High-voltage High-power Battery Cathode Based on PF_6^- Intercalation into Graphite

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High-voltage cathode materials such as $LiNi_{0.5}Mn_{1.5}O_4$, $LiCoPO_4$ that are based on lithium intercalation have been widely studied for lithium-ion batteries (LIB), but these materials contain transition metals that are not environmental friendly. Carbon, in the form of graphite, can also be used as cathode material in LIB because the graphitic layer can accommodate anions such as PF_6^- with a potential above 4.5V vs. Li/Li^+. This has given rise to the idea of a dual-carbon battery (DIB) where both the cations and anions are inserted into respective electrodes during charge, and released back into the electrolyte during discharge [1]. Because the ions do not have to traverse from one electrode into another during charge and discharge, DIB is expected to have high-power capability (see Fig. 1a).

In this study, we investigate the effects of different factors such as particle size, voltage range, salt content, binder type etc. on PF_6^- intercalation into graphite. Capacity is increased by increasing the surface area of the graphite material. Electrical conductivity and stability are enhanced with carbon addition in the electrode with reduced cut-off voltage. Operating voltage is reduced by increasing the salt concentration, and ionic conductivity is improved with the use of carboxymethyl cellulose as binder. Optimized graphite electrode delivers a capacity of about 90 mAh g^{-1} at 10 mA g^{-1}, and 90% of it can still be accessible at a rate of 500 mA g^{-1}, with excellent cycle stability for at least 200 cycles. The dual-ion battery is demonstrated to give power density superior to that of lithium-ion battery, and energy density superior to that of supercapacitor [2].

In addition, we also found that the charge-discharge potentials are highly influenced by the type of solvent. Ethylene carbonate and propylene carbonate raise the potentials for PF_6^- intercalation and de-intercalation, and reduces capacity of the graphite electrode. Investigation of the charge-discharge mechanisms is underway and will be presented at the presentation.

References

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2. C. Y. Chan, P.-K. Lee, Z. Xu & D. Y. W. Yu, Electrochim. Acta 263 (2018) 34-39.

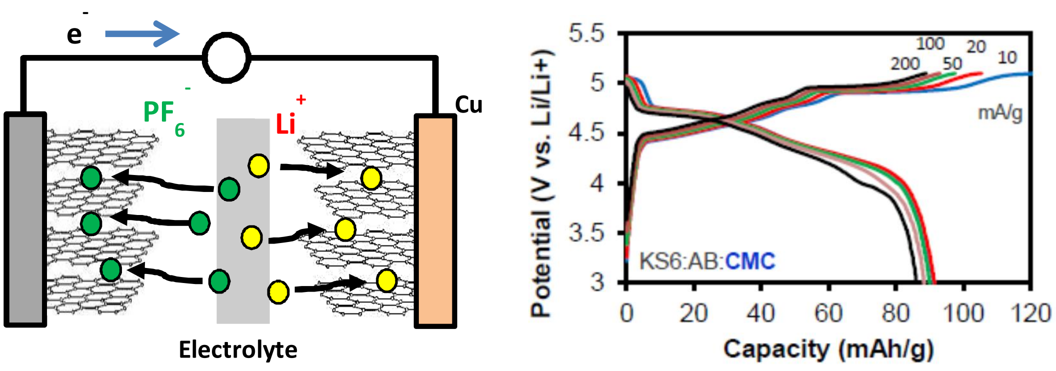

Figure 1. (a) Schematics of a dual-ion battery and (b) rate performance of KS6:AB:CMC electrodes with 3M $LiPF_6$ FEC/DEC = 1:1.