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Changes in small-angle X-ray scattering patterns of carbon fibers during axial compression

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Introduction

The present authors have been investigating the structure changes of fibers and composites during deformation by conducting time-resolved small-angle X-ray scattering (SAXS) measurements using synchrotron radiation in order to elucidate fracture mechanisms. Changes in the arrangement of fibrils and cavitation have been observed with relatively ductile materials such as poly(ethylene terephthalate) fibers [1]. For brittle materials such as carbon fibers (CF's), observation of the structure changes during deformation is not easy since the deformation is usually small and the materials fracture immediately after detectable amount of structure changes take place. Nevertheless, the present authors have successfully observed structure changes of CF's during axial compressive deformation as shown below.

Experimental

Polyacrylonitrile based CF's were formed into composite strands 1 mm in diameter and 10 mm long. The central portion of the strand was further thinned by grinding. These specimens were axially compressed at a velocity of 7.5 μm/min. During compression, the X-ray beam was incident upon the central portion of the specimen. The SAXS patterns were detected using an image intensifier and a CCD camera.

Results and discussion

Typical SAXS pattern of a CF is shown in Figure 1. The equatorial streak is produced by the needle-like microvoids preferentially oriented in parallel to the fiber axis. The degree of orientation is defined as (1 - [full-width at half-maximum of orientation distribution]/180°). The longitudinal length and the degree of orientation of the microvoids can be obtained from the intercept and the slope of the relationship between the square of the integral width of the equatorial streak, *B*, and the square of the magnitude of the scattering vector, *s*, at which *B* is measured. This relationship actually fits to a straight line as shown in Figure 1. Figure 2 represents the changes in the longitudinal length and the degree of orientation of the microvoids with the increase in the axial compressive stress of fibers which was obtained by dividing the force applied to the composite with the fiber cross section area. The longitudinal length and the orientation both continue to decrease during axial compression.

References

[1] M. Shioya, T. Kawazoe, R. Okazaki, T. Suei, S. Sakurai, K. Yamamoto, and T. Kikutani, Macromolecules, 41, 4758 (2008).

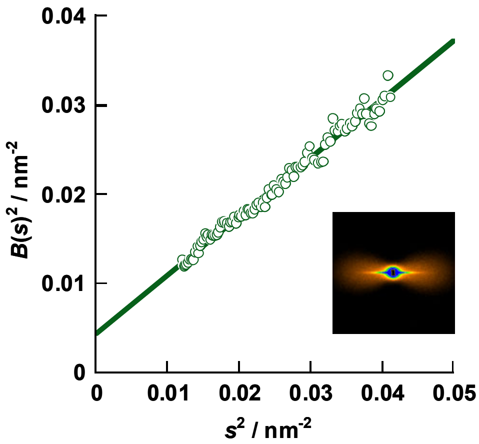

Figure 1 Relationship between square of integral width, *B*, of equatorial streak and square of magnitude of scattering vector, *s*, and SAXS pattern (inset) for a CF. Fiber axis is in top and bottom direction of the pattern.

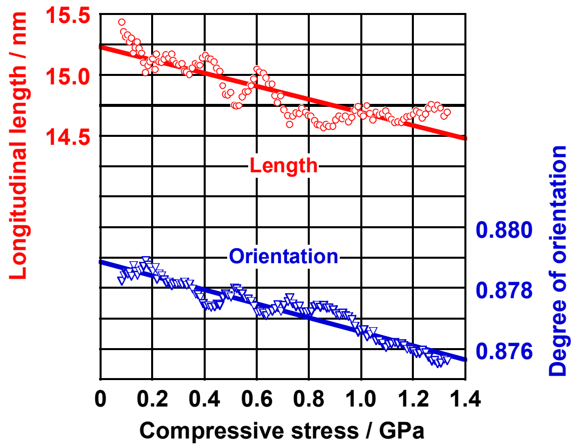

Figure 2 Longitudinal length and degree of orientation of microvoids in a CF versus axial compressive stress of fibers.

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