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This Week's Citation Classic

Peterlin A. Molecular model of drawing polyethylene and polypropylene. J. *Mater. Sci.* **6**:490-508, 1971. [Camille Dreyfus Lab., Research Triangle Inst., Research Triangle Park, NC]

This paper reviews the transformation from the lamellar into the fibrous structure and the subsequent drawing of the fibrous material under the influence of an uniaxial tensile force. The model is based on an analysis of the load-elongation curves, small- and wide-angle x-ray diffraction, electron microscopy, and infrared dichroism. [The *SCI*® indicates that this paper has been cited over 155 times since 1971.]

Anton Peterlin
Polymer Science and Standards Division
National Bureau of Standards
United States Department of Commerce
Washington, DC 20234

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"From the early beginnings *of* the investigation of the large-scale plastic deformation of linear polyethylene we were convinced that the transformation from the initial lamellar into the final fibrous structure is only possible by the destruction of the lamellae and the incorporation *of* the crystalline debris in the newly formed microfibrils which are the basic element of the fibrous material. By iodine staining of the microfibrils obtained from the plastically deformed single crystals, we demonstrated the almost regular alternation of crystalline and amorphous regions in the microfibrils pulled out of broken single crystals. This was corroborated by the dark field electron microscopy. In the neck of bulk samples, the work of the drawing force is not sufficient for material melting or a large-scale pulling of single chains out of the lamellae. The thus collected experimental observations were the basis of a well consistent model of the drawing and the mechanical and transport properties of the material as drawn and after annealing. The axial elastic modulus and strength of the microfibril is a consequence of the taut intramicrofibrillar tie molecules bridging the amorphous layers separating the crystal blocks. The microfibrils seem to be highly aligned and bundled into fibrils which show up in the fractured fibers and in the surface replicas of the annealed drawn material

"The drawing of the fibrous structure is only possible by the shear displacement of adjacent fibrils. It extends the interfibrillar and to a minor extent the intermicrofibrillar tie molecules. They thus become taut and hence contribute to the axial elastic modulus of the fibrous material. Their volume fraction almost linearly increases with the draw ratio and the same applies to the axial elastic modulus. With the drawing performed at 60°C we obtained E = 30 CPa while later experiments at a slightly higher temperature *of* drawing yielded E up to 70 GPa.[1] The tensile strength, however, increases more slowly. It depends on the defects of the microfibrillar structure, i.e., on the strength of the areas at the ends of the microfibrils where the conventional connection by taut intramicrofibrillar tie molecules is completely absent. In such a place all the load transfer is performed by the interfibrillar taut tie molecules which increase in number with the draw ratio and the molecular weight M of the sample.[2] But high M prevents a high draw ratio. After this serious hurdle was overcome one obtained even with M above one million, a draw ratio about 30, and a high tensile strength, about 3 CPa, which is almost three times as high as that obtained with the medium M material.[3]

"The knowledge of the molecular mechanism is a prerequisite for the improvement of the technical process of drawing and extrusion of polymer fibers and films. It is this which accounts for the article's frequent citation."

1. **Capacclo G & Ward I M.** Preparation of ultra-high modulus linear polyethylenes; effect of molecular weight and molecular weight distribution on drawing behaviour and mechanical properties. *Polymer* **15**:233-8, 1974.
2. **Peterlin A.** Elastic modulus and strength of fibrous material. *Polym Eng. Sci.* **19**:118-24, 1979.
3. **Smith P & Lemstra P J.** Ultra-high-strength polyethylene filaments by solution spinning/drawing. *J. Mater. Sci.* **15**:505-14, 1980.