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Structure change of PET fiber during tensile deformation up to fracture

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Introduction

High strength fibers can be produced from both rigid and flexible chain polymers. In contrast, the achieved strengths of the fibers from semiflexible chain polymers like poly(ethylene terephthalate) (PET) are relatively low at the present levels of technology. In order to consider the fiber structure which exerts high strength, it is desired to clarify the structure change of the fiber during tensile deformation up to fracture. In this study, time-resolved small-angle X-ray scattering (SAXS) measurements have been conducted during tensile deformation of a PET fiber and the structure changes have been investigated.

Experimental

The fibers melt-spun from a PET with an intrinsic viscosity of 1.00 g dl^{-1} and a density of 1.41 g cm^{-3} were used for the experiments. After the fibers were spun at a spinning velocity of 30.8 m min^{-1}, they were drawn to a ratio of 6.2. The fiber diameter was about 130 µm. Single PET fibers were loaded in tension at a strain rate of 0.12 min^{-1} at room temperature using a miniature tensile testing machine. Simultaneously, synchrotron X-ray with the beam size of about 0.2 by 0.3 mm was incident on the fiber and the SAXS patterns were recorded using a CCD camera and an image intensifier.

Results and discussion

The PET fiber used in this study initially showed layer-line scattering with a four-spot nature as shown in Figure 1 (a) where the layer-line scattering stands for the striation parallel to the equator and intersecting the meridian apart from the center of the pattern. The intensity distributions along the layer-line scattering at the initial stages of tensile deformation are shown in Figure 1 (b). It is found that the four-spot nature suddenly disappears with the application of small strain and the scattering gradually concentrates on the meridian.

The changes of the scattering pattern shown in Figure 1 (b) were analyzed based on the structure model [1] shown in Figure 1 (c). This model consists of the bundle of long-period structures in which the amorphous and crystalline regions alternate. It is assumed that the positions of the unit cells are disturbed with the distortion of the 2nd kind and the extent of the distortions are represented by the parameters ω_{ij}. The values of the structure parameters were determined so that the scattering patterns calculated with the model represent the observed ones. The calculated intensity distributions along the layer-line scattering are shown in Figure 1 (c). The values of the structure parameters showed that at the beginning of the tensile deformation, the extent of distortion (ω_{23} and ω_{13}) decreased with the application of strain.

When the strain was increased up to 0.3, strong equatorial streak appeared and increased its intensity with increasing strain. Finally the fiber broke at the strain of about 0.5. The equatorial streak is considered to be produced by the voids formed in the fiber.

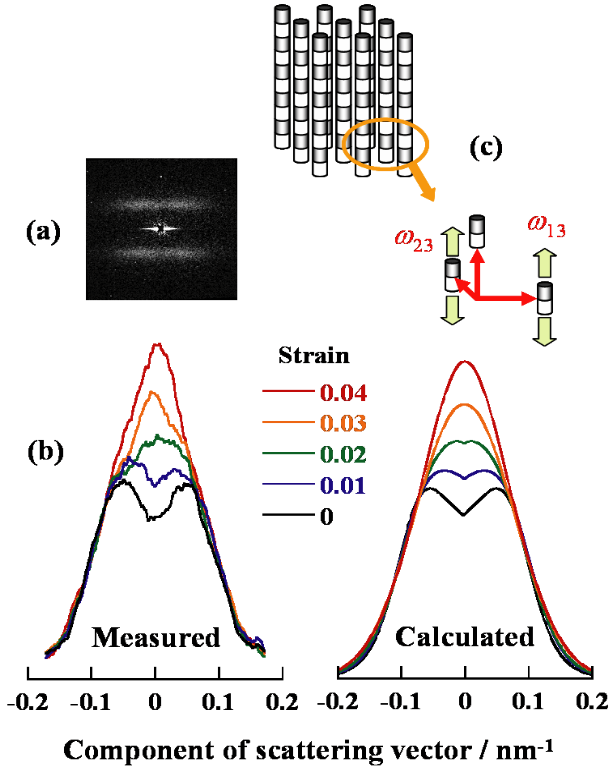

Figure 1 (a) SAXS pattern of PET fiber. (b) Intensity distributions along layer-line scattering of PET fiber at various strain levels. (c) Structure model used for analysis.

Reference

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