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# Fracture toughness of PET fibers, PET films and CNT/PET composite films

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## Introduction

Polymeric materials subjected to tensile stress often cause cavitaton when the local hydrostatic stress becomes a large negative pressure. The energy dissipated during development and growth of the cavities contributes to the fracture toughness of the materials. In the present study, time-resolved small-angle X-ray scattering (SAXS) measurements have been conducted during tensile deformation of poly(ethylene terephthalate) (PET) fibers, PET films and multiwalled carbon nanotube (CNT)/PET composite films. The fracture toughness of these materials has been correlated with the cavitation behavior detected with SAXS and the stress distribution analyzed using a finite element method (FEM).

## Results and discussion

Figures 1(A) to (C) show the SAXS patterns of the PET fiber during tensile deformation. Figure 1(D) shows the SAXS pattern of the surface notched PET film near tensile fracture. The equatorial streak in figure 1(C) and the cross-shaped pattern in figure 1(D) indicate that microvoids and crazes were developed with the fiber and the film, respectively, during tensile deformation. Although microvoids and crazes have different sizes, shapes and internal structures, both of them contribute to the fracture toughness if they stably develop and grow [1]. The crazes were also developed in the CNT/PET composite films, and produced cross-shaped SAXS patterns superimposed on the circular patterns from CNTs [2].

The results of the SAXS measurements and the fracture toughness tests showed that CNTs enhance the plastic work needed to grow the fibrils in the crazes and thereby increase the fracture toughness of PET. The enhancement of the fracture toughness due to the addition of CNTs, however, markedly differed depending on the specimen geometry. The enhancement of the fracture toughness was much larger with the surface notched specimens than with the side notched specimens. The stress distributions of the surface notched specimens and the side notched specimens loaded in tension were analyzed with a FEM. An example of the stress distribution of a surface notched specimen is shown in figure 2. The relative volume of the plastic deformation zone was larger with the surface notched specimens than with the side notched specimens, which explained the difference in the effects of the CNT addition.

## References

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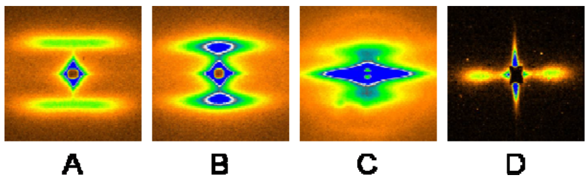


Figure 1 SAXS patterns of PET fiber changed in the order of (A), (B) and (C) during tensile deformation. Surface notched PET film produced SAXS pattern of (D) near tensile fracture. Loading axis is in the top and bottom direction.

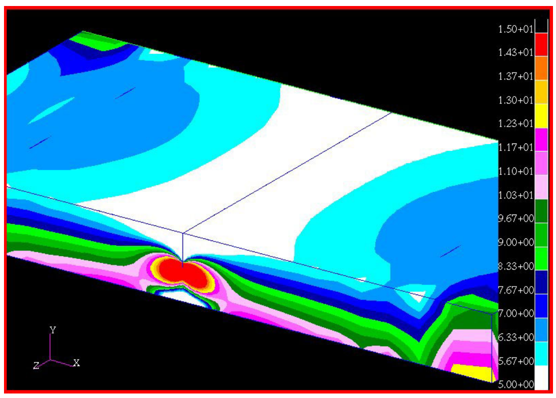


Figure 2 Stress distribution of surface notched CNT/PET composite film longitudinally loaded in tension, calculated with a FEM.

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