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ORIGINAL RESEARCH

Mesopores variation in polyacrylonitrile fibers during dry-jet wet spinning process

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Abstract

The mesopore structures in polyacrylonitrile (PAN) fibers during dry-jet wet spinning process were investigated by high-resolution transmission electron microscopy (HRTEM) and image analysis utilizing the ultrathin section technique. The morphologies and dimension distribution of the mesopores in the surface and core regions of the nascent fibers and PAN fibers are presented. All fibers exhibited lamellar-like structures perpendicular to the fiber axis and the mesopores were distributed between the lamellae. For nascent fibers, the size and volume of the mesopores increased with increasing air gap and decreased with increasing drawing ratio. In addition, the widths of the mesopores were larger than their lengths. Consequently, the size and content of the mesopores in nascent fibers could be adjusted by controlling coagulation conditions. During the post-spinning process, the size and volume of the mesopores in PAN fibers decreased efficiently by hot drawing in a hot water washing bath, in hot steam chambers or on hot rollers. Moreover, the lengths of the mesopores were larger than their widths. In all fiber samples, the number and size of the mesopores in the core region were larger than those in the surface region. In addition, the mechanical properties of fibers were correlated with dimension of the mesopores. Their tensile strength increased with decreasing mesopore widths and lengths.

Keywords PAN fiber · Nascent fiber · Mesopore · Ultrathin section · Mechanical properties

Introduction

Porosity is an intrinsic property of the polyacrylonitrile (PAN) fibers that is due to their microstructures and exists as voids (pores) between the lamellae, crystals and other elements of the fibers' texture [1, 2]. Their mechanical properties are largely limited by the presence of the pore defects where the stress accumulates, accelerating the formation and the development of cracks, which eventually results in catastrophic break [3, 4].

At present, there are many spinning techniques to make PAN precursor fibers, including wet spinning, dry spinning, and melt and electrospinning. However, to date, the dry spinning and melt spinning have yet not been reached the carbon fiber qualities by wet spinning, since they bring many defects into the fibers [5]. Meanwhile, in electrospinning, the fibers are short and are collected in the form of fiber mats rather than a continuous fiber filament [5, 6]. Therefore, the traditional wet spinning is the preferred technique for manufacturing carbon fiber precursors. Furthermore, to reduce the processing cost, the dry-jet wet spinning with high speed is developed to prepare high-quality precursor fibers [7]. During fiber formation and conversion process, the morphologies and size distribution of the pores in fibers were adjusted through controlling the spinning conditions [8]. Therefore, to decrease fiber porosity and increase fiber mechanical properties, it is important to study the evolution of pore structures and the relation between pores and mechanical properties during the dry-jet wet spinning process.

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