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Morphology study of nanofibers produced by extraction from polymer blend fibers using image processing

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Abstract−The morphology of nanofibers extracted from the industrial-scale produced polypropylene/polybutylene terephthalate (PP/PBT) blend fibers was studied. To study the morphology and diameter measurements of the nanofibers, image processing method was used, and the results were compared with the results of a conventional visual method. Comparing these two methods indicated the good performance of image processing methods for the measuring of nanofiber diameter. Among the various applied image processing methods, the fuzzy c-means (FCM) method was determined as the best for image thresholding. Additionally, the distance transform method was determined as the best way for measuring nanofiber diameter. According to high regression coefficient (R=0.98) resulting between the draw ratio and nanofibers diameter, the high effectiveness of draw ratio to nanofiber diameter is concluded. The spherical (drop) shapes of the PBT dispersed phase particles were eventually deformed into very thin fibrils during the drawing process. The results of measuring the nanofiber diameters showed that the diameter means of nanofibers varied from 420 nm to 175 nm with the highest draw ratio. Good uniformity for diameter of nanofibers was observed, which had not been observed in previous works.

Keywords: Polymer Blend Fibers, Nanofibers, Morphology, Draw Ratio, Image Processing

INTRODUCTION

The main purpose of blending polymers is to obtain materials suitable for specific needs by creating or improving one or more properties with minimum destruction in other properties. Different shapes of dispersed phase (as minor phase) such as sphere, laminar and fibrillar may form in the matrix phase (as major phase) of polymer blends. Production of blend fibers during the melt spinning can result in more effective fibrillar phase morphology than in other methods because of the existence of elongational force field, which are also called matrix-fibrill fibers [1]. In a matrix-fibril fiber, the fibrils are placed randomly within the matrix. By dissolving the matrix component, a set of very thin fibrils is obtained [2].

Recently, many researchers have focused on micro- and nanofibril formation in the matrix phase of immiscible blend fibers [3-6]. The processing parameters and characteristics of polymers affect the size of fibrils. Some of these factors are various rheological and processing factors. These parameters include the viscosity ratio of components [2], the blend ratio of component [7], the presence of compatibilizer agent [8,9], the type of flow field (whether shear or elongational) [10], the type of dispersed or matrix component, stress rate, extrusion temperature, winding or take-up speed, etc. [1].

Drawing operation is conducted to obtain the desired characteristics of the fibers during or after the fiber formation process. This operation makes appropriate values o f tensile and structural properties such as elongation at break, tenacity, orientation and the crystallinity of fibers in terms of their final consumption [11]. The length over diameter ratio of the dispersed phase particles could be increased by drawing blend fibers. Furthermore, these particles could be changed to microfibrils and even nanofibrils by drawing operation [12,13]. The fibrils had a wide range of sizes, considering their production methods.

The drawing operation can be performed in two ways: in hot (feeding roller at a temperature higher than the glass transition temperature (T_g) (for both polymers)) and cold conditions. Cold drawing creates aligned fibrils into the matrix phase of blend fibers. Moreover, hot drawing can makes a possible higher draw ratio of blend fibers compared to cold drawing [9]. Often with the increase of draw ratio, in addition to decreasing fibril diameter, the uniformity of the fibrils length increases [1]. Changes in the morphology of micro- and nanofibrils resulting from blend fibers were studied by various researchers [9,13,14].

Jayanarayanan et al. observed that fibril diameter in dispersed phase of the PP/PET injection molded composite decreases with increasing of the draw ratio [14]. Bagheban et al. [9] observed that polypropylene dispersed phase particles deform during the drawing process. Their fibril diameters in the blends with compatibilizer agent were smaller and more uniform, compared to the blend without compatibilizer agent. The diameter of the thinnest fibril was around 300 nm.

Falahi et al. studied the production of nanofibrils from a PP/PA6 blend fiber. They observed that fibrils were oriented toward the drawing direction, whichever the ratio of undrawn fibrils mean diameter over drawn fibrils mean diameter was reported as 1.2. A wide range of 300 nm to 1,200 nm was also reported for fibril diameter [13].

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