Green is live cells).