GeO$_2$/C Composite Fabricated by Sol-gel Method as an Anode Material for Lithium Ion Batteries

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Germanium and its compounds have shown the most promising properties as an anode material for Li-ion batteries due to their high specific capacity, high electrical and ionic conductivities. Theoretical specific capacity of Ge is 1624 mAh g$^{-1}$ corresponding to Li$_2$Ge, which is four times higher than that of commercial graphite (372 mA h g$^{-1}$ corresponding to LiC$_6$). Nevertheless, the specific capacity of Ge (1624 mA h g$^{-1}$) is smaller compared to that of Si (4200 mA h g$^{-1}$). The higher capacity of Si than that of Ge is due to their density differences which are 2.329 g cm$^{-3}$ and 5.323 g cm$^{-3}$, respectively. However, Si and Ge show almost similar volumetric capacities i.e. 9782 Ah l$^{-1}$ for Si and 8644 Ah l$^{-1}$ for Ge.

 Unfortunately, the capacity of germanium/germanium compound based electrodes declines after a few cycles due to their volume expansion during charge/discharge. It is important to suppress capacity fading of germanium/germanium compound based anodes for Li ion batteries. Many researches have focused on resolving this crucial problem by making germanium/germanium compound based anodes either in thin film form or its composites with carbon. Currently, the Ge/GeO$_2$ compound based anode materials are prepared by many methods such as sputtering [1], CVD [2], and wet chemical routes [3]. However, each of these techniques involves the use of expensive chemical or equipment. In this research, GeO$_2$ was synthesized by simple sol-gel method, and after that the GeO$_2$ was encapsulated with carbon to make GeO$_2$/Carbon composite.

Germanium ethoxide, polyvinyl-pyrrolidone and ethanol were used as the precursors to synthesize the GeO$_2$/carbon. Fig. 1 shows the XRD pattern of GeO$_2$ and GeO$_2$/carbon. The XRD pattern was compared and matched with GeO$_2$ (PDF#43-1016; hexagonal); confirmed the formation of single phase GeO$_2$ in the product.

Fig. 1. XRD pattern of GeO$_2$ and GeO$_2$/carbon.

GeO$_2$ and GeO$_2$/carbon can be used as an active Li storage material for lithium ion batteries due to their high specific capacity, high electrical and ionic conductivities. Theoretical specific capacity of Ge is 1624 mAh g$^{-1}$ corresponding to Li$_2$Ge, which is four times higher than that of commercial graphite (372 mA h g$^{-1}$ corresponding to LiC$_6$). Nevertheless, the specific capacity of Ge (1624 mA h g$^{-1}$) is smaller compared to that of Si (4200 mA h g$^{-1}$). The higher capacity of Si than that of Ge is due to their density differences which are 2.329 g cm$^{-3}$ and 5.323 g cm$^{-3}$, respectively. However, Si and Ge show almost similar volumetric capacities i.e. 9782 Ah l$^{-1}$ for Si and 8644 Ah l$^{-1}$ for Ge.

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Fig. 2 shows the SEM micrograph of as-synthesized GeO$_2$ and GeO$_2$/carbon. It can be clearly seen that the nano particles with size ranging from 10 to 15 nm for GeO$_2$ and 15 to 20 nm for GeO$_2$/carbon.

Fig. 2. SEM micrograph of (a) GeO$_2$ and (b) GeO$_2$/carbon.

Obtained GeO$_2$ and GeO$_2$/carbon were characterized for their electrochemical charge-discharge behaviors. Fig. 3 shows the specific reversible capacities of GeO$_2$ and GeO$_2$/carbon. The specific capacities of GeO$_2$ and GeO$_2$/carbon at 0.1C-rate were about 1410 and 910 mA h g$^{-1}$ respectively at the first cycle.

Figure 3: Specific reversible capacities of GeO$_2$ and GeO$_2$/carbon.

The cyclic lives of synthesized anodes are under-investigation and it can be observed from its initial data that the anode shows steady performance till the obtained data. However, further cycling data is necessary for making any staments about the stability in its performance. The initial results demonstrate that the synthesized GeO$_2$/carbon can be used as an active Li storage material for lithium ion batteries.

References