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An elastic microporous material with tunable optical property

Feng Wang, Hailin Zhu, Huapeng Zhang, Hongyan Tang, Jianyong Chen, Yuhai Guo *

Key Laboratory of Advanced Textile Materials and Manufacturing Technology of Education Ministry, Zhejiang Sci-Tech University, Hangzhou 310018, PR China

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ABSTRACT

Taking advantage of the fibrillous network structure, polytetrafluoroethylene (PTFE) microporous materials with different structures were fabricated by a series of mechanical operations including preforming, extrusion, calendaring and stretching. Transparent PTFE microporous materials become inherent white gradually during their elastic deformation, exhibiting the tunable optical property. Liquid penetration induced by the pore size variation during the elastic deformation is proposed to be responsible for such transmittance variation. Meanwhile, transmittance variation can be controlled by manipulating the anisotropy of PTFE microporous materials, which is also closely related to the mechanical property. Therefore, this easily prepared and unique elastic microporous material with tunable optical property has significant potential for optical and dynamical sensor fields.

1. Introduction

Materials that can response to external stimulus, such as temperature, pH and deformation have been utilized in drug carrier and surface wettability manipulation [1–7]. Fabrication of such materials and response mechanism are multitudinous based on its intrinsic features and applications. The pH can be used to reverse the surface charge of the delivery system in drug carrier, leading to the safe delivery and internalization by cells, which promotes the research about matters with the pH-triggered feature. Many smart surfaces were fabricated based on the surface wetting theory, which indicates that surface chemistry and physical factors are the significant governing factors [8–15]. Chemical substances with low surface energy and micro-nano structures bring about the superhydrophobic surface. Recently, surface morphology evolution induced by external environment has become a promising variable for controlling surface wettability and is an increasingly appealing target for adaptive manipulation [16–20]. Microporous materials with tunable surface wettability resulting from the elastic deformation have been reported before. Reversible superhydrophobicity to superhydrophilicity of polyamide (PA) and polytetrafluoroethylene (PTFE) membrane is obtained by the extension and unloading [6]. Pore size variation of such membranes is proposed to be responsible for the tunable surface wettability [21].

Herein, we fabricate a microporous material with tunable optical property induced by an elastic deformation. Effect of microstructure evolution during the elastic deformation on the optical property was carefully discussed.

2. Experimental section

2.1. Fabrication of PTFE microporous materials

We used the mechanical stretching method to fabricate our samples, which could be achieved by a series of equipment with systematic parameter setting function, such as extruder, calendar and stretcher. PTFE particles (Algoflon® DF130F, Specific Gravity: 2160, Average Particle Size: 600 μm, Solvay, Belgium) and lubricant (Isopar M, Exxon Mobil, USA) with mass ratio of 3:1 were stirred mildly to form the paste at 19 °C. Then the paste was preformed to prepare the cylindrical parison at 20 °C. PTFE rod was obtained after extrusion of the cylindrical parison at 20 °C. A tape could be prepared by a calendaring process at 40 °C, the thickness of which could be controlled. The PTFE sheet with micropore was obtained by the longitudinal stretching at 150 °C after removal of lubricant. Finally, the PTFE microporous materials were prepared after the transverse stretching at 150 °C. Average pore size and thickness of PTFE microporous materials were controlled by the calendaring process and stretching operation [22].

2.2. Elastic deformation

In order to observe the transmittance variation process, PTFE microporous materials with the same thickness were immersed in the Galwick liquid (Porous Materials Inc., USA) with low volatility until transparent materials were obtained. Then such transparent

* Corresponding author.
E-mail address: gyh@zstu.edu.cn (Y. Guo).

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microporous materials were stretched periodically in the longitudinal and transverse directions to evaluate the stability of transmittance variation.

2.3. Characterizations

SEM images were obtained with an EVO MA 25 scanning electron microscope. The samples were platinum-sputtered for the SEM observation using a HITACHIE-1010 Ion Sputtering device. The mechanical property was evaluated by the KES-G1 multipurpose-tensile tester. Average pore size was measured using a CFP-1500AE Capillary Flow Porometer. All samples were wetted using the Galwick liquid with the surface tension of 15.9 dynes/cm. The optical images were photograph using the Canon digital single lens reflex. The light transmittance values of all samples were tested using Lambda 900 UV/VIS/NIR Spectrometer (PerkinElmer instruments, USA).

3. Results and discussion

Fig. 1 shows surface microstructure evolution of PTFE microporous materials during the elastic deformation. Typically, the surface microstructures of all PTFE microporous materials could be described as a network structure composed of continuous fibrils conjoined by nodes. The original microporous materials exhibit an incompact network structure, in which the fibrils arrange randomly (Fig. 1 A_O–C_O). Primary, the tangly PTFE particles in tape are stretched in the two stretching operations, leading to the fresh fibrils formation arranged along the longitudinal and transverse direction, respectively. Secondly, the rotation of PTFE particles induced by split of nodes brings about the slant fibril. The distances between a node and its adjoining nodes distributing in the longitudinal and transverse directions are nearly the same, which can be deftly manipulated by the stretching operation. Furthermore, the micropore shape of the original microporous materials is similar to rectangle. However, surface microstructure evolution of all PTFE microporous materials occurs as they deform (Fig. 1 A_L–C_T). All PTFE microporous materials are difficult to deform in the longitudinal direction because the fibrils arranged in the longitudinal direction are highly oriented in the preparation and provide high strength (Fig. 2). Therefore, transverse shrinkage can be clearly observed and the distances between fibrils arranged in the longitudinal direction decrease, leading to the nodes' agglomeration (Fig. 1 A_L–C_L). In addition, the rhombus micropore shape can be observed owing to the shift of nodes and fibrils. However, the distances between nodes along the transverse direction is longer than it of the released microporous materials

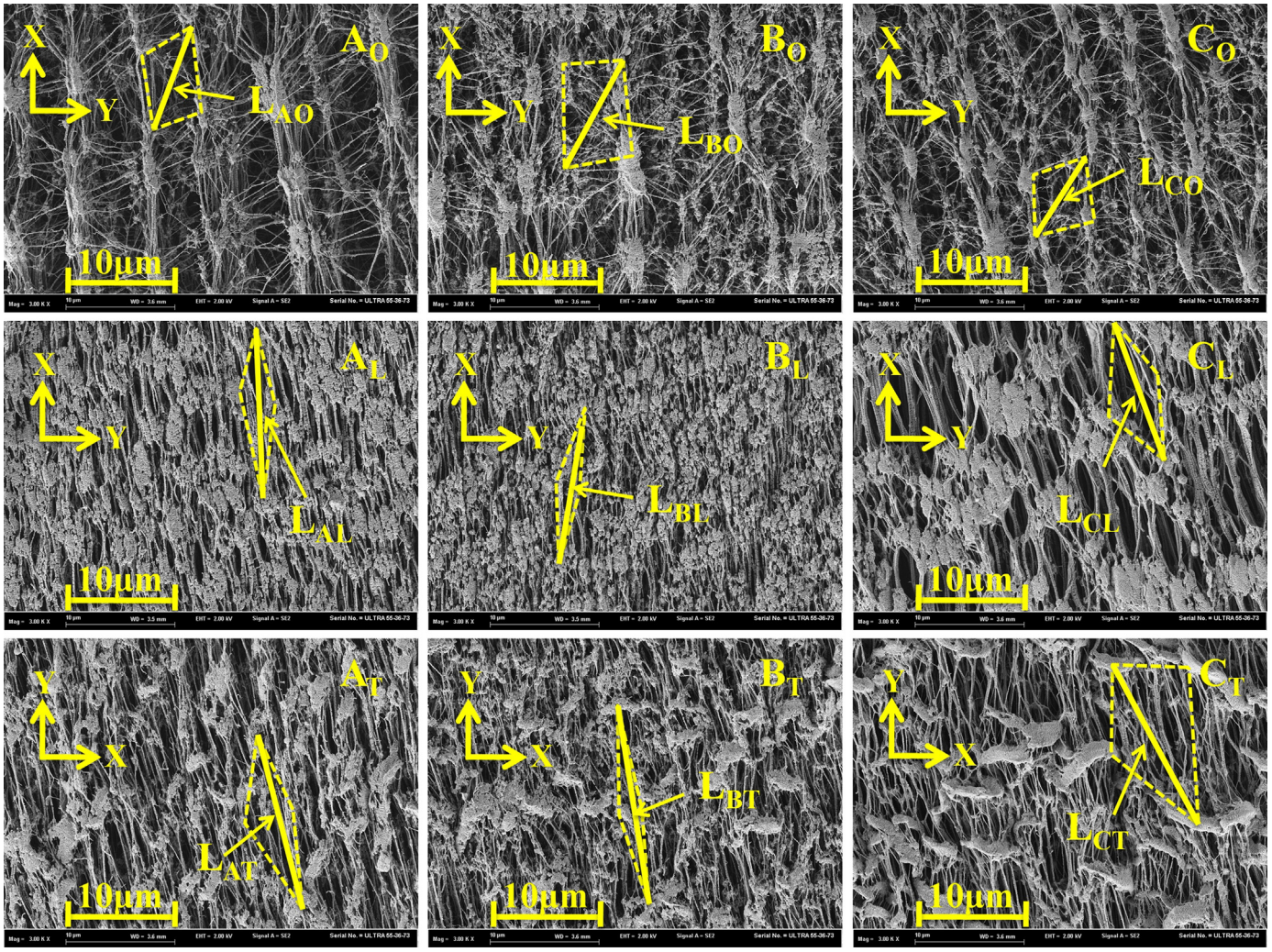

Fig. 1. SEM images of the released and stretched PTFE microporous materials. A_O, B_O and C_O refers to the released samples with average pore size of 0.22 μm, 0.17 μm and 0.2 μm, respectively. A_L, B_L and C_L refer to the stretched samples after longitudinal elastic deformation. A_T, B_T and C_T refer to the stretched samples after transverse elastic deformation.