Battery electrode slurries under flow

A new method for high shear rate and relaxation rheology.

Shelly Tchoutezo[1,2], Dr Carl Reynolds[1,2], Dr Giar Alsofi[1,2], Prof Emma Kendrick[1,2]

[1]School of Metallurgy and Materials, University of Birmingham, B15 2TT

[2]The Faraday Institution, OX11 ORA

1 - We need better batteries

To meet rising demand for advanced batteries in the UK's sustainable energy shift, the automotive sector requires:

☑ Fast Charging Batteries - to reduce vehicle charging times.

☑ High Power Batteries - to produce faster vehicles.

☑ High Energy Density Batteries - to extend vehicle travel range.

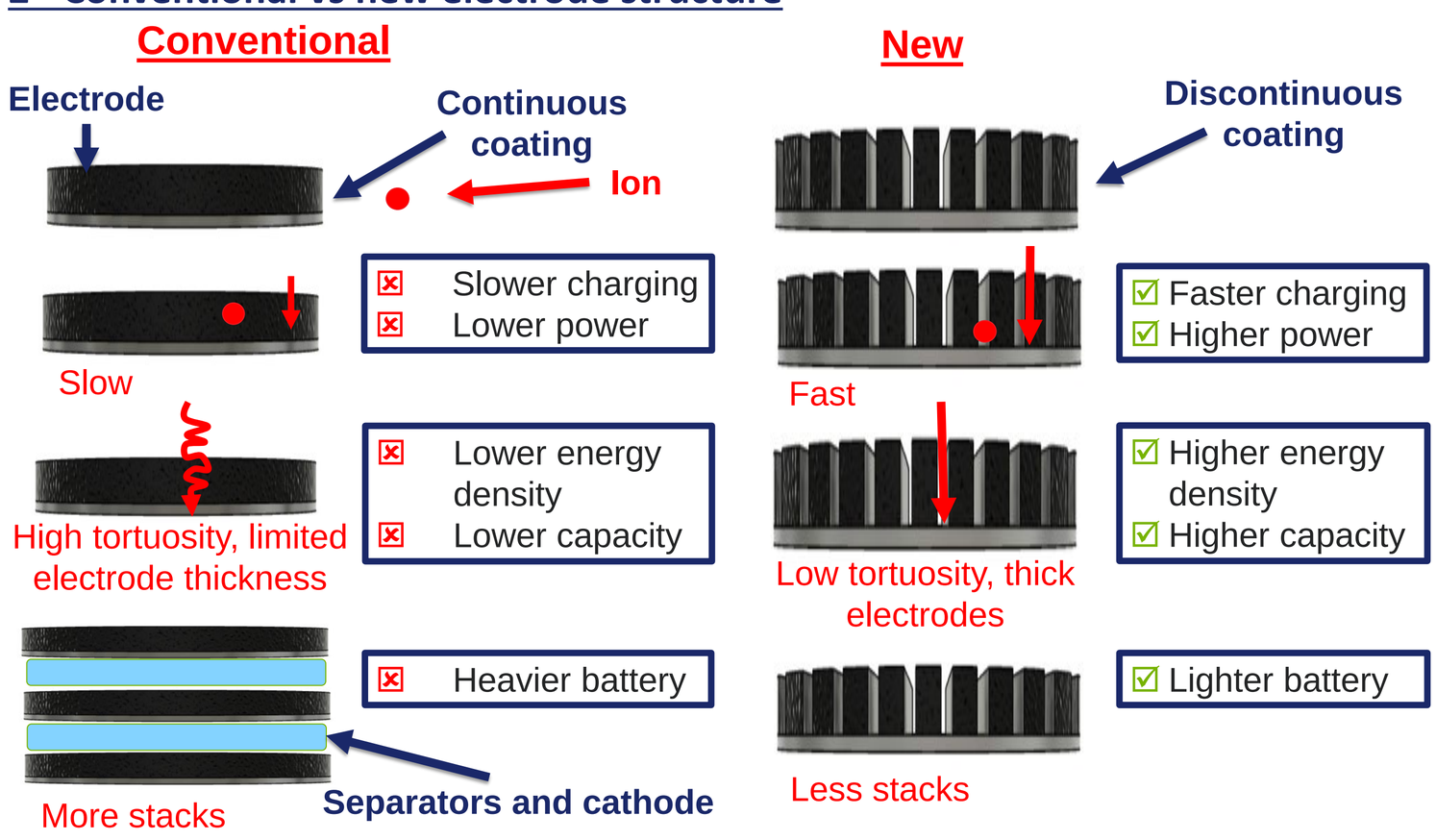
3D printing can meet these demands with smarter electrode structures. [1]

However, shear thinning, and relaxation are 2 behaviors of electrode slurries that can affect this process and thus need investigating.

The current metrology technique has limitations.

Thus, this research aimed to investigate a new metrology technique to extract high shear rate data from flowing anode electrode slurries.

2 - Conventional vs new electrode structure



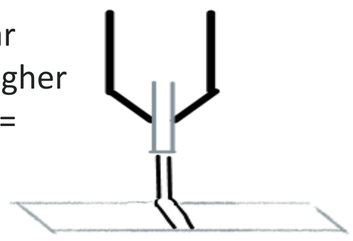
The gaps are crucial for improved performance in the new structure. Hence, the factors affecting gap formation in 3D printing need investigation.

3 - Factors affecting 3D Printing

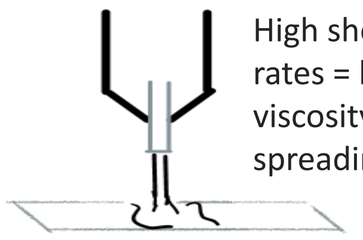
There are 2 rheological behaviors of slurries that can affect the ability to produce gaps during 3D printing.

Shear thinning

Low shear rates = higher viscosity = defined structure



☑ Gaps

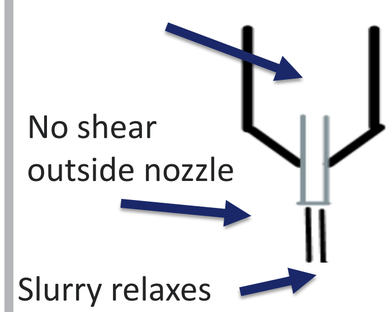


☒ No Gaps

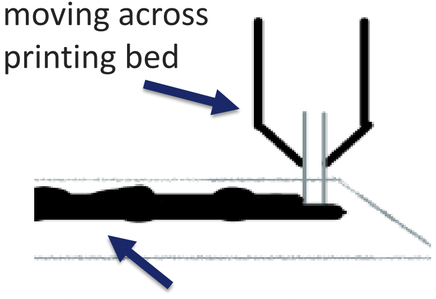
High shear rates = lower viscosity = spreading

Relaxation

Shear inside nozzle



Shear when moving across printing bed



Instabilities if slurry has not fully relaxed

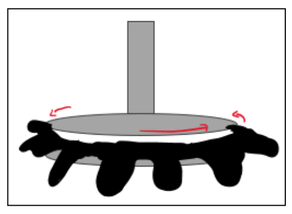
☒ Instabilities affect gaps

We need to understand the effect of high shear rate on viscosity and relaxation as this can affect gap formation.

4 - Methods: current vs new metrology technique

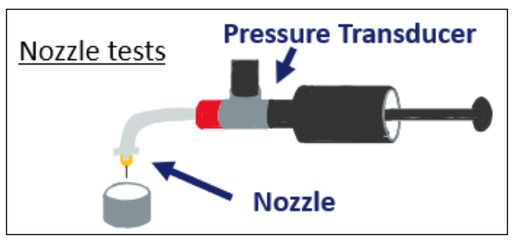
Parallel Plate Rheometer

- If shear rate is too high slurry will spill.

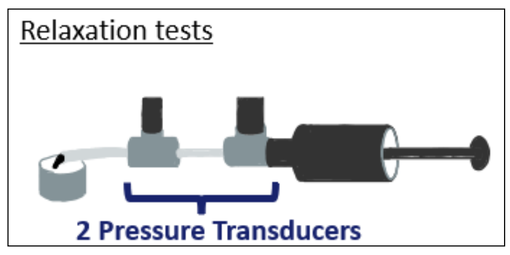


☒ Low shear rate data

Capillary Rheometer



- Slurry can only exit at one end (no spill).
- Tube and nozzle diameters can be decreased, and flow rate can be increased to increase shear rate.



☑ High shear rate data

5 - Results

Table 1: Relaxation behaviour of CMC showing 2 relaxation times.

Relaxation Time (s)	1.5% CMC
Fast	0.001
Slow	32.1

Table 2: Relaxation behavior of Guar showing 3 relaxation times.

Relaxation Time (s)	1.5% Guar
Fast 1	0.001
Fast 2	0.009
Slow	66.5

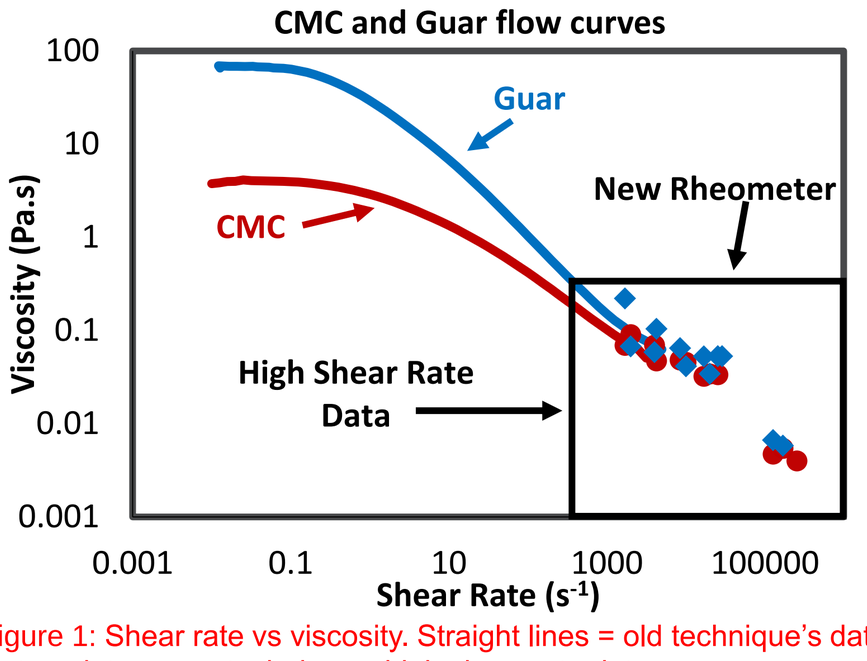


Figure 1: Shear rate vs viscosity. Straight lines = old technique's data. Data points = new technique's high shear rate data.

- The parallel plate rheometer only subjected the binders to shear rates between 1000 – 6000 s^{-1}.
- The new capillary rheometer was able to reach shear rates between 2000 – 250,000 s^{-1}.
- Relaxation tests, performed at 150 ml per min, subjected the binders to shear rates of 25,000 s^{-1}.

6 - Analysis

- Figure 1: Shear thinning in CMC leads to lower viscosities than in Guar. This is undesirable for 3D printing.
- Tables 1 and 2: As Guar is branched it exhibits multiple relaxation times, and a longer slow relaxation than the linear CMC. [2] This can be undesirable. However further study is required on the percentage of Guar's recovery during fast relaxations compared to CMC.
- Viscosity Advantage: Guar's higher viscosity means less is needed to increase viscosity of the slurry. This enables higher active material content, which increases the energy density.

7 - Conclusions

- 3D printing enhances performance with discontinuous slurry coatings.
- A capillary rheometer can be used for suitability assessments by subjecting systems to shear rates of 250,000 s^{-1}, similar to 3D printing conditions.
- Using the data, binder systems for 3D printed slurries can be compared.

8 - Next steps

- Obtain higher shear rate data.
- Compare slurries and optimize 3D printing.
- Add microscopy for further relaxation studies.
- Apply high shear data to the current slot die coating method.

9 - References

- [1] Dunlap, N. Sulas-Kern, D. Weddle, P. (2022) Laser ablation for structuring Li-ion electrodes for fast charging and its impact on material properties, rate capability, Li plating, and wetting. Journal of Power Sources. p.1.
- [2] Reynolds, C. (2018) Rheological behavior of polymer melts and its relationship with underlying structure and topology. Durham e-Theses. p.36.

Intern bio

Shelly Tchoutezo is studying Mechanical Engineering and Materials Science at the University Of Birmingham. She is interested in new methods of storing energy that will pave the way for a net zero future. After graduating, she is hoping to go into the energy sector.

THE FARADAY INSTITUTION NEXTRODE ELECTRODE MANUFACTURING

UNIVERSITY OF BIRMINGHAM

UK Research and Innovation

@Shelly Tchoutezo