Diblock copolymer bridges: the break-up dynamics and enhanced stability of structured liquids

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Newtonian liquid break-up

- Background
- Creating homopolymer and diblock copolymer bridges
- Results
  - Effect of diblock copolymer microstructure on break-up dynamics

\[ \lambda_c > 2\pi r \]

\[ d_{min} = d_0 - \alpha \frac{\gamma}{\eta} t \]


- Physics of Newtonian liquid jets and bridges: Plateau, Rayleigh, Eggers, Bazilevsky, Renardy, Brenner, Entov, Hinch, Papageorgiou, McKinley, Tripathi, ...
Non-newtonian liquids

- High $M_w$ polymer solutions
- Shear thickening due to elongational flow.


Symmetric diblock copolymers

Ordered, (Low $T$)  \( T_{ODT} \)  Disordered, (High $T$)
Experimental setup

Side View

Top View

Heating Block
Homopolymer bridge evolution

8.8k Polystyrene annealed at $T = T_g + 35^\circ C$
Homopolymer bridge evolution

\[ d_{\text{min}} \]
Viscosity calculation

\[ d_{\text{min}} = d_0 - \alpha \frac{\gamma}{\eta} t \]
Shear rates in thinning filaments

\[
\frac{d\varepsilon}{dt} = \frac{1}{l} \frac{dl}{dt} = -\left(\frac{2}{d_{\text{min}}}\right) \frac{d}{dt} (d_{\text{min}})
\]

\[
d_{\text{min}} = d_0 - \alpha \frac{\gamma}{\eta} t
\]
Temperature dependence

\[ \frac{d\varepsilon}{dt} (\text{min}^{-1}) \]

\[ \eta/\gamma (\text{min/\mu m}) \]
Homopolymer dynamics

Shear Thinning

Shear Thickening

\( \frac{d\varepsilon}{dt} (\text{min}^{-1}) \)

\( \eta/\gamma (\text{min/\mu m}) \)

112 °C

155 °C
Symmetric diblock copolymer

PS-b-P2VP measurement @ 155 °C,
Order-Disorder Transition ~ 160 °C
Diblock bridge evolution

The graph illustrates the evolution of $d_{\text{min}}$ (in $\mu$m) over time $(t - t_0)$ (in minutes), showing a decreasing trend. The data point indicates $\text{PSP2VP, 155}^\circ\text{C}$.
Homopolymer vs. Diblock

- PSP2VP, 155 °C
- PS, 155 °C

Graph showing the change in minimum distance ($d_{min}$, in µm) over time ($t - t_0$, in min) for two different polymers at 155 °C.
Homopolymer vs. Diblock

![Graph showing comparison between Homopolymer and Diblock at different temperatures. The graph plots the penetration depth ($d_{min}$) against time ($t - t_0$) with red dots representing PSP2VP at 155°C and black dots representing PS at 125°C.]
Temperature dependence

\[
\frac{d\eta}{d\epsilon}(\text{min}^{-1}) = 10^{-2}, 10^{-3}, 10^{-4}
\]

Ordered
Disordered

150 °C
180 °C
Ordering induced shear thinning
Ordering induced shear thinning
Ordering induced shear thinning
Shear induced disorder

\[ \eta > \eta_{\text{dis}} \]

\[ \eta = \eta_{\text{dis}} \]
Shear induced disorder
Summary

- Symmetric diblock ordering stabilizes liquid bridges.
- Order of magnitude increase in effective viscosity.
- Shear thinning viscosity due to domain alignment or destruction in shear flows.