Flow-induced crystallization: from the beginning to the end

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Introduction

Flow-induced crystallization is one of the fundamental issues in polymer physics and also one of the most important determining factors in polymer processing. This is because flow can significantly vary the formed crystal structures (e.g. from isotropic to oriented) [1] and consequently determine the ultimate mechanical properties [2]. Therefore, a full understanding on how crystallization is altered by flow and further develops after cessation of flow is of importance for both academic and industrial societies. In this work, we are aiming at tracking the entire process of flow-induced crystallization from start-up of flow (the beginning) to completion of solidification (the end).

Material and methods

The material used is a commercial IPP (Borealis HD601CF) with a molecular weight, Mw = 365,000 g/mol and a polydispersity, Mw/Mn = 5.4.

Experimental equipments:
- Multi-Pass Rheometer executes a very strong flow field.
- European Synchrotron Radiation Facility provides a high intensity X-ray source.
- The “Pilatus” detector provides a high-speed acquisition of 30 frame/s.

Experimental conditions:
- apparent wall shear rate = 560 s⁻¹, flow time = 0.20s
- temperature for shear and isothermal crystallization = 145°C

Results

1) During flow

- Full width at half maximum (FWHM) of equatorial (110) diffraction
- Crystal-shish nuclei are formed during flow.

2) Growth kinetics of crystallization

- Peak area of (110) diffraction (Area₁₁₀) can be used to indicate the amount of crystal.

Fig. 3 Area of equatorial and daughter (110) diffraction during crystallization. Selected 2D patterns are shown in the right column. Flow direction is vertical.

- Crystallization is effectively triggered by shish nuclei.
- Daughter lamellae appear later than parent lamellae.

3) Orientation during crystallization.

- Full width at half maximum (FWHM) of equatorial (110) diffraction can be used to indicate orientation.

Fig. 4 FWHM evolution of equatorial (110) diffraction during crystallization. Selected 2D pattern is shown. Flow direction is vertical.

- Orientation is very high (low FWHM value) at the beginning and decreases (FWHM increases) with crystallization.

Conclusions

By combining slit flow with ultra-fast X-ray, the entire flow-induced crystallization is tracked from the start-up of flow until the end of crystallization. It is found that shish nuclei can be generated during flow. Growth of parent lamellae is effectively started by shish nuclei, but daughter lamellae appear later. Moreover, orientation decreases with crystallization.

References