Stabilization of High CNT loaded pyrolyzed nanofiber in a mixed polymer matrix for lithium-ion batteries applications

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Lithium-ion battery (LIB) has become a front-runner for several decades since its innovation as the standard energy storage material which provides a wide-range of application down from portable electronic devices (e.g. cellphones, laptops) to large electrical vehicles and energy grids.[1] As an electrode material, carbon material has been and still currently being used as the sole active material for commercial application due to the many advantages that it offers as a primary option because of its good electrical conductivity, good electrochemical properties and relatively low cost.[2] Aside from graphite, CNT has been explored for LIB application but the performance suffers from agglomeration of the particles. Thus, formation of void spaces and discontinuity of the electrical pathway is observed. This results to low performance and high resistance of the material. By using different fabrication method such as electrospinning nanofibers prevents the CNT fibers from agglomerating with each other by providing a strong matrix confinement and locks the fibers in a specific position as compared to a free standing CNT. In addition, it also renders the CNT to form proper alignment of the individual fibers for better conductivity, hence, higher capacitive performance.

Electrospinning technique was chosen as the fabrication method with Polyacrylonitrile (PAN) as the polymer due to its high carbon retention after pyrolysis and forms good graphitized nanofibers as compared to other polymeric carbon precursors.[3] Pyrolyzed nanofibers with high CNT loading of as high as 50 wt% based on polymer weight was obtained after ultrasonicating for 1 hour and electrospinning at a flow rate of 1mL/hr and 18kV of voltage. However, as CNT loading increases, the diameter of the polymer fibers also increases resulting to a high degree of void spacing between nanofibers (interpore), hence, larger resistance. In order to decrease the fiber diameter of PAN nanofiber, polyvinylpyrrolidone (PVP) was mixed with PAN in a ratio of (1:1) with a total of 10wt% polymer based on solution and the fabricated polymer nanofibers with a narrow diameter range of 500-700nm was obtained and were calcined at 280˚C in air for 1 hour and 800˚C in N_2 atmosphere for another 1 hour before obtaining the Pyrolyzed CNT nanofiber. This was used directly to fabricate a coin cell and measured its electrochemical performance.

The high CNT loaded (~50wt% based on polymer weight) nanofiber fabricated by electrospinning and pyrolyzed at 800˚C has a relatively high specific surface area of 388 $m^2\ g^{-1}$ and gave rise to a high initial discharge capacity (3478 mA h g^{-1} at 500 mA g^{-}). The subsequent long term cycle exhibited a stable discharge capacity (2677 mA h g^{-1} at 500 mA g^{-1} after 50 cycles). As a result of the nanofiber fabrication technique to stabilize the CNT, excellent cycling stability with a higher theoretical capacity than graphite (372 mA h g^{-1})[4] was observed as a preliminary data. This material can provide good insight towards the development of all carbon-based anode materials for LIB application.

References:

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