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INVESTIGATION OF LTO/GRAPHENE COMPOSITE ELECTRODE ON THE PERFORMANCE OF LTO BATTERIES

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ABSTRACT

In this work, $Li_4Ti_5O_{12}$ /graphene nanoplate composite with different graphene additives (3% 6%) was prepared by sonication method and followed by sintering at 500 ◦C. The electrochemical performance of composite and pure LTO was investigated in half-cell and full-cell with NCA cathode. Electron transport is improved by forming a conductive graphene network throughout the insulating $Li_4Ti_5O_{12}$ particles. Identification of the composite structure was performed by X-ray diffraction and showed no change in the crystal structure of lithium titanate particles. The difference between charge and discharge plateau potentials becomes much smaller at all discharge rates because of lowered polarization. With 3 %wt. graphene, the hybrid materials deliver a specific capacity of 113 mAh/g at a charge/discharge rate of 5C. While the capacity of pure lithium titanate electrode was only 75 mAh/g. The GLTO-3 composite exhibits the best rate and cycling performance, GLTO-3 and LTO showed a capacity retention of 93% and 74% after 200 cycles at 5C, respectively. Also, the capacity of the TNR2032-G3 full cell was 109 mAh/g at 2C rate, while the TNR2032 full cell had a capacity of 17 mAh/g. The internal resistance of the batteries was measured by DC method. The curve of DCIR vs SOC was investigated was found that the TNR2032-G3 battery has less internal resistance than the TNR2032 battery. The outstanding electrochemical performance of G-LTO3 makes it a promising anode material for high-rate lithium-ion batteries.

Keywords: lithium-ion battery, graphene, composite

INTRODUCTION

Over the past century, fossil fuels, including petroleum, coal, and natural gas, have been the bedrock of global industrial development, economic growth, and societal progress. These resources, predominantly used through combustion methods, have had significant environmental consequences, such as atmospheric pollution and anthropogenic climate change. As these non-renewable energy resources gradually deplete and environmental concerns intensify, there is a pressing need to shift towards more sustainable energy models. Solar and wind energy have emerged as leading renewable alternatives because of their widespread availability and potential for scalability. However, their inherent intermittent, characterized by fluctuations in energy generation, poses a challenge to their seamless integration into existing power grids. This intermittency underscores the importance of developing innovative and efficient energy storage methods. Among various energy storage solutions, electrochemical energy storage, represented mainly by secondary batteries, has gained considerable attention from both academic and industrial sectors. Their high energy density and economic viability make them appealing choices. The rapid growth of the electronics industry, coupled with the increasing use of portable electronic devices, has created a strong demand for reliable energy storage solutions. Rechargeable batteries, in this scenario, stand out as essential components underpinning these electronic devices [1].
Moreover, the automotive industry is undergoing a transformative shift. With rising environmental concerns, car manufacturers are redirecting their efforts towards the research and production of electric vehicles (EVs) and hybrid vehicles (HEVs). One of the primary challenges with these vehicles is the effective storage and delivery of electrical energy, and here again, rechargeable batteries present an optimal solution, marking a significant change in vehicular energy systems [2] [3].

MATERIALS AND METHODS

In this study, two lithium titanate-graphene composite samples, named G-LTO3 and G-LTO6, were prepared using the sonication method, with graphene concentrations of 3% and 6% relative to the total composition. The initial phase involved mixing specific amounts of graphene nanosheet powder and lithium titanate powder, followed by the addition of absolute ethanol. The mixtures were then homogenized and subjected to a 2-hour sonication process [4]. This ultrasonic treatment disrupted the internal cell walls of the solid materials, enabling the formation of new bonds between the two constituents.

Post-sonication, the solvent was evaporated, and the residue was oven-dried to yield a gray powder. This was followed by the crucial calcination step, where the materials were heated in an electric tube furnace at 500°C for four hours, in an atmosphere regulated with argon gas to prevent oxidation. This process ensured the thorough integration of graphene within the lithium titanate matrix, culminating in the successful derivation of the G-LTO3 and G-LTO6 composite samples [5].

RESULTS AND DISCUSSION

In the results illustrated in the figure below, a distinct relationship between the C-rate and the voltage curve is observed. As the C-rate escalates, the plateau region of the voltage curve diminishes and exhibits a progressive inclination. In contrast, the electrode voltage curve for G-LTO remains predominantly flat. This behavior can be attributed to the increasing polarization of LTO in the absence of graphene, especially as the current rate intensifies.

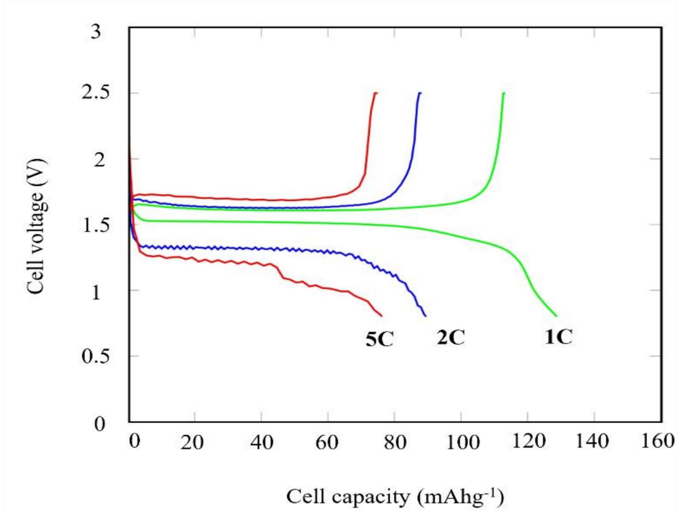

Figure 46: Charge and discharge profile of half-cell with LTO electrode

Figures 2 and 3 illustrate the charge and discharge profiles for G-LTO3 and G-LTO6 composites, respectively. For the half cell with a G-LTO3 anode, the capacity value when discharged at 1C is 149 mAh/g. On the other hand, the half-cell with a G-LTO6 anode shows a capacity value of 136 mAh/g under the same discharge conditions.

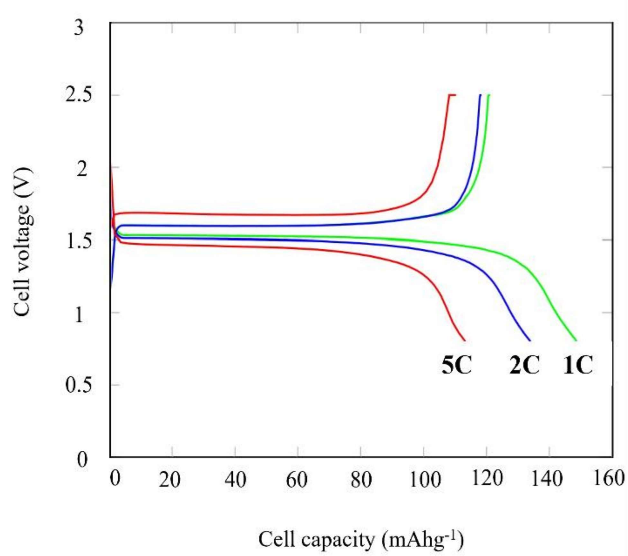

Figure 47: Charge and discharge profiles for G-LTO3 and G-LTO6 composites

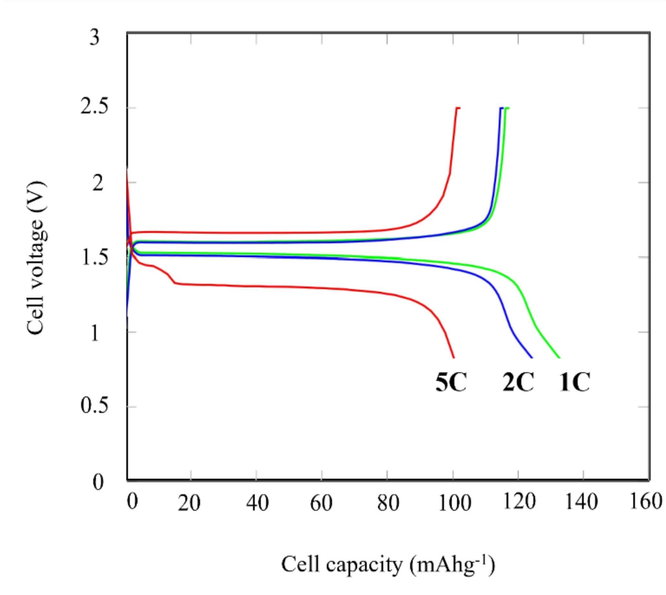

Figure 48: Charge and discharge profile of half-cell with G-LTO6 electrode

Figures 4 and 5 present a comparison of the discharge profiles of half-cells and full batteries subjected to a constant current of 2C. The data reveals that the lithium titanate composite electrode with 3% graphene exhibits a longer discharge profile than both the 6% graphene composite sample and the sample without graphene. Additionally, the 3% graphene composite showcases a higher energy density and capacity.

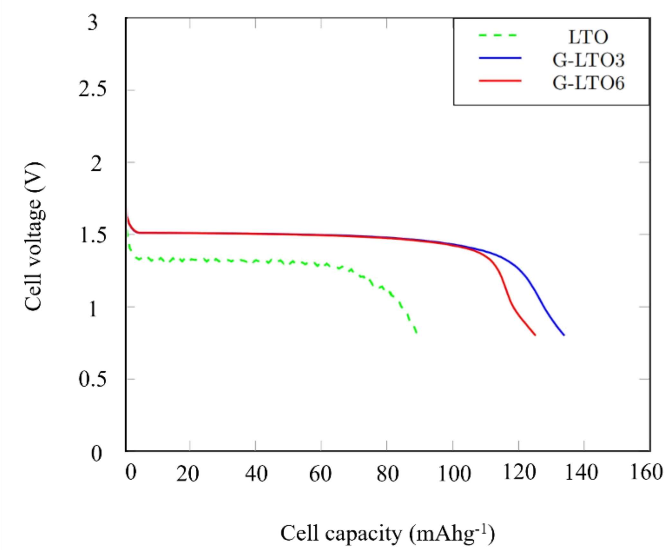

Figure 49: Comparison of the discharge curve of half-cells in constant current 2C