Ceramic Nanocomposite Negative Electrodes for Li-ion Batteries

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ABSTRACT

Electrochemical energy storage has become a critical technology for a variety of applications, including grid storage, electric vehicles, and portable electronic devices. Ceramic based anodes (SiOx, GeO, SnO_2, ZnO, Fe_2O_3 or more complex stoichiometry, etc.) have much higher Li storage capacity than the intercalation-type graphite anode that is currently used in Li-ion batteries (LIBs). Almost all the ceramic based or ceramic supported negative electrodes are considered as a promising anode material for rechargeable LIB, owing to their high theoretical specific capacity. Despite the low capacity, graphite anodes still dominate the marketplace due to the fact that alloy anodes have two major challenges that have prevented their widespread use. However, the practical implementation of metal (M) and metal oxide (MO) anodes is still blocked due to three major problems [1]: poor cycle-life results from pulverization during the huge volumetric fluctuations (>300 %), drastic irreversible capacity loss and low coulombic efficiency, the solid electrolyte interphase (SEI) breaks as the nanostructure shrinks during delithiation. This results in the exposure of the fresh MO or similar active material surfaces to the electrolyte and the reformation of the SEI, resulting in the SEI growing thicker with each charge/discharge cycle and highly possible particle aggregation [2]. The critical issue of fabricating high specific capacity, high rate capability, and long cycle life LIB device is the advanced nano architectured design and flexible electrode materials with good mechanical deformations. Nanocomposite structures are pivotal for the progresses in electrode materials due to their manageable surface-area, stunted mass and charge-diffusion span, and volume change acclimatization during charging/discharging. CNTs, CNFs and Graphene with their special structures provide excellent conductivity, mechanical flexibility and significantly large surface-area, are considered ideal additives to enrich chemistry of electrodes [3].

In order to prevent these challenges, most common and effective strategy to adopt nanoscale materials with various morphologies, including nanoparticles and, nanowires, nanotubes and hollow spheres. Compared to bulk active materials, such nanostructured ceramic based oxides, nitrides and carbides are able to accommodate elevated mechanical stress, resulting in prolonged cycling stability. Optimization of ceramic based electrodes can be achieved by incorporating nano structures with various conductive matrixes, such as graphene and, carbon nanotubes, and carbon and to form core-shell and yolk-shell nanocomposites. The introduction of such a carbon architectures with ceramic phases play a key role in alleviating the agglomeration of nano structured active materials [4]. In this review, we summarized the recent progresses on developments of ceramic based nanocarbon supported (CNT, CNF, Graphene etc.) negative electrodes for high performance Li-ion batteries. The synthesis techniques of the 1-D, 2-D and 3-D electrodes has been discussed for special hierarchical structures and free standing electrodes. The main research activities of Sakarya University electrochemical energy storage group has also summarized. The electrochemical performances of the ceramic based active materials and their nanocomposite structures were reviewed.

References

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