Batteries from Rolling Licorice Donuts

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1. Introduction

If you guessed that the 3-word phrase at the end of the title of this paper is a whimsical name for those round things on a road-vehicle that come in contact with the road, you get the prize (to read the rest of this post).

The source for this comes from a paper in a book that I bought recently that is basically a collection of papers about sustainable Development.[1]

2. Creative Problem-Disposing

Disposing of waste is a big and rapidly growing problem, both in the U.S. and world-wide. Some waste is relatively easy to recycle, like paper, cardboard, glass and wood. Although a bit harder-to-recycle, metal-waste also typically has a higher value, and many metals can also be easily sorted via electric-conduction- and magnetic-methods. Then we start getting to the objects that are difficult to recycle, and the resulting raw materials have a low value. These are currently prime-candidates for land-fills, but these facilities are not the best use for land, especially in areas with high population densities.

Worn-out tires are mostly on the "land-fill" end of this spectrum, and this is a world-wide issue. Much of the material in auto-tires (and most other types of tires) is carbon. And, speaking of autos, a rapidly-emerging evolution of autos, trucks and other road-vehicles is electric vehicles, and these are mostly powered by Lithium-Ion Batteries.[2] Obviously, lithium is a major component in these batteries, but so is carbon. Do you catch my drift. The text in the next paragraph is the **Abstract** for the source paper (Reference 1). Note that I have deleted secondary references from excerpts from Reference 1. Go through the link in this reference to see the original paper, including secondary references.

The rapidly growing automobile industry increases the accumulation of end-of-life tires each year throughout the world. Waste tires lead to increased environmental issues and lasting resource problems. Recycling hazardous wastes to produce value-added products is becoming essential for the sustainable progress of society.

A patented sulfonation process followed by pyrolysis at 1100 °C in a nitrogen atmosphere was used to produce carbon material from these tires and this was utilized as an anode in lithium-ion batteries. The combustion of the volatiles released in waste tire pyrolysis produces lower fossil CO_2 emissions per unit of energy (136.51 $gCO_2/kW \cdot h$) compared to other conventional fossil fuels such as coal or fuel–oil, usually used in power generation. The strategy used in this research may be applied to other rechargeable batteries, supercapacitors, catalysts, and other electrochemical devices.

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[1] Grigorios L Kyriakopoulos, Book: "Sustainable Development of Electrical Energy Storage Technologies in Energy Production," Article: "Sustainable Waste Tire Derived Carbon Material as a Potential Anode for Lithium-Ion Batteries," https://www.mdpi.com/2071-1050/10/8/2840

[2] EV sales grew 55-times in the past decade (2014–2024) and 6-times since 2020. In 2024, the U.S. sold 1.52 million EVs (passenger cars), about 8% of total new light-duty vehicle sales, up from 4.6% in 2021 Fortune Business Insights. By mid-2025, plug-in vehicle sales (BEVs + PHEVs) averaged 131,062 units/month.

The carbon material derived from tires was used as an anode in lithium-ion batteries. This showed a reversible capacity of 360 mAh/g at C3[3]*. The reversible capacity rose to 432 mAh/g at C10 when this carbon particle was coated with a thin layer of carbon.*

2.1. Introduction

Rechargeable lithium-ion batteries (LIBs) are being used as the most promising power source for small-scale applications such as consumer portable electronics, power tools and large-scale applications such as advanced power load leveling for smart grids to meet the energy demands of modern mobile technology, electric vehicles (EVs), and hybrid electric vehicles (HEVs). Graphite is the most widely used anode material due to its high thermal and chemical stabilities, and the practical reversible specific capacity reaching closer to the theoretical capacity of 372 mAh/g corresponding to a fully-lithiated stoichiometric LiC_6 *compound. Currently, graphite is being used as an anode in LIBs that powers electric vehicles such as Tesla Model S. However, fast charging LIBs pose safety concerns due to lithium platting on the surface of the graphite anode leading to the formation of lithium dendrites, causing inner short-circuiting and capacity fading.*

Other types of carbonaceous materials such as hard carbons (HCs) and soft carbons (SC) have been investigated as alternate anode materials to enhance the performance characteristics of LIBs. The unique amorphous structure in SC enables fast charging in LIBs even when the micron-sized particles are used, but it suffers from very low specific capacity of 250 mAh/g. The disordered structure in HC is a short-range order which cannot be graphitized even upon high temperature treatments. Hard carbon is less susceptible to exfoliation[4] *due to the random orientation of the small graphitic grains.*

The nanovoids present between the grains reduce isotropic volume expansion. Thus, nanovoids and defects provide additional gravimetric capacity, allowing the capacity to exceed the theoretical capacity of graphite. HCs have demonstrated the ability to store more lithium than graphite and do not exfoliate during repeated cycling in LIBs. Together, these properties make HCs a high-capacity, high cycle life material. Nevertheless, it suffers from large irreversible capacity loss, which is generally attributed to the high surface area, exposed edge planes in high fraction that increase the absolute quantity of solid electrolyte interphase (SEI) formed, reducing the coulombic efficiency in the first few cycles, and voltage hysteresis. The first cycle irreversible capacity loss in LIBs has been studied extensively and is attributed to the formation of a passivating SEI during the first lithiation process, due to the electrolyte reduction at the negatively polarized graphite surface and the deposition of a number of organic and inorganic compounds, trapping lithium irretrievably in the inner pores of carbon.

Various surface pretreatment methods, such as carbon coating, chemical fluorination, oxidation, doping, etching, and acid treatments, are reported to improve the electrochemical characteristics of the active carbon material. The surface treatment allows a more defined control in terms of surface chemistry, composition, and reactivity, eliminate surface functional groups and reduce the surface area and thereby reducing the irreversible capacity loss due to SEI formation.

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[3] A battery's C-rate refers to the rate at which a battery is charged or discharged relative to its maximum capacity. A 1C rate means the battery discharges (or charges) its entire capacity in one hour, while higher C-rates (e.g., 2C, 3C) indicate faster charge or discharge times.

[4] Exfoliation, generically, is the removal of an inactive surface from an active solid body. This (and related words) are most often used in the process of removing dead skin cells from the surface of your skin.

Graphitic carbon material production requires expensive synthesis conditions and very high temperature treatments close to 3000 °C, to provide the mobility for carbon atoms to rearrange and crystallize carbon into a graphite structure. However, carbon produced from waste tires requires a simple sulfonation process followed by pyrolysis in a nitrogen atmosphere at 1100 °C. Sulfonated tire-derived carbons have been tested as anodes in a half-coin cell lithium-ion battery configuration. This process needs to be scaled up and demonstrated in a pouch full-cell configuration. The waste tires as a raw material also add a high value to the end-of-life tire rubber and provide a sustainable solution to the huge amount of waste tires generated worldwide on an annual basis. The carbon production cost and energy savings can be less than half of the graphite production cost, due to low temperature pyrolysis and the availability of low-cost raw waste tire rubber material. The demand to produce new tires to meet the needs of the rapidly growing auto industry increased to 4.3 percent every year to 2.9 billion tires in 2017. This paper demonstrates the successful scale up production of carbon material in kg quantities with 20–40 μm size particles from waste tires and reported its electrochemical performances as a promising anode in both coin and pouch LIB cell configurations. The micronized carbon materials coated with a thin layer of carbon using a chemical vapor deposition (CVD) approach and investigated the effects of carbon coating towards the improvements in electrochemical performances in LIB cells is also reported. In addition, a simple pre-lithiation strategy to improve the first cycle efficiency to 94% is also presented.

2.2. Conclusions

In summary, battery grade tire-derived carbon material was successfully prepared in high purity in large quantities and demonstrated as a potential anode material for LIBs. The combustion of waste tire rubber produces lower fossil CO_2 emissions per unit of energy (136.51 $gCO_2/kW\cdot h$) compared to other conventional fossil fuels such as coal or fuel–oil, usually used in power generation. The surface coating of the carbon improved the reversible lithium capacity by 20% and yielded 437 mAh/g, which is 20% higher than that of the commercial graphite. A novel pre-lithiation approach also yielded the first cycle efficiency of 94%. This novel green process can promote environmental sustainability to add value to the waste tires and benefit the battery industry to solve future energy crises.