

### Effects of Temperature on Electrochemical Double Layer Capacitor Performance using Activated Carbon Electrodes

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Activated carbon (AC) has received considerable interest as a possible electrode material for electrochemical double layer capacitors (EDLC). AC is a highly porous carbonaceous material which presents very high specific surface area and good conductivity<sup>[1]</sup> making it ideally suited for an EDLC electrode. Two types of AC were used in this analysis, the first was generated from waste petroleum fluid coke through chemical activation using potassium hydroxide and the second was coconut shell derived AC generated with CO<sub>2</sub> activation. The electrodes were fabricated using 90 wt% AC, 6 wt% carbon black and 4 wt% PTFE.

The effectiveness of the EDLC design is partially determined by the capacitance and the equivalent series resistance (ESR). To increase the energy density of the EDLC, the capacitance must be increased, while the equivalent series resistance must be minimized to avoid losses during charging and discharging. The goal of this research is to determine the effects of temperature on the EDLC's overall equivalent series resistance and capacitance.

The equivalent series resistance and capacitance are derived from Galvanostatic-Cycle (GC) charge and discharge analysis. The capacitance is also determined using cyclic voltammetry analysis for comparison to the GC results. Thermal Analysis was performed on three different electrolytes, 4 M aqueous potassium hydroxide solution, 1 M tetraethylammonium tetrafluoroborate in acetonitrile, and an inorganic molten salt. This data was used to determine if the effects of temperature on equivalent series resistance and capacitance are consistent among the different electrolytes. As well, the data was used to identify potential models and values for the activation energy of charging and discharging.

Analysis with coconut shell derived AC in 4 M potassium hydroxide electrolyte illustrates that the equivalent series resistance of the cell decreases with increasing temperature, whereas the capacitance of the cell increases with increasing temperature, as seen in Figure 1 and Figure 2.

The resistivity of the electrolyte is affected by changes in solution properties that take place when the temperature is varied – temperature change causes alterations in the electrolyte density, viscosity, charge dissociation, dielectric constant and ion mobility. In general, the electrolyte resistivity decreases as the operating temperature increases. The equivalent series resistance of the cell increases as the resistivity of the electrolyte increases for the 4 M KOH electrolyte with coconut shell derived AC electrodes. The relationship between resistivity and the cell's equivalent series resistance is linear, as seen in Figure 3. These results suggest that the overall equivalent series resistance of the EDLC device is proportional to the electrolyte resistance to ion transfer. Therefore, by minimizing the resistivity of the electrolyte, a decrease in the equivalent series resistance will be observed.

Therefore, by increasing the operating temperature of the aqueous electrolyte based EDLC, the overall capacitance is increased, while the equivalent series resistance is decreased. As a result, the increased operating temperature leads to improved energy and power output from the electrical energy storage device.

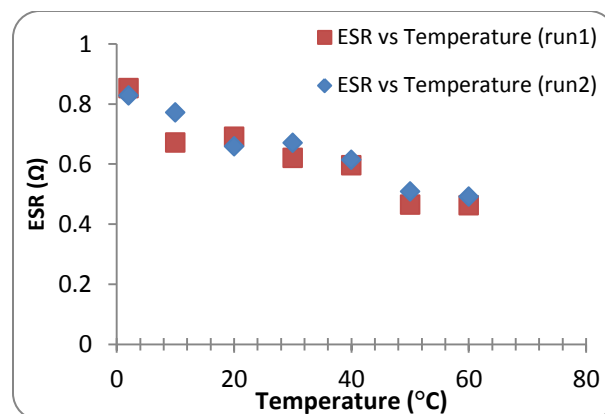


Figure 1 - Effect of Temperature on Equivalent Series Resistance for EDLC with Coconut shell derived AC electrodes and aqueous 4 M KOH electrolyte. The ESR was measured using GC analysis.

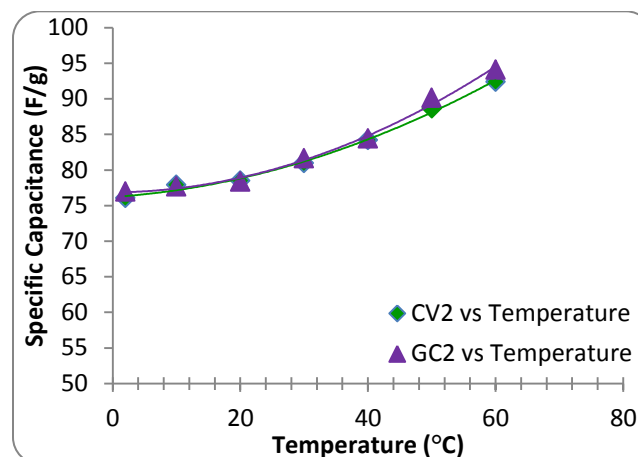


Figure 2 - Effect of Temperature on Specific Capacitance for EDLC with Coconut shell derived AC electrodes and aqueous 4 M KOH electrolyte. The Capacitance was measured using CV and GC analysis

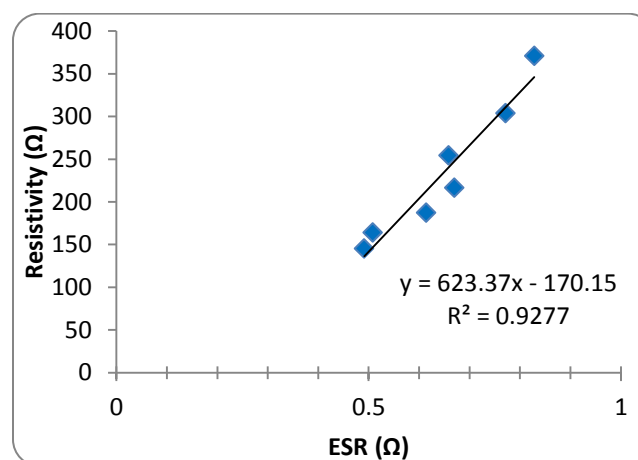


Figure 3 - Relationship between Resistivity of 4 M KOH electrolyte and Equivalent Series Resistance of EDLC in 4 M KOH electrolyte with Coconut Shell derived AC electrodes

#### Reference

[1] Ghosh, A.; Lee, Y.H. ChemSusChem. 480 (2012), 5.