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Ionic Liquids as electrolyte additives for Li-S battery applications

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Among all the available secondary battery systems, lithium-sulfur (Li-S) couple is quite attractive due to the usage of elemental sulfur as cathode. Sulfur is an important candidate that has the ability to accommodate two Li^+ ions according to the non-topotactic assimilation reaction: $16Li+S_8 \leftrightarrow 8Li_2S$ [1]. The theoretical capacity of sulfur cathode as per the proposed redox reaction can be calculated to be 1672 mAh/g, which represents a minimum of three to fourfold increase over the state of the art Li-ion battery cathode materials. Also, unlike other transition metals, sulfur is inexpensive and eco-friendly which makes it more attractive as a cathode candidate for next generation Li-ion batteries. Despite the excellent specific capacity and energy density, sulfur has practical impediments that prevent the material from achieving commercial status. Additional advantages of using sulfur as the cathode are its intrinsic protection mechanism from overcharging, which enhances battery safety, wide operating temperature range, and the potential for a long life-cycle.

The primary setback with sulfur, which is known to form more than 30 solid allotropes, is its insulating property. It restricts active material utilization as a result of poor electrochemical contacts within the material. The second detrimental problem is the dissolution of intermediate charge/discharge lithium polysulfide products (Li_2S_x, $4\leq x\leq 8$) in the electrolyte that leads to decreased utilization of the overall active material during discharge, triggering parasitic side reactions with Li metal anode, poor cycleabilty, and reduced columbic efficiency. The third is the possible dendrite formation due to the use of lithium metal as the anode, which poses serious safety concern.

To overcome these issues, sulfur is nano-structured into a suitable conductive matrix (such as: meso-porous carbon and conductive polymers). In this work, several carbon hosts are investigated to sequester sulfur. Figure 1. depicts the capacity *vs* voltage plots for various carbons. It is clearly evident that the type of carbon drastically affects the charge/discharge characteristics of Li-S batteries. We will present how specific properties of carbon affect the performance of the Li-S battery. Electrolyte plays a major role in dictating the overall performance of Li-S battery. Intermediate charge/discharge products (poly sulfides) dissolve in the electrolyte and diffuse to Li anode surface and form insoluble lower order sulfides. This process is detrimental and results in low coloumbic efficiency and poor cycle life.

Additives like $LiNO_3$ and P_2S_5 showed improved cycle life and coloumbic efficiencies by protecting the Li-anode. In this study, we investigated several ionic liquids as electrolyte additives to improve the Li-S battery performance. Electrochemical and spectroscopic studies will be presented to reveal the effect of ionic liquid additives on Li-S battery performance.

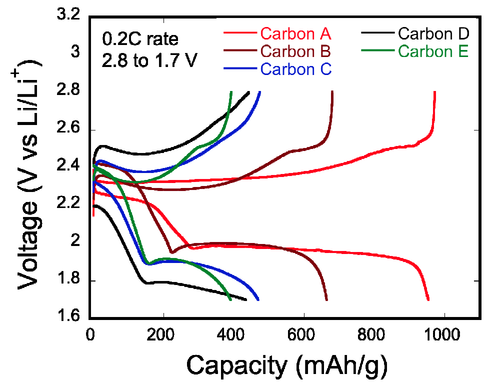

Figure 1. Charge/discharge plots for different carbon hosts. Capacity is calculated based on the sulfur weight percentage (70%) in the cathode.