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Scientists convert waste paper into battery parts for smartphones and electric vehicles

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Summary: Scientists have developed a technique to convert waste paper, from single-use packaging and bags, and cardboard boxes, into a crucial component of lithium-ion batteries. Through a process called carbonisation which converts paper into pure carbon, the researchers turned the paper's fibers into electrodes, which can be made into rechargeable batteries that power mobile phones, medical equipment, and electric vehicles.

FULL STORY

Scientists from Nanyang Technological University, Singapore (NTU Singapore) have developed a technique to convert waste paper, from single-use packaging and bags, and cardboard boxes, into a crucial component of lithium-ion batteries.

Through a process called carbonisation which converts paper into pure carbon, the NTU researchers turned the paper's fibres into electrodes, which can be made into rechargeable batteries that power mobile phones, medical equipment, and electric vehicles.

To carbonise the paper, the team exposed the paper to high temperatures, which reduces it to pure carbon, water vapour and oils that can be used for biofuel. As carbonisation takes place in the absence of oxygen, this emits negligible amounts of carbon dioxide, and the process is a greener alternative to disposing of kraft paper through incineration, producing large amounts of greenhouse gasses.

The carbon anodes produced by the research team also demonstrated superior durability, flexibility, and electrochemical properties. Laboratory tests showed that the anodes could be charged and discharged up to 1,200 times, which is at least twice as durable as anodes in current phone batteries. The batteries that use the NTU-made anodes could also withstand more physical stress than their counterparts, absorbing crushing energy up to five times better.

The NTU-developed method also uses less energy-intensive processes and heavy metals compared to current industrial methods of manufacturing battery anodes. As the anode is worth 10 per cent to 15 per cent of the total cost of a lithium-ion battery[1], this latest method, which uses a low-cost waste material, is expected to also bring down the cost of manufacturing them.

The findings were published in the scientific peer-reviewed journal *Additive Manufacturing* in October.

Using waste paper as the raw material to produce battery anodes would also ease our reliance on conventional sources for carbon, such as carbonaceous fillers and carbon-yielding binders, which are mined and later processed with harsh chemicals and machinery.

Paper waste, which comprises disposed paper bags cardboard, newspaper, and other paper packaging, accounted for nearly a fifth of the waste generated in Singapore in 2020[2].

Kraft paper bags, which make up the bulk of Singapore's paper waste, were also found to have large environmental footprints compared to their counterparts made of cotton and plastic, due to their greater contribution to global warming when incinerated and the eco-toxicity potential in producing them, a separate 2020 NTU study[3] found.

The current innovation which presents an opportunity to upcycle waste products and reduce our dependence on fossil fuels, accelerating our transition towards a circular economy, green materials, and clean energy, reflects NTU's commitment to mitigate our impact on the environment, which is one of four humanity's grand challenges that the University seeks to address through its NTU 2025 strategic plan.

Assistant Professor Lai Changquan, from NTU's School of Mechanical & Aerospace Engineering, who led the project, said: "Paper is used in many facets in our daily lives, from gift wrapping and arts and crafts, to a myriad of industrial uses, such as heavy-duty packaging, protective wrapping, and the filling of voids in construction. However, little is done to manage it when it is disposed of, besides incineration, which generates high levels of carbon emissions due to their composition. Our method to give kraft paper another lease of life, funnelling it into the growing need for devices such as electric vehicles and smartphones, would not only help cut down on carbon emissions but would also ease the reliance on mining and heavy industrial methods."

The research team has filed for a patent with NTUitive, NTU's innovation and enterprise company. They are also working towards commercialising their invention.

The recipe for greener battery parts

To produce the carbon anodes, the NTU researchers joined and laser cut several thin sheets of kraft paper to form different lattice geometries, some resembling a spikey piñata. The paper was then heated to 1200°C in a furnace without the presence of oxygen, to convert it into carbon, forming the anodes.

The NTU team attributes the anode's superior durability, flexibility, and electrochemical properties to the arrangement of the paper fibres. They said the combination of strength and mechanical toughness shown by the NTU-made anodes would allow batteries of phones, laptops and automobiles to better withstand shocks from falls and crashes.

Current lithium battery technology relies on internal carbon electrodes that gradually crack and crumble after physical shocks from being dropped, which is one of the main reasons why battery life gets shorter with time.

The researchers say that their anodes, which are hardier than current electrodes used in batteries, would help address this problem and extend the life of batteries in a wide array of uses, from electronics to electric vehicles.

Co-author of the study Mr Lim Guo Yao, a research engineer from NTU's School of Mechanical & Aerospace Engineering, said: "Our anodes displayed a combination of strengths, such as durability, shock absorption, electrical conductivity, which are not found in current materials. These structural and functional properties demonstrate that our kraft paper-based anodes are a sustainable and scalable alternative to current carbon materials, and would find economic value in demanding, high-end, multifunctional applications, such as the nascent field of structural batteries."

Asst Prof Lai added: "Our method converts a common and ubiquitous material -- paper -- into another that is extremely durable and in high demand. We hope that our anodes will serve the world's quickly growing need for a sustainable and greener material for batteries, whose manufacturing and improper waste management have shown to have a negative impact on our environment."

Highlighting the significance of the work done by the NTU research team, Professor Juan Hinestroza from the Department of Human Centered Design of Cornell University, US, who was not involved in the research, said: "As kraft paper is produced in very large quantities and disposed likewise all over the world, I believe that the creative approach pioneered by the researchers at NTU Singapore has a great potential for impact at a global scale. Any discovery that will allow the use of waste as a raw material for high-value products like electrodes

and foams is indeed a great contribution. I think that this work may open a new avenue and motivate other researchers to find pathways for the transformation of other cellulose-based substrates, such as textiles and packaging materials, which are being discarded in large quantities all over the globe."

The NTU team will be conducting further research to improve the energy storage capacity of their material and minimise the heat energy required to convert the paper into carbon.

Notes:

[1] Lux Research. Li-ion Battery Innovation Roadmap (2019).

[2] Singapore National Environmental Agency. Reduction In Overall Waste Generation In 2020, With Less Waste Sent To Semakau Landfill (2021).

[3] Nanyang Technological University. NTU Singapore scientists report that plastic bags could be 'ecofriendlier' than paper and cotton bags in cities like Singapore (2020).

Story Source:

Materials provided by **Nanyang Technological University**. *Note: Content may be edited for style and length.*

Journal Reference:

1. Chang Quan Lai, Guo Yao Lim, Kai Jie Tai, Kang Jueh Dominic Lim, Linghui Yu, Pawan K. Kanaujia, Peiyuan Ian Seetoh. **Exceptional energy absorption characteristics and compressive resilience of functional carbon foams scalably and sustainably derived from additively manufactured kraft paper**. *Additive Manufacturing*, 2022; 58: 102992 DOI: 10.1016/j.addma.2022.102992

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