Ancient red dye powers new 'green' battery

December 11 2012

More than 3,500 years ago, civilizations in Asia and the Middle East first boiled madder roots to color fabrics in vivid oranges, reds and pinks. In its latest technological incarnation, the climbing herb could lay the foundation for an eco-friendly alternative to traditional lithium-ion (Li-ion) batteries. Chemists from the City College of New York teamed with researchers from Rice University and the US Army Research Laboratory to develop a non-toxic and sustainable lithium-ion battery powered by purpurin, a dye extracted from the roots of the madder plant (Rubia species). Credit: John/Vijai

Rose madder – a natural plant dye once prized throughout the Old World to make fiery red textiles – has found a second life as the basis for a new "green" battery.

Chemists from The City College of New York teamed with researchers from Rice University and the U.S. Army Research Laboratory to develop a non-toxic and sustainable lithium-ion battery powered by purpurin, a dye extracted from the roots of the madder plant (*Rubia* species).

More than 3500 years ago, civilizations in Asia and the Middle East first boiled madder roots to color fabrics in vivid oranges, reds and pinks. In its latest technological incarnation, the climbing herb could lay the foundation for an eco-friendly alternative to traditional lithium-ion (Li-ion) batteries. These batteries charge everything from your mobile phone to electric vehicles, but carry with them risks to the environment during production, recycling and disposal.

"Purpurin," on the other hand, said team member and City College Professor of Chemistry George John, "comes from nature and it will go back to nature." The team reports their results in the journal *Nature*'s online and open access publication, *Scientific Reports*, on December 11, 2012.

Most Li-ion batteries today rely on finite supplies of mined metal ores, such as cobalt. "Thirty percent of globally produced cobalt is fed into battery technology," noted Dr. Leela Reddy, lead author and a research scientist in Professor Ajayan's lab in the Department of Mechanical Engineering and Material Science at Rice University. The cobalt salt and lithium are combined at high temperatures to make a battery's cathode, the electrode through which the electric current flows.

Madder plant (Rubia tinctorum)

Mining cobalt metal and transforming it, however, is expensive, he explained. Fabricating and recycling standard Li-ion batteries demands high temperatures, guzzling costly energy, especially during recycling. "In 2010, almost 10 billion lithium-ion batteries had to be recycled," said Dr. Reddy.

Production and recycling also pumps an estimated 72 kilograms of carbon dioxide – a greenhouse gas – into the atmosphere for every kilowatt-hour of energy in a Li-ion battery, he noted. These grim facts have fed a surging demand to develop green batteries, said Dr. Reddy.

Fortunately, biologically based color molecules, like purpurin and its relatives, seem pre-adapted to act as a battery's electrode. In the case of purpurin, the molecule's six-membered (aromatic) rings are festooned with carbonyl and hydroxyl groups adept at passing electrons back and forth, just as traditional electrodes do. "These aromatic systems are electron-rich molecules that easily coordinate with lithium," explained

Professor John.

Moreover, growing madder or other biomass crops to make batteries would soak up carbon dioxide and eliminate the disposal problem – without its toxic components, a lithium-ion battery could be thrown away.

Best of all, purpurin also turns out to be a no-fuss ingredient. "In the literature there are one or two other natural organic molecules in development for batteries, but the process to make them is much more tedious and complicated," noted Professor John.

Purpurin, left, extracted from madder root, center, is chemically lithiated, right, for use as an organic cathode in batteries. The material was developed as a less expensive, easier-to-recycle alternative to cobalt oxide cathodes now used in lithium-ion batteries. Credit: Ajayan Lab/Rice University

Made and stored at room temperature, the purpurin electrode is made in just a few easy steps: dissolve the purpurin in an alcohol solvent and add lithium salt. When the salt's lithium ion binds with purpurin the solution turns from reddish yellow to pink. "The chemistry is quite simple," coauthor and City College postdoctoral researcher Dr. Nagarajan explained.

The team estimates that a commercial green Li-ion battery may be only a few years away, counting the time needed to ramp up purpurin's efficiency or hunt down and synthesize similar molecules. "We can say it is definitely going to happen, and sometime soon, because in this case we are fully aware of the mechanism," said Professor John.

"When you can generate something new or unheard of, you think of chemistry in a different way," he added. "That a natural material or dye can be used for a battery, that is exciting, even for me."

More information: Reddy, A.L.M. et al. Lithium storage mechanisms in purpurin based organic lithium ion battery electrodes. Sci. Rep. 2, 960; doi:10.1038/srep00960 , 11 Dec 2012.

Provided by City College of New York

Citation: Ancient red dye powers new 'green' battery (2012, December 11) retrieved 3 May 2024 from https://phys.org/news/2012-12-ancient-red-dye-powers-green.html