Shish-kebab structure during hot stretching of UHMWPE fiber

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Introduction

Ultrahigh-strength polyethylene (UHSPE) fiber with an extremely high strength and high modulus has already been applied for various uses. The manufacturing process, well known as gel spinning, was invented by Smith and Lemstra in late 1970s. In the past few decades, there have been quite a number of reports on UHSPE fibers, especially on the relationship between the morphologies and their mechanical properties. The shish-kebab structure is commonly generated as the morphology of UHMWPE when elongational deformation is effective.

Indeed it is well known that shish kebabs are produced when a swollen network obtained by prior chemical crosslinking is stretched at temperatures otherwise appropriate for shish kebab formation. Shish kebab crystals are formed by stretching and subsequently crystallizing chains.

Experiments

I Small-Angle X-ray Scattering

SAXS is used to monitor the evolution of structure and morphology during crystallization process.

II Scanning Electron Microscopy (SEM)

All samples were extracted in n-hexane and were covered with a thin layer of gold and observed by and SEM instrument

III Mechanical Properties Tests

Tensile properties of fibers hot stretched at different strains were measured at 23℃ using homemade tensile stretcher.

Results and Discussion

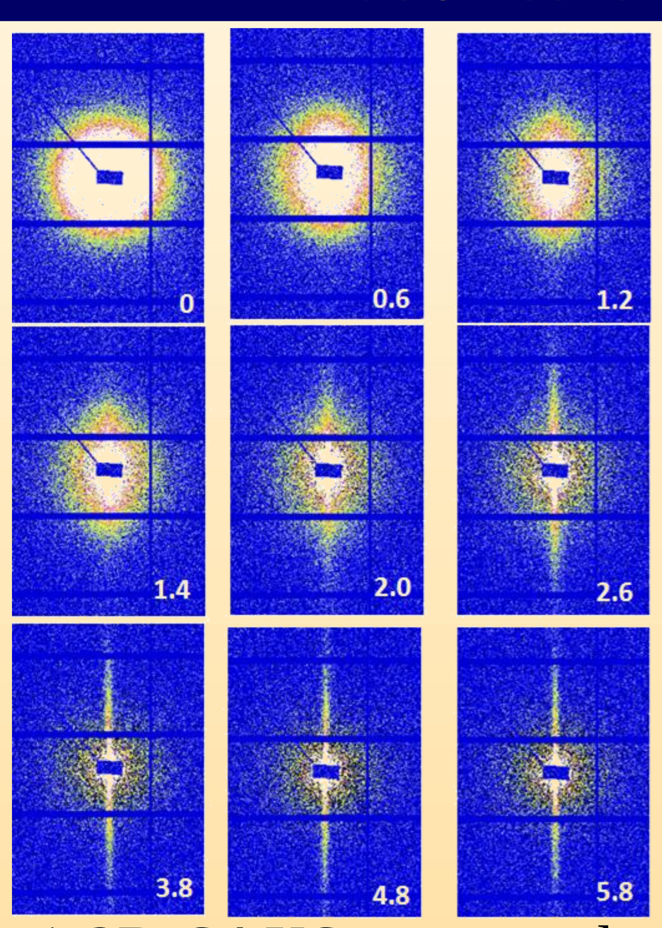

Fig 1 2D SAXS patterns during hot stretching of UHMWPE fibers at different strains

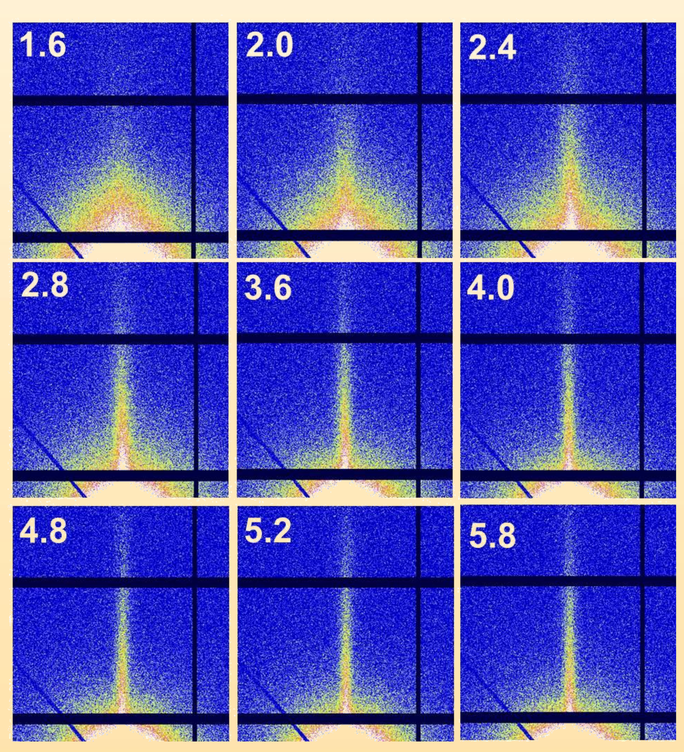

Fig 2 Zoom in of shish signal in different 2D SAXS patterns

Fig 1 presents selected 2D SAXS patterns during hot stretching of UHMWPE fibers with different strains. The 2D SAXS patterns collected at different strains show clearly different features in equatorial direction. With the increasing of strain, the SAXS pattern transforms from an isotropic ring to elliptic shapes, which eventually results into equatorial streaks perpendicular to the stretching direction. The streaks become stronger and extend to larger q in Fig 2 which represents longer shish and better orientation in stretching direction.

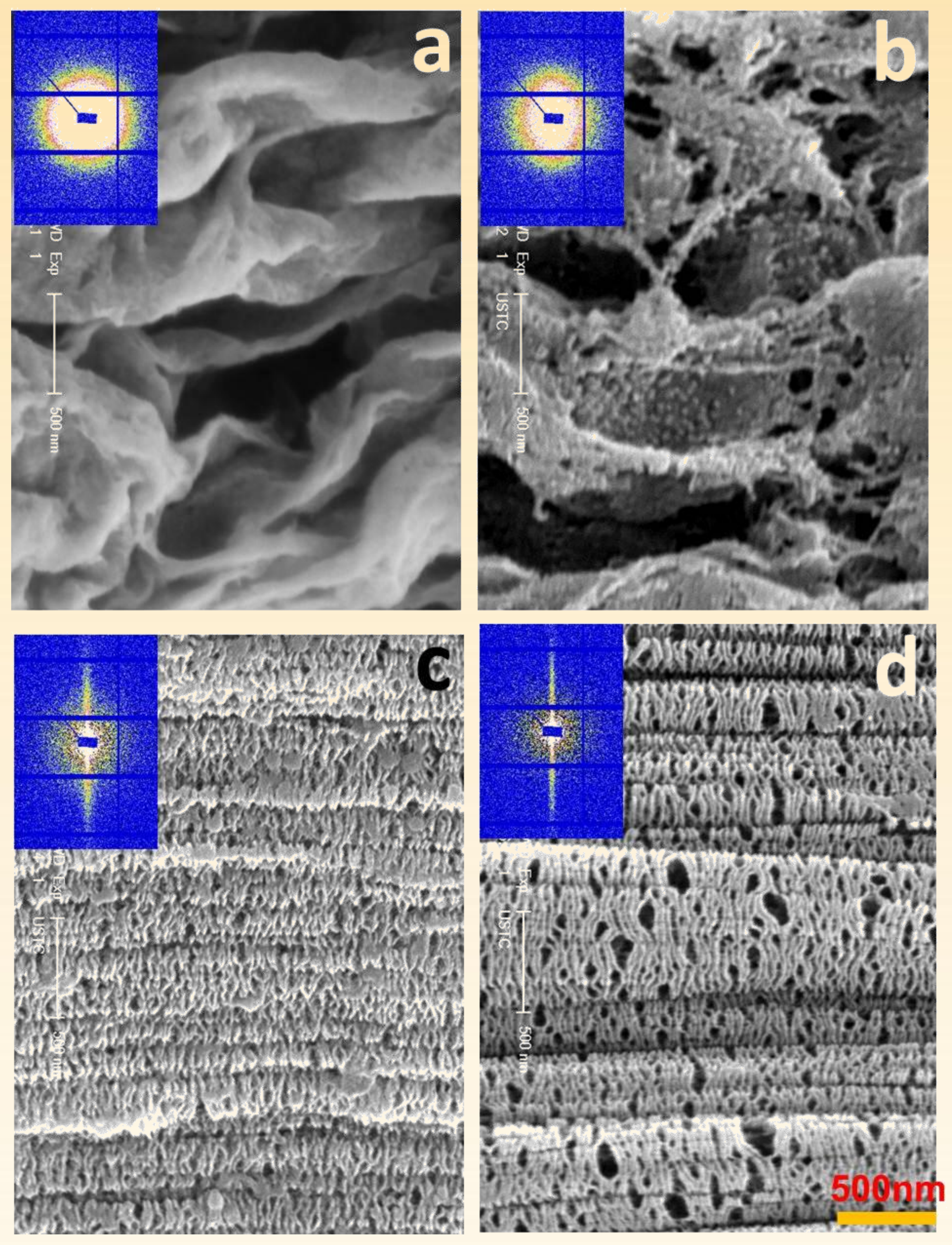

Fig 3 SEM images of UHMWPE fibers after extraction in n-hexane. a, b, c and d represent the SEM images of different strains.

Fig 3a shows the morphology before drawing with no shish-kebab structure. When strain increase to 0.6 morphology in SEM images shows a little orientation in stretching direction. With further increasing strain to 2.6, obvious shish-kebab morphology can be obtained in Fig 3c, which still exists at strain of 5.8 before fiber is snapped.

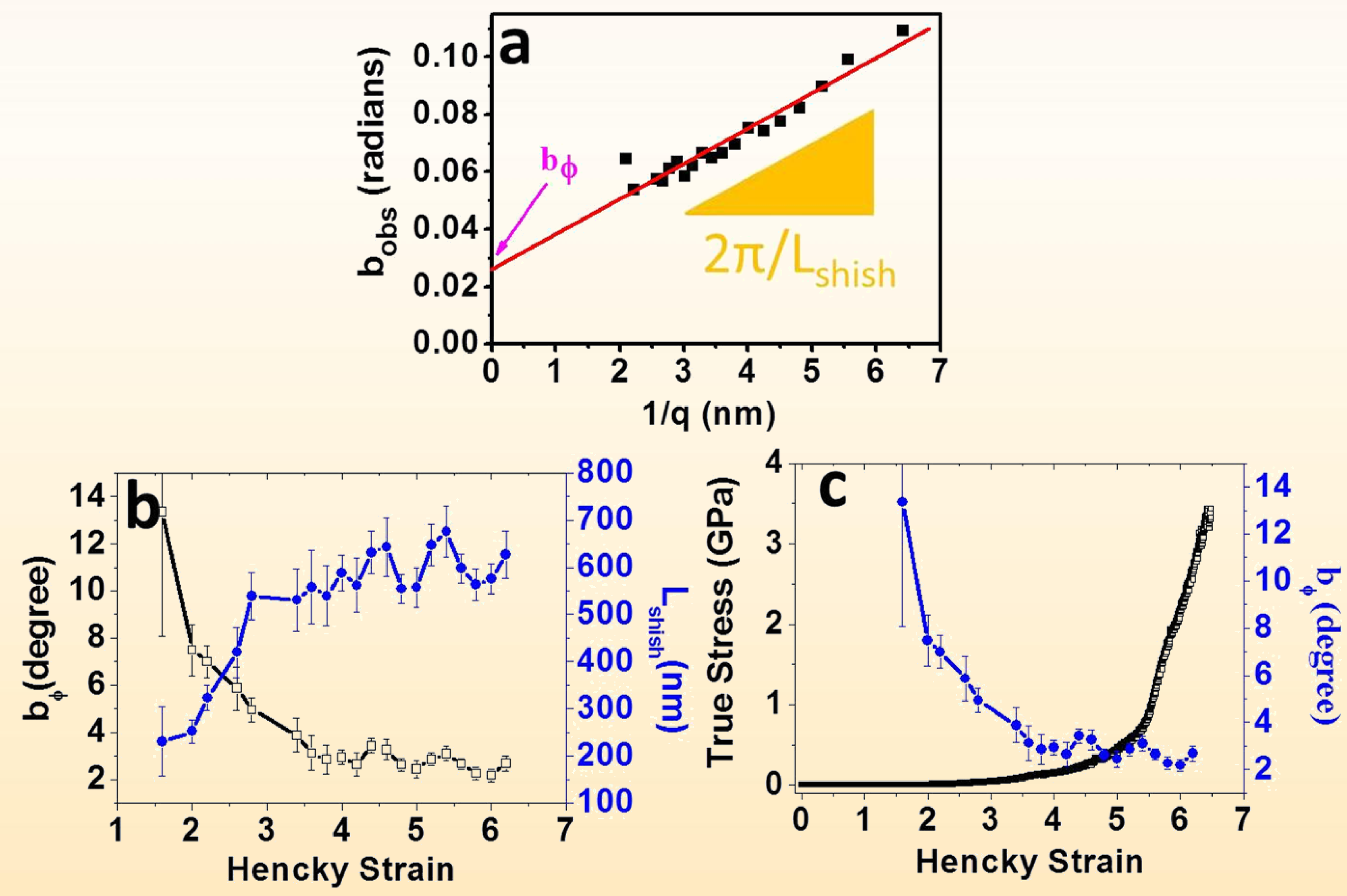

Fig 4 (a)Plot of azimuthal integral breadth (b_{obs}) as a function of 1/q showing the method used to separate out the contributions of the misorientation of shish (b_{Φ}) and the shish length L_{shish} at low scattering vectors (q). (b) Calculated length of shish (L_{shish}) and shish misorientation (b_{Φ}) during stretching at different strains. (c) Calculated misorientation (b_{Φ}) and true stress during stretching.

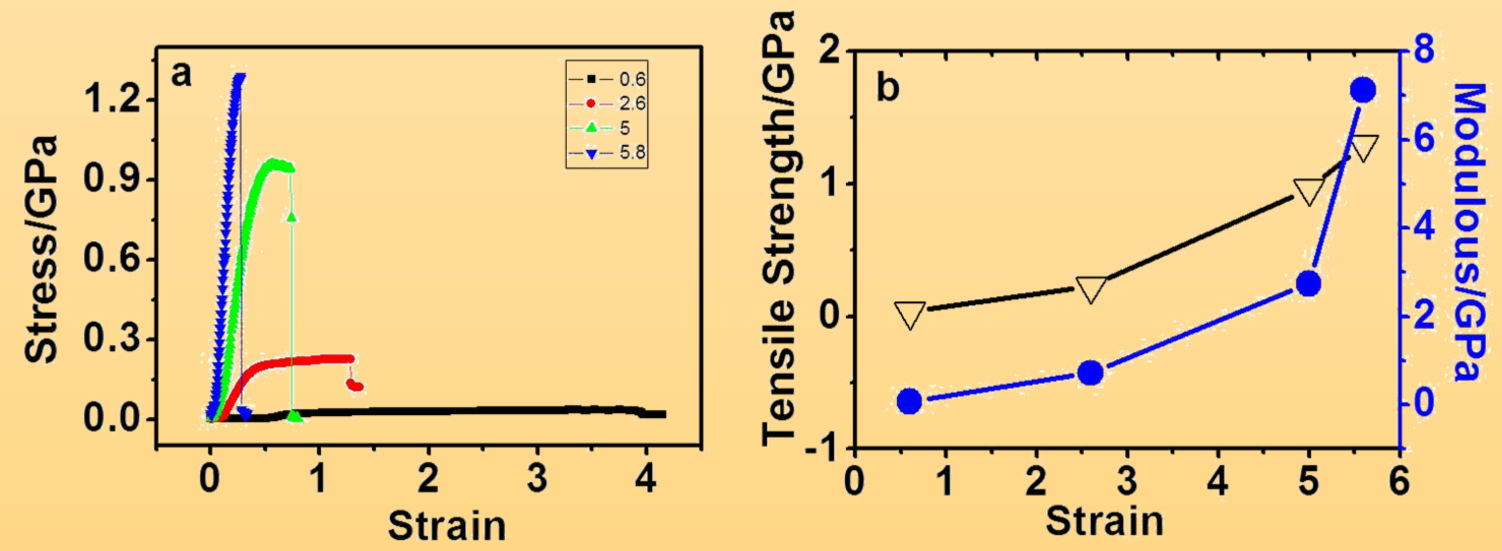

Fig 5 (a) stress-strain curves of different samples which is hot stretched to different strains (b) tensile strength and modulus

Acknowledgement: This work is supported by the National Natural Science Foundation of China (50973103, 51120135002, 11204285, U1232129)