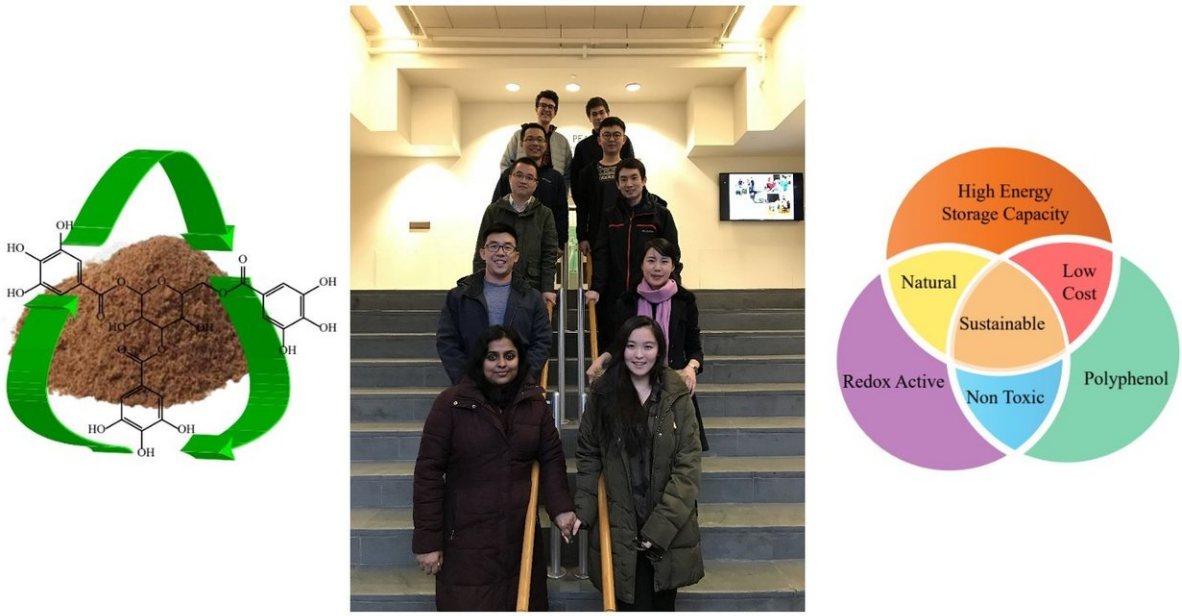
Cheap, sustainable battery made from tree bark tannins

December 18 2017, by Lisa Zyga



(Left) Tannin powder, (center) photo of the researchers, (right) some of the features of tannins when used as a sustainable battery cathode material. Credit: Mukhopadhyay et al. Figures ©2017 American Chemical Society

(Phys.org)—Tannins may be best known for their presence in red wine and tea, but in a new study researchers have demonstrated for the first time that tannins from tree bark can also serve as battery cathode materials. As tree bark is approximately 15% tannins by weight, tannins are naturally abundant, which is one factor that makes them a promising

material for designing sustainable, low-cost, metal-free, high-performance batteries.

Besides their widespread availability, another reason why tannins appear to be such a promising battery material is their high levels of phenol—they have the highest phenol content among any polymer produced by living organisms. High levels of phenol are important because the primary charge storage mechanism of the tannin-based battery is a reversible chemical reaction in which phenol is converted into quinone.

The researchers, led by Hongli Zhu at Northeastern University in Boston, along with PhD student Alolika Mukhopadhyay as the lead author and coauthors from the National Renewable Energy Laboratory in Golden, Colorado, have published a paper on the tannin battery cathode in a recent issue of *Nano Letters*.

"The greatest benefit of using a renewable polymer tannin is that Nature produces a huge amount of tannin, which can be extracted from underused bark with minimal cost and efforts," Zhu told *Phys.org*. "The redox-active phenolic hydroxyl groups of tannins are more than 5000 times higher than lignin, which was previously considered to be the most promising biopolymer for electrochemical energy storage. Due to tannin's significant low molecular weight and extremely high phenolic hydroxyl content, the interpenetrating network of tannins and polypyrrole shows an outstanding electrochemical performance. We think tannin is the new champion of naturally occurring redox-active biopolymers."

In experiments, the researchers demonstrated that a type of tannin called "ellagitannin" extracted from the bark of a chestnut tree can be used to fabricate battery cathodes for batteries that exhibit an excellent overall performance, including large capacitance and high energy density. The

design consists of ellagitannin combined with the polymer polypyrrole for high conductivity, which is placed on top of a carbonized wood substrate.

The wood substrate also contributes to the good battery performance due to the highly aligned channels in its cellular structure. These channels, which the plant once used to transport water and nutrients, are now used to transport electrons and ions in the new battery.

Although making batteries from tannins represents a big shift from using conventional metal materials such as lithium, the naturally occurring compound may offer solutions to two of the biggest challenges facing future energy storage systems: the shortage of metal materials and the high cost of material synthesis. As the researchers demonstrate in the new study, naturally occurring tannins can be purified at low cost for their use in batteries.

Previous research has indicated that other plant-based materials also appear promising as alternative battery materials. One biopolymer that has been extensively studied is lignin, which is found in the cell walls of plants and gives wood and bark their rigid structure. Although widely abundant, lignin has a high molecular weight compared to its relatively low phenol content. As phenol content largely determines the electrochemical performance, such as the energy density and storage capacity, the low phenol content of lignin limits the potential performance of lignin-based batteries.

One of the biggest advantages of tannins is that they have a lower molecular weight than lignin, while their phenol content is 5,000 times higher. These differences offer the potential for fabricating batteries with much higher energy densities and capacities.

As the researchers have just begun to investigate the potential of tannins

in batteries, they expect that it will be possible to further improve the performance of these batteries in the future.

"The charge storage capacity of tannin is high," Zhu said. "However, the intrinsically high aqueous solubility of tannin led to the loss of effective material, causing capacity fade over time. Therefore, we are trying to chemically modify tannin to secure a stable and safe performance in a harsh environment."

More information: Alolika Mukhopadhyay, Yucong Jiao, Rui Katahira, Peter N. Ciesielski, Michael Himmel, and Hongli Zhu. "Heavy Metal-Free Tannin from Bark for Sustainable Energy Storage." *Nano Letters*. DOI: 10.1021/acs.nanolett.7b04242