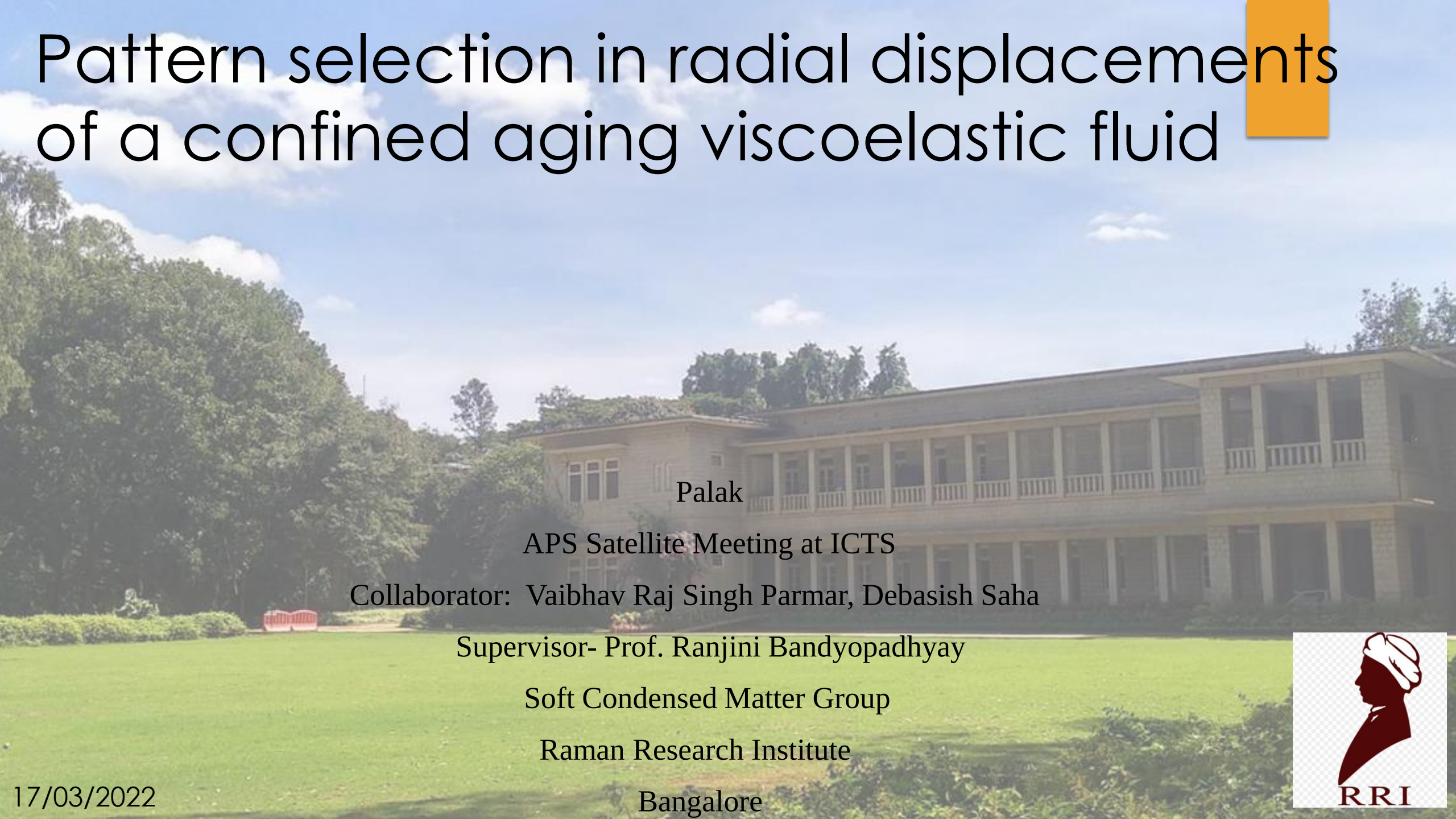
Pattern selection in radial displacements of a confined aging viscoelastic fluid



Palak

APS Satellite Meeting at ICTS

Collaborator: Vaibhav Raj Singh Parmar, Debasish Saha

Supervisor- Prof. Ranjini Bandyopadhyay

Soft Condensed Matter Group

Raman Research Institute

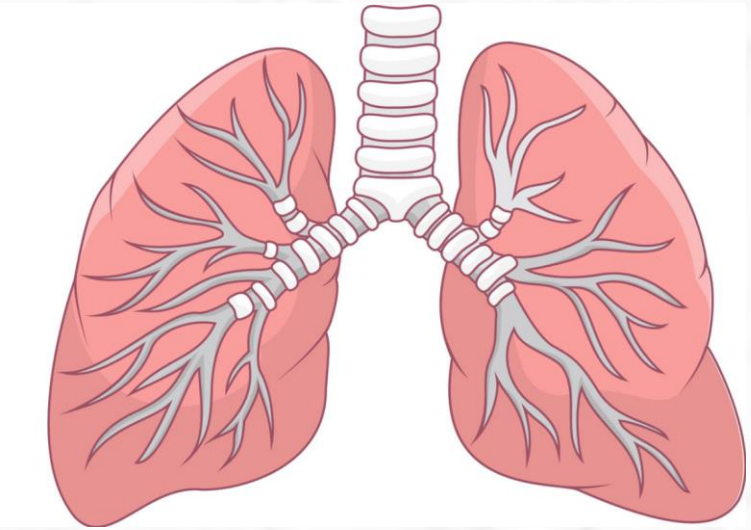
Bangalore

17/03/2022

https://fineartamerica.com/featured/fractal-tree-branches-colin-drysdale.html

https://upload.wikimedia.org/wikipedia/commons/7/75/Dried_mud_creeks_on_the_shores_of_the_Wash_-_geograph.org.uk_-_10669.jpg

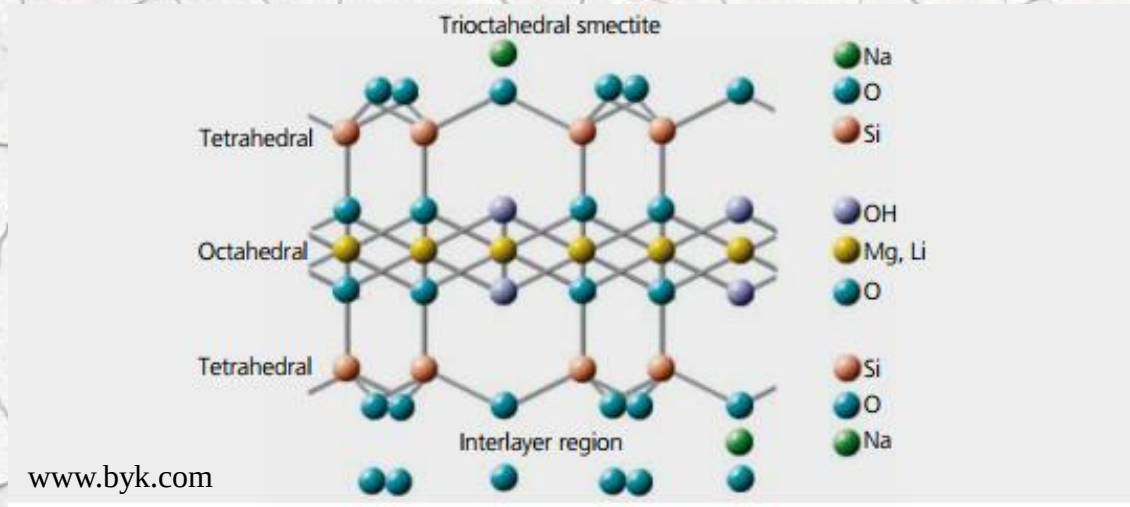
https://live.staticflickr.com/65535/49033660791_56b0e44ea2_b.jpg



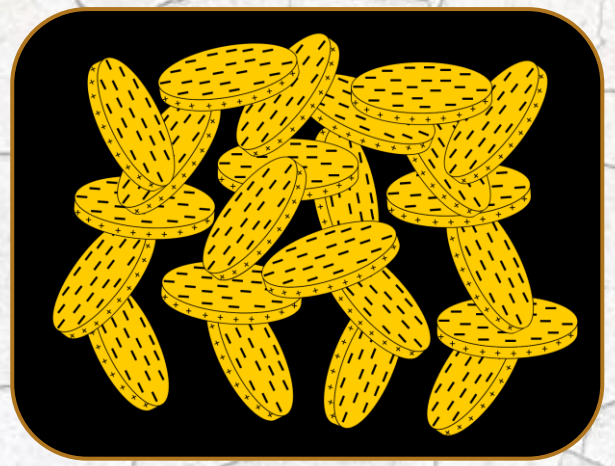
https://www.vectorstock.com/royalty-free-vector/human-lung-cartoon-vector-1268051

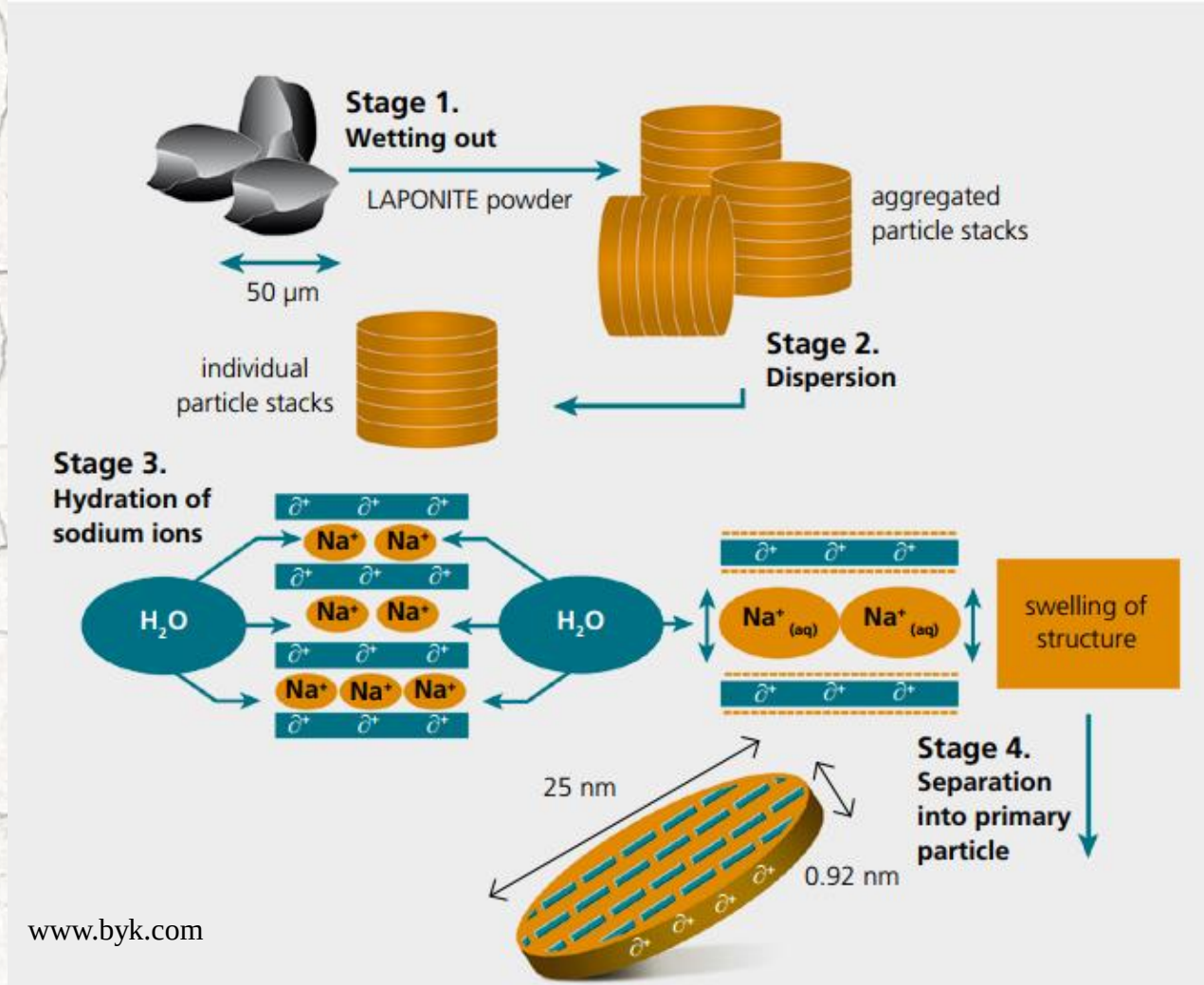
Laponite® ⟶ Synthetic Clay

$Na_{+0.7}[(Si_8 Mg_{5.5} Li_{0.3}) O_{20}(OH)_4]_{-0.7}$



www.byk.com





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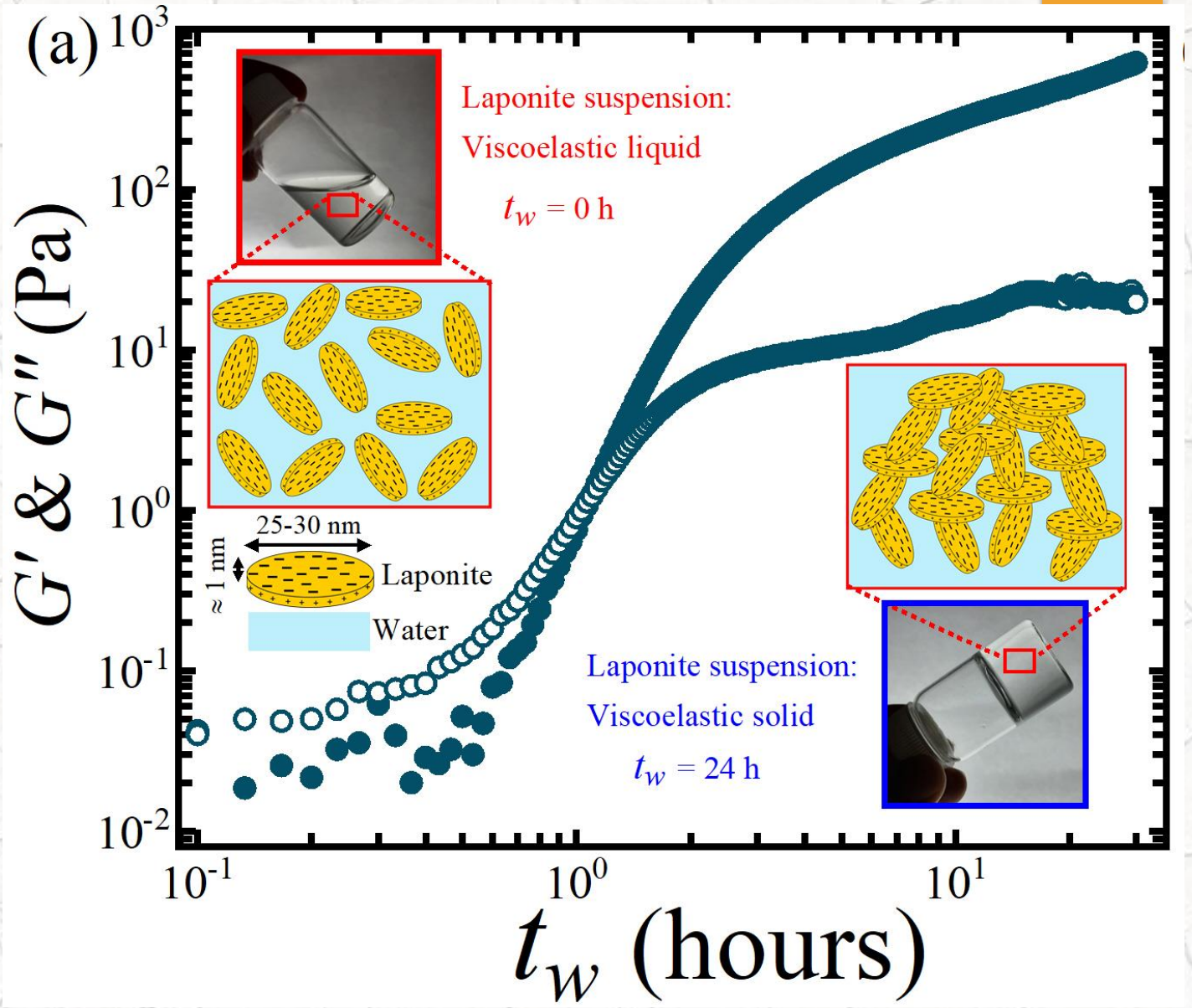
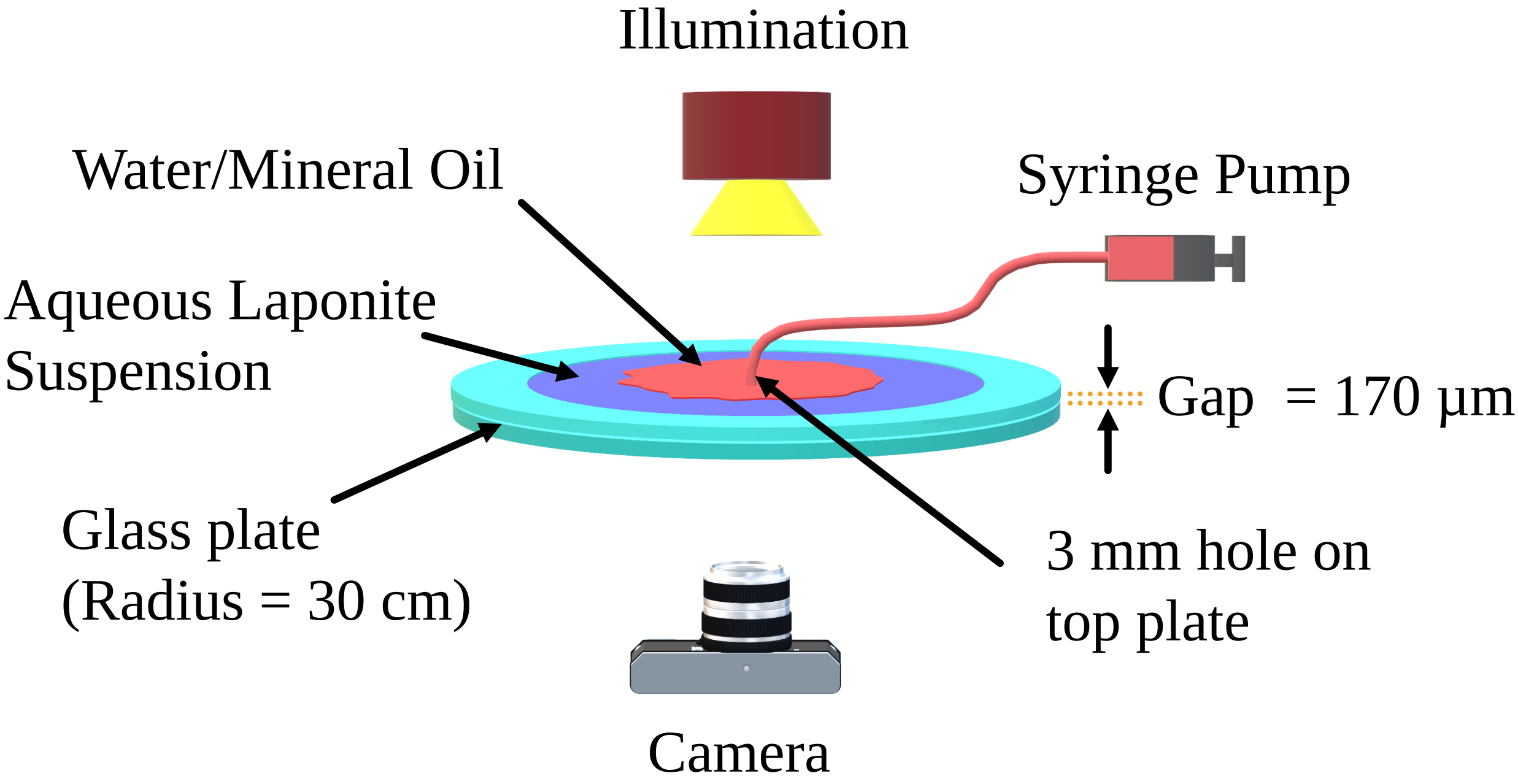
Laponite® ⟶ Synthetic Clay

After 24 h

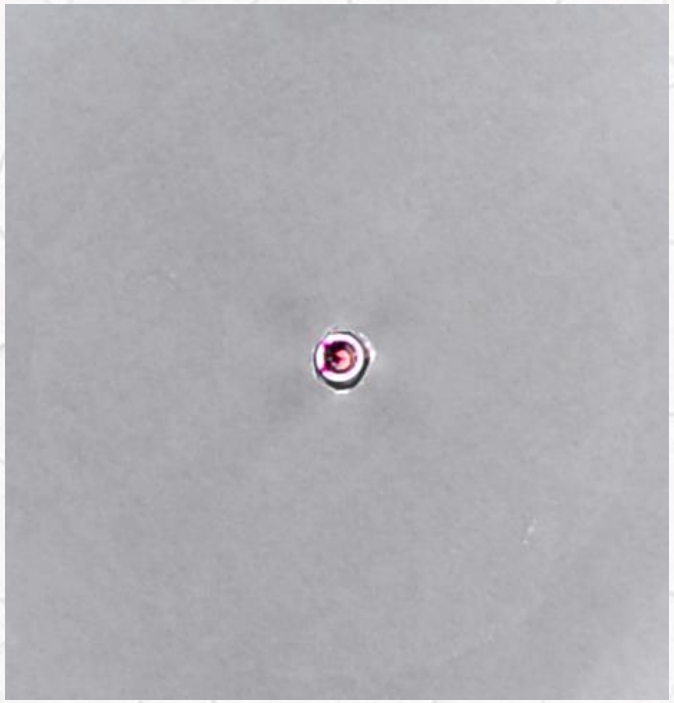


Radial Hele-Shaw Cell

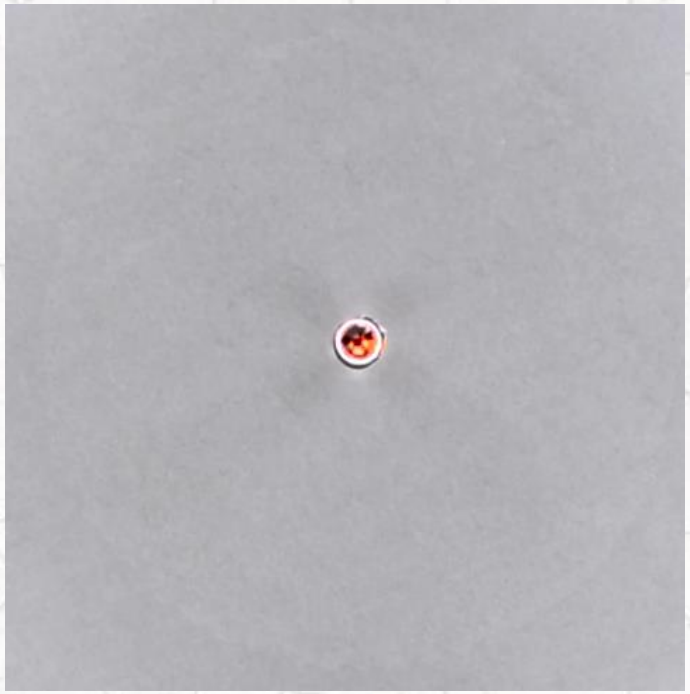


Varying waiting time (t_w)

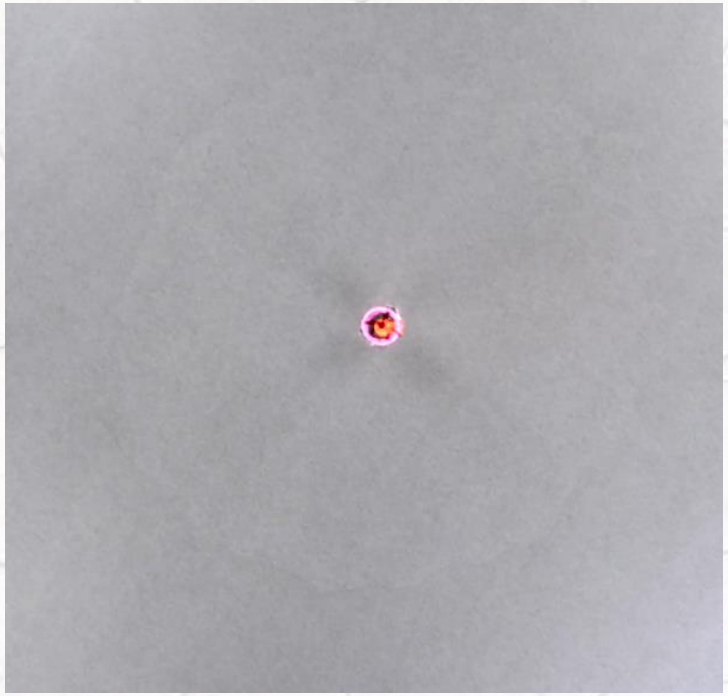
Laponite Susp. -3.25 % w/v
Inner fluid – water
Flow rate – 5 ml/min



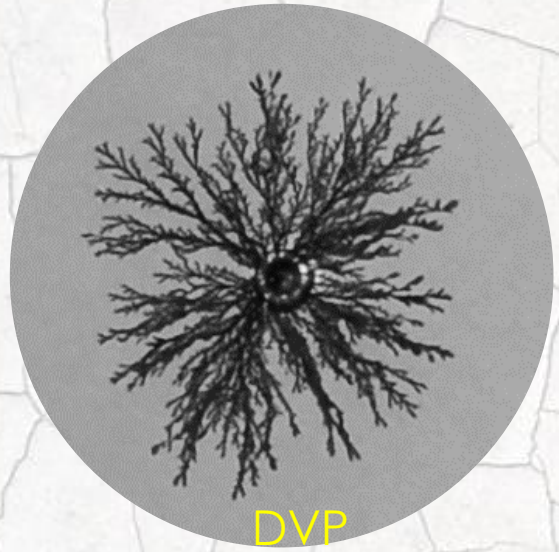
t_w = 2 hrs



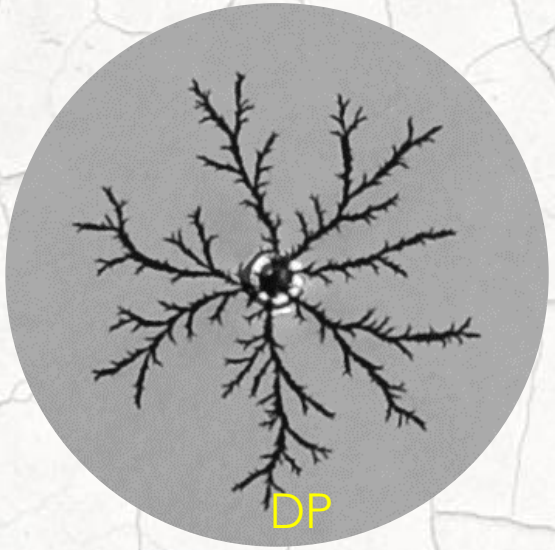
t_w = 3 hrs



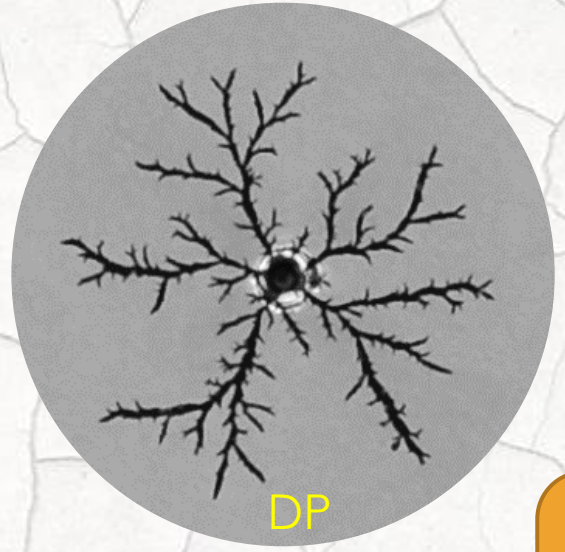
t_w = 24 hrs



t_w = 2.0 h

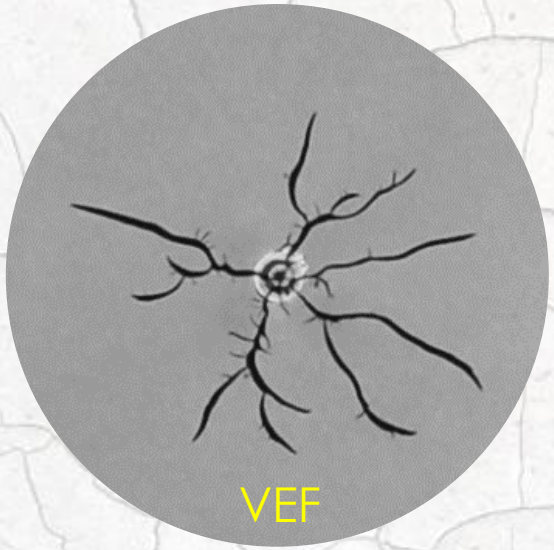


3.0 h

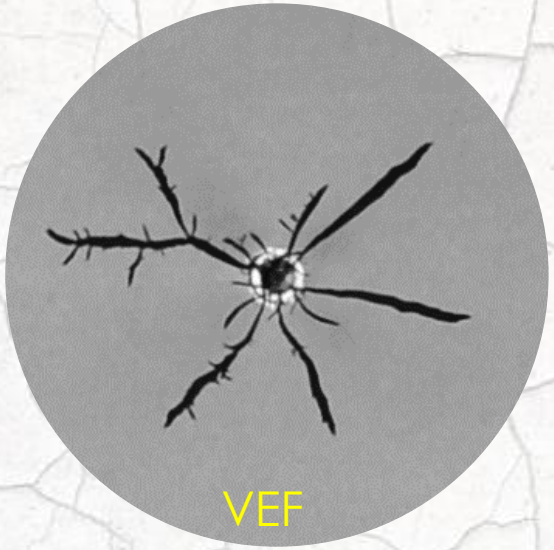


5.0 h

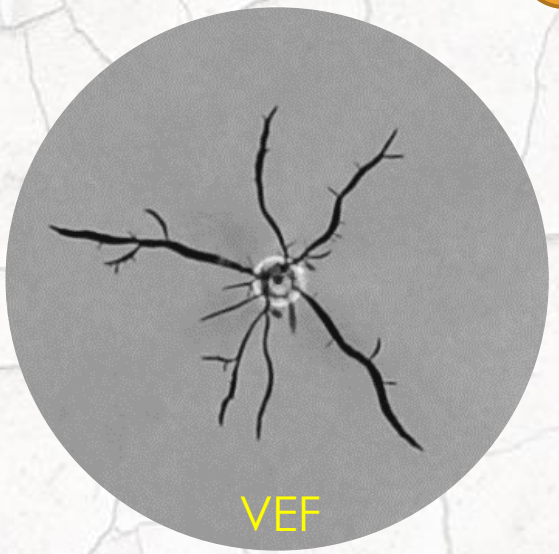
Laponite Susp. -3.25 % w/v
Inner fluid – Water
Flow rate – 5 ml/min



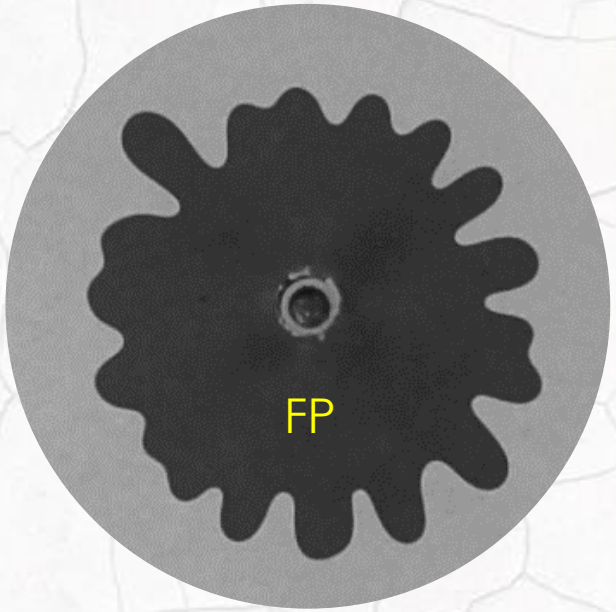
16.0 h



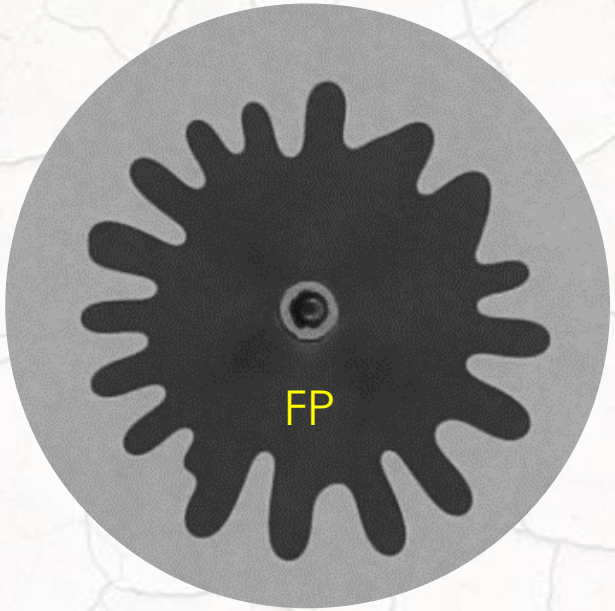
20.0 h



24.0 h

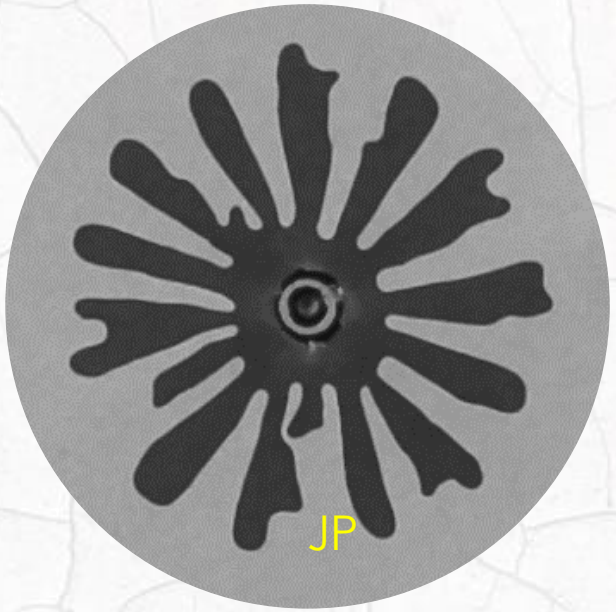


t_w = 1.0 h

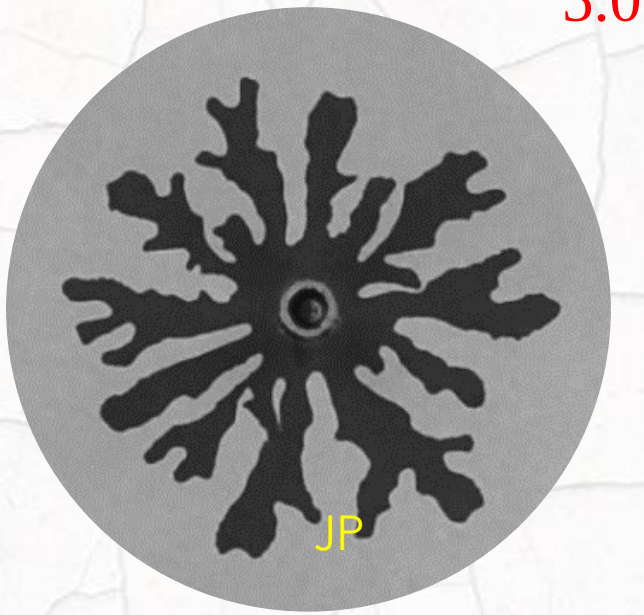


3.0 h

5.0 h



16.0 h

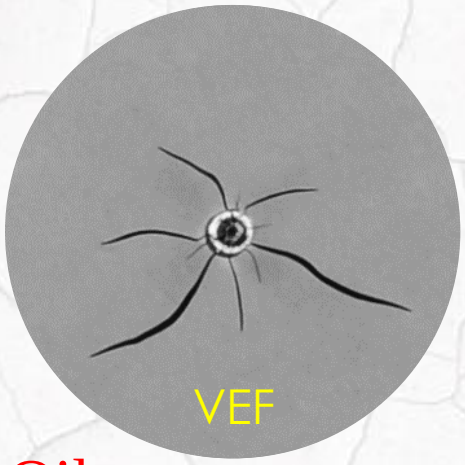


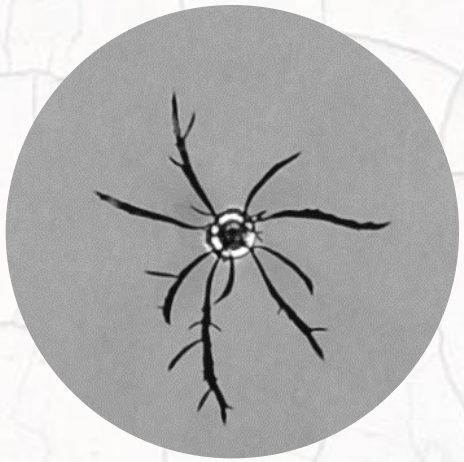
24.0 h

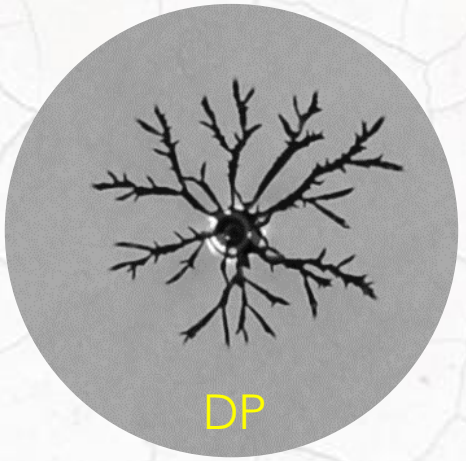
Laponite Susp. -3.25 % w/v
Inner fluid – mineral oil
Flow rate – 5 ml/min

Laponite Susp. - 3.25 % & t_w = 24 h

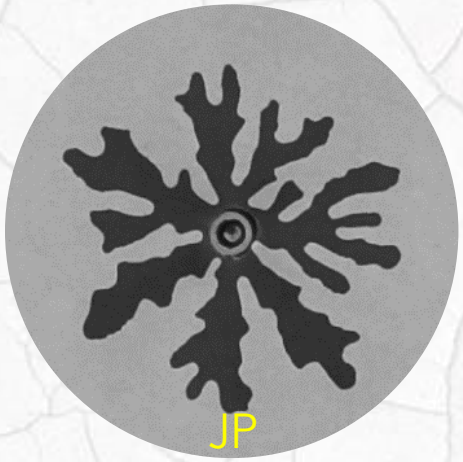
Water

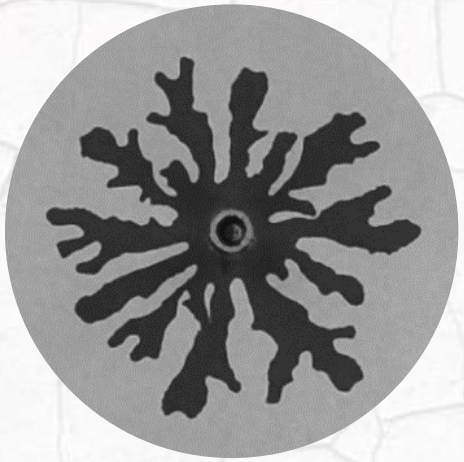


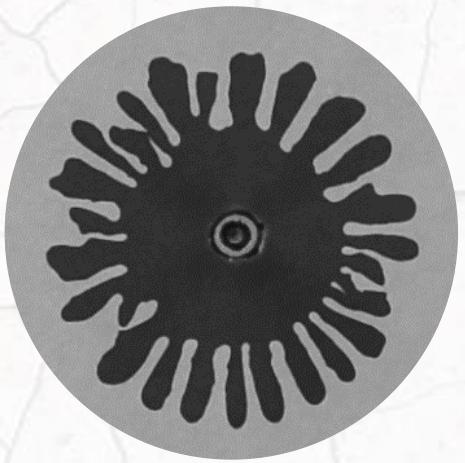


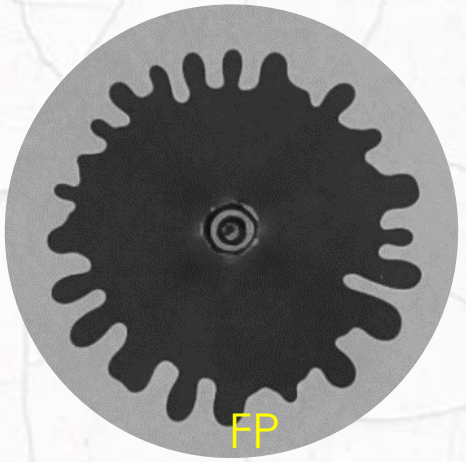


Oil









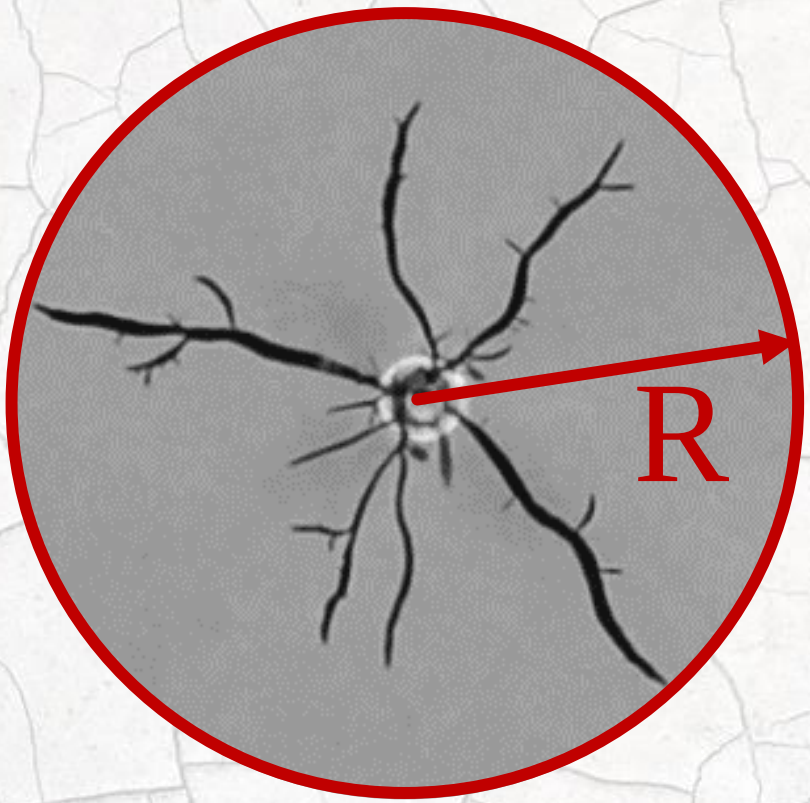
1.0 ml/min

5.0 ml/min

15.0 ml/min

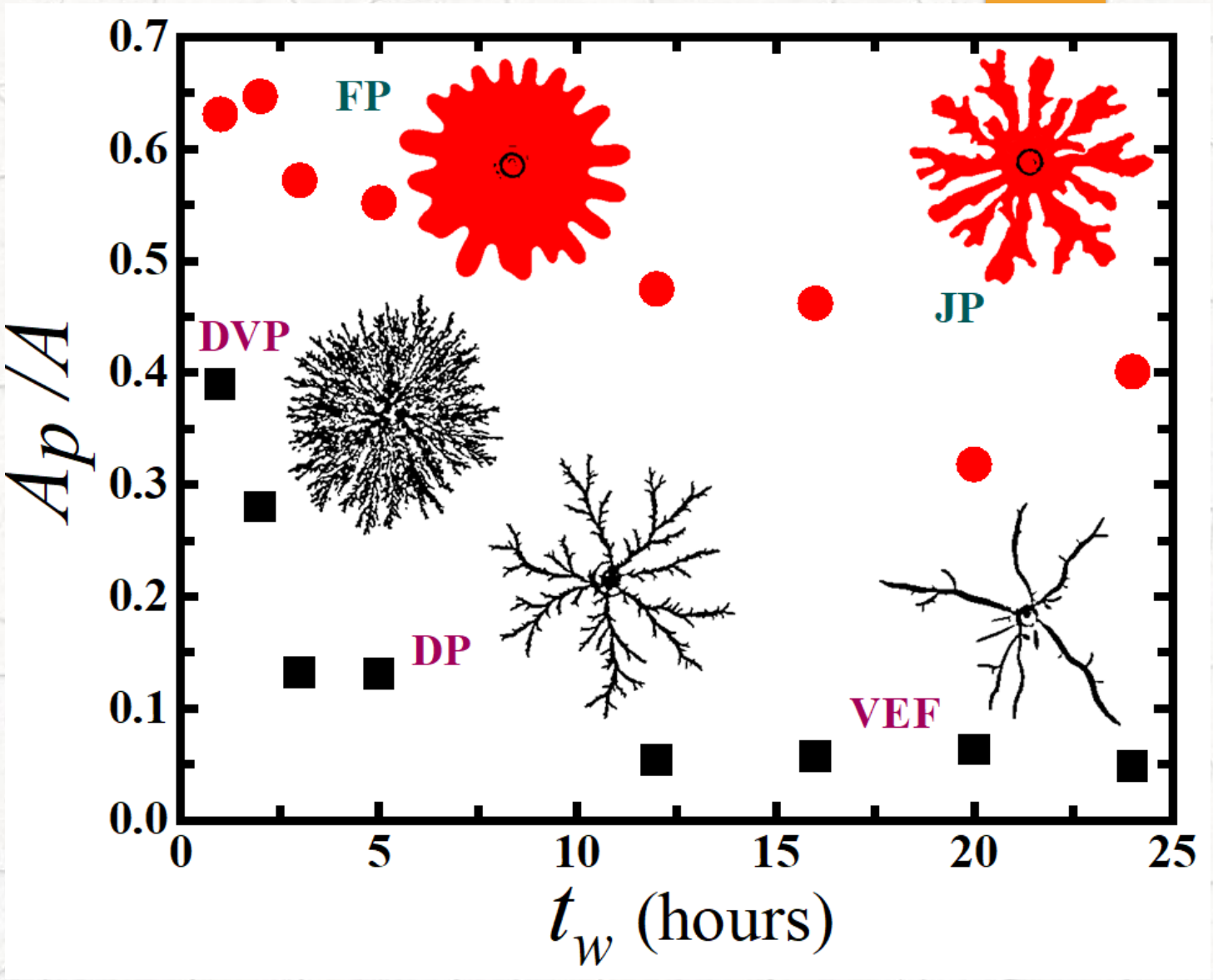
30.0 ml/min

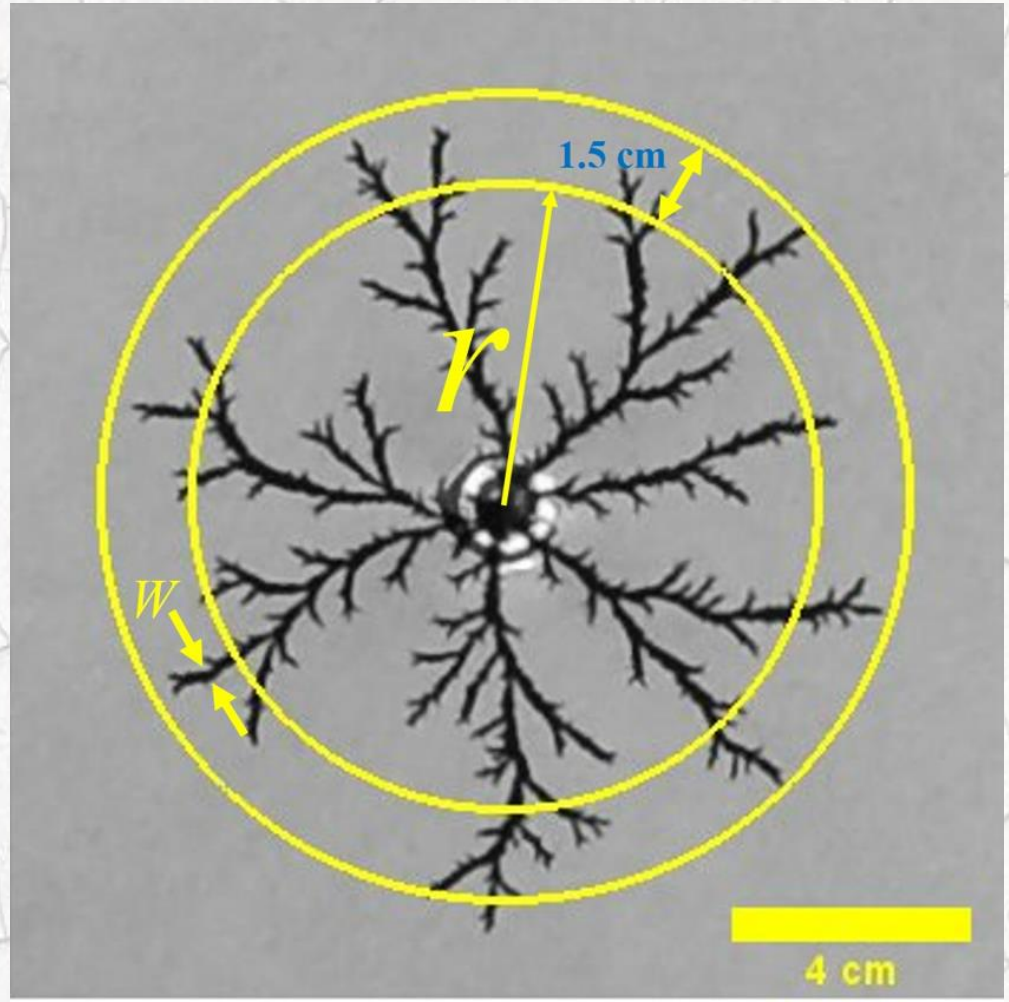
50.0 ml/min



A_p = area of pattern

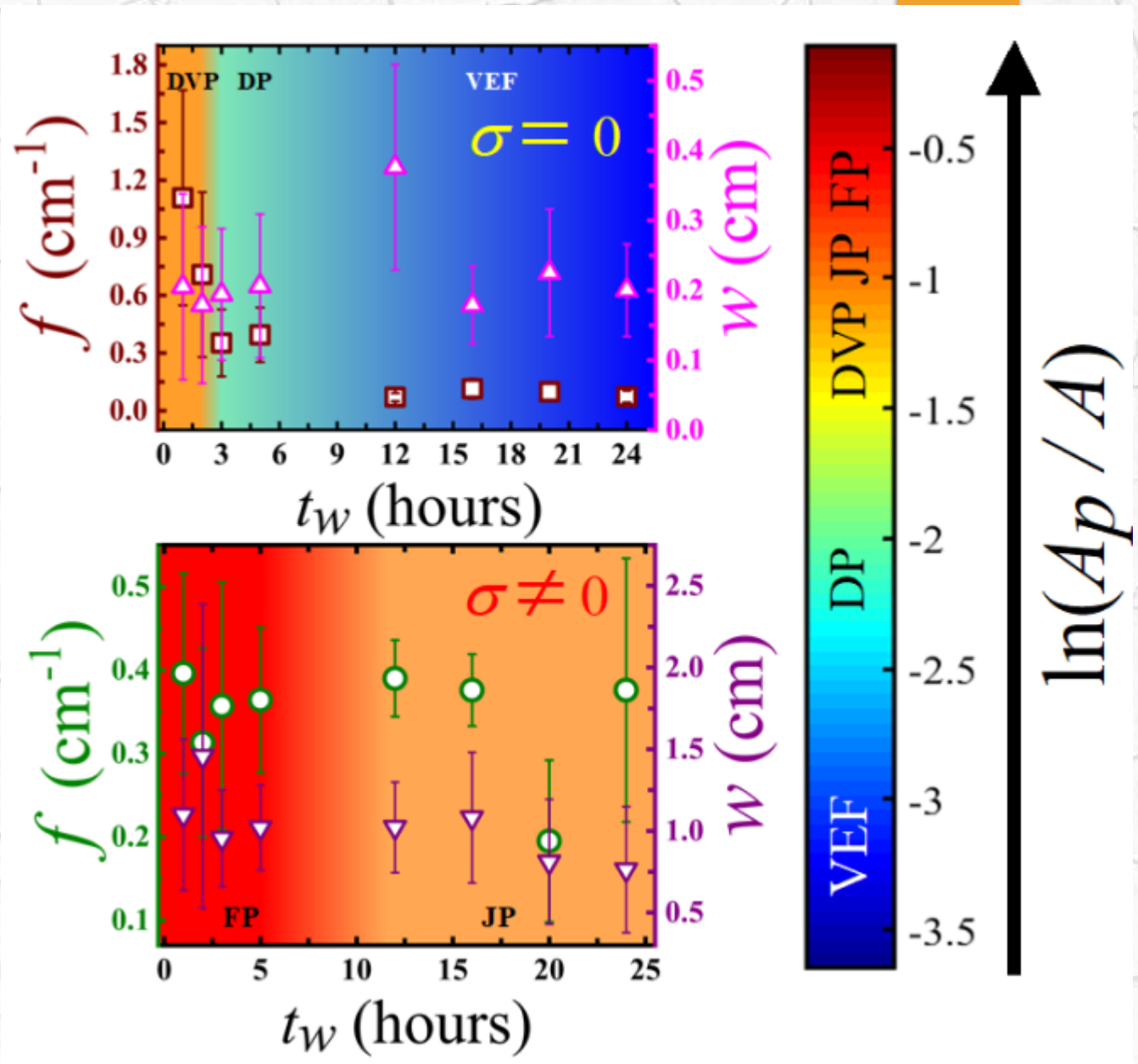
$A = \pi R^2$

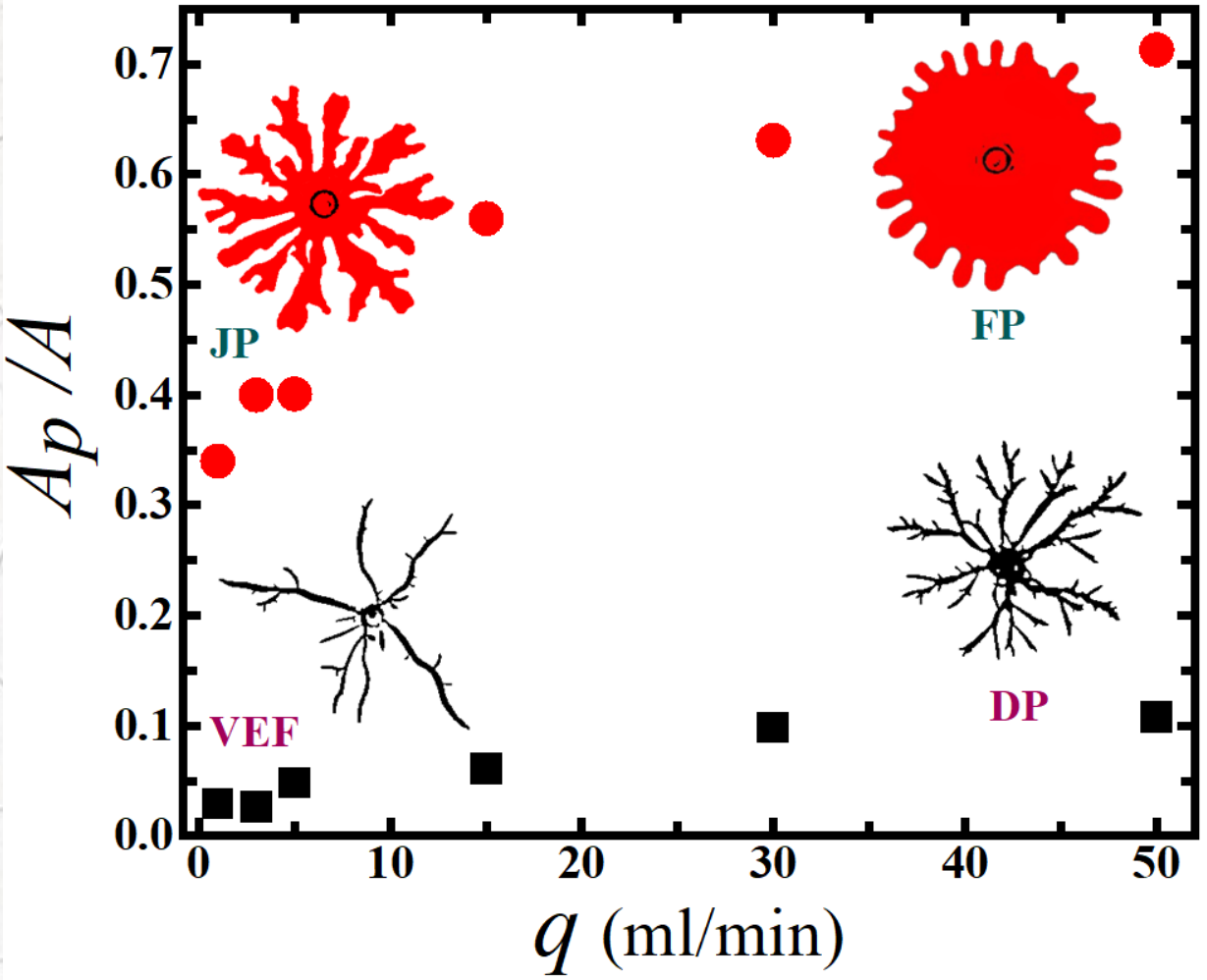


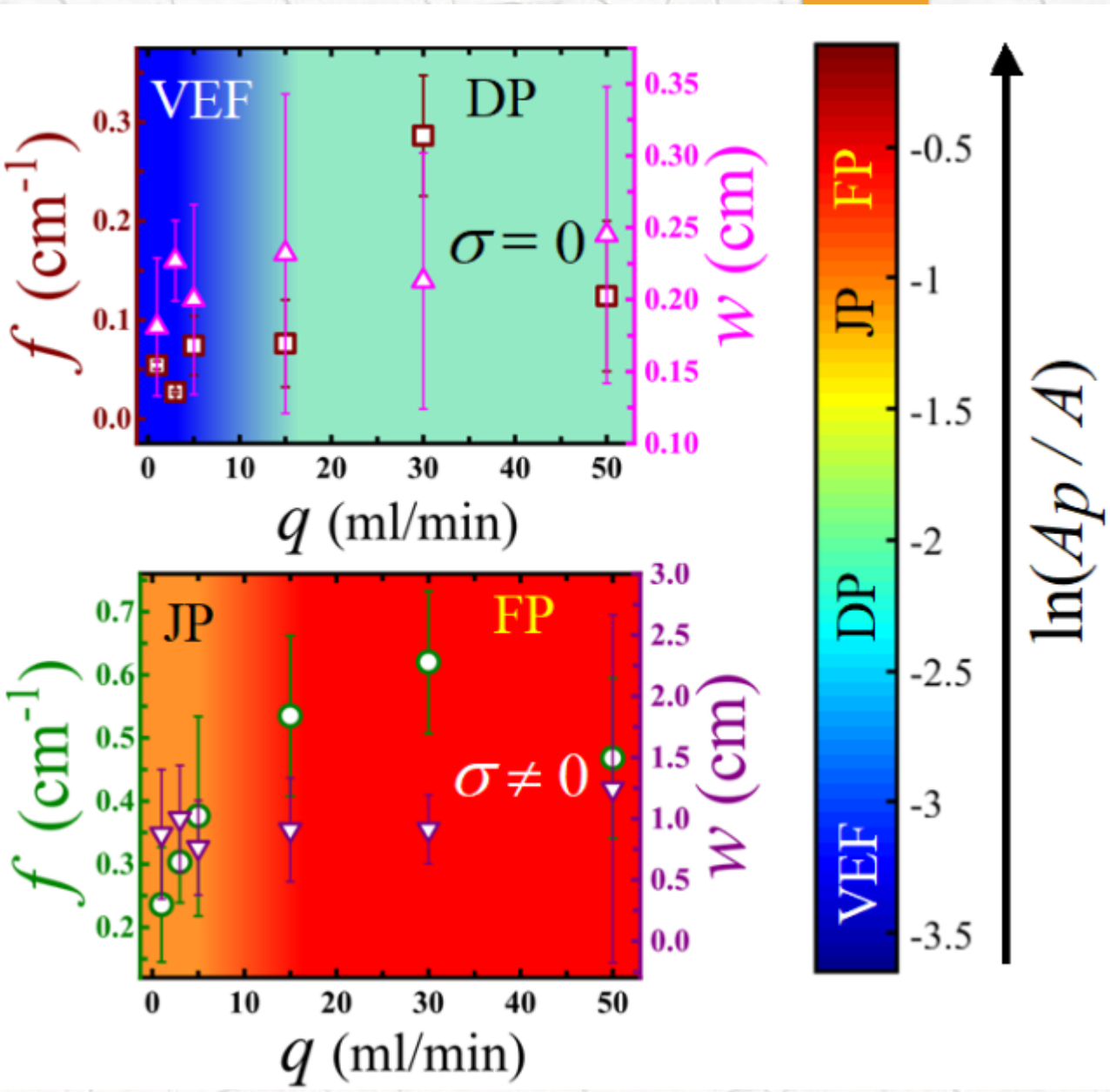

1.5 cm
r
W
4 cm

$$f = < N/2\pi r >_r$$

$$w = < W >_r$$


DVP
DP
VEF
σ = 0
f (cm⁻¹)
w (cm)
t_W (hours)
σ ≠ 0
FP
JP
DVP JP FP
DP
VEF
ln(Ap / A)

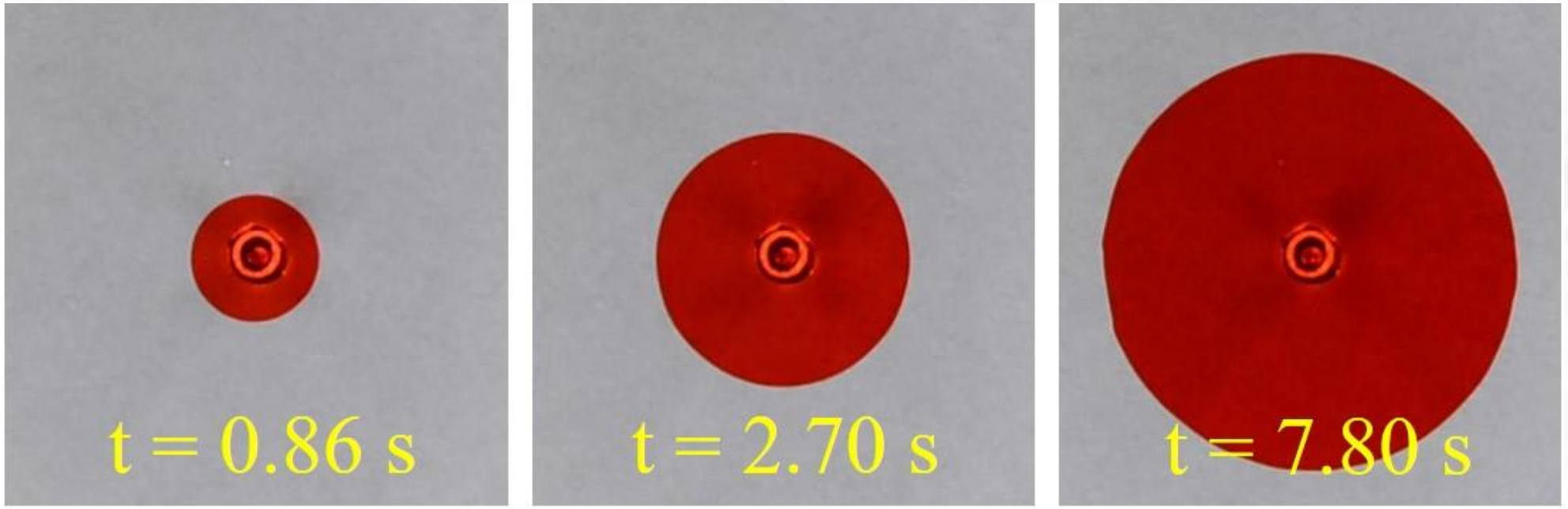

Ap /A
q (ml/min)
JP
FP
VEF
DP

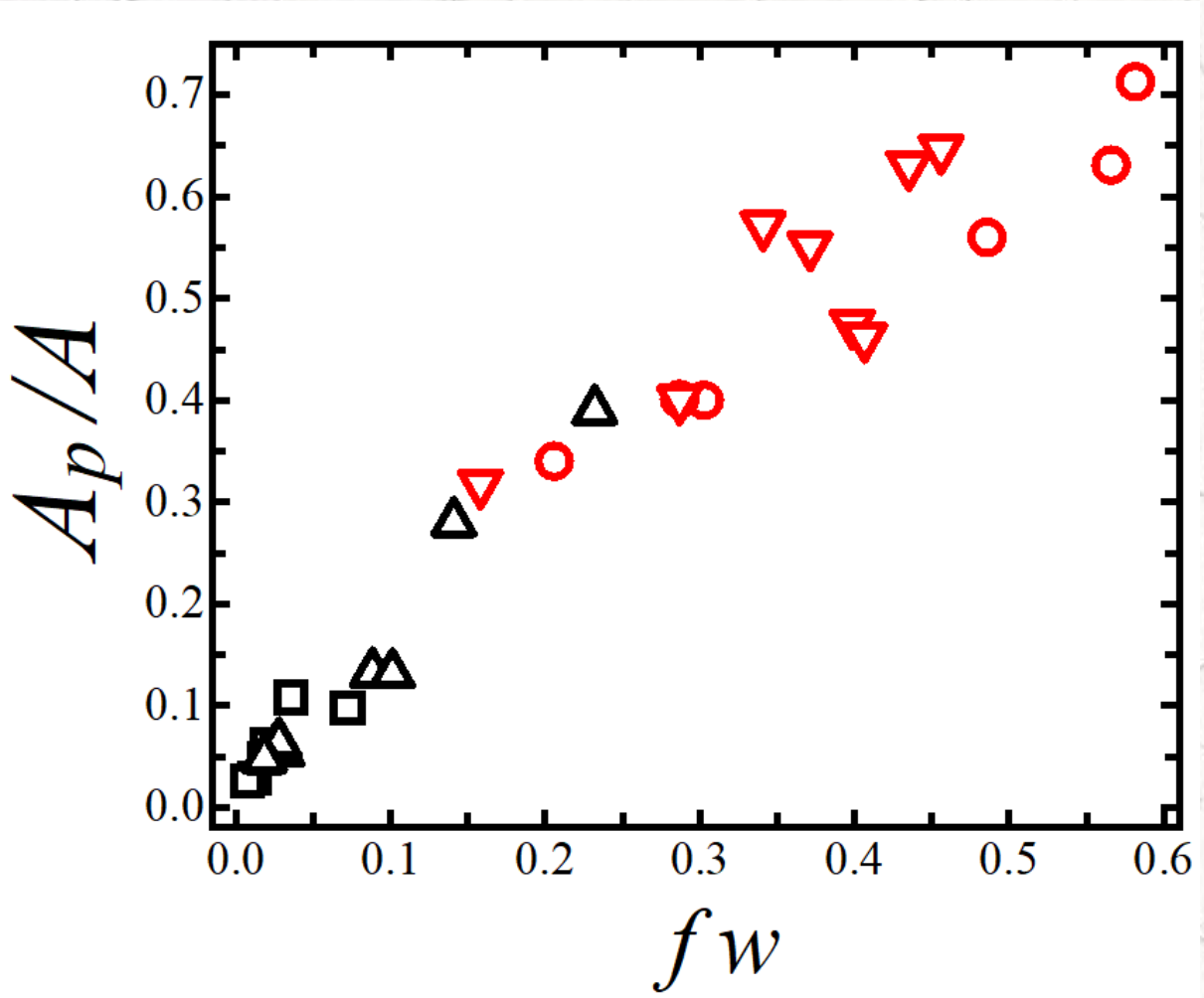

VEF
DP
σ = 0
f (cm-1)
w (cm)
q (ml/min)
JP
FP
σ ≠ 0
ln(Ap / A)

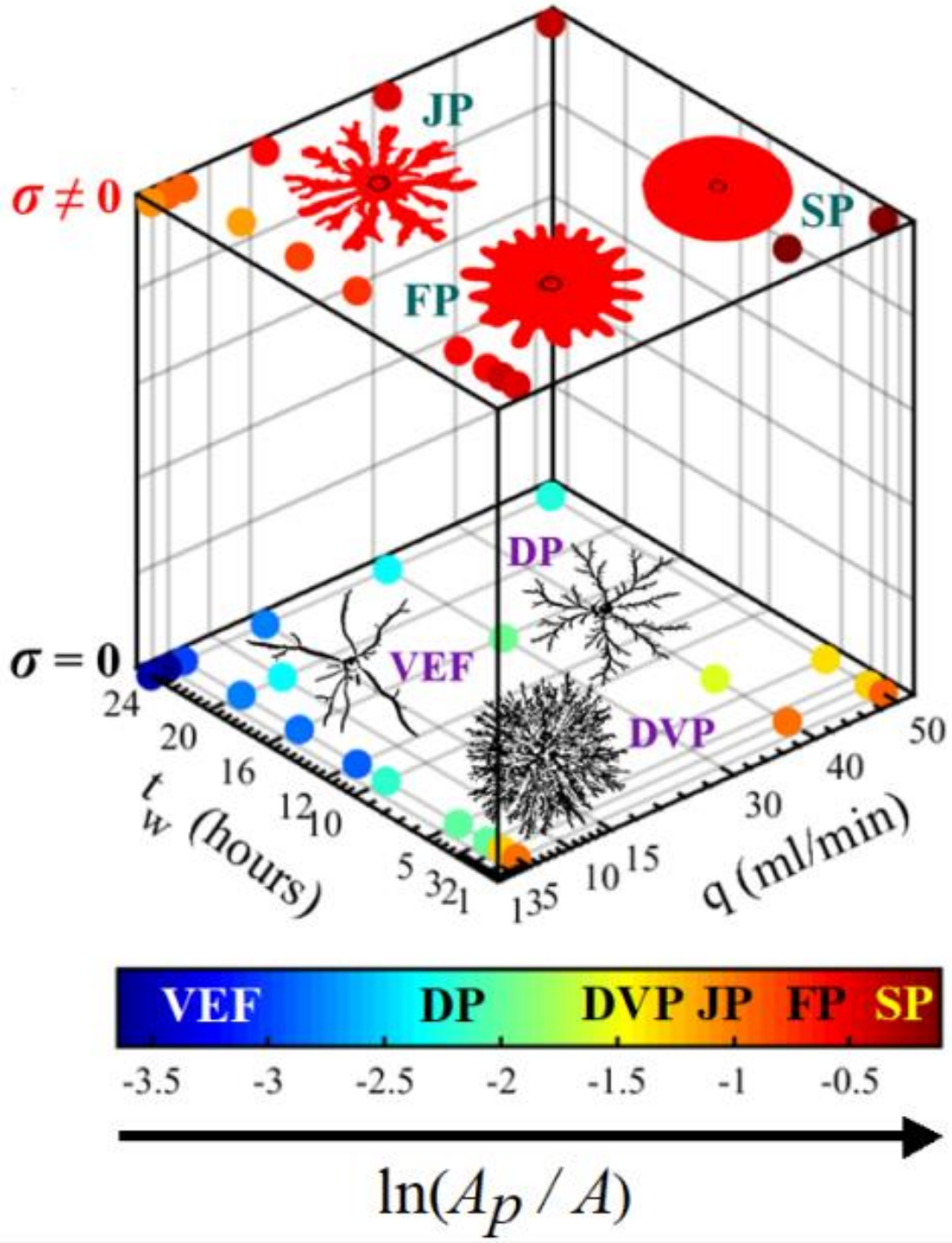
Laponite Susp. -3.25 % w/v; t_w = 1 h

Inner fluid – Mineral oil & Flow rate – 50 ml/min

SP




A_p/A
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
$f\,w$


$\sigma \neq 0$
JP
SP
FP
$\sigma = 0$
DP
VEF
DVP
24
20
16
12
10
5
3
2
1
t_w (hours)
1
3
5
10
15
30
40
50
q (ml/min)
VEF
DP
DVP
JP
FP
SP
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
$\ln(A_p / A)$

Summary

- The morphology of the patterns is determined by the waiting time of the outer viscoelastic fluid, the flow rate of the inner Newtonian fluid and the interfacial tension between the two fluids.
- Shear and time-dependent rheology of the suspension governs pattern morphologies.
- Our results present an additional parameter, waiting time t_w to control morphology of interfacial pattern in soft glassy suspensions.
- The natural logarithms of pattern areal ratio uniquely identifies each distinct pattern morphology.
- Growth of interfaces in mud/slurry displacements can be successfully predicted.

https://doi.org/10.48550/arXiv.2201.06088

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- Labmates - Chandeshwar, Rajkumar, Vaibhav, Yogesh, Zaibudeen, Anson.
- Workshop for their help with experimental setup.

PC: Chaithanya, RRI

THANK YOU!

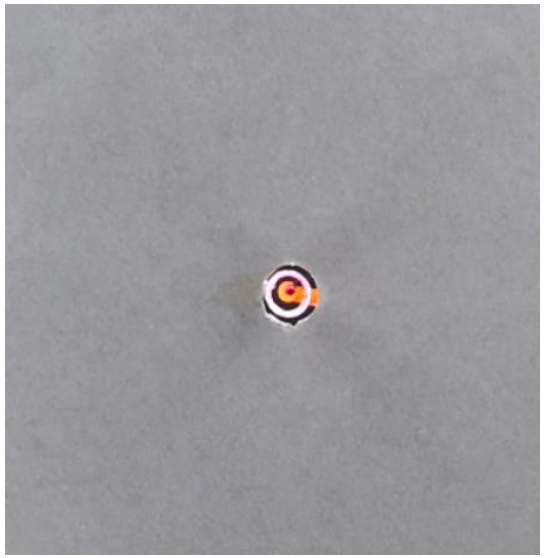
Vaibhav, RRI

Debasish Saha, HHU, Düsseldorf

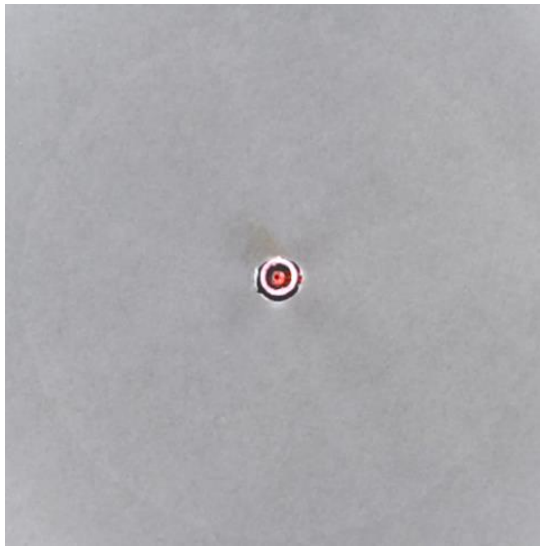
3.0 ml/min

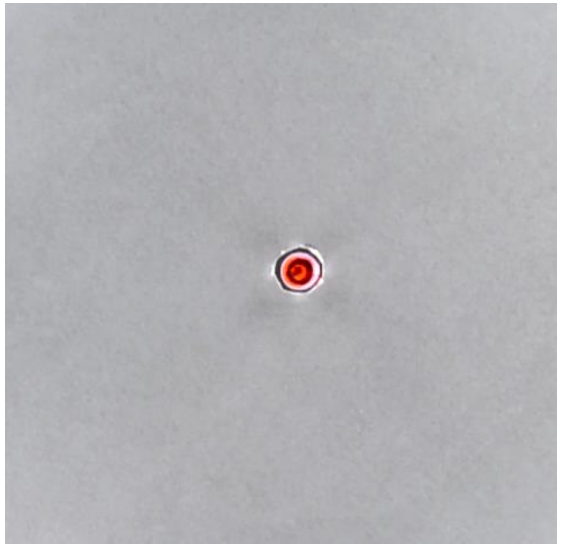
50.0 ml/min

Water

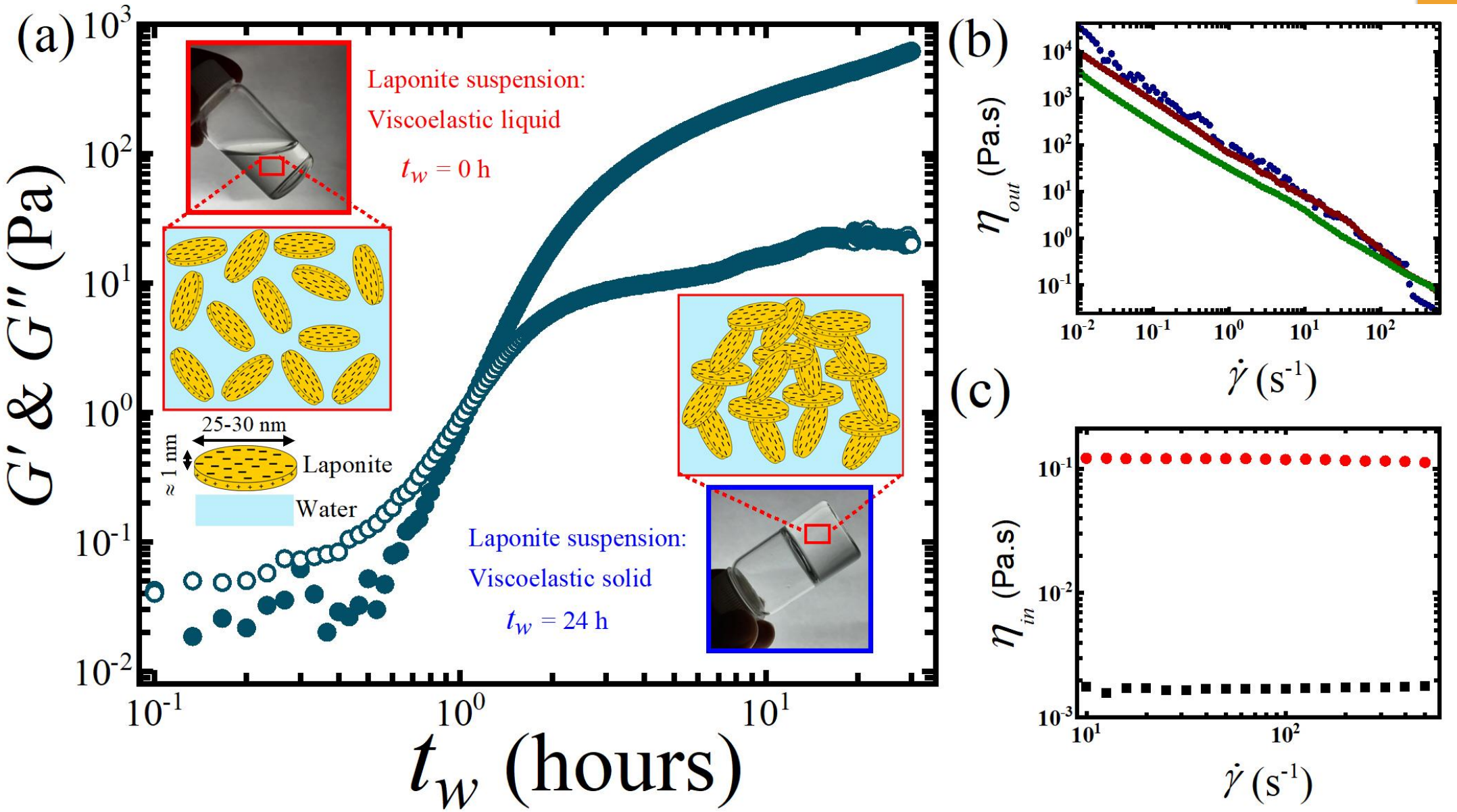


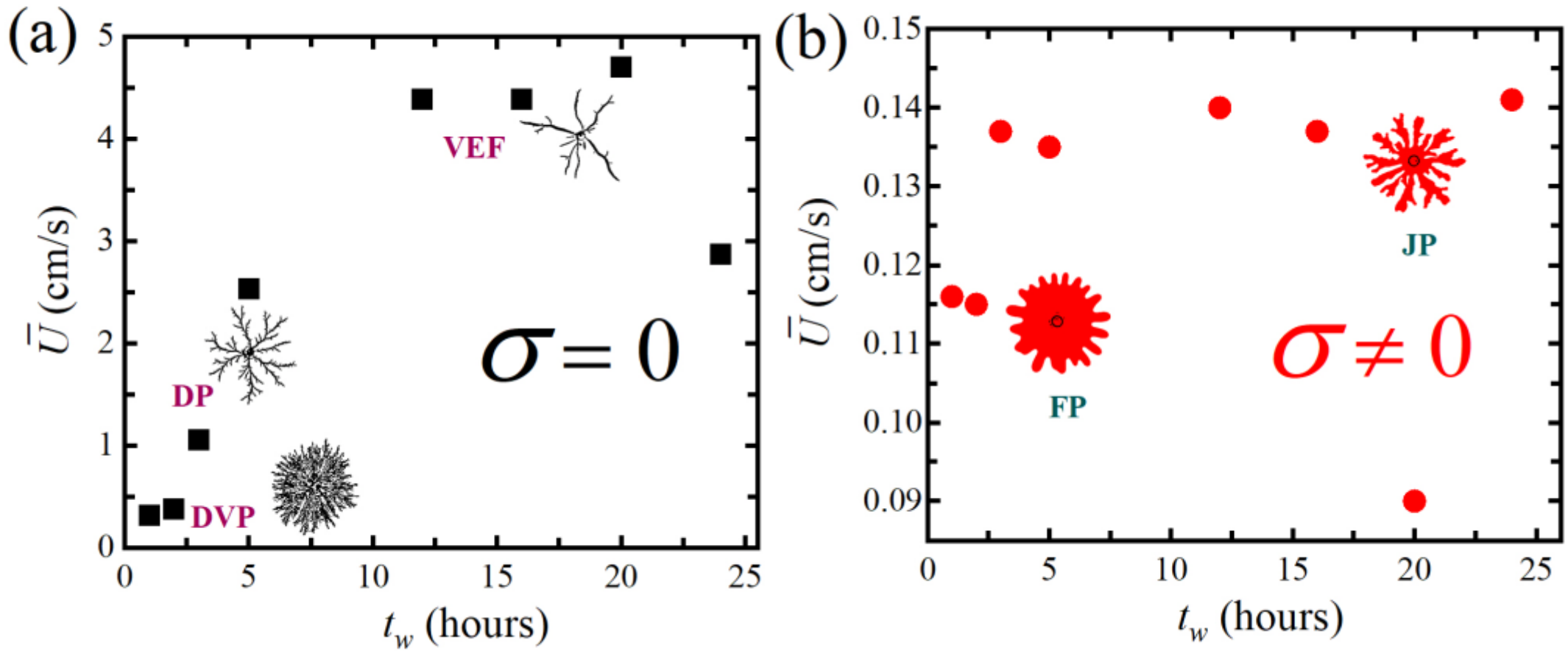
Oil

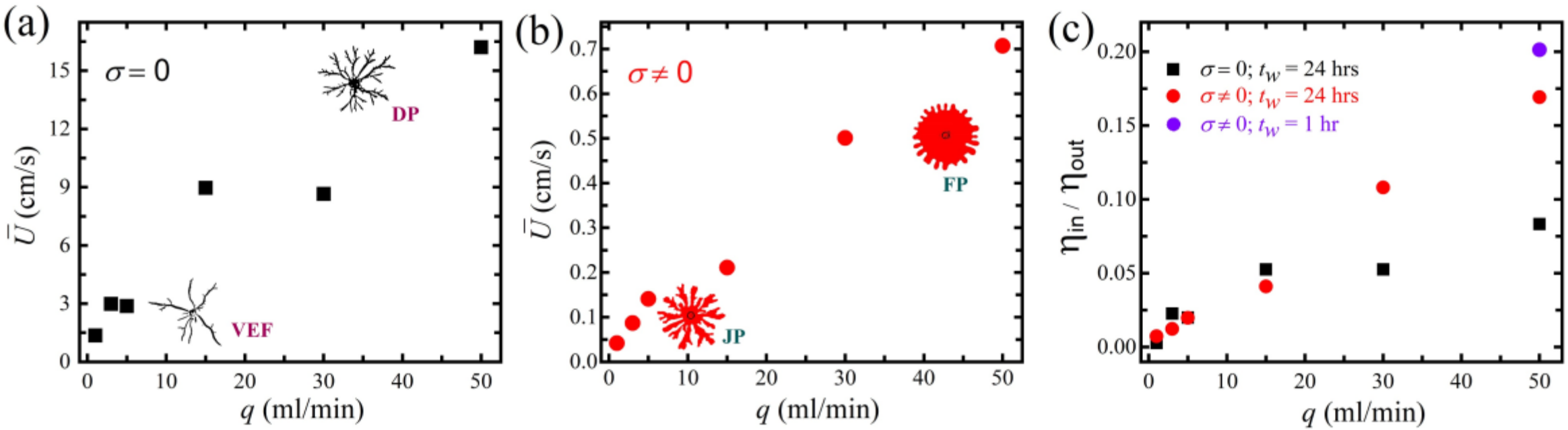




Laponite Susp. -3.25 % w/v, t_w = 24 hrs


(a)
G′ & G″ (Pa)
t_w (hours)
Laponite suspension:
Viscoelastic liquid
t_w = 0 h
25-30 nm
≈ 1 nm
Laponite
Water
Laponite suspension:
Viscoelastic solid
t_w = 24 h
(b)
η_out (Pa.s)
γ̇ (s^-1)
(c)
η_in (Pa.s)
γ̇ (s^-1)


(a)
VEF
DP
DVP
σ = 0
$\bar{U}$ (cm/s)
t_w (hours)
(b)
JP
FP
σ ≠ 0
$\bar{U}$ (cm/s)
t_w (hours)


(a)
σ = 0
DP
VEF
$\bar{U}$ (cm/s)
q (ml/min)
(b)
σ ≠ 0
FP
JP
$\bar{U}$ (cm/s)
q (ml/min)
(c)
σ = 0; t_w = 24 hrs
σ ≠ 0; t_w = 24 hrs
σ ≠ 0; t_w = 1 hr
η_{in} / η_{out}
q (ml/min)