The reduction of graphene oxide by H$_2$S and its potential application in Li-S battery

Chen Zhang,\textsuperscript{1,2} Wei Lv,\textsuperscript{3} Quan-Hong Yang\textsuperscript{1,2,3,*}

\textsuperscript{1}School of Chemical Engineering and Technology, Tianjin University, Tianjin 300072; \textsuperscript{2}The Synergistic Innovation Center of Chemistry and Chemical Engineering of Tianjin, Tianjin, 300072; \textsuperscript{3}Engineering Laboratory for Functionalized Carbon Materials, Graduate School at Shenzhen, Tsinghua University, Shenzhen 518055.

E-mail: qhyangcn@tju.edu.cn

The increasing demands for electrical vehicles and portable devices push us to explore novel energy storage systems with higher energy density as well as lower cost. Li-S battery, which utilizes sulfur as the cathode material, is believed to be a promising candidate of the commonly used Li-ion batteries due to its high energy density (1675 mAh/g). Unfortunately, the poor electric conductivity of sulfur and the dissolution of the polysulfide cause low utilization efficiency of sulfur and fast capacity fade of the battery. To solve these problems and make the battery usable, sulfur is always combined with a conductive polymer such as PPy, CMK or a carbon matrix of CNTs or graphene. Graphene, as the basic unit for sp$^2$ hybridized carbon materials, is considered as appealing carbon matrix to incorporate with sulfur for Li-S batteries\textsuperscript{[1,2]}.

H$_2$S is a kind of toxic gas which is urgently required to be removed effectively, while sulfur is the main element of H$_2$S. Herein, we developed H$_2$S as a novel and effective reducing agent for the reduction of graphene oxide, and a graphene/S hybrid can be prepared within the reduction process\textsuperscript{[3]}. The abundant oxygen groups attached on graphene oxide layers help oxidize the H$_2$S and a homogeneous loading of S on the curly and interconnected graphene layers can be obtained as shown in Figure 1, such a structure ensures the contact between HRGO and S, which facilitates electron transfer when it is used as an electrode material. The resulting HRGO/S is further highlighted as a possible cathode of a Li-S battery, exhibiting good power performance and stability. A capacity of 683 mAh g$^{-1}$ can be retained at a current density of 2.0 A g$^{-1}$, and a capacity of 490 mAh g$^{-1}$ can still be obtained even at 5.0 A g$^{-1}$. The capacity retention is estimated to be about 72% (2.0 A g$^{-1}$ to 0.2 A g$^{-1}$), which is far superior to that of a GN/S cathode (melt-diffusion of S with low-temperature thermally exfoliated graphene powder). It also shows relatively stable cyclic ability, and the capacity retention achieves 71% after 100 cycles with Coulombic efficiency around 94%, which is higher than those of the GN/S (65% retention after 50 cycles and a Coulombic efficiency around 88%) that may be because of the interaction between the S and the graphene surface derived from chemical reaction process in preparation.

It is worth mentioning that this method is a fast and versatile approach for the preparation of a graphene/S hybrid and the structure can be readily controlled. More significantly, this work provides a method to totally green regeneration of pollutant H$_2$S gas towards high-performance Li-S battery with long life-span and superior power performance.

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References:

![Figure 1. (a) TEM image of graphene/S hybrid; (b) and (c) Element mappings of sulfur and carbon; (d) Rate performance of graphene/S electrode.](image_url)