EVALUATION OF THERMO-GELATION BY IMPEDANCE SPECTROSCOPY

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INTRODUCTION

Hydrogels have been intensively studied for drug delivery and tissue engineering applications. Of particular interest has been those hydrogels which undergo temperature induced sol-gel transitions and offer the possibility of *in situ* gel formation following injection. The main focus of this work was to evaluate the use of impedance spectroscopy in characterizing the thermo-gelation of hyaluronic acid (HA) and methylcellulose (MC) hydrogels, a system with potential to gel at body temperature.

MATERIALS AND METHODS

HA (0.9-2.0% w/v) and MC (10-14% w/v/) solutions in sodium citrate (SC) 1.75% w/v were prepared by simple addition and gentle agitation at room temperature and then introduced to the gold plated measurement cell having dimensions (width 20.41mm, thickness 4.87mm). Impedance spectra of the solutions were acquired over a frequency range (0.1-10^6 Hz) and a temperature range of 5 °C to 60 °C (at temperature increments of 1°C per scan) using a Novocontrol broadband dielectric spectrometer.

RESULTS AND DISCUSSION

Example impedance spectra for the temperature dependency of one of the hydrogels are given in Figure 1 (Impedance is a complex quantity comprising real and imaginary vectors; here we show the real part only). In all spectra, the impedance spectrum increases steeply at frequencies below 1 kHz which is a consequence of the predominance of the electrode interfacial impedance on the overall response.

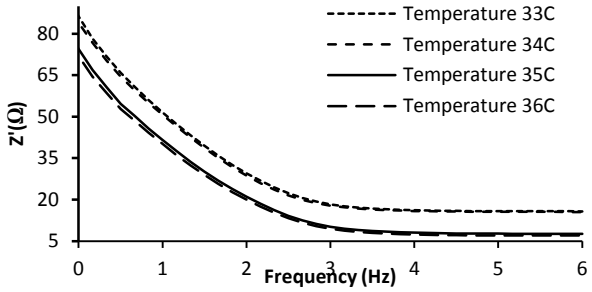

Fig.1 Real part impedance (Z′) spectra of the hydrogel comprising: 2% w/v HA and 10% w/v MC in 1.75% w/v SC

At higher frequencies the real part impedance (Z') plateaus at values which approximate to that of the sample resistance. In general a plot of the real part impedance (Z') at a representative frequency (say 10 or 100 kHz) against temperature would provide a convenient way in which to assess changes in sample resistance (R) at the gel point (Fig. 2). A distinct reduction in resistance occurs at a 34-35 °C, the temperature that corresponds to sol-to-gel transition (as was determined by other methods, including test tube inversion). The temperature coefficient below this transition (when the sample is in the sol state) is predictably higher than that above the transition (when the sample is in the gel state).

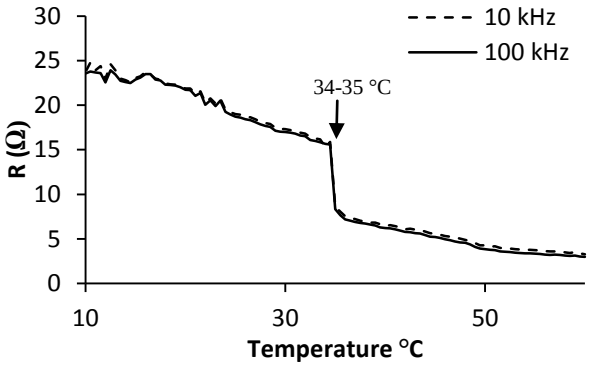

Fig.2 Temperature dependence of the sample resistance, R, taken from the 10 and 100 kHz frequency points from the real part impedance spectra.

Displaying the sample resistance on an Arrhenius plot (Fig. 3) shows that the activation energy for the principle charge transport mechanism increases by a factor of 2 from 16 to 31 kJ.mol^{-1} (as the temperature is raised through the gelation temperature). This is a probable consequence of the molecular rearrangements leading to the formation of the gel matrix (1).

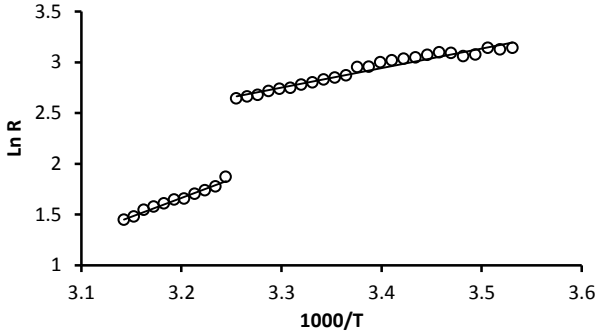

Fig.3 Arrhenius plot of sample resistance showing the change in activation energy for thermally activated charge transport at the gelation temperature.

CONCLUSION

This work clearly demonstrates the utility of impedance measurements in the characterization of thermo-gelation of hydrogels.

ACKNOWLEDGMENTS

Dr Marlow was a Gunn and Carter fellow at De Montfort University when undertaking this research, and was funded by the alumni of De Montfort University.

REFERNCES

1. Alexe-Ionescu AL, Barbero G, Freire FCM, Merletti R. Effect of composition on the dielectric properties of hydrogels for biomedical applications. Physiological Measurement. 2010;31(10):S169.