Developement and Study of High Performance Structures in Nylon 6.

Jong Geon Lim

School of Textile
North Carolina State University, NC. U.S.A.

ABSTRACT

LIM, JONG GEON. Development and Study of High Performance Structures in Nylon 6. (Under the direction of BHUPENDER SINGH GUPTA.)

High performance properties are increasingly needed in fibers for industrial applications. Such properties have been achieved in both flexible and intrinsically stiff polymers, but through special and expensive methods. In this work, the potential of achieving high performance mechanical behavior in nylon 6 using conventional spinning process was explored. The work was performed in three stages. In the first, the possibility of developing highly oriented chain structures in a sheared film of nylon 6 was explored. Small drops of 20% solution of nylon 6 in *meta*-cresol were sheared apart between two glass slides to produce a highly distorted smear of the polymer solution. The resulting structures were studied with optical microscopy and differential scanning calorimetry. DSC traces showed multiple peaks indicating that both α and γ crystalline fractions were present. One of these was assumed to be the highly oriented chain structure desired in high performance fibers.

In the second stage, melt spinning characteristics of nylon 6 were examined by melt extruding the fiber on a conventional equipment, and determining the spinline behavior and

the resulting fiber properties. The spinning conditions used were : four different molecular weight polymers (17000, 20000, 23000, 29000), three different spinning temperatures (240°C, 255°C, 270°C), and five different take-up speeds (25 m/min, 50 m/min, 100 m/min, 200 m/min, 400 m/min). The spinline behaviors examined included the diameter, the temperature, the velocity and the stress profiles. The fiber properties examined in the extended fibers were the birefringence and the tensile. The morphology and the properties obtained in the fiber could be successfully rationalized in terms of the spinline behavior observed. Increase of take-up speed led to increase in initial modulus and tenacity due to higher spinline stress. Increase in molecular weight led to an increase in tenacity but increase in initial modulus occurred only at high take-up speed. The effect of spinning temperature in the range used in the study was relatively little.

In the final experiment, the most promising of the as-spun fibers obtained was subjected to drawing and annealing treatments in order to achieve highly oriented chain structures and ultra high mechanical properties. This fiber was extruded from 29,000 molecular weight polymer using 270°C spinning temperature and 400 m/min take-up speed. It had a tensile factor of 63.8, the highest of all fibers made. The fiber was drawn on Instron using 2 x and 3 x draw ratios after equilibration with a surrounding temperature of 60°C. The drawn fibers were annealed under restraint for 2 hours in high vacuum. The fibers so treated were evaluated for their tensile, hot stage optical, DSC thermal, and X-ray diffraction behaviors. Tensile results showed that tenacity values of up to 12.7 g/d and initial modulus value of up to 87.7 g/d could be obtained. These values qualified the fiber to be termed high performance. The optical, DSC and the X-ray diffraction analyses indicate that the resultant structure obtained was highly oriented and most likely composed of significant proportion of extended chains.