Combined Passive and Active Microrheology Study of Protein-Layer Formation at an Air–Water Interface

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β-lactoglobulin

Figure 4. A cartoon showing the idealized elements of secondary structure, drawn following the directions of Richardson (1985).

Monaco et al., Journal of Molecular Biology, 1987
Interfacial tension

The Surface Activity of $\alpha$-Lactalbumin, $\beta$-Lactoglobulin, and Bovine Serum Albumin

I. Surface Tension Measurements with Single-Component and Mixed Solutions

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\[ \Pi = \gamma_w - \gamma_{wp} \]
Interfacial rheology

Boussinesq number

\[ Bo = \frac{\text{surface drag}}{\text{subphase drag}} \]

\[ Bo = \frac{\eta_f \frac{V}{L_I} P_I}{\eta \frac{V}{L_S} A_S} = \frac{\eta_S}{\eta} \frac{1}{l_c} \]

<table>
<thead>
<tr>
<th>Method</th>
<th>Du Noüy Ring</th>
<th>Passive Microrheo</th>
<th>Active Microrheo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometrical parameter (l_c) (m)</td>
<td>700μm</td>
<td>1μm</td>
<td>~10μm</td>
</tr>
</tbody>
</table>

Vanderbril et al., *Rheologica Acta*, 2010
Passive Microrheology

Boussinesq number

\[ Bo = \frac{\eta_f}{\eta} \frac{1}{a} \]

http://savinlab.eng.cam.ac.uk/research.html

Lee et al., Soft Matter, 2011
Overview of Microrheology (plagiarism!)

\[ \approx 1\text{mm} \uparrow \]

\[ \approx 50\text{mm} \]

1\(\mu\)m beads

\[ < \Delta x^2 > \]

Average of N steps

Average of N-2 steps

\[ \tau = \Delta \tau \quad \tau = 3\Delta \tau \]

Camera frame rate \( f = 1 / \Delta \tau \)

\[ t_i - t_{i-1} = \Delta \tau \]

\[ \log(<\Delta x^2>) \]

Experimental notes

- Fewer statistical points at larger lag times. Image for longer than you need data!
- Heterogeneity at scales larger than the particles can result in a spectrum of particle walks and hence the MSD may not be representative of the medium properties

Carolyn Wagner, NNF Reading Group, 2017
Enhanced viscosity

\[ < \Delta r^2(\tau) > = 4D\tau \]

Mechanical heterogeneity

\[ < \Delta r^2(\tau) > = K \]

Elastic

Lee et al., Langmuir, 2010
Enhanced Viscosity

\[ D \sim \frac{k_B T}{\eta a} \]

Lee et al., *Langmuir*, 2010
Active Microrheology

\[ \mu B \sin \phi - \xi_r \frac{d\phi}{dt} = 0 \]

\[ \phi(t) = \frac{\pi}{2} - 2 \tan^{-1}[\exp(-\frac{\mu B t}{\xi_r})] \]

Enhanced viscosity

\[ \theta(t) = \frac{\pi}{2} - 2 \tan^{-1} \left[ \exp \left( -\frac{\mu B t}{\xi_r} \right) \right] \]

Lee et al., Langmuir, 2010
Enhanced viscosity

$\langle \Delta r^2(\tau) \rangle \geq 4D\tau$

Mechanical heterogeneity

$\langle \Delta r^2(\tau) \rangle \geq K$

Elastic

Lee et al., Langmuir, 2010
Mechanical heterogeneity

Heterogeneity size $\gg$ Particle size

Lee et al., Langmuir, 2010
Towards elastic response

Lee et al., Langmuir, 2010
pH Influence

pH = 5.2

\[ y (\mu m) \]
\[ x (\mu m) \]

pH = 7.0

\[ n_{app} \text{ (nPa.m.s)} \]
\[ t_a (\text{minutes}) \]

Lee et al., Langmuir, 2010
Enhanced viscosity

$< \Delta r^2(\tau) >= 4D\tau$

Mechanical heterogeneity

$< \Delta r^2(\tau) >= K$

Elastic

Lee et al., Langmuir, 2010