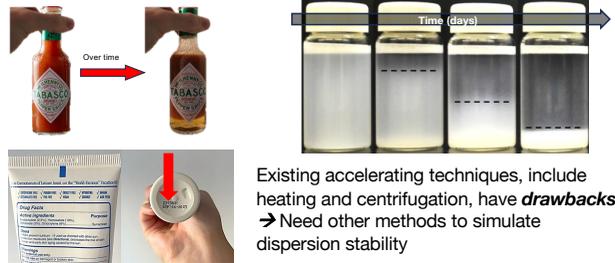# Accelerated acoustic prediction of aging and failure

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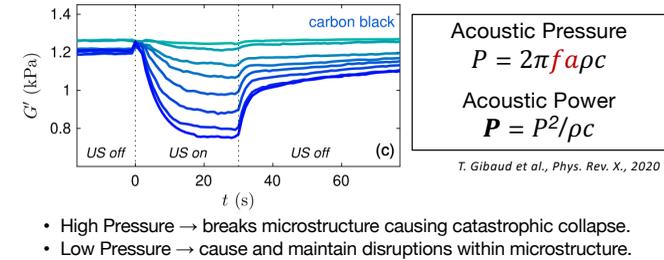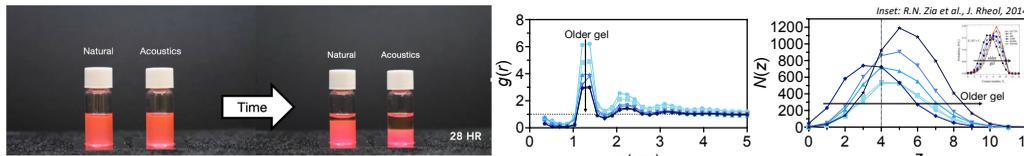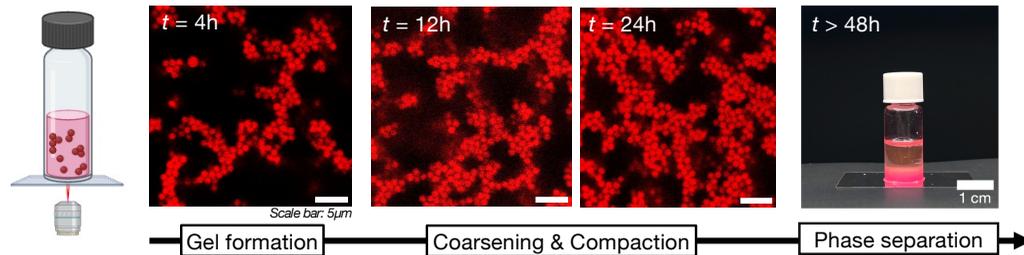
IFPRI
International Fine Particle Research Institute

Hsiao Lab
Re-imagining Interfaces

Motivation

Existing accelerating techniques, include heating and centrifugation, have **drawbacks**
➔ Need other methods to simulate dispersion stability

Materials

PMMA depletion gel formulation:

Polymethyl methacrylate(PMMA)	10% vol
Tertbutyl Ammonium Chloride(TBAC)	4 mM
Polystyrene stock solution	1.125 mg/mL

O/W Nanoemulsion formulation:

20% vol	Polydimethyl siloxane (oil)
200mM	Sodium dodecyl sulfate(surfactant)
33% vol	Polyethylene Glycol Diacrylate (co-surfactant)

Background

Acoustic Pressure
$$P = 2\pi f a \rho c$$

Acoustic Power
$$P = P^2/\rho c$$

T. Gibaud et al., Phys. Rev. X., 2020

- High Pressure → breaks microstructure causing catastrophic collapse.
- Low Pressure → cause and maintain disruptions within microstructure.

Solid particulate system – PMMA depletion gels

t = 4h t = 12h t = 24h t > 48h

Scale bar: 5µm   1 cm

Gel formation | Coarsening & Compaction | Phase separation

Natural Acoustics   Time   Natural Acoustics   28 HR

- Exposure to acoustics → Early onset of phase separation

$$Y = Hf + \frac{H_0 - Hf}{\exp\left(\frac{-t_0 + X}{tau}\right) + 1}$$
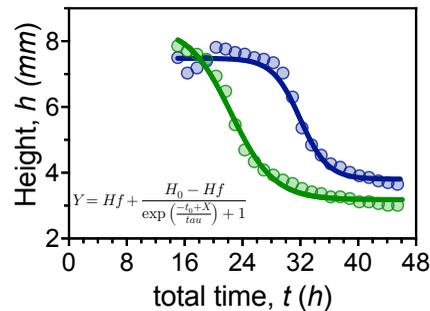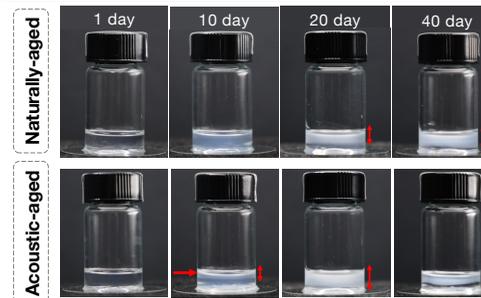
- g(1) decreases as gels age → transition to a less ordered state
- Acoustic application → jump in most probable z from get go
  - Curve fitting: $t_{0, acoustics}$= 22h; $t_{0, natural}$= 32h; α = 1.45

Inset: R.N. Zia et al., J. Rheol, 2014

Older gel

- Most probable z transitions from 4 → 5 as gel ages

Nanoemulsion system

Naturally-aged   1 day   10 day   20 day   40 day
Acoustic-aged
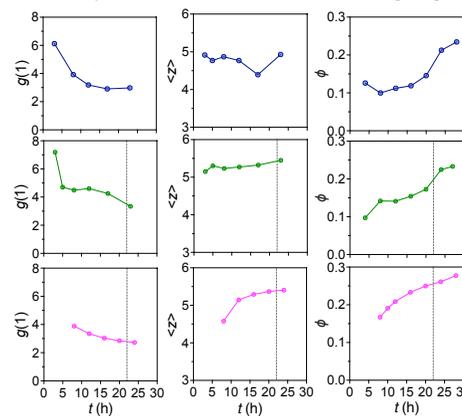
Voltage (V)	Amplitude (µm)	Power (W)
10	0.8	1.1
20	0.95	1.5
30	1.1	2.1
40	1.25	2.6
50	1.4	3.1

● 10V ● 20V ● 30V ▼ 40V ◆ 50V ★ Naturally-aged

Ostwald ripening

- Growth of larger droplets at the expense of the smaller ones due to diffusion and droplets capillary pressure
- Linear plot of r^3 vs time an indicative of Ostwald ripening as the main driving force for instability
- **Lifshitz - Slezov and Wagner (LSW) theory**

$$\omega = dr^3/dt = \frac{8}{9}\left[(C_\infty \gamma V_m D)/\rho RT\right]$$
ω: Ostwald ripening rate

Highest rate for 50V aged and **lowest** rate for the naturally-aged sample

Coalescence

- Smaller droplets merge into larger ones resulting in a bigger mean droplet size
- Linear plot of $1/r^2$ vs time indicative of coalescence as the main driving force for instability
- **Deminiere model**

$$1/r^2 = 1/r_0^2 - (8\pi/3)\alpha t$$
α: frequency of rupture per unit of surface of the film

No obvious trend of coalescence rate with acoustic power