Enhanced Redox Flow Battery Performance By Nitrogen Doping of Graphite Felt Using Choline-Glycine Protic Ionic Liquid

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Introduction:

To mitigate the intermittentness of renewable energy, efficient storage systems like redox flow batteries (RFBs) are required [1]. In the vanadium redox flow battery (VRFB), different oxidation states of vanadium are used within liquid electrolytes and drive the storage and release of electrical energy [2]. However, the VRFB suffers from high costs and low power density [2]. To address this, the performance of the graphite felt electrodes (GF) need to be improved [3]. In this research, the protic ionic liquid choline-glycine ([Ch][Gly]) has been novelly used to dope the GF electrodes of a VRFB by creating nitrogen doped carbon surfaces.

The redox flow battery

The active species are dissolved within liquid electrolytes and drive the storage and release of energy by reaction with inert electrodes. In a VRFB. all active species present are different oxidation states of vanadium (V^{2+}, V^{3+}, VO^{2+}, VO_2^+)

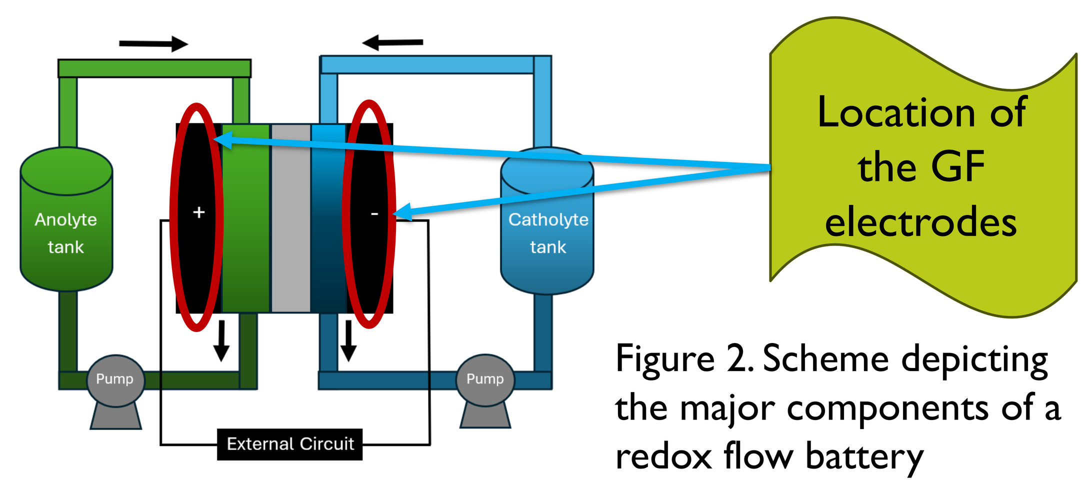


Figure 2. Scheme depicting the major components of a redox flow battery

✓	✗
Long life cycle Energy and power decoupled Deep discharge tolerance	Low power density (GF partially responsible) Uncompetitive £/kWh

Problems with graphite felt

- **Poor reversibility**
- **Small surface area**
- **Hydrophobic**

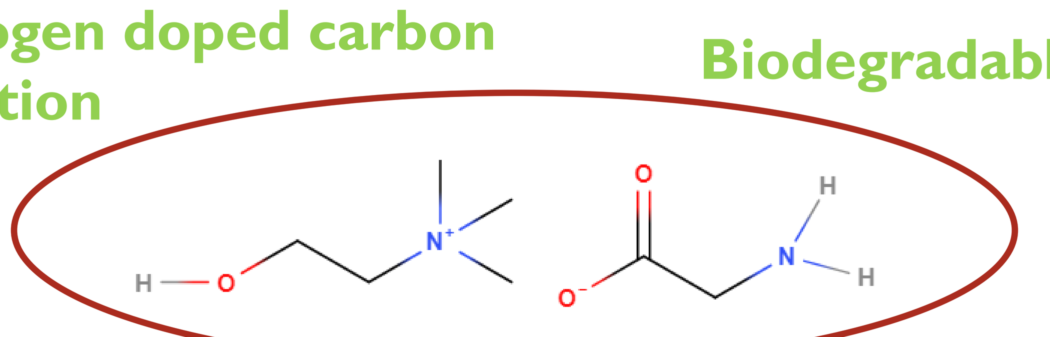
Requires modification!

Figure 3. Image of graphite felt electrode material

Why use Choline-Glycine?

Effective structure for nitrogen doped carbon creation

Biodegradable



Inexpensive

Harmless

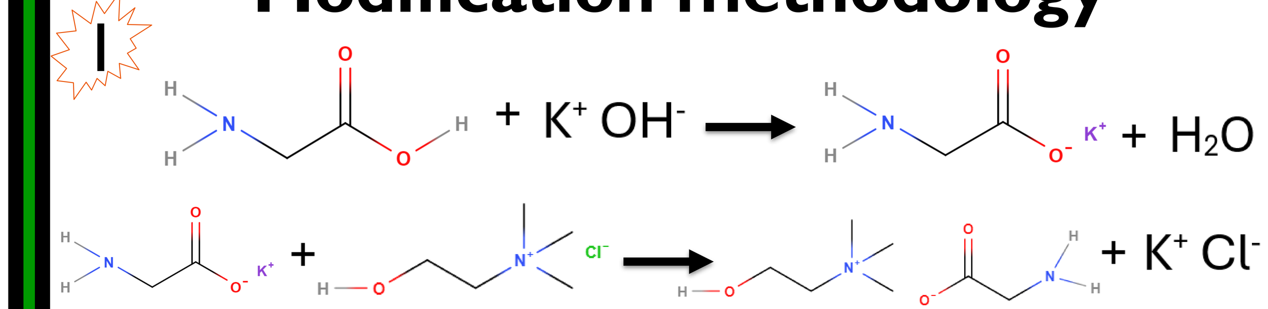
Figure 4. Skeletal formula of Choline-Glycine

Modification methodology

1. Synthesize [Ch][Gly] using a one-pot synthesis methodology
2. Coat thermally activated graphite felt (600 °C, 5 hrs) with [Ch][Gly] utilising the drop-casting technique
3. Conduct pyrolysis on the coated felt (800 °C, 2 hrs, N_2) to decorate with nitrogen-doped carbon (NDC)

Modification methodology

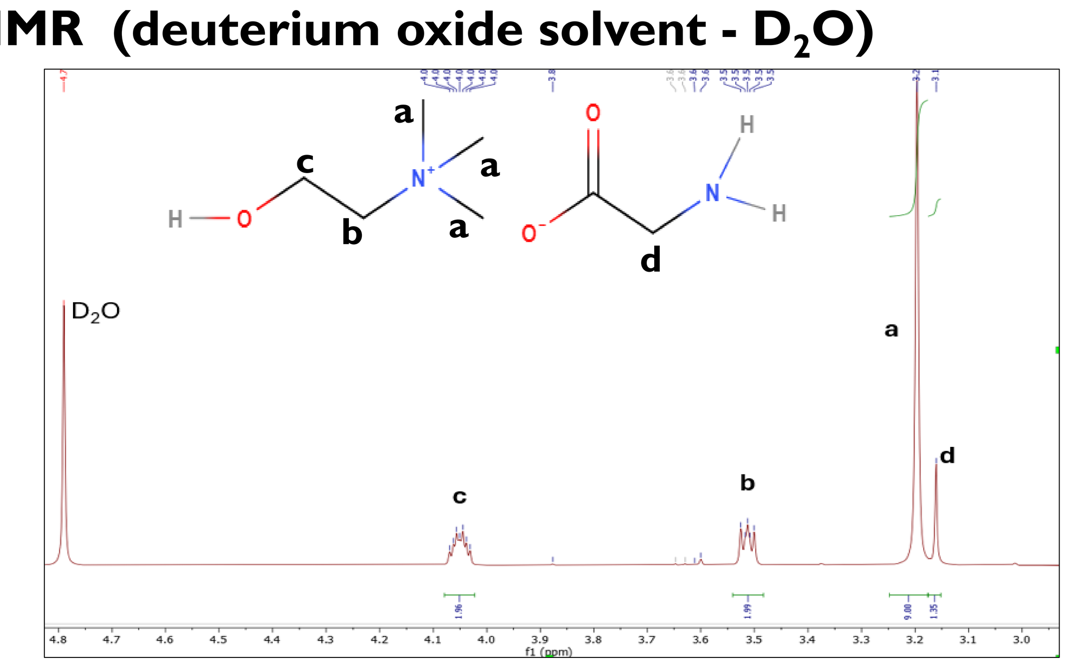
1



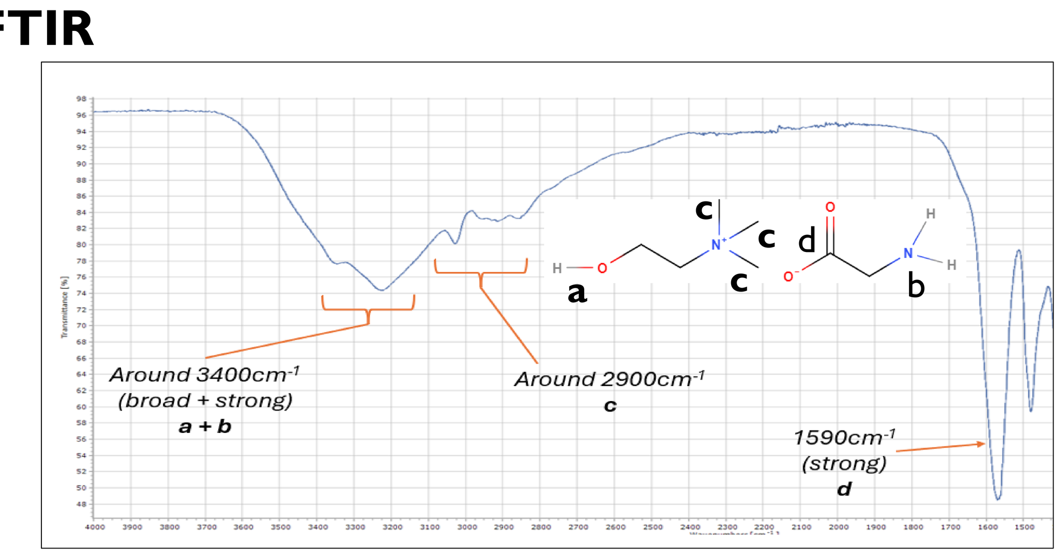
Rotary evaporation (water + ethanol) → Schlenk line

[Ch][Gly] characterisation

NMR (deuterium oxide solvent - D_2O)

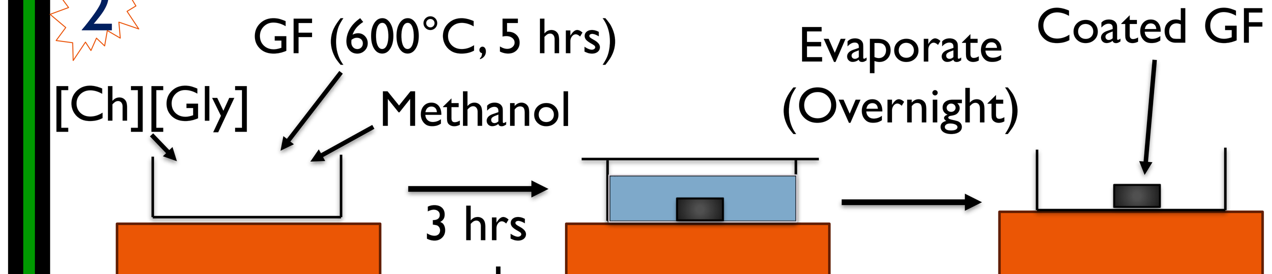


FTIR



The characteristic peaks of [Ch][Gly] are present within both the NMR and FTIR spectrums

2



3

Choline-Glycine coated GF →

→ NDC doped felt

✓ 800 °C ✓ 2 hrs ✓ N_2

SEM and EDX

Location of SEM imaging

Untreated felt

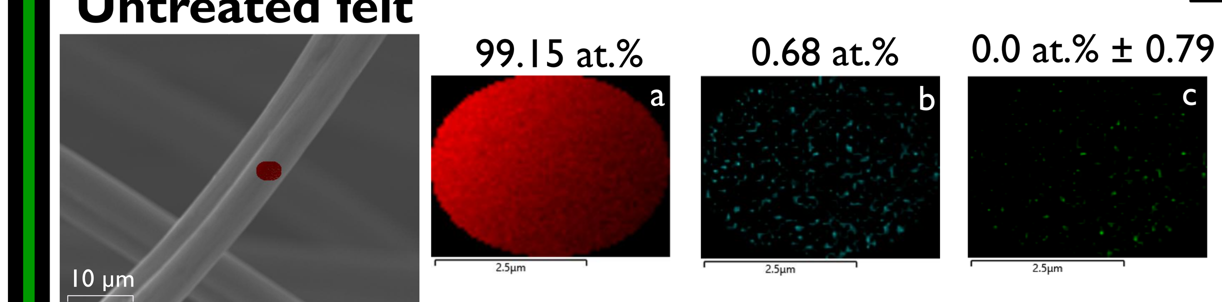


Figure 5. SEM + EDX of untreated felt: (a) carbon (b) oxygen (c) nitrogen (outstanding percentages are trace elements)

Heat treated felt

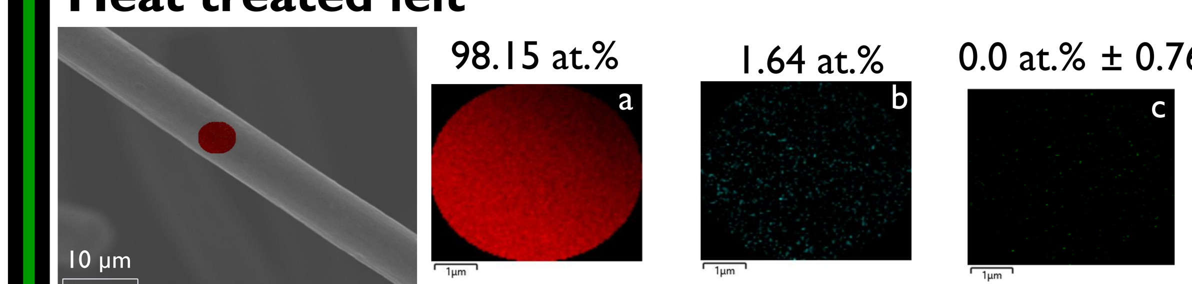


Figure 6. SEM + EDX of thermally treated felt: (a) carbon (b) oxygen (c) nitrogen (outstanding percentages are trace elements)

[Ch][Gly] doped felt

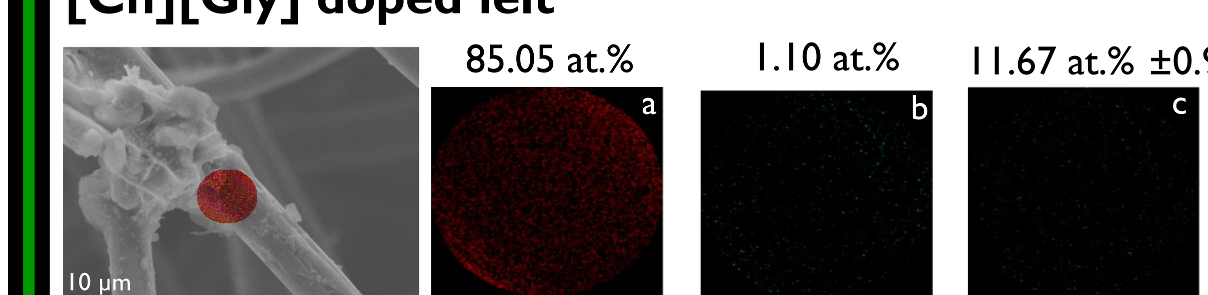
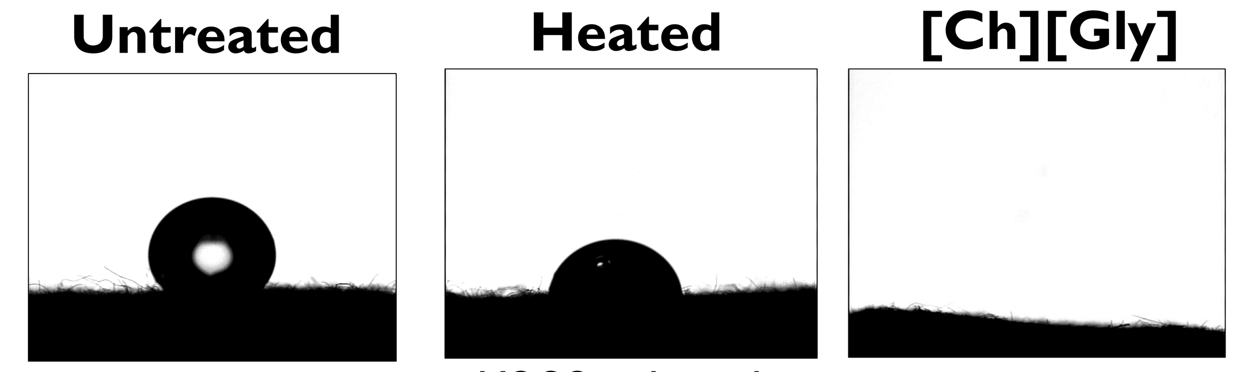


Figure 6. SEM + EDX of [Ch][Gly] treated felt: (a) carbon (b) oxygen (c) nitrogen (outstanding percentages are trace elements)

[Ch][Gly] has significantly increased nitrogen content on the surface of GF.

Contact angle testing



$VOSO_4$ electrolyte

	Water	Electrolyte
Untreated	107°	123°
Heated	47°	51.2°
[Ch][Gly]	0°	0°

[Ch][Gly] NDC decoration makes GF hydrophilic and allows it to completely absorb both water and electrolyte

Future Research

Electrode performance will be measured using cyclic voltammetry, electrochemical impedance spectroscopy and single cell tests. It is expected that there will be at least a threefold improvement in VRFB capacity and no less than a 10% increase in energy efficiency when the current density is 150 mAcm^{-2} [5].

References: [1] Alotto, P., Guarnieri, M., & Moro, F. (2014). *Renewable and Sustainable Energy Reviews*, 325-335.
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