Lithium-sulfur (Li-S) batteries represent one of the most promising technologies to meet the needs for large scale energy storage systems such as transportation applications. Major hurdles to overcome in developing Li-S batteries with long cycle life is achieving close to theoretical capacity, and minimizing capacity fading of the sulfur electrode upon discharge/charge cycling. This is mostly due to the diffusion of the active mass in the form of soluble polysulfide anions ($S_{n}^{2-}$) from sulfur electrode into the organic electrolytes. To address this problem, sulfur has been encapsulated in carbon/sulfur nanocomposites based on various nanoporous carbons. $^{1,2,3}$ The carbon host provides not only good electronic/ionic conductivity but retards polysulfide diffusion. However, complete confinement of the active mass including the soluble reaction intermediates during cycling is very challenging. The diffusion of polysulfides which is mostly retarded by the nanostructure may occur at a very slow rate, which limits the long term cycling performance. Formation of the porous carbon host on a large scale is also required for practical applications.

Herein, we discuss the merit of a variety of different approaches to these challenges. These include a) modification of the pore morphology to achieve optimal pore size distribution for polysulfide containment; b) the importance of surface modifiers; c) the role of electrode additives; d) methods to prepare mesoporous carbons using simplified routes that are amenable to scale-up. Achieving conversion of the intermediate polysulfides to $Li_{2}S$ vs $Li_{2}S_{2}$, and the effect of increasing sulfur/carbon content are also evaluated.

For example, we have developed porous carbons with large mesopores (ca 10 nm) as shown in Figure 1, that can be prepared by relatively easy methods - and which can also be tuned to achieve bimodal or hierarchical porosity to optimize transport. Methods to entrap polysulfide species using multi component electrodes stabilize capacity fading and improve coulombic efficiency (Figure 2), even at relatively fast rates of C/2 (based on the capacity of the electrode).