[No Title]

UNIVERSITY OF LIVERPOOL

MATERIALS INNOVATION FACTORY

Designing colloidal formulations and bespoke rheological tests for 3D printing

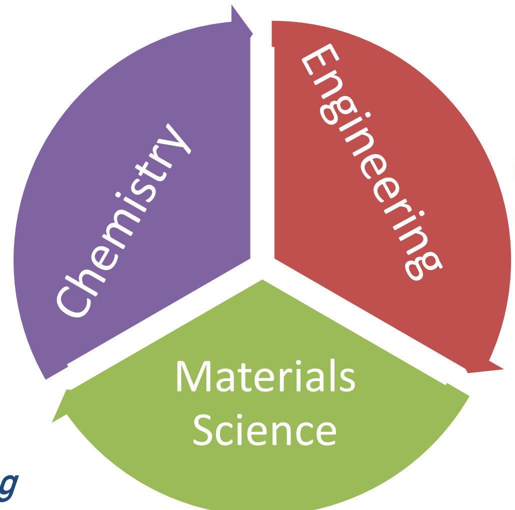
*Andrew Corker, Dr Henry Ng, Prof Robert J Poole & **Dr Esther García-Tuñón***

FORMATIVE FORMULATION

Formative Formulation: a technical meeting for early career formulation scientists in industry and academia

Maxwell Centre, University of Cambridge, JJ Thomson Ave, CB30HE

18th March 2019



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Colloidal Processing and Rheology Research @UoL

TEAM

Andrew Corker
(Second year PhD student)

Emma Jones
(First year PhD student)

Alice Brettle
(First year PhD student)

Open PhD opportunities

FindAPhD

'Inside' personal care products: developing characterisation protocols combining microfluidics and advanced imaging techniques

iCASE Unilever

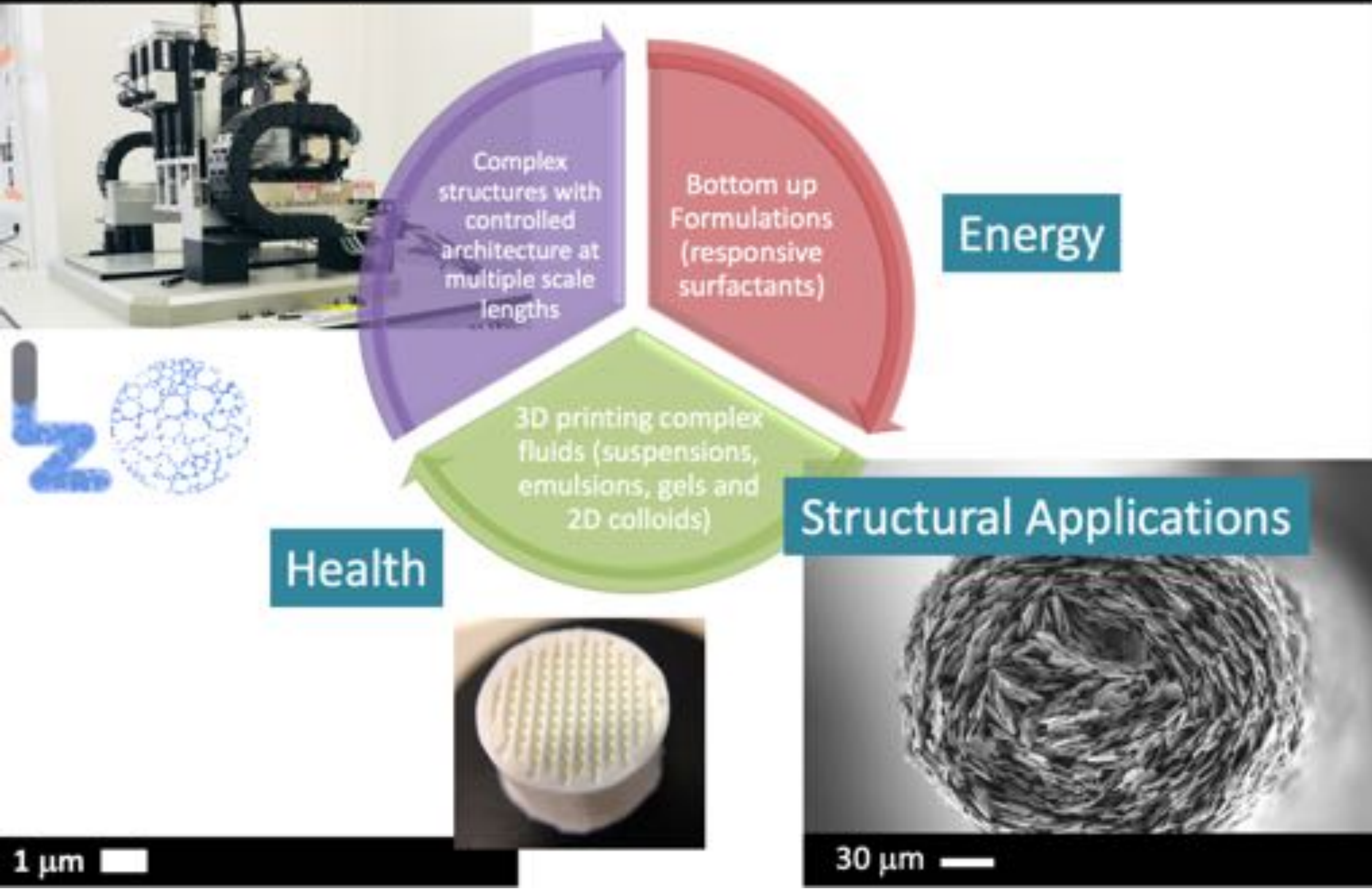
Multiscale Quasiperiodic Metamaterials

Project with
Physics Department

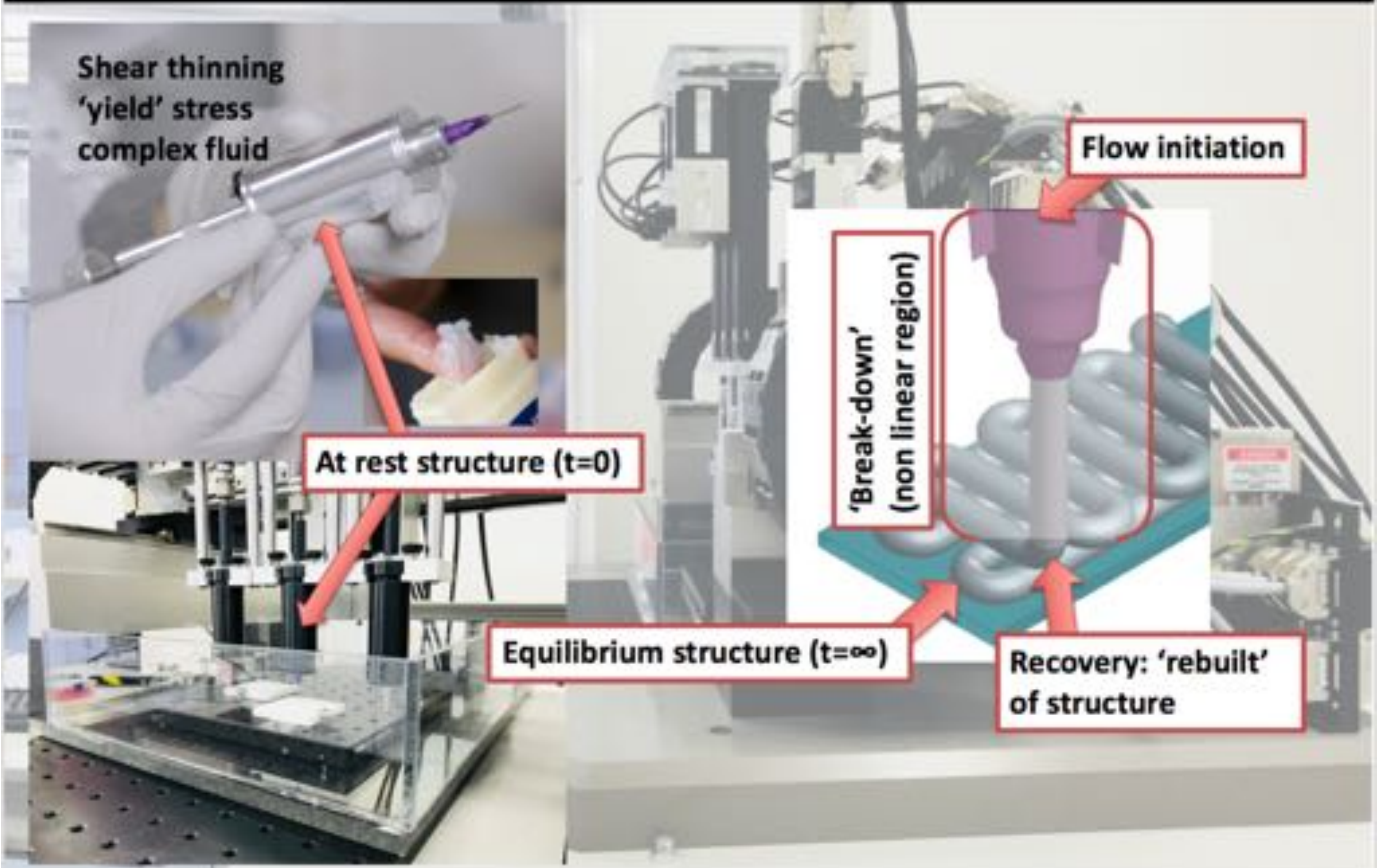
Synthesis of responsive surfactants.
Formulation & colloidal processing.
Rheology of complex fluids.
3D printing of advanced materials.

Research overview

Engineering complex fluids

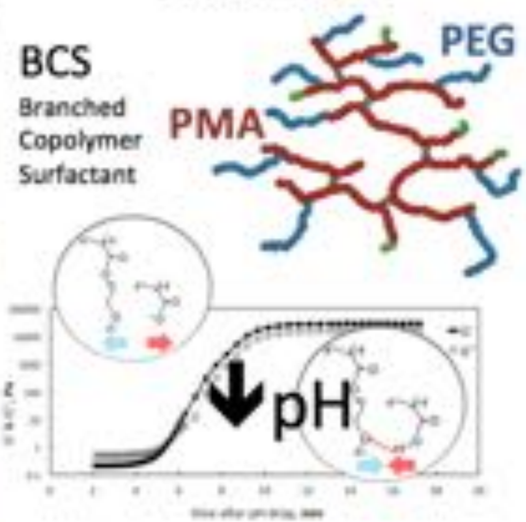


DIW: Rheological demands and ‘*printability*’



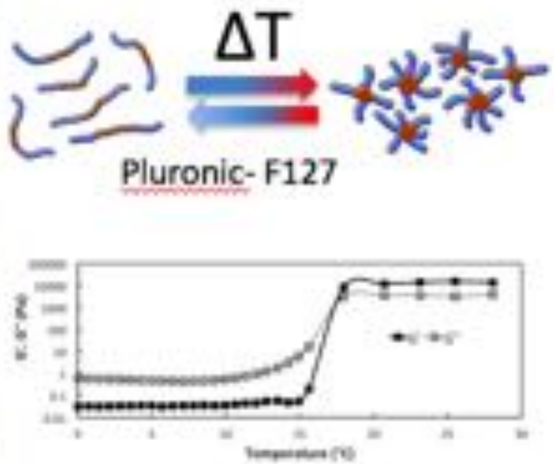
Engineering formulations for DIW

pH responsive surfactants



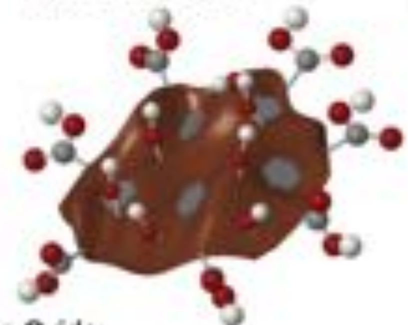
Printing in Three Dimensions with Graphene

Thermo-responsive hydrogels



Multimaterial 3D Printing of Graphene-Based Electrodes for Electrochemical Energy Storage Using Thermoresponsive Inks

2D colloids

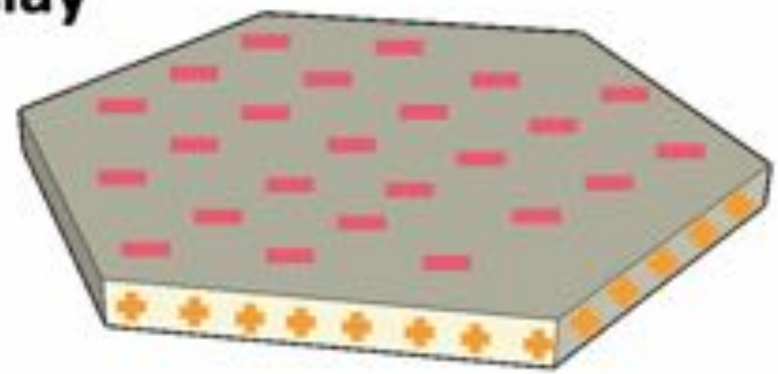


GO
Graphene Oxide

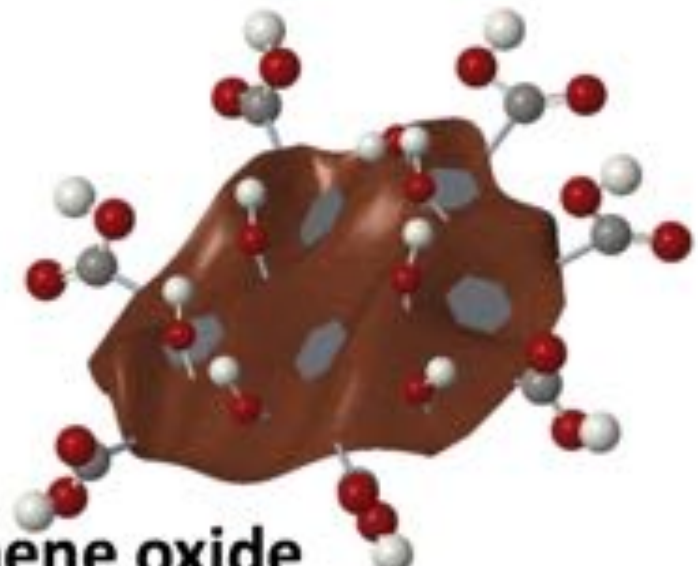
Graphene Oxide: An All-in-One Processing Additive for 3D Printing

Clay vs. Graphene oxide (GO)

Clay



'House-of-cards'



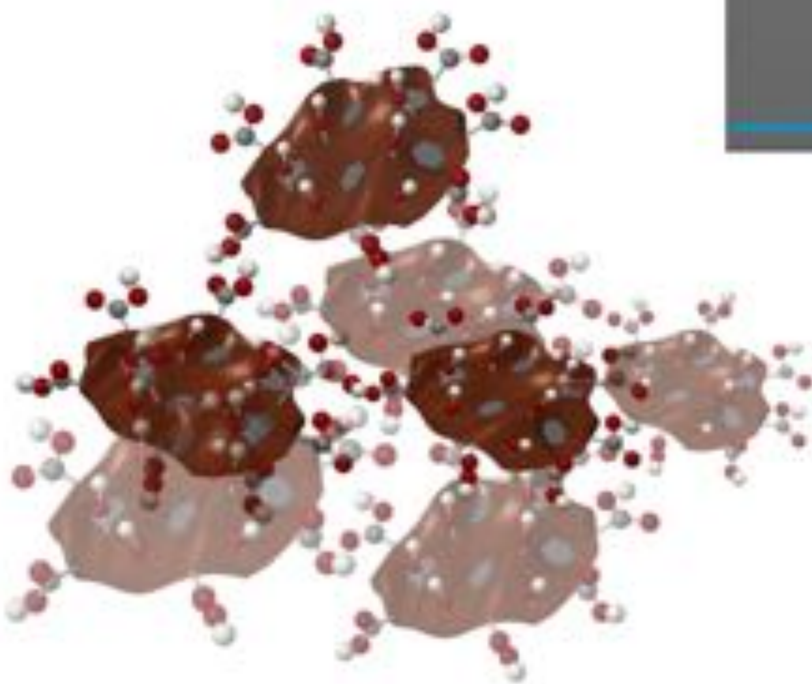
GO
Graphene oxide

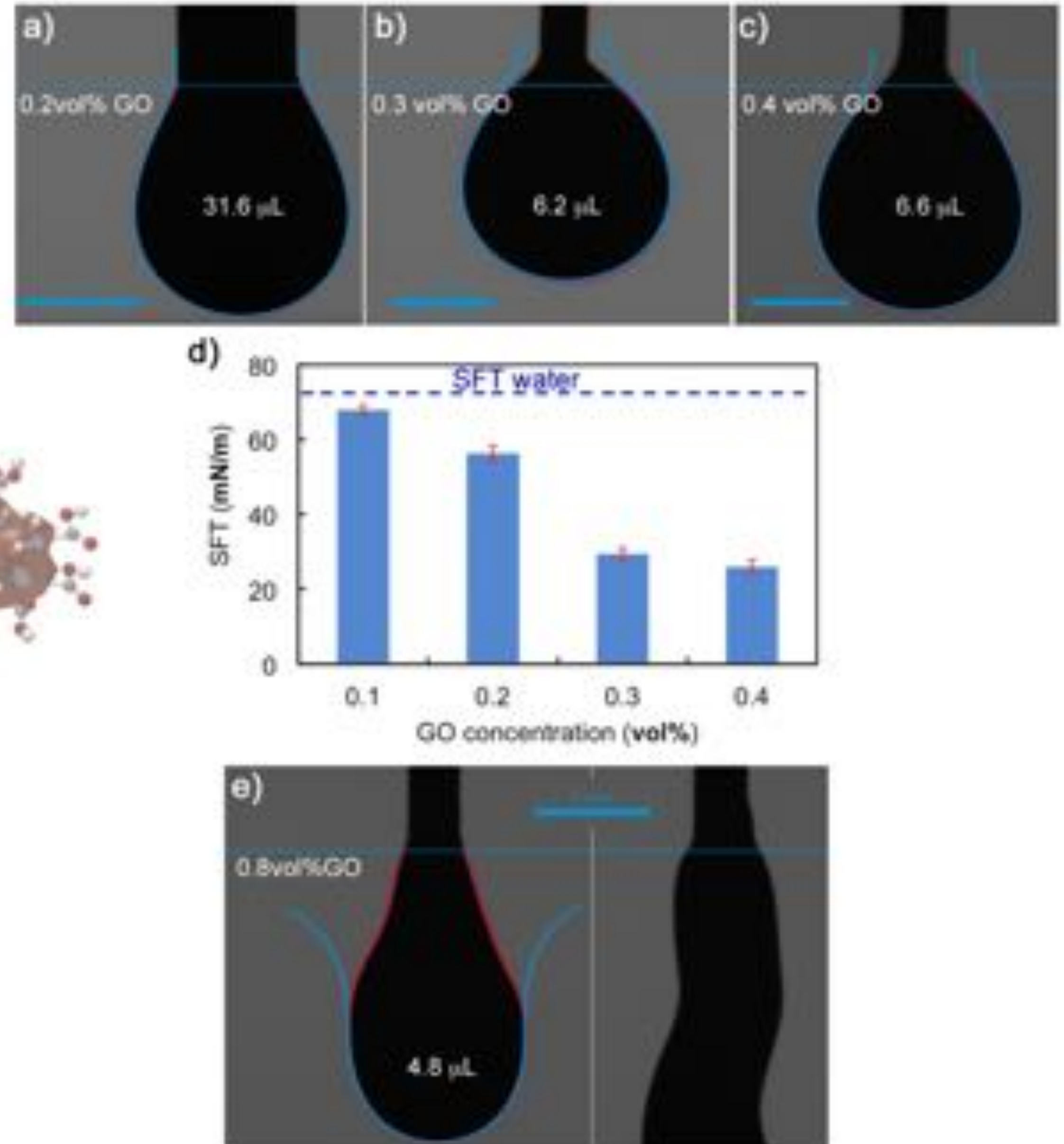
2D
Amphiphile
Multiple functionalities
Interactions across flakes
Flexible (can twist and bend)

MULTIPLE ROLES AS AN ADDITIVE

Graphene oxide networks

Surface tension – pendant drop

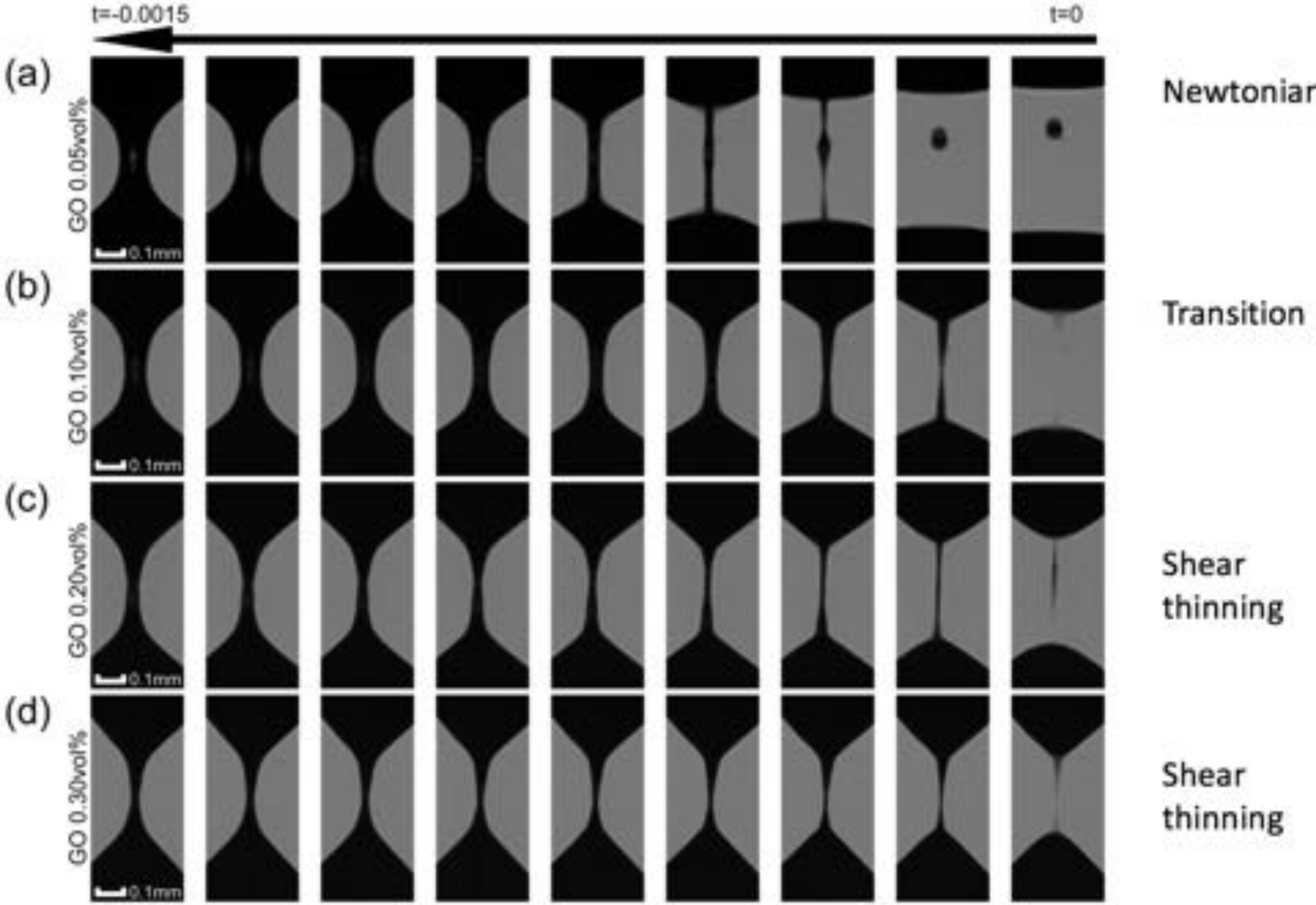




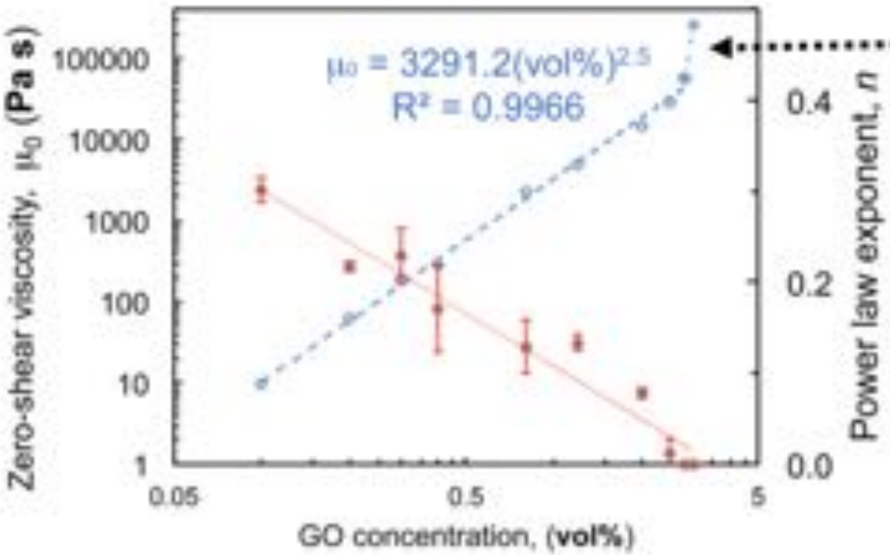
Soft Matter Emerging Investigators Issue 2019

3D printing with 2D colloids: designing rheology protocols to predict 'printability' of soft-materials

Extensional rheology of GO networks



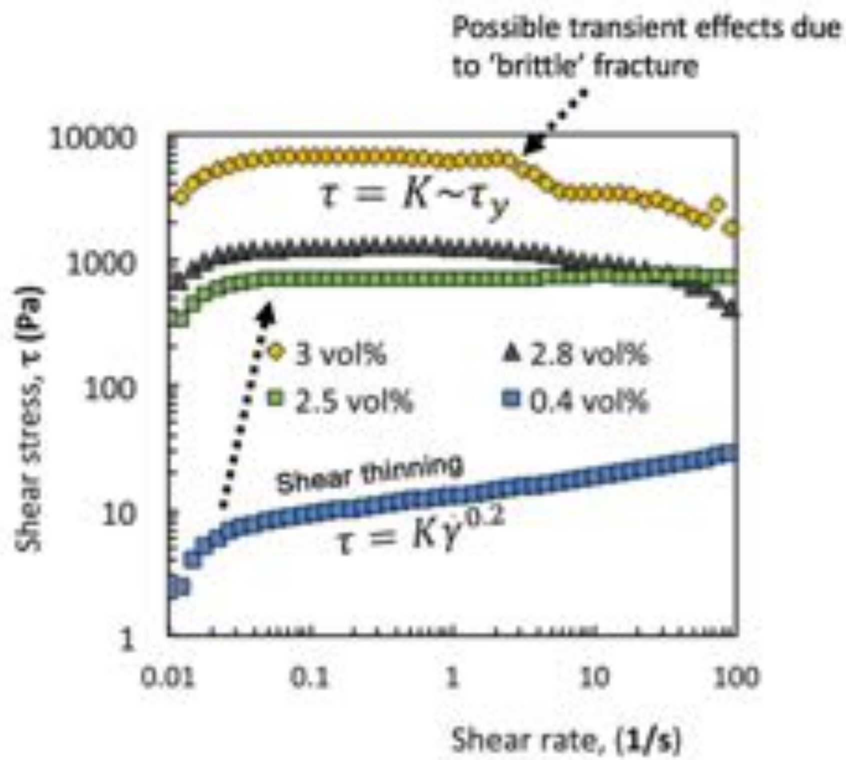
Shear rheology of GO networks



At concentrations of 3 vol% GO μ_0 increases up to values in the order of 250 kPa and does not follow the same power-law exponent.

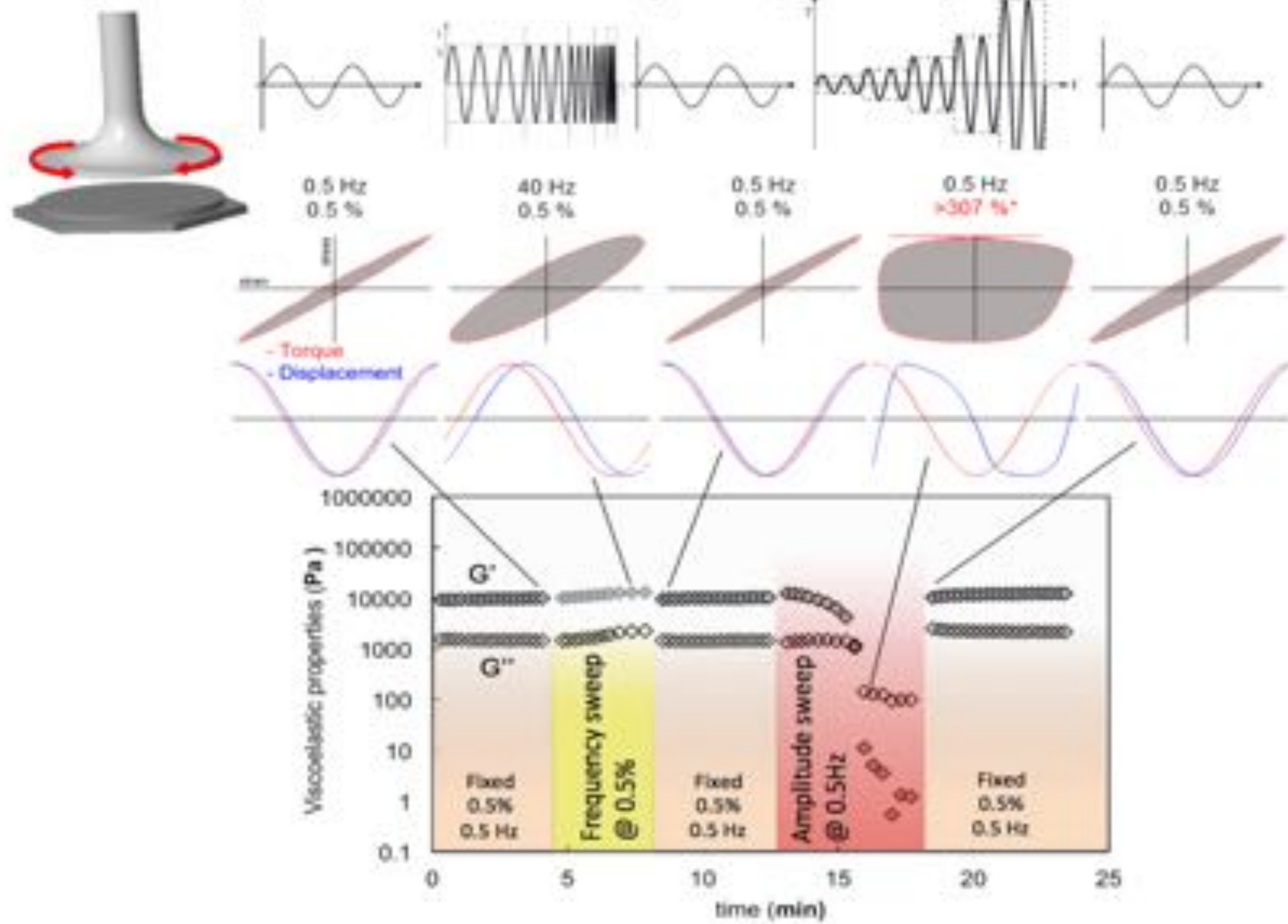
At 'printable' concentrations (2.5-3 vol%) the stress becomes essentially independent of the shear rate.

Transition from a power law behaviour ($\tau \sim K\dot{\gamma}^n$) to a regime where the stress is constant ($\tau = K \sim \tau_y$).



Oscillatory rheology of GO networks

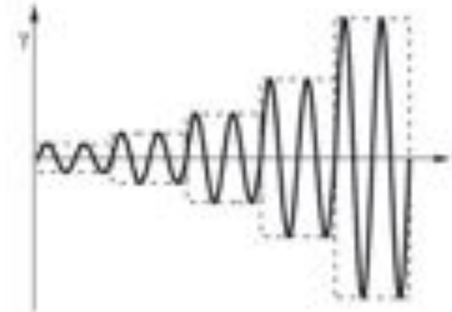
Example: 5-steps 'structure' evolution (TA HR1, ARES G2)

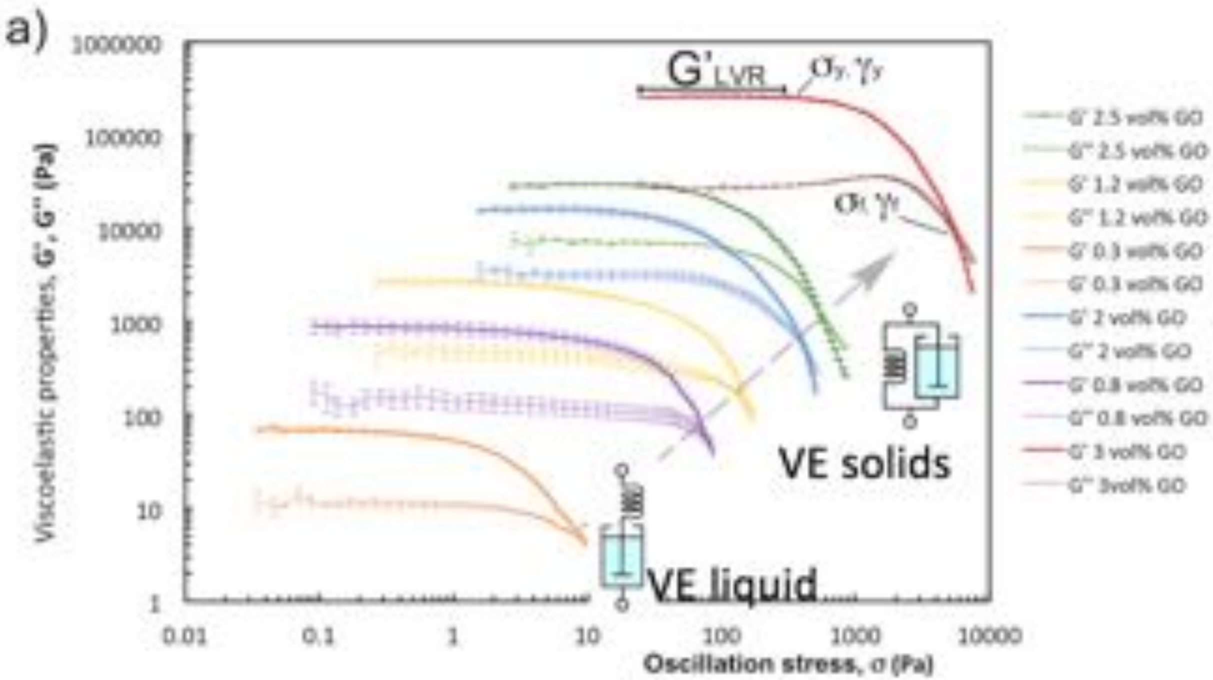


García-Tuñón, E., Feilden, E., Zheng, H., D'Elia, E., Leong, A., & Saiz, E. (2017). Graphene Oxide: An All-in-One Processing Additive for 3D Printing. *ACS Applied Materials & Interfaces*, *9*(38), 32977–32989

Quantifying printability: break down and flow

From an amplitude sweep: we determine the @rest structure (G'_{LVR}) **'yield and flow stress values' σ_y and σ_f** to quantify the internal structure.





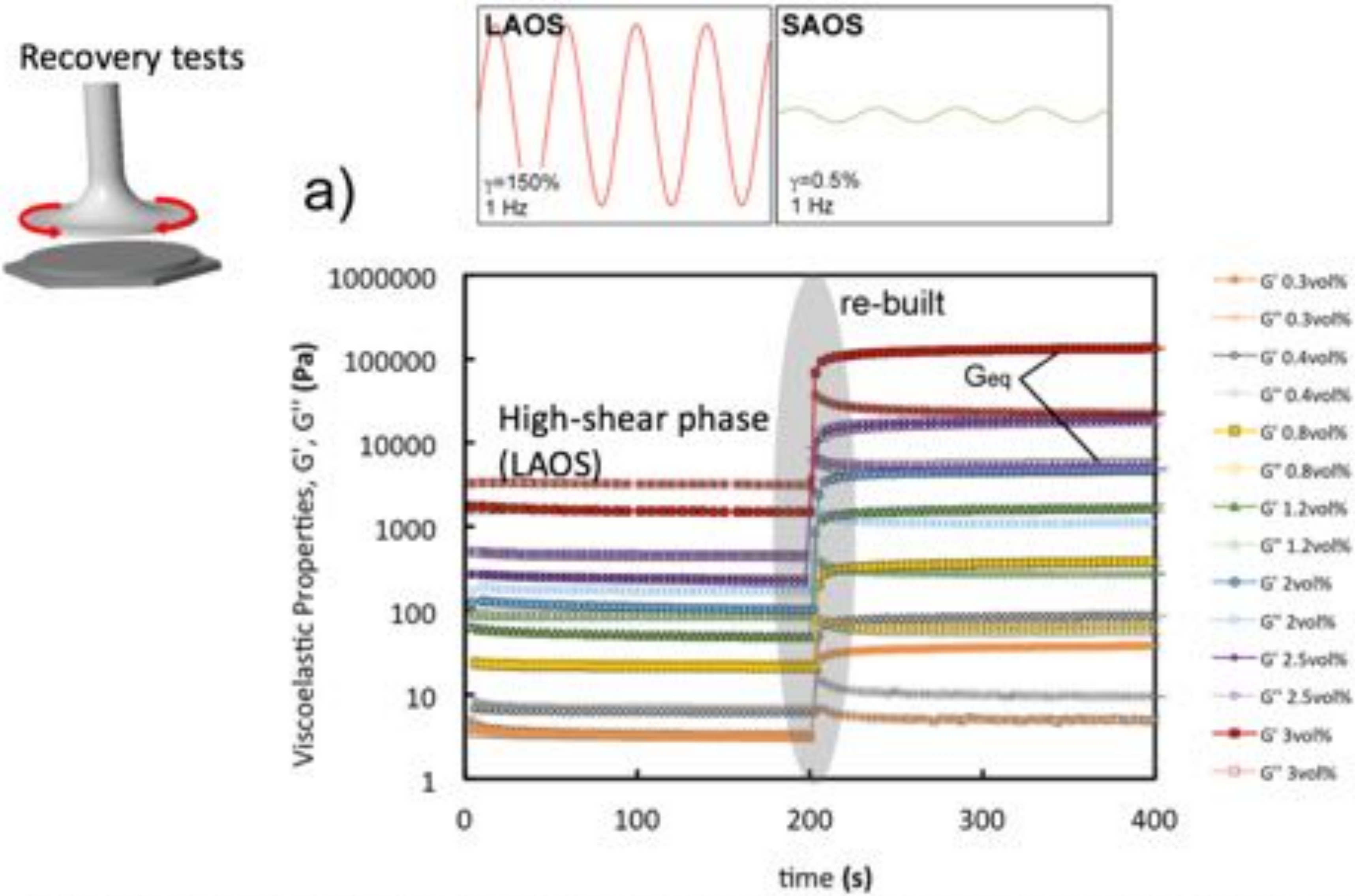
Flow transition index

$$FTI = \sigma_f/\sigma_y$$

Low FTI values 'brittle' soft material

Emerging Investigators 2019. Soft Matter, 2019,**15**, 1444-1456 Andrew Corker, Henry Ng, Robert J Poole & Esther Garcia-Tuñón* '3D printing with 2D colloids: designing rheology protocols to predict 'printability' of soft-materials'

Quantifying printability: rebuild



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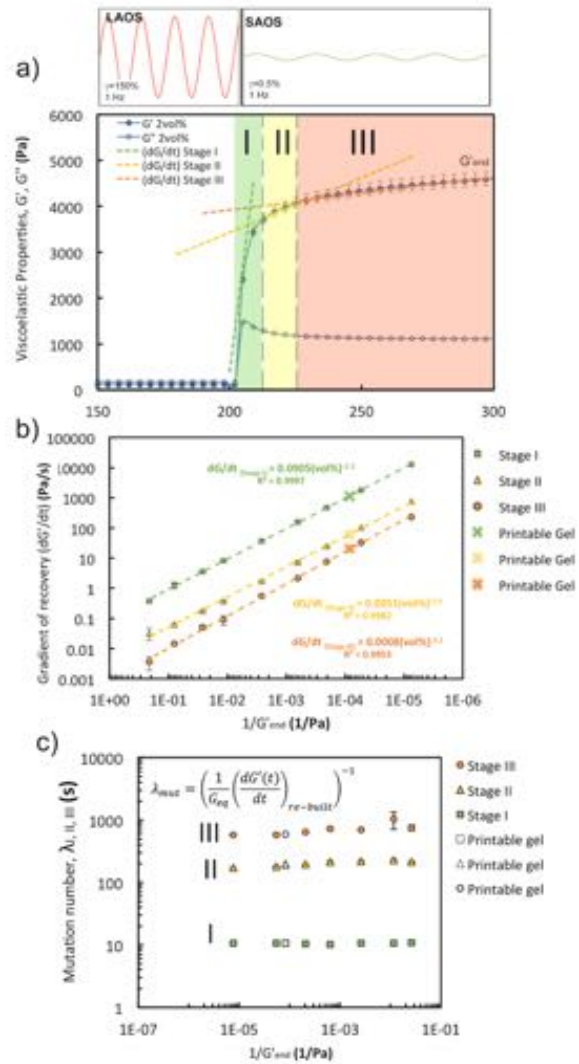

The recovery kinetics scales with G'!

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‘Printability’ of GO networks

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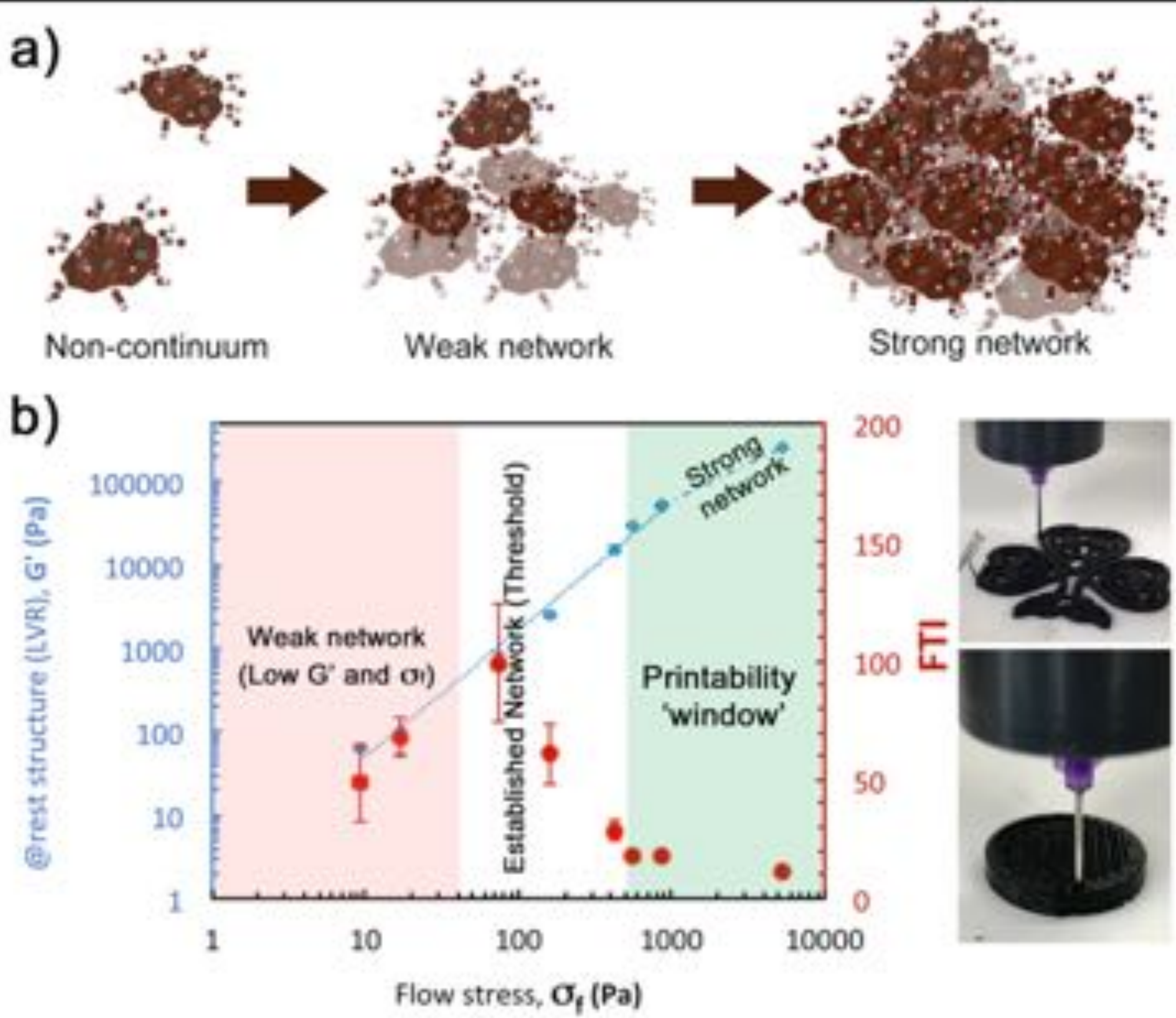
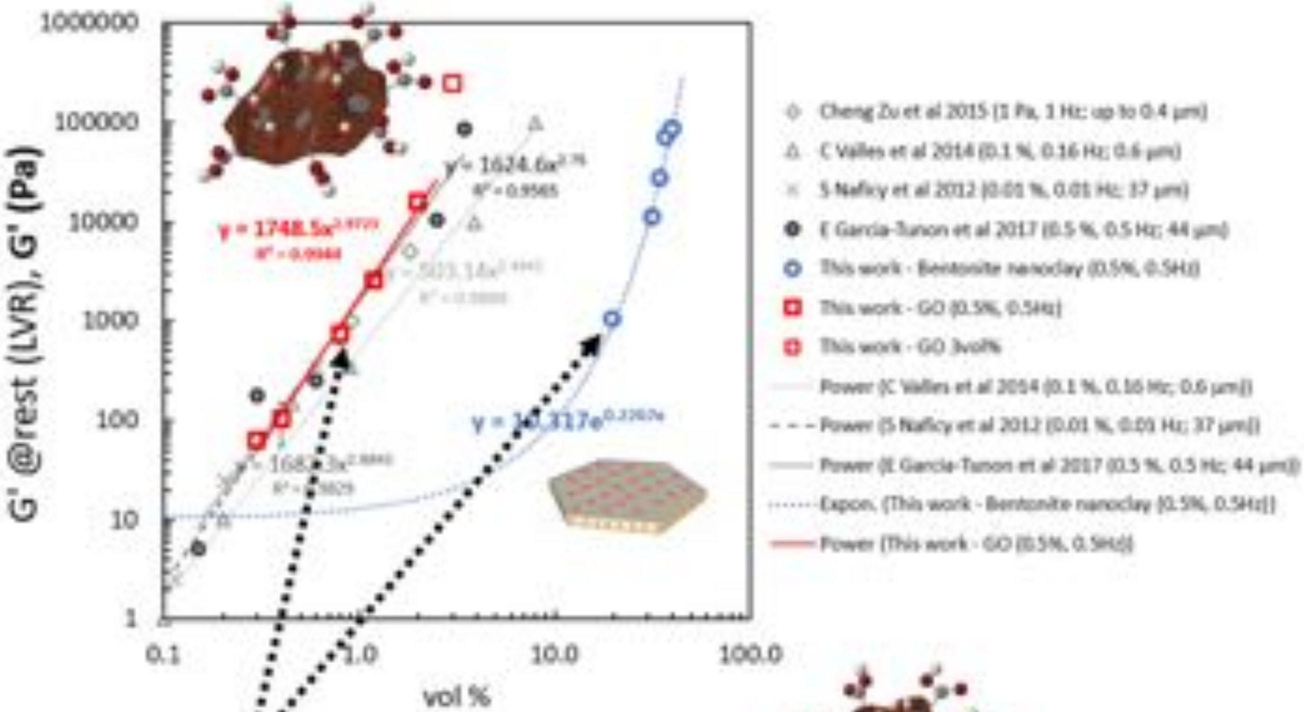
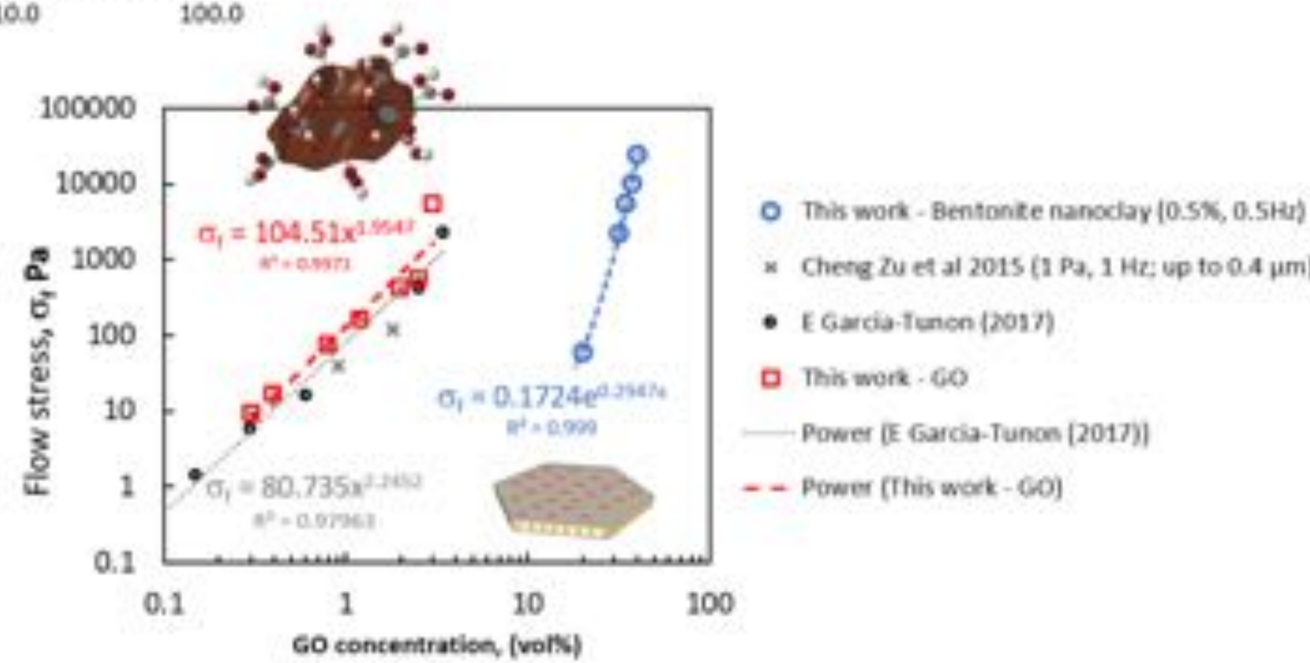


Emerging Investigators 2019. Soft Matter, 2019,**15**, 1444-1456 Andrew Corker, Henry Ng, Robert J Poole & Esther García-Tuñón* ‘3D printing with 2D colloids: designing rheology protocols to predict ‘printability’ of soft-materials’

2D Colloids of Graphene oxide (GO) vs nanoclay

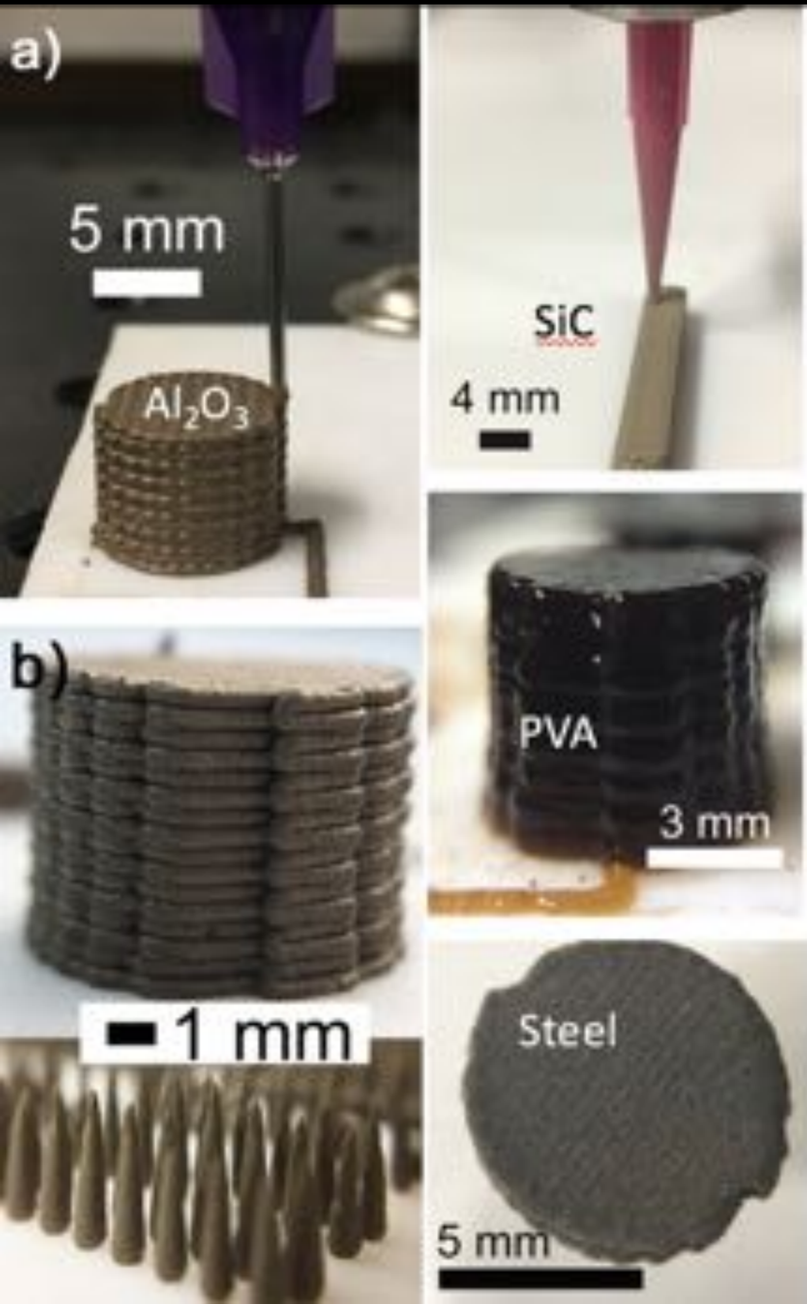


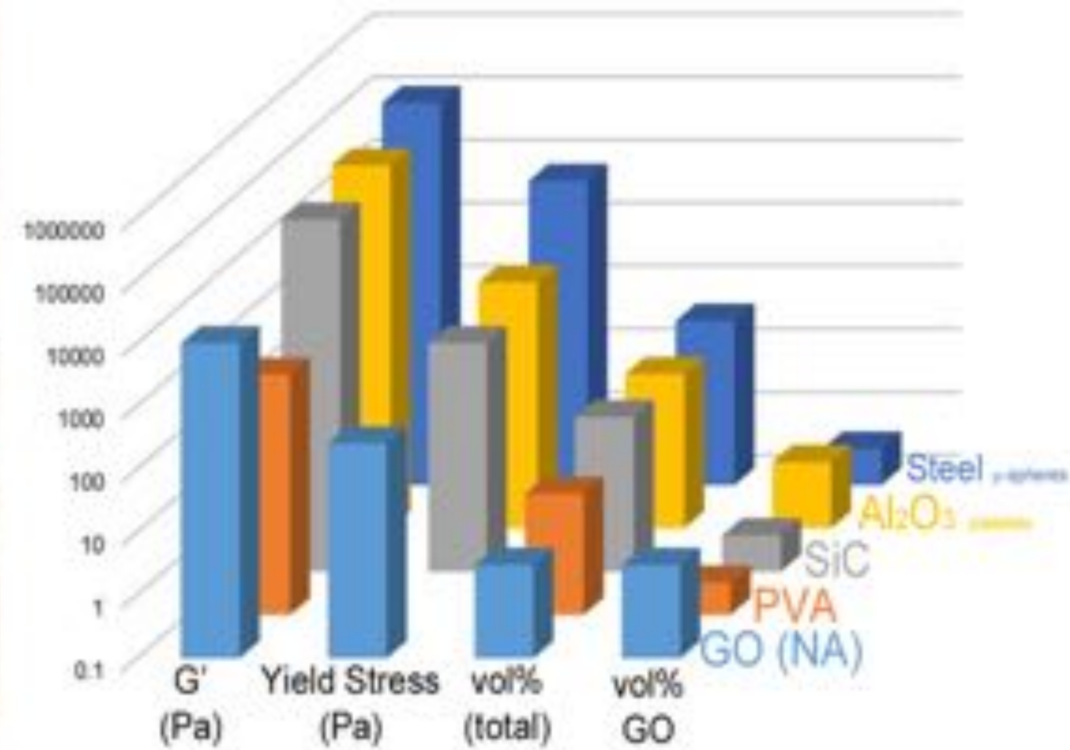
We need 10 times more nanoclay than GO to achieve G' and σ_f values in the same order of magnitude.



Unpublished

GO – multifunctional additive






APPLIED MATERIALS & INTERFACES

Graphene Oxide: An All-in-One Processing Additive for 3D Printing

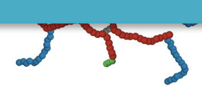
Summary

Library of water-based formulations with tuned rheology to aid the printing of advanced materials (*high added value 3D printing*).

pH responsive

Thermo-responsive
els

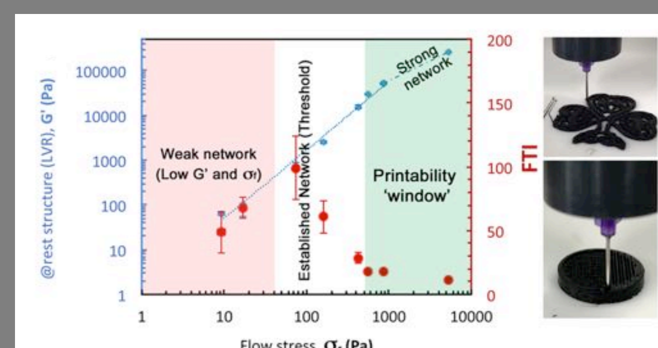
2D colloids



Poster: 'Tuning the rheology of hydrophobic materials in aqueous systems using responsive surfactants' **Emma Jones**

Poster: 'Formulation and 3D printing of carbon-based conductive inks for energy storage devices' **Andrew Corker**

Rheology protocol to quantify 'printability' of GO suspensions based on three rheology parameters:
@rest structure or network stiffness (G'_{LVR}),
flow stress, σ_f (when G'=G''),
and flow transition index FTI ($\sigma_{f/}$ σ_y).



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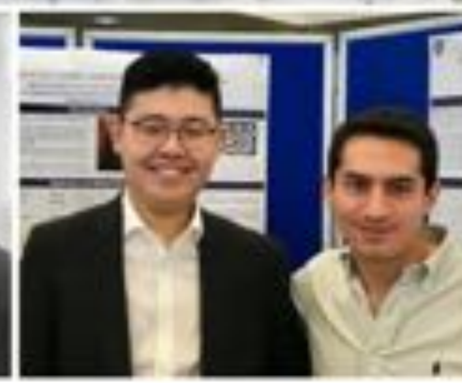
Jack Bentley
Jonathan Colville



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