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Structure of Twisted Yarn of Carbon Nanotubes under Tensile Deformation

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1. Introduction

A twisted yarn of carbon nanotubes (CNT) has the possibility to show very high strength, while more detailed studies are needed to optimize the processing method and the structure of the yarn. The change in the structure of the yarn under tensile deformation is one of the subjects to be studied. In this study, time-resolved small-angle X-ray scattering (SAXS) of the twisted yarn of CNT has been carried out and the results have been analyzed in more detail as compared with the previous study.

2. Experimental

The twisted yarn used in this study was 8 μm in diameter and consisted of multi-walled CNT having a diameter of 10 to 15 nm and a length of 200 μm. The single yarn with a length of 6 mm was stretched stepwise with an increment of 20 μm. At each step of stretching, SAXS was measured for 100 s. The SAXS patterns were detected using an image intensifier and a CCD camera.

3. Results and Discussion

The distribution of the CNT in the yarn varies depending on the processing method of the yarn and two typical distribution patterns are shown in Fig. 1. The pattern of Fig. 1(a) is developed when unidirectionally aligned CNT mat is wound and all the CNT have a constant inclination angle around the yarn axis. In this case, the azimuthal SAXS intensity distribution shows two maxima around the equator. On the other hand, the patterns of Fig. 1(b) is developed when unidirectionally aligned CNT yarn is twisted and the inclination angle of CNT varies in the radial direction. In this case, the azimuthal SAXS intensity distribution shows a maxima on the equator.

The measured azimuthal SAXS intensity distribution could be decomposed into two peaks as shown in Fig. 2. This indicates that the distribution pattern of CNT for the yarn used in this study is close to that of Fig. 1(a) whereas inclination angle is not constant but has some distribution around the average inclination angle. The changes of the average inclination angle with the displacement of the chucks during tensile deformation is shown in Fig. 3. It is known that the inclination angle decreases during tensile deformation of the twisted yarn. This result will be used for the simulation of the tensile properties of the twisted yarn of CNT.

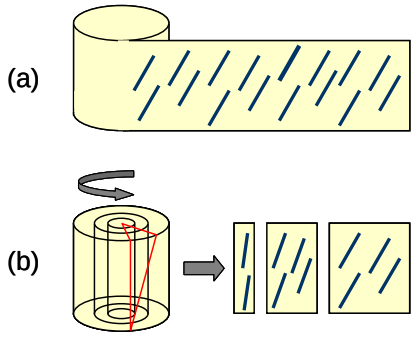

Fig. 1 Distribution patterns of CNT in twisted yarns where inclination angle is constant (a) and varies with radial distance (b).

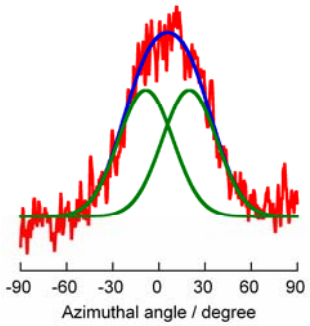

Fig. 2 Azimuthal SAXS intensity distribution of twisted yarn of CNT. Measured curve (red) could be decomposed into two peaks (green) and their sum (blue) reproduced the measured curve.

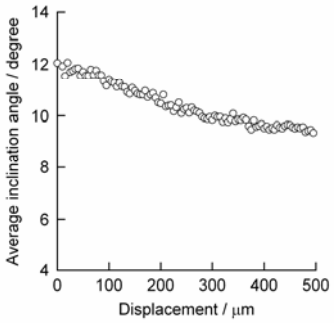

Fig. 3 Variation of average inclination angle of CNT with displacement of chucks.

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