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Surfactant Induced Changes on Carbon Black Slurry Electrodes used in Flow Batteries

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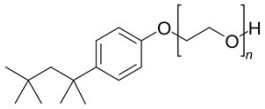
Introduction

Along with many advantages of using carbon black (CB) slurry as a flowing electrode, challenges such as clogging and sedimentation has been observed. Understanding the behavior of slurry electrodes are crucial in improving battery performance.

Non-ionic surfactants have been observed to be good dispersants for carbon black particles.[1] Here, we investigated the impact of non-ionic surfactant (Triton X-100) on CB slurry stability and performance by studying its gravitational settling, rheological response, and capacity/conductivity.

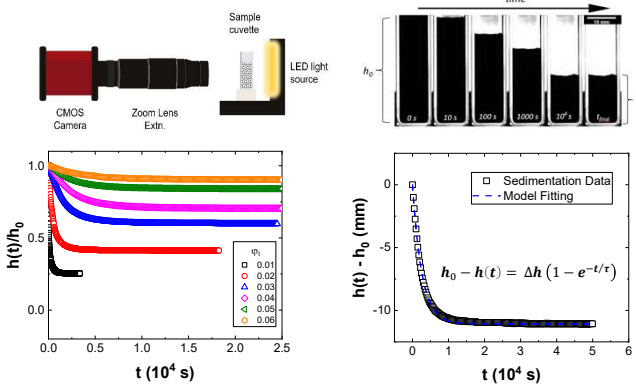
"Clogged" CB slurry



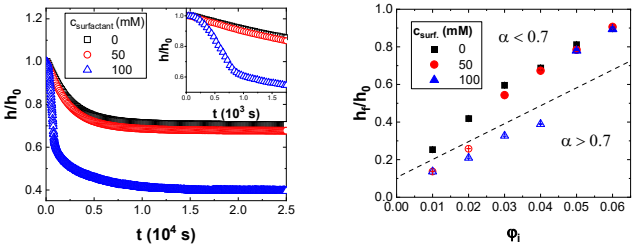
Triton X-100 (n = 9-10)

Slurry Stability - Mechanical Response

1. Sedimentation Experiment



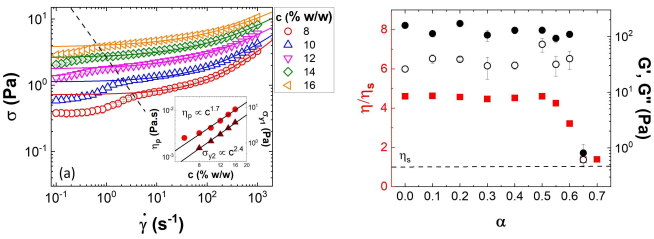
Fits an exponential decay model suggested by Manley *et al.*[2] of a gel collapse



Catastrophic collapse is observed at higher surfactant concentrations where $\boldsymbol{\alpha}\ (\frac{m_{surf.}}{m_{CB}}) \geq \mathbf{0.7}$ due to weak gel formation

2. Rheological Measurements

Flow curve *Gel strength*

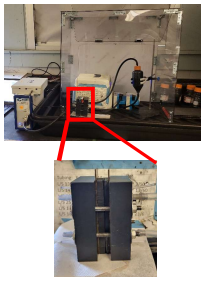


CB particles form percolated network (gelation) but sudden decrease in gel strength observed at $\boldsymbol{\alpha}\ (\frac{m_{surf.}}{m_{CB}}) \geq \mathbf{0.7}$

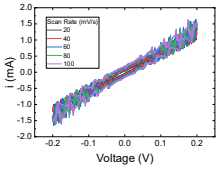
[1] Porcher, W., *et al. Journal of Power Sources*, **2010**, 195, 2835-2843
[2] Manley S., *et al. Physical Review Letters*, **2005**, 94(21).

Flow Battery Apparatus

Flow battery set-up



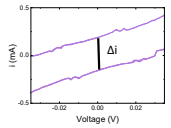
CV scans at different scan rates from -0.2 to 0.2 V



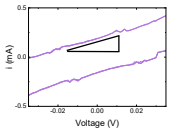
$\frac{\Delta i}{2} = \dot{V} C_{tot}$

$\frac{\partial A}{\partial V} = \kappa$

Capacity



Conductivity

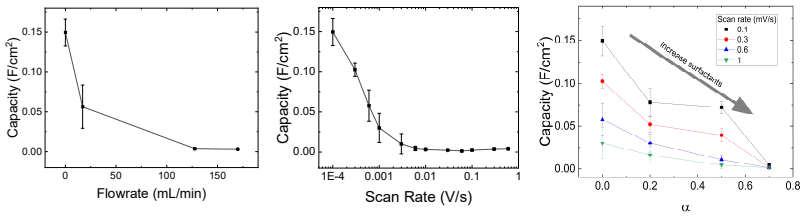


Slurry Performance - Electrical Response

The slurry conductivity and capacity is based on 3 variables:

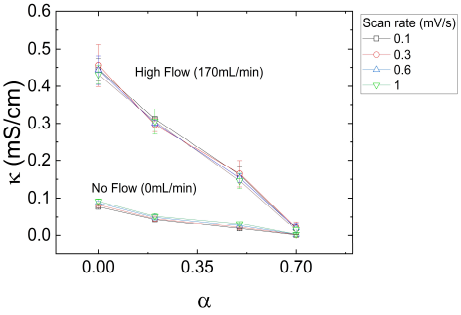
- **Slurry flowrate** – structure and residence time of particles
- **Scan rate** – effective surface area measured
- **Surfactant concentration (α)** – available surface area of CB particles

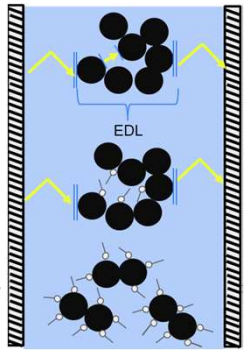
Flowrate *Scan rate* *Surfactants*



Gradual decrease in slurry conductivity observed with addition of surfactants

Conductivity





Conclusion

- CB particles aggregate when dispersed in electrolyte, forming percolated network arising from van der Waals attraction (gel formation)
- Percolated networks are weak and break under gravitational stress, leading to a gel collapse
- With addition of surfactants:
  - Sudden decrease in mechanical response is observed at $\boldsymbol{\alpha} \geq \mathbf{0.7}$ when the mechanical network is disrupted and slurry becomes a low viscosity fluid
  - Gradual decrease in electrical response is observed until $\boldsymbol{\alpha} = \mathbf{0.7}$ where the CB particles can no longer contribute to electrical network of the system

Acknowledgement

This work was funded through the U. S. Department of Energy, Office of Electricity, Pacific Northwest National Lab Contract #540358.

The authors would like to gratefully acknowledge Dr. Imre Gyuk, Chief Scientist of Energy Storage Research in the Office of Electricity, for financial support, and Dr. Akolkar, Dr. Savinell, and Dr. Wainright for their input in the project.