Natural Rubber based solid polymer electrolyte for electrochemical double-layer capacitors

M. Morgan,[1] K. S. Perera[1,2], K. P. Vidanapathirana[1,2], N. Balakrishnan[1]

1. *School of Chemical and Physical Sciences, Keele University, Staffordshire, ST5 5BG, UK.*
2. *Department of Electronics, Wayamba University of Sri Lanka, Kuliyapitiya, Sri Lanka.*

m.d.morgan@keele.ac.uk

Introduction

Ever increasing energy demands ands costs, combined with the depletion of fossil fuels has created demand for the development of a more sustainable electrochemical energy conversion and storage devices [1]. This demand has lead to an increased interest in supercapacitors as an energy storage device, with electrochemical double layer capacitors (EDLCs) [2]. EDLCs have gained prevalence in recent years, particularly those using solid polymer electrolytes (SPEs). This prevalence is attributed in their ability to meet the societal demand for devices that are more environmentally friendly, cheaper and safer. Here we demonstrate the fabrication and characterisation of EDLC contained natural rubber (NR) and sodium triflurومethanesulfonate [$Na(CF_3SO_3)$- NaTF] based SPE.

Preparation of solid polymer electrolyte (SPE)

Electrolyte was prepared via solvent casting method using NR and NaTF with a ratio of NR:NaTF = 1:0.6

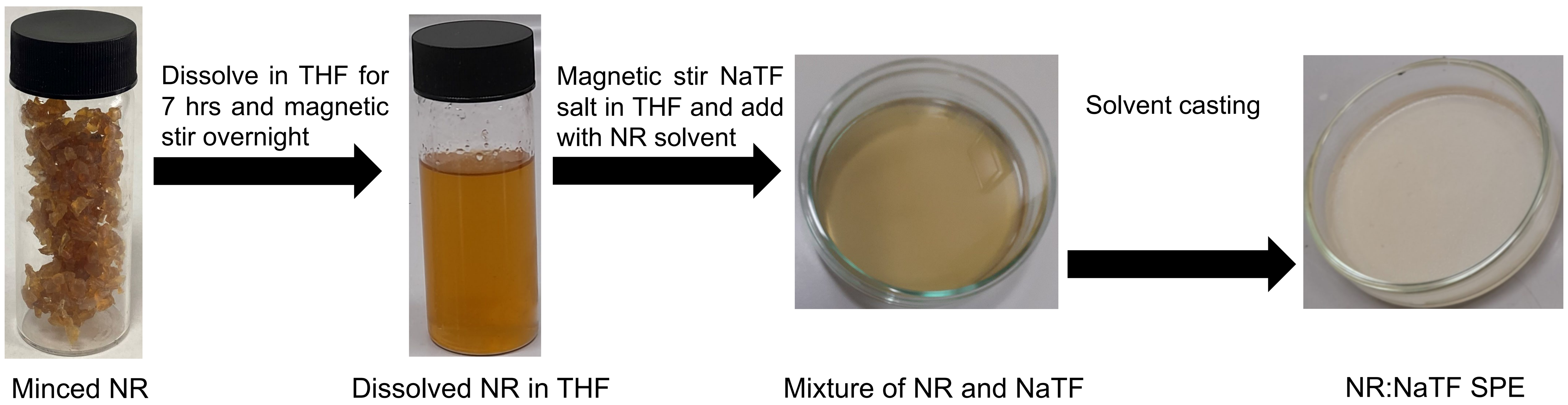
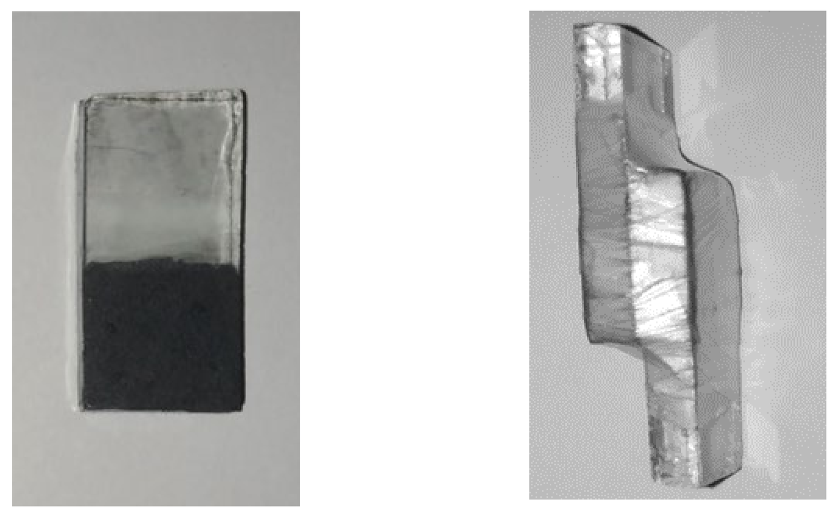


Figure 1: Preparation steps of NR:NaTF based SPE

Fabrication of EDLC

EDLCs were fabricated by sandwiched the SPE between a pair of natural graphite based composite electrodes



Natural graphite based composite coated FTO glass electrode

NR:NaTF SPE sandwiched between 2 electrodes

Figure 2: Optical image of EDLC

Conductivity measurements of SPE

- Circular pellet of SPE was cut from the film and the thickness and diameter were recorded
- Pellet was assembled between two stainless steel electrodes in a Teflon sample holder
- Impedance data was collected using a frequency response analyser in the range of 2 MHz-100 Hz

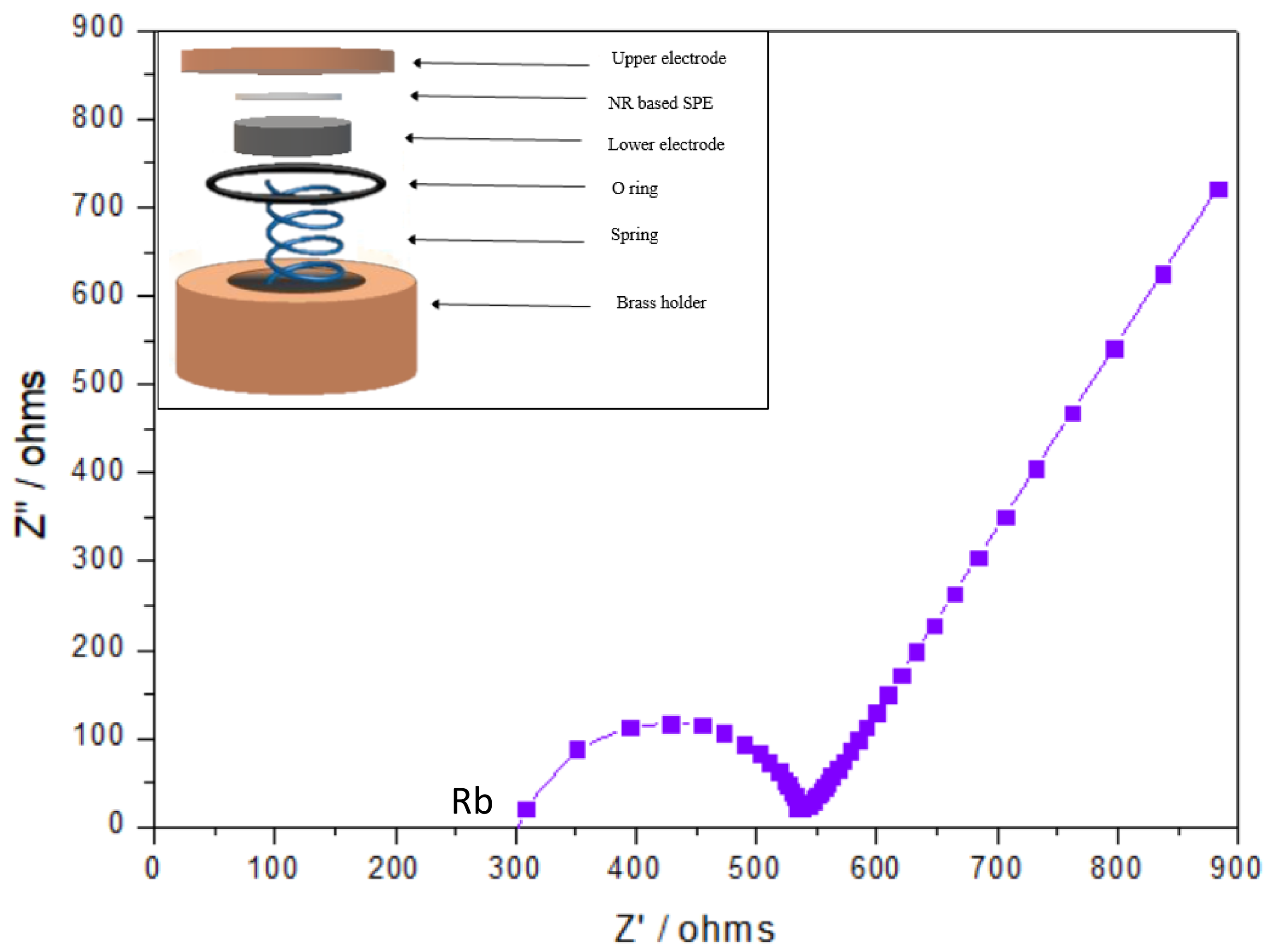


Figure 3: Impedance data of SPE. Inset illustrates the Teflon sample holder

- Impedance data (Figure 3) can be used to determine the value of R_b
- Conductivity can be determined using *eq.* 1, where t is thickness of the pellet and A is the cross-sectional area

$$\sigma = (1/R_b)\frac{t}{A} \qquad \dots\dots(eq.1)$$

- Conductivity was found to be σ = $1.22 \times 10^{-3} Scm^{-1}$ at room temperature

Characterisation of EDLC

- EDLC was characterised using the calculation of single electrode specific capacitance (C_s).
- C_s was calculated using electrochemical impedance spectroscopy (EIS) and cyclic voltrommetry (CV), which gave values of 1.21 Fg^{-1} and 4.57 Fg^{-1}, respectively.
- Difference in C_s is attributed to differences in the characterisation technique such as frequency and scan rate [3].

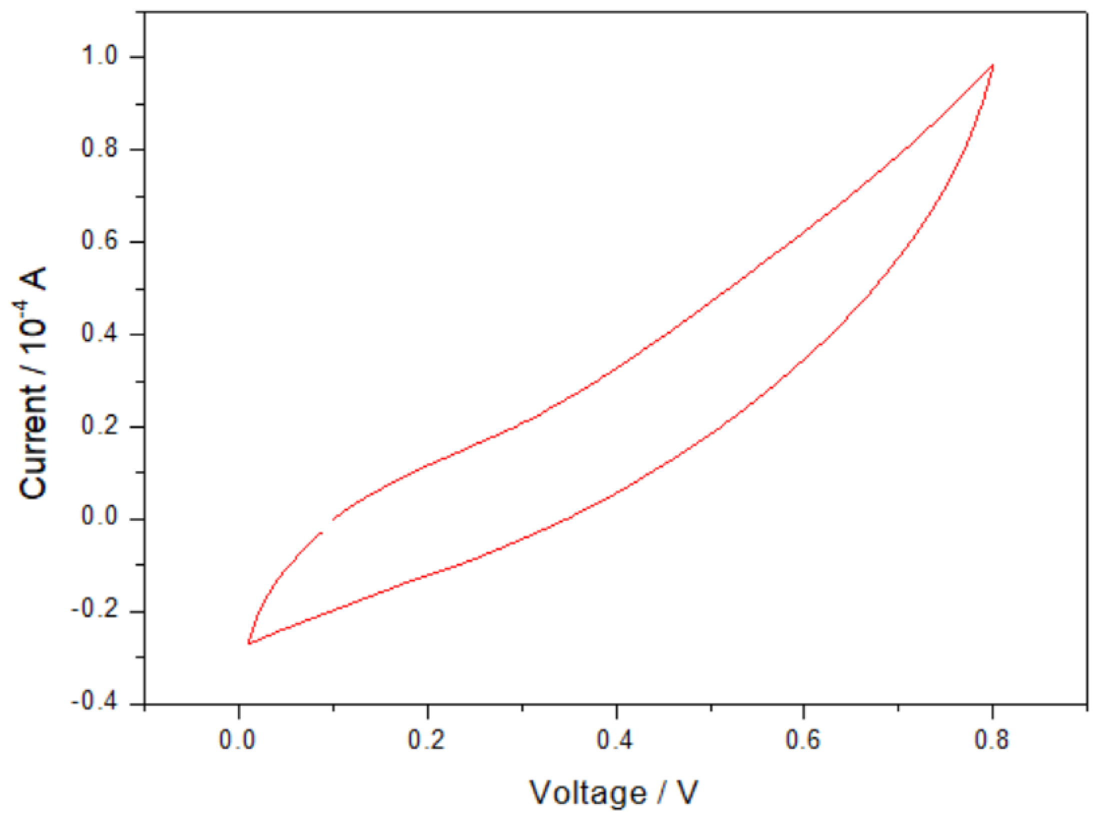


Figure 4: Cyclic voltammogram for the EDLC

C_s was calculated using *eq.* 2, where *s* is the scan rate and *ΔV* is the potential window.

$$C_s = 2(\int IdV)/s\Delta V \qquad \dots\dots\dots(eq.2)$$

- Single spike seen in Figure 5a, denotes the capacitive features of the EDLC [3].
- Resultant bode plot from EIS measurement can be seen in Figure 5b for the real part of the complex capacitance C'(ω) calculated using *eq. 3*.

$$C'_{(\omega)} = \frac{-Z''(\omega)}{[\omega(Z\omega)^2]} \qquad \dots\dots\dots(eq.3)$$

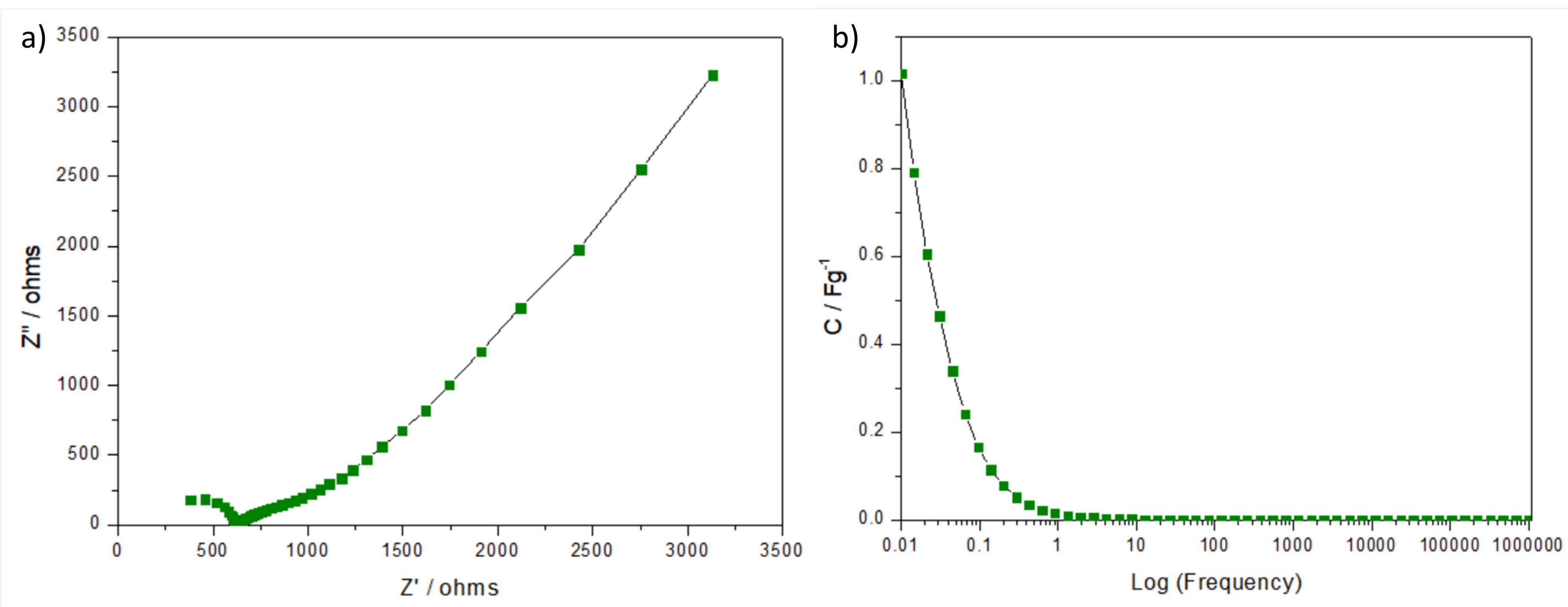


Figure 5: Plots for the EIS characterisation technique. a) Nyquist plot for the EDLC at room temperature. b) Bode plot of C'(ω) vs log frequency for the EDLC

References

[1] T. Palaniselvam, and J. Baek, 2015. *2D Materials*, 2(3), pp.032002.

[2] J. Libich, *et al.*, 2018. *Journal of Energy Storage*, 17, pp.224-227.

[3] H. Rajapaksha, *et al.*, *Journal of Rubber Research*, 24(1), pp.3-12.