

# Researchers Develop Eco-Friendly Method to Recycle Spent Lithium-Ion Batteries

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Headed by **Nanyang Technological University, Singapore** (NTU Singapore), a team of researchers has created a new technique through which fruit peel waste can be used to extract and reuse valuable metals from spent lithium-ion batteries to make new batteries.



*Image Credit: Nanyang Technological University.*

The researchers revealed their idea using orange peel, which efficiently recovered valuable metals from mere battery waste. From these recovered metals, the team subsequently created functional batteries without producing significant waste in the process.

According to the researchers, the new waste-to-resource method addresses both electronics waste and food waste and can promote the development of a circular economy with zero waste,

where resources are continuously used as long as possible. Every year, about 50 million tons of e-waste and 1.3 billion tons of food waste are produced worldwide.

To smelt precious metals, spent batteries are traditionally treated with extreme heat (more than 500 °C temperatures) but this method is known to release toxic, hazardous gases.

Scientists are exploring alternative methods in which strong acid solutions or even weaker acid solutions with hydrogen peroxide are used to isolate the metals, but these methods continue to release secondary pollutants that either depend on hydrogen peroxide, which is both unstable and hazardous, or pose health and safety risks.

*Current industrial recycling processes of e-waste are energy-intensive and emit harmful pollutants and liquid waste, pointing to an urgent need for eco-friendly methods as the amount of e-waste grows. Our team has demonstrated that it is possible to do so with biodegradable substances.*

*Madhavi Srinivasan, Professor, Nanyang Technological University*

Professor Srinivasan is also the co-director of the NTU Singapore-CEA Alliance for Research in Circular Economy (NTU SCARCE) lab.

Professor Srinivasan continued, *“These findings build on our existing body of work at SCARCE under NTU’s Energy Research Institute (ERI@N). The SCARCE lab was set up to develop greener ways of recycling e-waste. It is also part of the NTU Smart Campus initiative, which aims to develop technologically advanced solutions for a sustainable future.”*

Dalton Tay, an Assistant Professor from the School of Materials Science and Engineering and the School of Biological Sciences at the Nanyang Technological University, stated: *“In Singapore, a resource-scarce country, this process of urban mining to extract valuable metals from all kinds of discarded electronics becomes very important.”*

*“With this method, we not only tackle the problem of resource depletion by keeping these precious metals in use as much as possible, but also the problem of e-waste and food waste accumulation—both a growing global crisis,”* added Assistant Professor Tay.

The study findings were published in *Environmental Science & Technology*, a scientific journal, in July 2020.

### A Low-Cost, Sustainable Approach

Since industrial methods used for recycling battery waste release toxic pollutants, hydrometallurgy, in which water is used as a solvent for extraction, is increasingly being

investigated as a potential alternative. In this process, spent batteries are first shredded and crushed to produce a crushed material known as a black mass.

Precious metals from the black mass are subsequently extracted by dissolving it in a mixture of weak acids or strong acids as well as other chemicals, such as hydrogen peroxide under heat, prior to allowing the metals to precipitate.

While the use of these strong chemicals on an industrial scale is much more eco-friendly when compared to conventional techniques, it could still release a significant amount of secondary pollutants, posing considerable health and safety risks, added Assistant Professor Tay.

The team from Nanyang Technological University found that the same goal can be achieved by using a combination of citric acid—a weak organic acid present in citrus fruits—and orange peel that has been dried in the oven and then ground into powder.

During laboratory experiments, the researchers found that the new method effectively isolated about 90% of manganese, nickel, lithium, and cobalt from the spent lithium-ion batteries—a similar efficacy to the method in which hydrogen peroxide is used.

*The key lies in the cellulose found in orange peel, which is converted into sugars under heat during the extraction process. These sugars enhance the recovery of metals from battery waste. Naturally-occurring antioxidants found in orange peel, such as flavonoids and phenolic acids, could have contributed to this enhancement as well.*

*Dalton Tay, Assistant Professor, School of Materials Science and Engineering and School of Biological Sciences, Nanyang Technological University*

Most significantly, solid residues resulting from this procedure were found to be harmless, indicating that this is an environmentally sound method, Assistant Professor Tay further added.

The team subsequently assembled new lithium-ion batteries from the recovered materials and these batteries displayed a charge capacity similar to that of commercial ones.

More studies are being performed to improve the charge-discharge cycling performance of such novel batteries developed from recovered materials.

This implies that the novel technology is “*practically feasible for recycling spent lithium ion batteries in the industrial sense,*” the researchers added.

The researchers are currently seeking new ways to further enhance the performance of their batteries produced from treated battery waste. Furthermore, they are improving the conditions to expand production and also studying the feasibility of eliminating the use of acids in the procedure.

According to Professor Madhavi, also from the School of Materials Science and Engineering at Nanyang Technological University and ERI@N, “*This waste-to-resource approach could also potentially be extended to other types of cellulose-rich fruit and vegetable waste, as well as lithium-ion battery types such as lithium iron phosphate and lithium nickel manganese cobalt oxide.*”

*This would help to make great strides towards the new circular economy of e-waste, and power our lives in a greener and more sustainable manner.*

*Madhavi Srinivasan, Professor, Nanyang Technological University*

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