SEM studies on helically oriented polypropylene fibres

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The surface morphology of the PP fibres with internal helical texture were studied. The studies were carried out by the direct observation of the untreated fibre surface, and by the 'marked deformation' method of microscopical objects using a 'JEOL' scanning electron microscope. The results showed the helical internal texture of these fibres.

INTRODUCTION

The orientation of macromolecules, crystalline elements or other morphological elements is one of the most important factors determining the physical properties of polymers, particularly the mechanical properties of fibres. The relationship between the properties and orientation parameters of man-made fibres is still a subject of intensive studies in which the highest attention is given to the uniaxial orientation obtainable by longitudinal deformation of polymer extruded from a spinneret.

As is known, the greatest changes in fibre properties are observed when the total orientation is different from the uniaxial one.[1] Particularly important is the helical orientation.[2] This type of orientation is known in various natural fibres. It is also possible to obtain it in man-made fibres by a special spinning technique including simultaneous translation and rotation of filament during take-up. The ratio of spinning rate to rotation rate determines the helix pitch value.

Our previous paper[3] and that of Andersen and others[4] were concerned with polypropylene fibres obtained by the method mentioned above. Internal helical texture of these fibres was then found by X-ray diffraction and optical birefringence. The aim of the present paper was to study the surface morphology of polypropylene fibres of various helix pitch values.

METHODS, RESULTS AND DISCUSSION

The study of the surface of helically oriented fibres was carried out by direct observation of the untreated fibre surface by SEM and using a new technique of 'marked deformation' of microscopical objects.

A scanning electron microscopie, 'JEOL' type, was used for the observation.

The SEM observations have shown that the surface of the polypropylene fibres obtained is smooth and independent of the helix pitch value. A scanning electronmicrograph of fibre surface of 1.8 mm helix pitch is shown in *Figure 1* as an example.

Further examination of the fibres was carried out by the 'marked deformation' method of microscopical objects, as

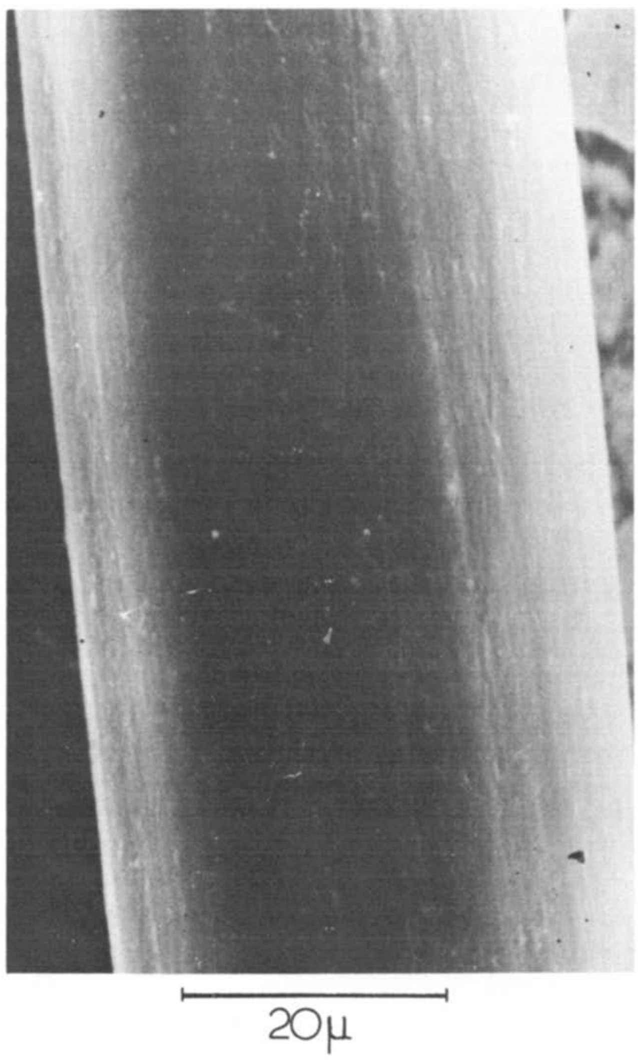

Figure 1 Surface of helically oriented polypropylene fibre of 1.8 mm helix pitch

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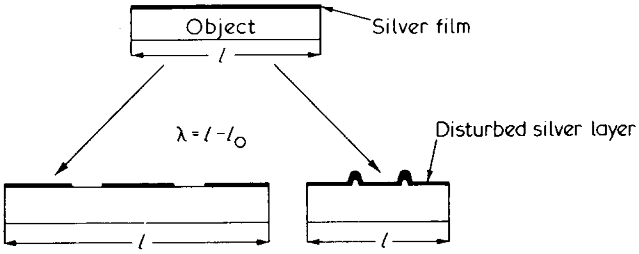

Figure 2 The principle of 'marked deformation'

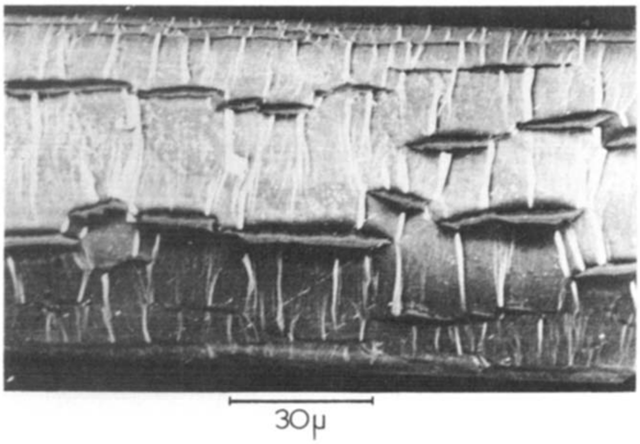

Figure 3 Silver layer on the surface of untwisted fibre, subjected to relaxation with unfixed ends

developed by Pelzbauer and coworkers.[5,6] The principle of this method for the uniaxial deformation is shown in *Figure 2.* The surface of the object under investigation is coated under vacuum with a uniform continuous layer of carbon or metal of tens of nanometers in thickness. The object is then subjected to the required deformation which also deforms the coated layer. During stretching the coated layer breaks, forming a system of slits and continuous fragments; when compressed the layer undergoes folding.

We used this technique to define the nature of deformation in fibres of various helix pitch during their thermal relaxation. The fibre surface was coated with silver and then subjected to relaxation at 165°C, the latter treatment being carried out with unfixed and fixed fibre ends (changeable and constant sample length, respectively).

The fibre surfaces with the deformed silver layer after relaxation were observed in a scanning electron microscope. *Figure 3* shows a micrograph of surface of untwisted fibre. The surfaces of helically oriented fibres with helix pitch values of 1.95 mm and 2.8 mm are shown in *Figures 4a* and *4b*, respectively.

As is seen in *Figure 3*, the thermal relaxation of fibre with longitudinal uniaxial orientation results in deformation of the silver layer in the form of folds perpendicular to the fibre axis. This means that the relaxation develops a simple shrinkage of the sample in the fibre axis direction. In the case of helically oriented fibres the relaxation causes the smooth continuous silver layer to deform and consequently to develop a deformed system of helical layers (*Figure 4*).

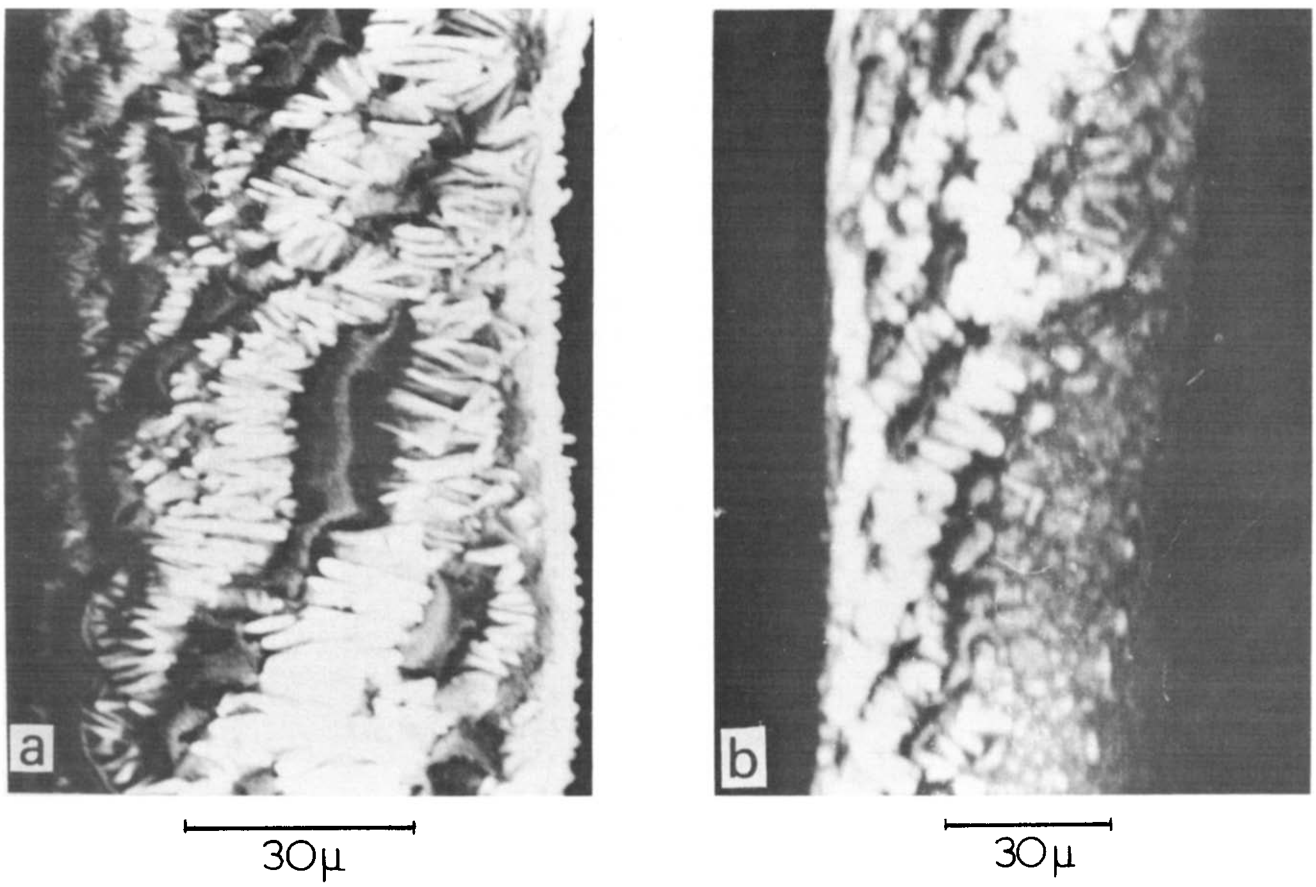

Figure 4 Silver layer on the surface of twisted fibres subjected to thermal relaxation with unfixed ends: (a) helix pitch 1.95 mm; (b) helix pitch 2.8 mm

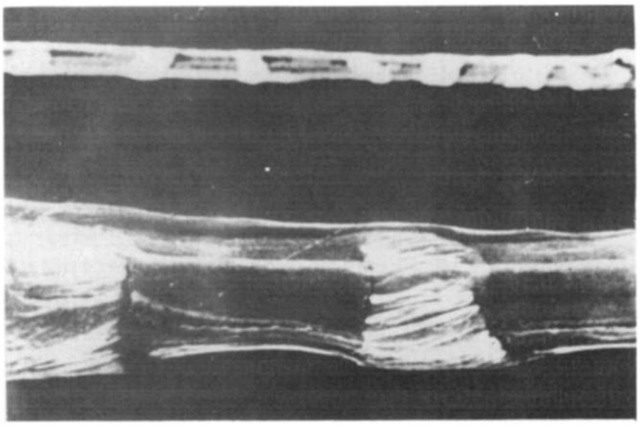

Figure 5 Silver layer on the surface of twisted fibre subjected to thermal relaxation with fixed ends

The observed character of the silver layer suggests that in these fibres the axial shrinkage is accompanied by an effect of 'unscrewing' which confirms the helical nature of orientation inside the unrelaxed fibre.

In the case of the relaxation of fibre with constant length, the thermal shrinkage of fibre, developing inner tensions, resulted in deep and complex morphological changes which were revealed by deformation of the silver layer as shown in *Figure 5*. As is seen in this micrograph, along the length of the fibre there are regions of different thickness and orientation, the latter being parallel to the fibre axis in regions which underwent crosswise shrinkage; in the remaining regions the orientation was helical.

CONCLUSIONS

From these results, one may state that the observations carried out by the marked-deformation method confirm the helical orientation of the investigated polypropylene fibres despite the fact that observations of untreated fibre surface do not provide such information. The local changes in morphology allow us to draw conclusions on the deformation mechanism of helically oriented fibres, which consequently should be useful in building a model of the mechanical behaviour of these fibres.

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