# The Influence of Porosity and Ionic Conductive Additives on the Apparent Diffusion Coefficient in Hard Carbon Electrodes in Sodium Ion Batteries

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The most commonly used anode material in sodium ion batteries is hard carbon. Hard carbon offers a potentially sustainable anode material derived from organic materials such as coconut shells [1]. As hard carbon is a non-graphitic carbon, the distance between single graphene sheets is larger than within graphite and the mixed $sp^2$ and $sp^3$ hybridization leads to a cross-linking between the layers and a lack of long range ordering in the c-direction. This decreases the average resistivity of the hard carbon particles compared to graphite [2].

Study of both ionic and electronic properties of composite electrodes rather than active material alone are often neglected. Galvanostatic intermittent titration technique, electrochemical impedance spectroscopy and galvanostatic cycling were used to characterize different compositions of hard carbon electrodes with different electronic and ionic conductive additives. These show different apparent diffusion coefficients, surface layer formation, and ohmic resistance depending on state of charge and state of health. Further, the influence of electrode parameters such as tortuosity, porosity and volume changes on rate capability have been investigated to identify the limitations of hard carbon. An example of changes in diffusion coefficient is shown in Figure 1. In future, the outcome of these experiments will be used to modify electrode parameters to further improve the cycle life and cycling performance required by the desired applications.

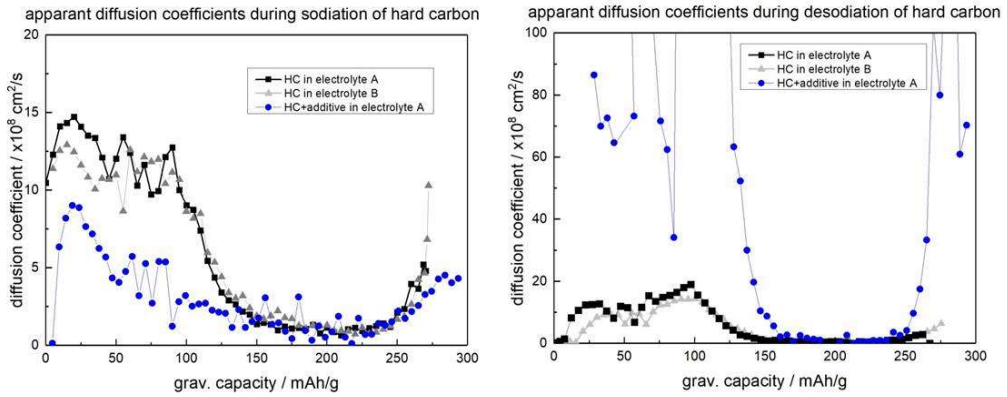


Fig 1. Apparent diffusion coefficients during sodiation (left) and desodiation (right) for three different test cells; black squares: standard HC electrode in electrolyte A; grey triangles: standard HC electrode in electrolyte B; blue circles: HC electrode comprising an ionic conductor in electrolyte A.

**References:**

[1] Y. Li, Y.S. Hu, M.M. Titirici, L. Chen, and X. Huang, Adv. Energy Mater., (2016) 1-9.
[2] H. O. Pierson, in: Handbook of carbon, graphite, diamond, and fullerenes: properties, processing, and applications, William Andrew, 1993, p. 61.