NOTES

The Fracture Surface of Poly(ethylene Terephthalate) Fiber as Revealed by Scanning Electron Microscopy

Hardly any published information exists on the fracture surfaces of heat-set poly(ethylene terephthalate) fibers. We have examined two specially prepared samples made from commercial PET multifilament yarn (24 filaments, 76 denier, zero twist) by annealing the commercial yarn for 30 min in silicone oil under two conditions: first, at 176°C while free to relax; and second, at 220°C while constrained to remain at constant length. The fibers were characterized for structure using methods described in detail elsewhere.[1] The crystallinity and crystallite orientation of the fibers were determined with the help of x-ray diffraction. The birefringence was found using the Becke line method. Combining birefringence with the degree of crystallinity and crystallite orientation, amorphous orientation was determined. The results obtained are summarized in Table I.

It is seen from Table I that the free-annealed fiber has a higher denier and a higher diameter compared to the tension-annealed fiber. This is expected since the fiber is free to shrink in free annealing but not in tension annealing. The two fibers have the same degree of crystallinity. The tension-annealed fiber has, however, higher crystallite orientation, birefringence, and amorphous orientation. These are also expected results because higher disorientation can take place if shrinkage is allowed during annealing.

A number of single filaments from these yarns were mounted to give a gauge length of 2 cm and stretched in tension on an Instron tensile tester at a strain rate of 1.7×10^{-2} sec^{-1}. The fractured ends of the filaments, in which the break was close to the middle of the fiber, were mounted on a stub, coated with an approximately 300-Å-thick layer of gold in a Polaron coating unit, and examined in a scanning electron microscope. The fracture surfaces of the various samples that were examined show similar broad features as illustrated in Figures 1,2a, and 2b.

The following points are of interest: (i) The break results in the formation of a V-notch. (ii) The fibers appear to have a skin and a core; typically, the skin is 2 to 3 microns deep in a filament of 10-micron radius. (iii) The V-notch appears to be confined to the skin; on reaching the core, the crack propagates transversely without any further appreciable extension of the remaining part of the fiber. (iv) In the core, there are, along the fiber axis, layered platelet-like structural entities about 0.1 to 0.4 micron thick, a few microns wide, and apparently many microns long. (v) The V-notch faces the platelets sideways.

The above features can be important in understanding the fracture behavior of PET fiber and its dependence on morphology. A few comments on the above observations can be made at this stage.

TABLE I
Fibre Characteristics

Parameter	Free annealed at 176 °C	Tension annealed at 220 °C
Denier	3.77	3.22
Diameter, cm	20.22×10^{-4}	18.50×10^{-4}
Degree of crystallinity	0.36	0.36
Herman's crystallite orientation factor	0.953	0.983
Birefringence	0.152	0.170
Herman's amorphous orientation factor	0.425	0.540

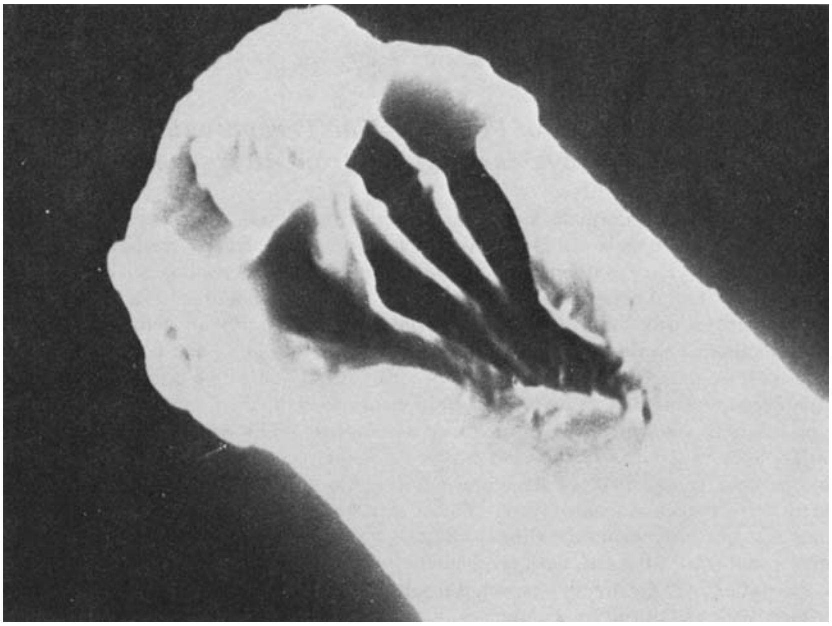
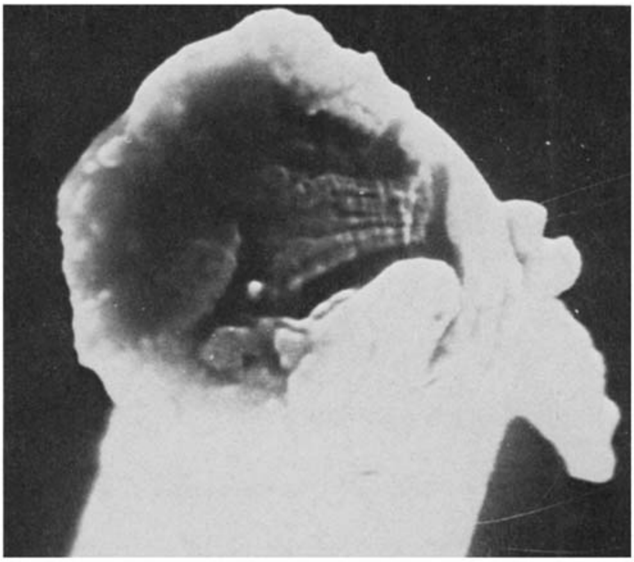


Fig. 1. PET filament annealed at 176°C in free condition at breaking extension of 60% (×4550).

Before the fiber breaks, a crack is initiated on the fiber surface, and while this crack propagates, the rest of the fiber is still being stretched; this results in the formation of a V-notch. Now, for a crack, the easiest path of propagation will obviously be through the smallest dimension of the stacked platelets; thus the crack appears to prefer an initiation point such that the

(a)

Fig. 2 (*continued*)



(b)

Fig. 2. PET filament annealed at 220°C at constant length at breaking extension of 35%: (a) first sample (×4550); (b) second sample (×4900).

V-notch faces the platelets sideways. The characterisation of (i) the differences in structure between the skin and the core and (ii) the platelets will require further work and is under progress. It might be remarked that the fracture surface morphology may not represent the average internal morphology of the fiber and, as pointed out by Schultz,[2] the weakest elements need not be typical. Nevertheless, from the practical point of view, an understanding of the fracture surface can be important as it can throw light on the nature of these weak elements in the fiber.

It may be noted in conclusion that though initially the fibers show differences in structure, as shown in Table I, the broad features of the fracture surface are the same. It should be emphasized that these structural parameters relate to annealed but undeformed fibers. Since the tension-annealed fibers elongate up to 35% before breaking compared to 60% elongation at break for the free-annealed fibers, it is likely that the crystallite orientation, birefringence, and amorphous orientation of the free-annealed samples will register a greater relative increase during their elongation and thus, just before fracture, the two sets of fibers may be much closer as regards their structural characteristics than is indicated by Table I.

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References

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