

Effect of Nitrogen Doping on the Electrochemical Properties of Lithium Battery Anode of Activated Carbon

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This research discusses the effect of using nitrogen-doped activated carbon as an anode material for lithium batteries on the resulting electrochemical properties. The performance of pure activated carbon was compared with that of nitrogen-doped activated carbon with concentrations of 1:3 and 1:5. Activated carbon that has been synthesized into nitrogen-doped activated carbon is tested for its physical properties through Fourier-transform infrared spectroscopy and scanning electron microscopy instruments. The galvanostatic charge–discharge test results showed that each sample had a smaller loss of capacity as the nitrogen doping concentration increased. Pure activated carbon has a specific capacity of 105.549 mAh/g, 1:3 nitrogen-doped activated carbon of 108.214 mAh/g, and 1:5 nitrogen-doped activated carbon of 113.635 mAh/g.

topics: activated carbon, nitrogen doping, anode, lithium battery

1. Introduction

New and renewable natural resources are needed, especially due to increasing global warming and limited fossil resources [1]. One of the most important aspects of utilizing new renewable energy sources is access to energy transmission and storage technology. Currently, the limited development of renewable energy is hindered by storage and transmission technologies due to their environmental impacts [2]. Lithium batteries are one type of excellent energy storage device that can convert chemical energy into electrical energy. However, producing these batteries with high energy density and power density through economical and environmentally friendly processes is still a big challenge.

Current anode materials exhibit high specific capacity, cycle stability, and safety, but their high cost and relatively small current density limit their practical application [3]. Activated carbon, which has a large surface area, high absorption, and minimal charging time, is suitable for application in several materials, including anode materials in batteries. In maximizing the potential of activated carbon in the form of its capacitance properties, nitrogen doping can be utilized to increase the capacity of activated carbon [4].

Doping nitrogen in the carbon structure will result in a reduction of solutes in the battery cell electrolyte. This mechanism makes the electron capture greater, and the battery performance increases [5]. This research discusses the effect of nitrogen doping on the electrochemical properties of lithium battery anodes. Activated carbon was synthesized with the addition of nitrogen doping and then tested for physical properties using scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier-transform infrared spectroscopy (FTIR). The synthesized material was fabricated in the form of battery cells and then tested for performance using galvanostatic charge–discharge (GCD).

2. Materials and method

The main materials used include activated carbon, urea ((NH₂)₂CO) as a doping source, and KOH as an activator. Other materials include distilled water and HCl acid.

Activated carbon was impregnated in a solution of urea and KOH activator. The mass ratio of activated carbon:KOH:urea is (12 g):(24 g):(36 and 60 g). The solution was homogenized using a magnetic stirrer for 2 h at 750 rpm. The resulting

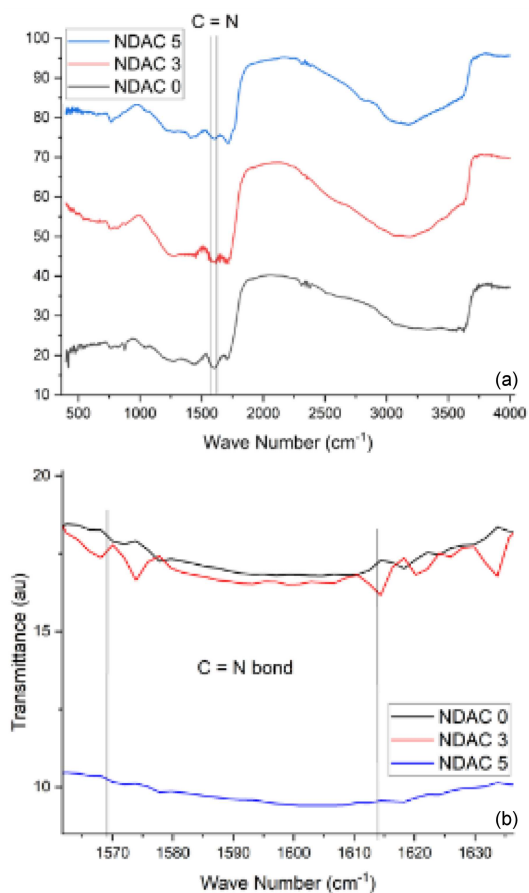


Fig. 1. (a) Result of FTIR functional group (b) C=N bonding functional group.

solution was then sonicated for 30 min. After sonication, the solution was heated in an oven at 200°C for 4 h. The resulting material was crushed for 1 h. The resulting powder was then soaked in an HCl solution for 24 h to neutralize the pH. Then, the solution was filtrated with filter paper and dried in the oven. After that, the resulting material was crushed for 1 h and sieved through a 200 mesh. Each sample was named according to the doping ratio of urea as a nitrogen source (NDAC 3 and NDAC 5), and pure activated carbon was named NDAC 0.

3. Results and discussion

Figure 1 shows the transmittance intensity of the C=N bond at wave numbers from 1565 to 1615 cm^{-1} . The decrease in transmittance absorption value in each sample indicates an increase in C=N absorption intensity as the nitrogen doping concentration increases [6]. This increase causes the breaking of inter-carbon bonds by nitrogen atoms [4]. This nitrogen doping affects the structure of the carbon battery anode, causing the grain size to decrease, the structure to become more crystalline, and the surface area to increase [7].

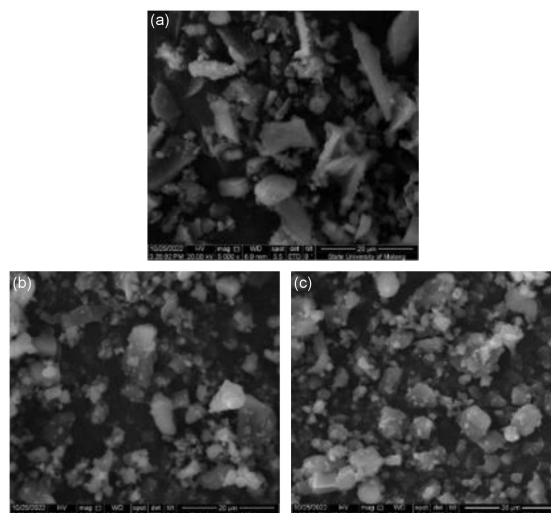


Fig. 2. The morphology of samples (a) NDAC 0, (b) NDAC 3, (c) NDAC 5.

SEM morphology is shown in Fig. 2. The morphology of the pure activated carbon sample (NDAC 0) shows a larger grain size compared to the NDAC 3 and NDAC 5 samples. This morphology is influenced by nitrogen doping and the addition of KOH, which reacts to form CO and CO₂. The smaller grain size results in a higher surface area of the activated carbon. This high surface area improves the absorption of the electrolyte by the anode. This mechanism also increases the good electronic conductivity of the electrode [7].

Figure 3 shows the specific capacity of each sample at 0.2 C of C_{rate} . The specific capacity is influenced by the amount of current that the material can store, voltage, C_{rate} , the number of test cycles, and battery conditions. The amount of voltage is directly proportional to the specific capacity of the battery [8]. The more cycles the battery passes, the smaller the specific capacity produced. This is due to the formation of the solid electrolyte interphase (SEI) layer by lithium ions [9].

Figure 3 shows the slope of the graph that occurs in the range from 3.4 to 4 V, which indicates a change in chemical potential due to changes in the concentration of the electrolyte solution due to the incoming and outgoing currents during the battery charge-discharge process [10]. The addition of nitrogen doping affects the specific capacity, which makes the carbon structure more porous. An optimized porous structure can increase ion/electron transfer faster [11]. Nitrogen doping results in a smaller sample grain size, thanks to which the surface area is high and the capacity is higher [3].

Figure 4 shows that battery capacity tends to decrease as the battery usage cycle increases. This is due to the poor condition of the battery. Figure 4 also shows that nitrogen-doped samples tend to have lower capacity loss compared to pure activated carbon samples. The decrease in battery

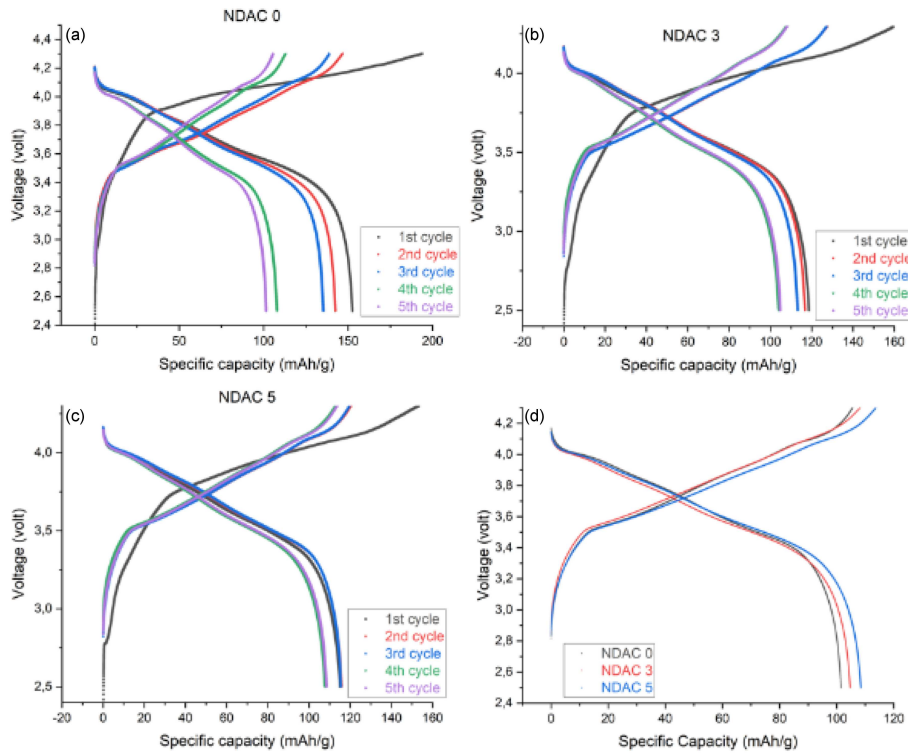


Fig. 3. Graphic of specific capacity of battery anode materials at 5 testing cycles (a) NDAC 0, (b) NDAC 3, (c) NDAC 5, (d) 5th cycle of each sample.

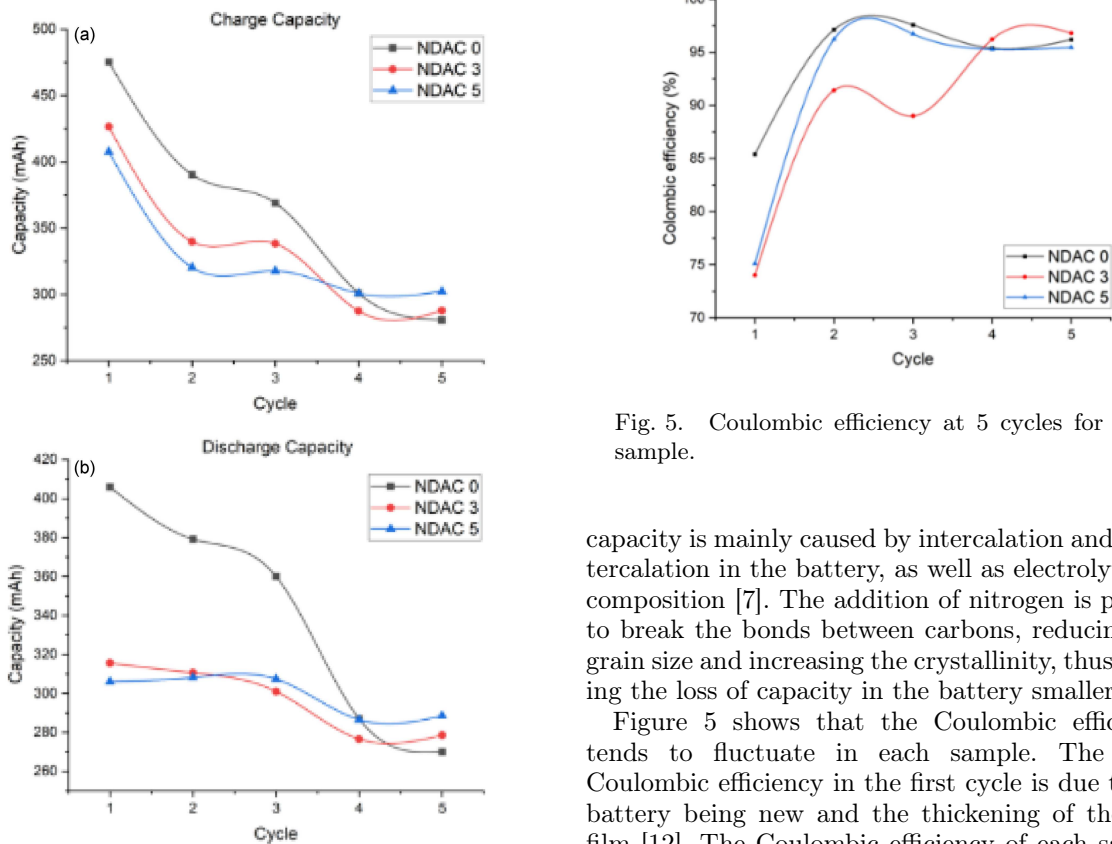


Fig. 4. Response and recovery of Sn-doped ZnO at the exposure of 200 ppm ammonia.

Fig. 5. Coulombic efficiency at 5 cycles for each sample.

capacity is mainly caused by intercalation and deintercalation in the battery, as well as electrolyte decomposition [7]. The addition of nitrogen is proven to break the bonds between carbons, reducing the grain size and increasing the crystallinity, thus making the loss of capacity in the battery smaller [4].

Figure 5 shows that the Coulombic efficiency tends to fluctuate in each sample. The poor Coulombic efficiency in the first cycle is due to the battery being new and the thickening of the SEI film [12]. The Coulombic efficiency of each sample is also affected by the electrical conductivity of the anode due to the addition of nitrogen, which affects the physical properties of the material [13].

4. Conclusions

Nitrogen doping causes an increase in the bonding intensity of carbon atoms and nitrogen atoms. This leads to an increase in the size of the smaller grains. Nitrogen doping also affects the capacity and Coulombic efficiency of the battery.

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