

Melting and Crystallisation of UHMWPE Skived Film

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Commercial skived film of ultra-high molecular-weight polyethylene (UHMWPE) with high uniaxial orientation¹ was studied by USAXS during melting and crystallisation with a time-resolution of 30 s (exposure: 28 s) in order to identify the crystallisation mechanisms (Fig. 1). It was found that isotropic crystallisation occurs whenever the melt is heated to 140°C or above. Oriented crystallisation occurs, if the melt is kept at 138°C or below. An optimum melt annealing temperature appears to be 136°C. At this temperature the semicrystalline nanostructure of the original film is completely erased, whereas the orientation memory of the melt is preserved. Moreover, isothermal crystallisation cannot be initiated at a temperature of 110°C and higher. At a temperature of 105°C oriented crystallisation starts after 2.5 min. Lamellae with slowly decreasing thickness are growing during an isothermal period of 20 min. During the following non-isothermal crystallisation (cooling rate: 20°C/min) small crystalline blocks with next-neighbour correlation are formed. Thus the crystallisation mechanisms are similar to those found with other polyethylene materials with sufficiently high chain entanglement density studied earlier[1, 2, 3], except for the considerable undercooling required for the initiation of isothermal crystallisation.

Analysis of the data in real space by means of the multidimensional CDF[4] has been performed. During the melting of the material the average thickness of the crystalline layers remains constant (27 nm), while the long period is strongly increasing from 60 nm to 140 nm. Because the analysis shows that even the original nanostructure is dominated by next-neighbour correlations only this means that the stability of a lamella is monotonously increasing as a function of the distance to its neighbours. While the original structure exhibits extended lamellae, the recrystallised domains are not wider than the distance between them in fibre direction s_3 .

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References

- [1] Stribeck N, Almendarez Camarillo A, Cunis S, Bayer RK, Gehrke R (2004) *Macromol Chem Phys* 205:1445
- [2] Stribeck N (2004) *Macromol Chem Phys* 205:1455
- [3] Stribeck N, Almendarez Camarillo A, Bayer R (2004) *Macromol Chem Phys* 205:1463
- [4] Stribeck N (2001) *J Appl Cryst* 34:496

¹UHMWPE (Stamylan UH210 of DSM Inc., The Netherlands, $M_W = 4.6 \times 10^6$ g/mol processed by RAM extrusion and skiving to films of 0.76 mm thickness, not cross-linked) is a commercial product used as a wear layer of skis ("isosped film" by Isosport GmbH, Austria).

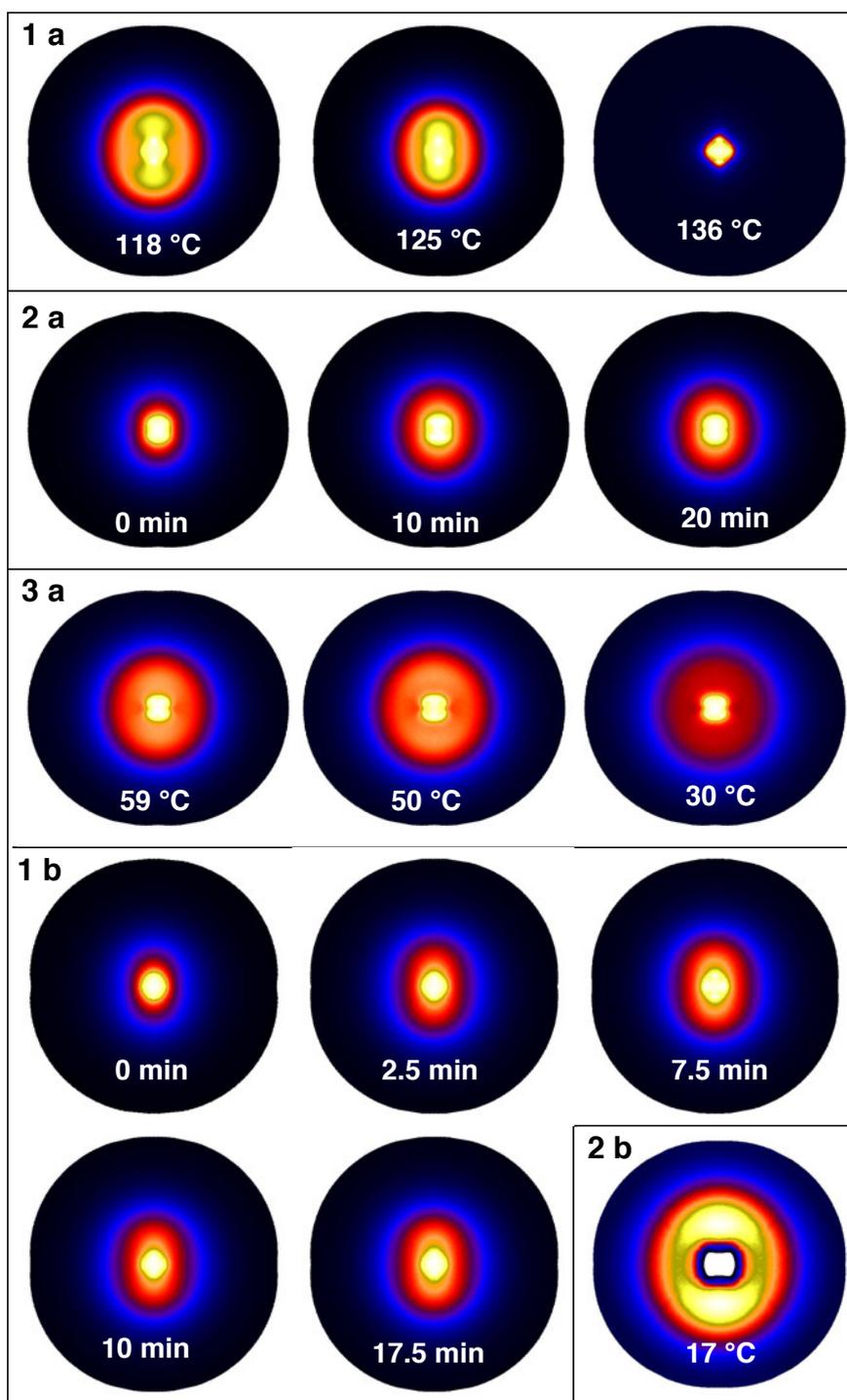


Figure 1: USAXS of skived film UHMWPE during temperature treatment. The temperature is indicated. Fibre axis s_3 is vertical. Each pattern shows a range $-0.05 \text{ nm}^{-1} < s_{12}, s_3 < 0.05 \text{ nm}^{-1}$. Logarithmic intensity scale. Top row (1a) shows the melting. 2a: Very slow isothermal crystallisation at 110°C . 3a: Quenching to room temperature after 20 min at 110°C . 1b: Isothermal crystallisation at 105°C . 2b: Ultimate structure after crystallisation at 105°C