Rice cultivates green batteries from plant

Eurekalert!

HOUSTON – (Dec. 11, 2012) – Here's a reason to be glad about madder: The climbing plant has the potential to make a greener rechargeable battery.

Scientists at Rice University and the City College of New York have discovered that the madder plant, aka Rubia tinctorum, is a good source of purpurin, an organic dye that can be turned into a highly effective, natural cathode for lithium-ion batteries. The plant has been used since ancient times to create dye for fabrics.

The discovery is the subject of a paper that appears today in Nature's online, open-access journal Scientific Reports.

The goal, according to lead author Arava Leela Mohana Reddy, a research scientist in the Rice lab of materials scientist Pulickel Ajayan, is to create environmentally friendly batteries that solve many of the problems with lithium-ion batteries in use today.

"Green batteries are the need of the hour, yet this topic hasn't really been addressed properly," Reddy said. "This is an area that needs immediate attention and sustained thrust, but you cannot discover sustainable technology overnight. The current focus of the research community is still on conventional batteries, meeting challenges like improving capacity. While those issues are important, so are issues like sustainability and recyclability."

While lithium-ion batteries have become standard in conventional electronics since their commercial introduction in 1991, the rechargeable units remain costly to manufacture, Reddy said. "They're not environmentally friendly. They use cathodes of lithium cobalt oxide, which are very expensive. You have to mine the cobalt metal and manufacture the cathodes in a high-temperature environment. There are a lot of costs.

"And then, recycling is a big issue," he said. "In 2010, almost 10 billion lithium-ion batteries had to be recycled, which uses a lot of energy. Extracting cobalt from the batteries is an expensive process."

Reddy and his colleagues came across purpurin while testing a number of organic molecules for their ability to electrochemically interact with lithium and found purpurin most amenable to binding lithium ions. With the addition of 20 percent carbon to add conductivity, the team built a half-battery cell with a capacity of 90 milliamp hours per gram after 50 charge/discharge cycles. The cathodes can be made at room temperature, he said.

"It's a new mechanism we are proposing with this paper, and the chemistry is really simple," Reddy said. He suggested agricultural waste may be a source of purpurin, as may other suitable molecules, which makes the process even more economical.

Innovation in the battery space is needed to satisfy future demands and counter environmental issues like waste management, "and hence we are quite fascinated by the ability to develop alternative electrode technologies to replace conventional inorganic materials in lithium-ion batteries," said Ajayan, Rice's Benjamin M. and Mary Greenwood Anderson Professor in Mechanical Engineering and Materials Science and of chemistry.

"We're interested in developing value-added chemicals, products and materials from renewable feedstocks as a sustainable technology platform," said co-lead author George John, a professor of chemistry at the City College of New York-CUNY and an expert on bio-based materials and green chemistry. "The point has been to understand the chemistry between lithium ions and the organic molecules. Now that we have that proper understanding, we can tap other molecules and improve capacity."

Recent work by the Ajayan Group combines silicon and a porous nickel current collector in a way that has proven effective as a high-capacity anode, the other electrode in a lithium-ion battery. That research was reported recently in the American Chemical Society journal Nano Letters.

But Reddy hopes to formulate completely green batteries. The team is looking for organic molecules suitable for anodes and for an electrolyte that doesn't break the molecules down. He fully expects to have a working prototype of a complete organic battery within a few years. "What we've come up with should lead to much more discussion in the scientific community about green batteries," he said.

Co-authors of the paper are visiting scholar Porramate Chumyim and former graduate student Sanketh Gowda of Rice; postdoctoral researcher Subbiah Nagarajan, facilities manager Padmanava Pradhan and graduate student Swapnil Jadhav of the City College of New York; and Madan Dubey of the U.S. Army Research Laboratory.

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Read the paper at
http://www.nature.com/srep/2012/121211/srep00960/full/srep00960.html

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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)

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Scientists at Rice University and City College of New York are making organic elements for lithium-ion batteries from the root of the madder plant, historically used as a red dye. (Credit: Creative Commons/Wikipedia)

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Arava Leela Mohana Reddy. (Credit Jeff Fitlow/Rice University)

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