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Detecting and avoiding the necking deformation along polypropylene fibre axis using the fringe pattern analysis of multiple-beam microinterferometry

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Abstract

A fibre-drawing device attached with the system for producing multiple-beam Fizeau fringes in transmission is used to optimize the optical properties during the cold drawing of polypropylene (PP) fibres. This system is automated for interference pattern analysis. Two drawing processes for the PP fibres are applied and investigated. The first one is fast drawing in which the necking deformation is predicted and the other is the slow (step) drawing in which the necking can be avoided. The refractive index profiles ($n^{\parallel}$ and $n^{\perp}$) of PP fibres are determined at different positions along the fibre axis during the fast and slow drawing processes. The fibre interference patterns are automatically digitized and stored in a computer storage media. The slow drawing technique for PP fibres is recommended to overcome the deformation difficulties along the fibre axis due to necking during the drawing processes. Microinterferograms in case of light vibrating parallel and perpendicular to the fibre axis are given for illustration.

Keywords: Polypropylene fibres; Refractive index; Drawing; Necking deformation; Multiple-beam interferometry; Fringe pattern analysis

1. Introduction

Nowadays polymer-based fibres are becoming ubiquitous in a variety of high-tech applications, e.g. specialty coating, automotive, aerospace, semiconductors, composites, optics, etc. [1].

The cold drawing of a polycrystalline polymeric film induces a deep structural rearrangement as the initial morphology is transformed into the final fibrous organization. Since the transformation is irreversible and occurs under non-equilibrium thermodynamic conditions, the fibre obtained is a system in a metastable state. The consequence is the tendency of the newly formed system to relax from the metastable state to approach equilibrium. This drawing generates a new morphological unit, the microfibril, which is absent in the initial film. In the microfibril, crystalline blocks and amorphous layers are arranged with a regular alternating distribution along the sample axis [2].

Semi-crystalline polymers that crystallize under quiescent conditions often have a spherulitic morphology. The remarkable drawability of the semi-crystalline polymers makes it possible to high orient them in the solid state. Solid state processing techniques, such as drawing fibres or stretching films, depend upon the plastic deformation characteristics of the given polymer [3]. Upon uniaxial drawing, the spherulites are deformed to an ellipsoidal shape with the radial fibrils of the spherulites orienting in the drawing direction. However, the crystallites in the radial fibrils of the deformed spherulites generally tend to reorient with their chain axes along the drawing direction [4].

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