Spinning Process of UHMWPE Porous Fibers

Tian Cao

National Synchrotron Radiation Lab (NSRL) & School of Nuclear Science and Technology

University of Science and Technology of China (USTC), Hefei, China

Introduction

Due to the considerable advantages such as ultra-high strength, high modulus, low density, excellent chemical, ultraviolet, abrasion and impact resistance, Ultra-high molecular weight polyethylene (UHMWPE) fibers have recently generated extensive interest .

The porous fibers were obtained by spinning a semidilute solution of the polyethylene in paraffin-oil followed by extraction of the solvent. Fiber preparation, started from semidilute solutions of the high-molecular-weight polyethylene, results in a considerable reduction of the number of defects, such as trapped entanglements, interwinings, chain ends, kinks, jogs, etc. These topological defects impede the alignment of the molecules during drawing and reduce the ultimate tensile strength of the fibers. After extraction, a loosely connected lamellar network is formed, showing a high porosity. Additionally, the large free volume and the high surface-free energy in this structure are also factors that promote the performance of fibers .

Experiments and data

◆Experiments

The UHMWPE used in this study was Tecona 4150 with $\overline{M}_w$ =4.5 $\times 10^6$ gmol^{-1}. 8wt% of this polyethylene was dissolved in paraffin oil(containing 0.5 % anti-oxidant (BHT) and 0.5 % aluminum stearate) at 120 ℃ and continuous stirring for 2h, and then this solution was fed to a twin-screw extruder at temperatures varying from 185 to 235 ℃. The fibers formed by extruding through the spinneret with an exit of 0.8mm. Then the as-spun fibers were cooled through cooling bath and hot-drawn at 110 ℃ with various strains at strain rate of 0.5 s^{-1} followed by extracting with n-hexane and drying at 50 ℃ for 2 h.

Fig.1. photos of fibers spinning scene

◆Data

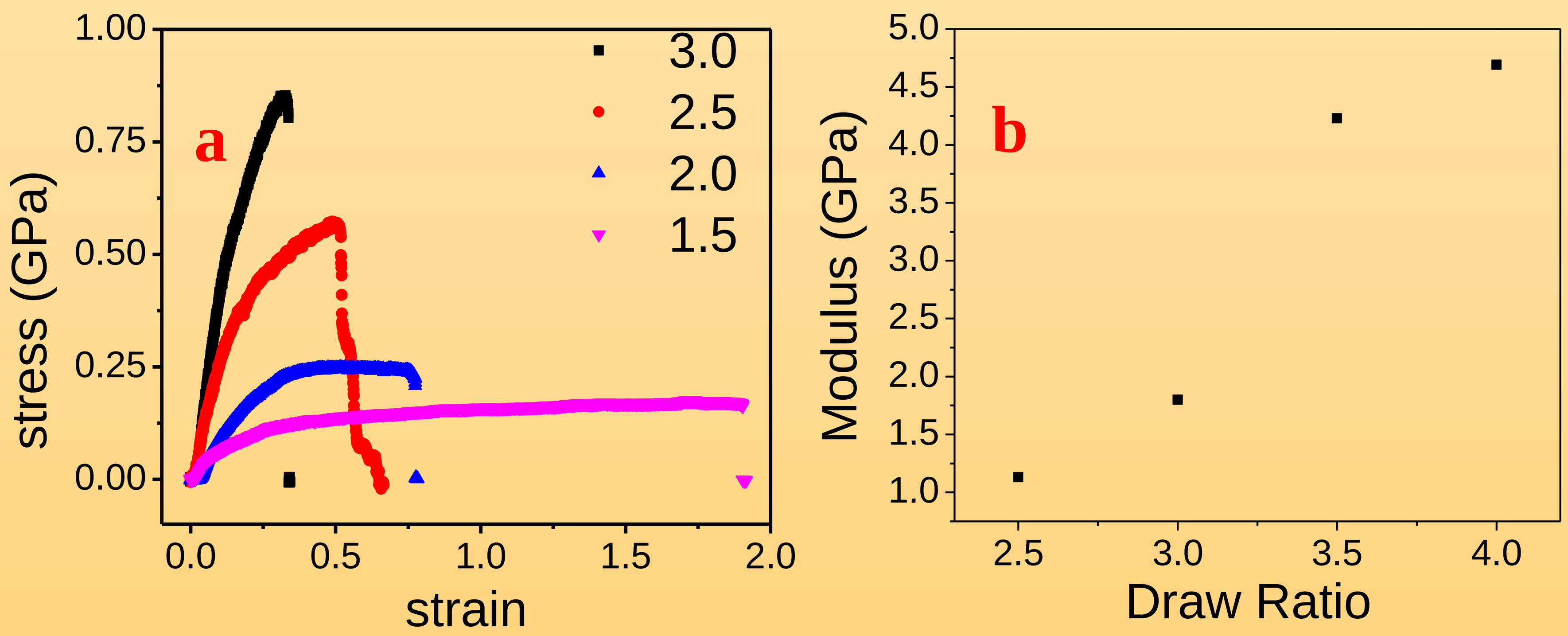

Fig.2. graphs of stress and modulus against strain

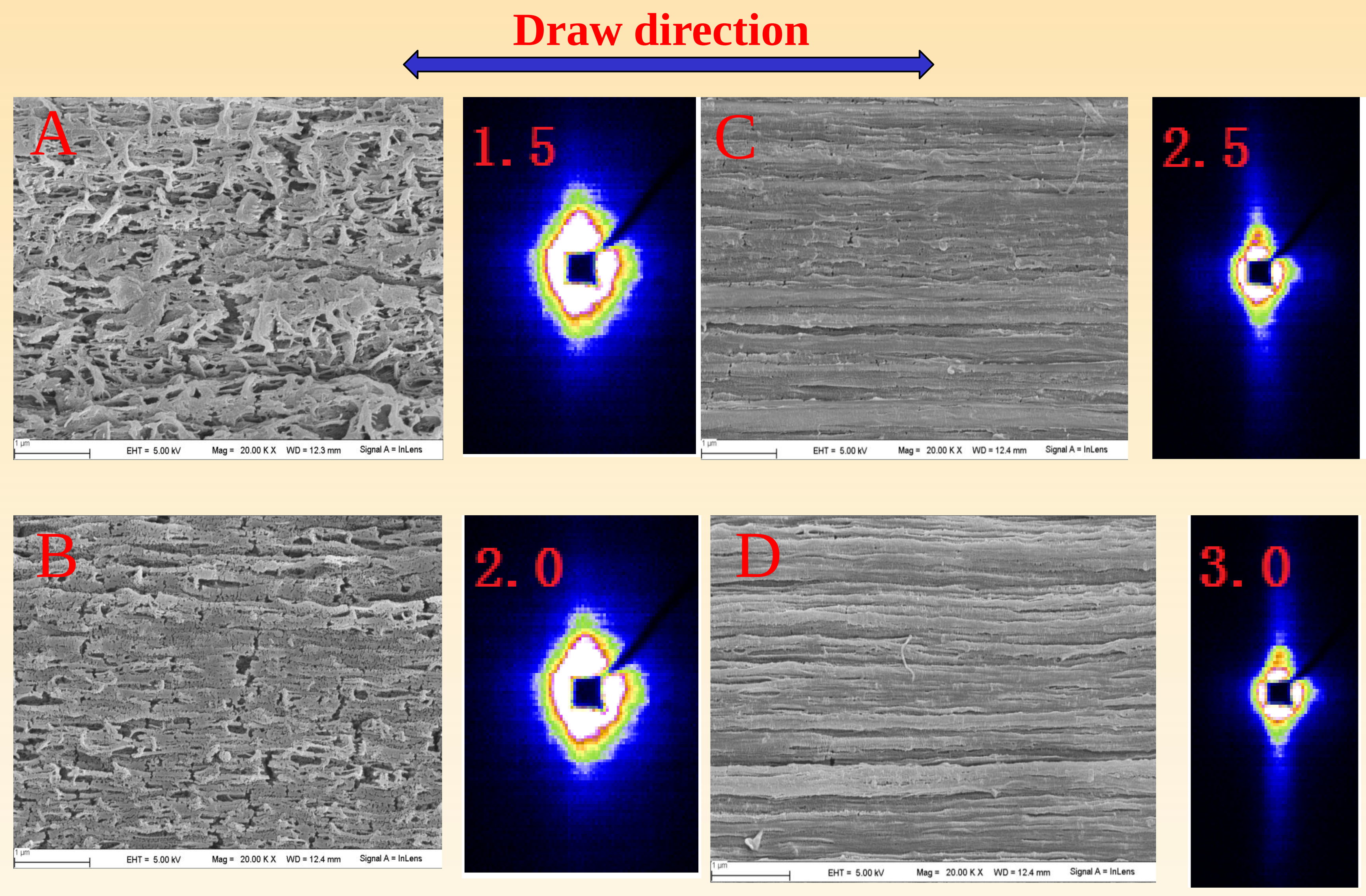

Fig.3. SEM micrographs and SAXS patterns of different strain

Discussion and Conclusion

◆Mechanical Properties of Drawn Fibers

The results on stress versus strain at room temperature are represented in Figure 2(a). As shown in the figures, with an increase of DR(ε) in order of 1.5, 2.0, 2.5 and 3.0 gives rise to a systematic decrease in the strain at breakage. However, the maximum force at break exhibit apparent increase with the increase of DR (ε) . Figure 2(b) shows the modulus against strain of different DR(ε) samples. As can see in this figure, the initial modulus increase from 1.13GPa to 4.69GPa with the increase of DR(ε). Results above shows that good mechanical properties can be achieved at large ε, even though the as-spun fibers had the morphology of the shish-kebab structure.

◆SEM and SAXS Observation

Drawing of as-spun fibers at 100 ℃ was found to proceed inhomogeneously on the macroscopic scale. Figure 3(a) represents a part of the surface of a filament which was drawn to a ratio of 1.5 at 100 ℃. Drawing has resulted in the formation of large cavities, which are spanned by fibrils and which are very similar to crazes in glassy polymers. From the Figure 3(b)-(d),we can see further extension results in a diminution of the entities from which the fibrils are drawn, and a concomitant reduction of their lateral size. Eventually,this leads to a highly fibrillar morphology with thinly dispersed lumps from which many fibrils originate.

Figure 3(a)-(d) also represents the dimensional SAXS patterns. As can be seen in Figure 3(a) and (b), The diamond shape indicates that the morphology is strongly oriented. The high intensity results from the porous structure which is a consequence of the presence of lamellar overgrowth prev-Enting a close packing of the backbone fibrils. With the increase of draw ratio, intensity on the meridian enhanced significantly. That is to say, the lamellar overgrowth was gradually pulled into the backbone fibrils.

Work Plan

◆Figuring out the relationship between the true strain and engineering stain of the dynamic stretching process.

◆ Mechanism of extraction kinetics

Acknowledgement: This work is supported by the Fundamental Research Funds for the Central Universities(WK2140000005) and the experimental fund of Shanghai Synchrotron Radiation Facility (SSRF).