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Abstract:

New processing methods for shape-memory polymers allow for tailoring material properties for numerous applications. Shape-memory nonwovens have been previously electrospun, but melt blow processing has yet to be evaluated. In order to determine the process parameters affecting shape-memory behavior, this study examined the effect of air pressure and collector speed on the mechanical behavior and shape-recovery of shape-memory polyurethane nonwovens. Mechanical behavior was measured by dynamic mechanical analysis and tensile testing, and shape-recovery was measured by unconstrained and constrained recovery. Microstructure changes throughout the shape-memory cycle were also investigated by micro-computed tomography. It was found that increasing collector speed increases elastic modulus, ultimate strength and recovery stress of the nonwoven, but collector speed does not affect the failure strain or unconstrained recovery. Increasing air pressure decreases the failure strain and increases rubbery modulus and unconstrained recovery, but air pressure does not influence recovery stress. It was also found that during the shape-memory cycle, the connectivity density of the fibers upon recovery does not fully return to the initial values, accounting for the incomplete shape-recovery seen in shape-memory nonwovens. With these parameter to property relationships identified, shape-memory nonwovens can be more easily manufactured and tailored for specific applications.

Keywords: nonwoven; shape-memory; melt blown; microcomputed tomography; structure; mechanical behavior

1. Introduction

Shape-memory polymers (SMP)s are a class of mechanically active polymers that change from a temporary programmed shape to an original permanent shape when exposed to a stimulus. These stimuli may be direct heat or indirect heat (e.g. current, magnetic field), solvent or water uptake, light, or mechanical force [1-6]. Acrylates, urethanes, and biodegradable esters represent only a handful of the eclectic chemistries used in SMPs, which typically rely upon either physical or chemical crosslinking for the shape-memory effect [7-10]. Studies have shown that the recovery behavior is highly tunable under different programming conditions and recovery environments [9, 11]. For thermoplastic polyurethanes, the recovery ratio is highly dependent upon the programming temperature, strain, strain rate, and recovery temperature [12].This allows for the SMPs to be tailored to specific applications including medical devices, aerospace structures, and composites [13-16]. In particular, SMP polyurethanes and their foams have attracted attention for use as minimally invasive tools for treatment of aneurysms, stents, and thrombectomy devices [17-22].

A growing part of the SMP field is the work on processing shape-memory polymers into textiles either as wovens or as nonwovens [23]. Some of the earliest work started with shape-memory polyurethanes being wet-spun into individual fibers with shape recovery as high as 92% [24]. Manufacturing technique considerably impacts the shape-recovery of the textile product. When generating SMP fibers, melt-spun SMP fibers have improved shape-recovery over wet-spun fibers because of a higher degree of phase separation [25]. Shape-