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Geometrical and Optical Properties of Irregular Fibers as a Function of Draw Ratio

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The Pluta polarizing interference microscope with a fiber rotator-mechanical device was used to detect the variation in the cross-sectional area, shapes and optical properties of irregular fibers during the cold drawing process. The rotation method was used to overcome the difficulty of measuring the transverse cross-sectional area of fibers with irregular shapes during their drawing process. Acrylic fibers of two denier were used during this investigation. Some optical parameters were measured, such as refractive indices and birefringence. The measurements of the refractive indices show that acrylic fibers have a negative birefringence. The polarizability-per-unit volume was used to clarify the negative birefringence of these fibers. Microinterferograms and the digitized images with their contour lines are given for illustration.

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INTRODUCTION

Synthetic polymer fibers play an important role in the textile industry. Most textiles, even those made from natural fibers, are mixed with

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synthetic yarns drawn from polymer melts. Drawing is an important operation that improves the textile characteristics of man-made fibers. Undrawn synthetic fibers are almost isotropic in their physical properties. When the fibers are mechanically drawn, these fibers become stronger, more birefringent and highly anisotropic [1].

The last three decades have witnessed phenomenal growth in the field of material sciences. Many interferometric methods [2–7] have been used to investigate the optical and geometrical properties of fibers. They usually produce contour maps in terms of fringe pattern. The power of the interferometric method changed greatly with the introduction of the automated method of detection and analysis of the fringe patterns [8–10]. Hamza et al. [11] used the rotator device attached to a Pluta polarizing interference microscope to determine the optical and geometrical properties of fibers having regular and/or irregular transverse sections. They introduced and modified a manipulation device [12,13] to detect the variation of the cross-sectional area, shape and optical properties of regular fibers due to the drawing process. Hamza et al. [14] used the double immersion microscopy method to determine the optical and geometrical properties of fibers with irregular transverse sections.

Acrylonitrile is polymerized by a free radical mechanism and the resulting polymer is mostly atactic [15]. However, some degree of order is present in the polymer due to the large magnitude of the dipole moment of the nitrile groups. This leads to strong intrachain and interchain interactions through secondary bonding. All commercial acrylic fibers are spun from acrylonitrile polymers containing 1–15 wt% comonomer [16]. The majority of textile fibers have a morphology that can be described by the classical two-phase model [17–19]. In this model, discrete crystalline domains of the order of several hundred angstroms (Å) are mixed with amorphous domains of similar or smaller size. A high degree of crystallinity and high orientation of the crystalline molecular segments impart high tensile strength and modulus to the fibers. The amorphous phase gives rise to toughness and dyeability. In contrast to the crystalline fraction, a low degree of orientation of the amorphous phase is preferred, in order to minimize shrinkage caused by stress relaxation upon heating the material above its glass transition temperature. Describing polyacrylonitrile by the classical model is debatable.

One of the biggest problems facing anyone dealing with the determination of the optical properties of fibers is the irregularity in their cross-sectional area. To overcome this problem, the rotation method has been used [11]. In this article, the opto-mechanical and the geometrical properties of acrylic fibers having irregular transverse sections will be investigated during the drawing process using the