Capillary-driven flow as a probe of enhanced surface mobility in glassy polymer films

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Motivation

May distinguish and quantify two mechanisms

\[ \frac{\partial h}{\partial t} = -\frac{1}{3} \frac{\gamma}{\eta} \frac{\partial}{\partial x} \left( \frac{\partial^3 h}{\partial x^3} h^3 \right) \]

Thin Film Equation


\[ \frac{\partial h}{\partial t} = -\frac{1}{3} \frac{\gamma h^*}{\eta} \frac{\partial}{\partial x} \left( \frac{\partial^3 h}{\partial x^3} \right) \]

Glassy Thin Film Equation
Profile comparisons

Surface flow $T < T_g$

Whole film flow $T > T_g$

Upper plots show Profiles $< T_g$ GTFE Profiles $> T_g$ TFE.

Errors of fitting with different theoretical models.

Indicates two mechanisms near $T_g$

Match-up of data to simulation

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Bump/Dip (b/d)

Can distinguish real ‘WHOLE FILM’ and ‘SURFACE’ flows

Above $T_g$
$$b/d = \frac{h_1+h_2}{h_2}$$

Below $T_g$
$$b/d = 1$$

Thermal expansion, ellipsometry
Viscosity and mobile layer

No any freedom in the figure, no shifting, no scaling

GTFE

\[
\frac{X}{T^{1/4}} = \left( \frac{3\eta}{\gamma h^3} \right)^{1/4} \frac{x}{t^{1/4}}
\]

TFE

\[
\frac{X}{T^{1/4}} = \left( \frac{3\eta}{\gamma h^3} \right)^{1/4} \frac{x}{t^{1/4}}
\]

Simulation  Extract  Data

\[\frac{\eta}{H^3}\]

Fit to GTFE  Fit to TFE

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