Hard Carbons for Li-, Na-, and K-ion Batteries

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Non-graphitizable carbons (i.e. hard carbons) have been studied as a negative electrode material of Li-ion batteries used in high-power applications such as HEV. In 2001, electrochemical Na intercalation into hard carbon was first reported by Stevens and Dahn [1]. In 2009, our group succeeded in demonstration of the satisfactory practical performance for 3 volt Na-ion battery by using a commercially available hard carbon [1]. Now, hard carbon is regarded as a promising candidate for practical sodium-ion batteries. Furthermore, a first report on K insertion into hard carbon just appeared in 2016 [2], which follows our lead report on electrochemical reversible K insertion into graphite on Al current collector [3]. In this study, we prepared hard carbons at different carbonization temperature and investigate the temperature dependency on their structure and electrochemical performance in alkali-metal cells.

Hard carbons were prepared by carbonization of sucrose at 700 - 2000ºC and tested in non-aqueous Li, Na, and K cells as seen in Figure 1. All of them show redox activity of alkali insertion in the voltage region between 0 and 1.5 V which would be acceptable for alkali-ion battery application. Because sodium hardly intercalates into graphene-stacked layers, sodium insertion into nano-sized pore is thought to be important. Due to the smallest atomic size of lithium, the larger specific capacity are observed whereas potential hysteresis appears as generally known. Potassium cells demonstrate about 250 mAh/g which is comparable to the graphite case to form KC_8. We will further discuss details structural and electrochemical properties of the hard carbon electrodes including functional binders.

References

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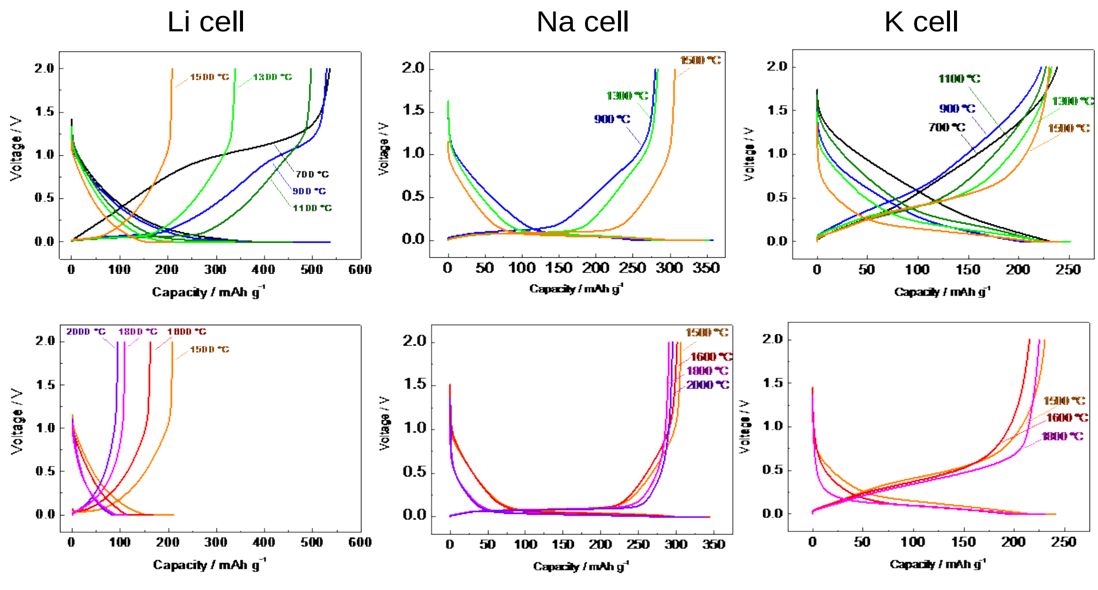

Figure 1. Second charge/discharge curves of hard carbons, prepared from sucrose at different carbonization temperatures, tested in Li/Na/K half-cells with 1 M $LiPF_6$/EC:DMC (1:1), 1 M $NaPF_6$/PC and 1 M KFSI/EC:DEC (1:1) electrolytes, respectively, at room temperature.