Microwave synthesis of Sulfur/Carbon Composite with an Enhanced Cycling Stability
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The plug-in electric vehicles, electric vehicles and the development of large scale energy storage systems call for high-energy-density and long-lasting batteries, since the former becomes mainstream in the future transportation to decrease the dependence on fossil fuel and diminish CO$_2$ emission from vehicles, and the latter is important for the utilization of green energy (wind and solar) and smart grid. The current Lithium-ion battery technologies based on transition metal oxides or phosphates cannot provide adequate energy density. Recently, elemental sulfur which can provide a high capacity of 1675 mAh·g$^{-1}$ has attracted increasing attentions. The adoption of sulfur as cathode has other advantages such as its natural abundance, low cost and environmental friendliness. With metallic lithium as anode, the redox reaction between Li and S forms several lithium polysulfides (Li$_2$S$_n$, 8$\leq n \leq$2) as the intermediate products, and provides energy density up to 2600 Wh·kg$^{-1}$ sulfur assuming that Li$_2$S is the final product.

However, the insulating nature of sulfur and lithium polysulfides prevents the full utilization of sulfur. Thus various conductive carbon and polymer materials have been used to accommodating S to improve the conductivity. Meanwhile, some polar organic solvents, such as 1,3-dioxolane, dimethoxyethane, and tetra ethylene glycol dimethyl ether, are introduced to dissolve the Li polysulfides (especially when n$>4$) which can make sulfur accessible for more complete reduction. The new problem aroused is that the dissolved $S_{2n}^-$ migrate to anode side and react with Li to generate $S_{2n-4}^-$, or even precipitates such as Li$_2$S$_2$ or Li$_2$S, resulting in corrosion to Lithium and also the internal resistance increase of a cell. Moreover, some soluble $S_{2n-4}^-$ can diffuse back to cathode and be re-oxidized to high order $S_{2n}^-$, creating the “shuttle mechanism” which leads irreversible capacity loss and low coulombic efficiency.

In order to realize the practical application of the Lithium Sulfur batteries, several approaches have been attempted to solve the “shuttle mechanism” issue. The most widely employed one is to impregnate sulfur into meso-porous carbon matrixes via heating process, thus limiting sulfur dissolution through physical barriers$^{2,3}$. In this study, a commercial conductive carbon black, ketjenblack EC-600JD, is employed as the matrix to host sulfur. 55wt% of Sulfur is impregnated into the pores of carbon by less than 10 minutes microwave irradiation. While during the traditional heating process, it takes about 11 hours to load only 45wt% of Sulfur into the carbon pores. Compared to the tediously normal heating process, obviously microwave irradiation method is much less time and energy consuming. Moreover, the S/C sample prepared by microwave irradiation shows enhanced cycle stability as shown in Figure 1. When both samples are discharged at 0.2C rate (1C = 1675 mA·g$^{-1}$), the microwaved S/C composite presents 880 mAh·g$^{-1}$ at the 50th cycle, while the heated sample only shows 813 mAh·g$^{-1}$.

![Figure 1 Cycle life test at a current level of 0.2 C for S/C samples prepared by microwave irradiation and regular heating](image-url)