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New battery manufacturing processes reduce time, expense

The electrification of vehicles is just a matter of time—but exactly how much time has a lot to do with the cost of lithium-ion large-cell batteries, which show great potential to power electric vehicles.

Right now, however, the expense of manufacturing these batteries is prohibitive, says Pravansu Mohanty, associate professor of mechanical engineering.

As a result, Mohanty says, "this is perhaps the biggest obstacle to the mass electrification of vehicles. The cathode of the battery cell alone accounts for 40 percent of the fuel cell's cost."

But this cost problem soon may be addressed, if his research continues as successfully as it has so far. Mohanty, who founded the college's Additive Manufacturing Process Laboratory, has focused his research on developing manufacturing processes that enable the synthesis of engineered materials and at the same time consolidate them, cost effectively, into component form.

Mohanty, working with the sponsorship of the U.S. Department of Defense and Applied Materials in Santa Clara, CA, has developed a new approach for direct deposition of phosphate and oxide compounds.

"The need for improving the electrode characteristics for lithium-ion batteries to achieve better specific capacity and cycling characteristics has been realized for some time," Mohanty says.

For years, he continues, researchers have worked on controlling the material chemistry, microstructure, and particulate size to achieve better performance. "With their high surface area, nanoparticulate materials with appropriate lattice structure facilitate the easy insertion and extraction of lithium ions and effectively accommodate the severe strain induced during battery operation."

Current synthesis approaches employed for manufacturing of $LiFePO_4$ (lithium iron phosphate) cathode batteries involve many steps and take hours of processing time—therein driving up costs. These three steps are: powder synthesis using approaches such as solid state syntheses, precipitation, sol-gel methods, and spray pyrolysis; annealing/carbonization; and binding the nano powders with a polymer to fabricate the electrode.

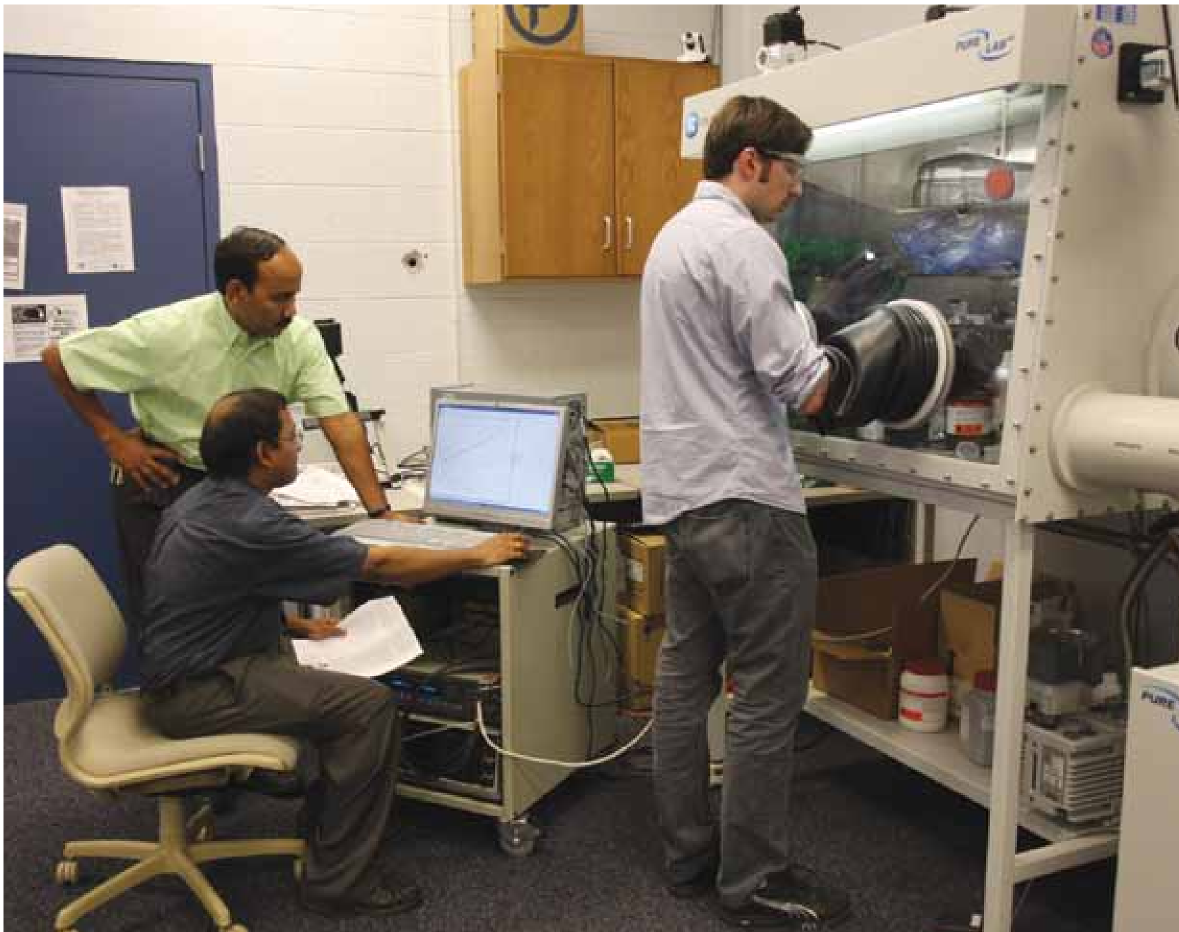
It is the chemistry and microstructure control in these approaches that dictate the performance of the final electrode, Mohanty explains. As a result, there is a need for new synthesis strategies that could reduce the processing time and also offer enough control over material chemistry and microstructure.

"Following this goal, we have developed a new approach for direct deposition for $LiFePO_4$ as well as other materials, using liquid precursors," Mohanty says.

The approach uses an appropriate liquid precursor for the electrode material, which is injected to a plasma jet to atomize/pyrolize and deposit the desired material directly on the substrate in thin film form, ready for device assembly and testing.

Other processes used to deposit films of these materials start from a preprocessed target of the desired electrode material, and usually offer less-than desired film growth rates.

Mohanty's new process, which he terms "direct plasma synthesis approach," changes that, decreasing the time for this process substantially.



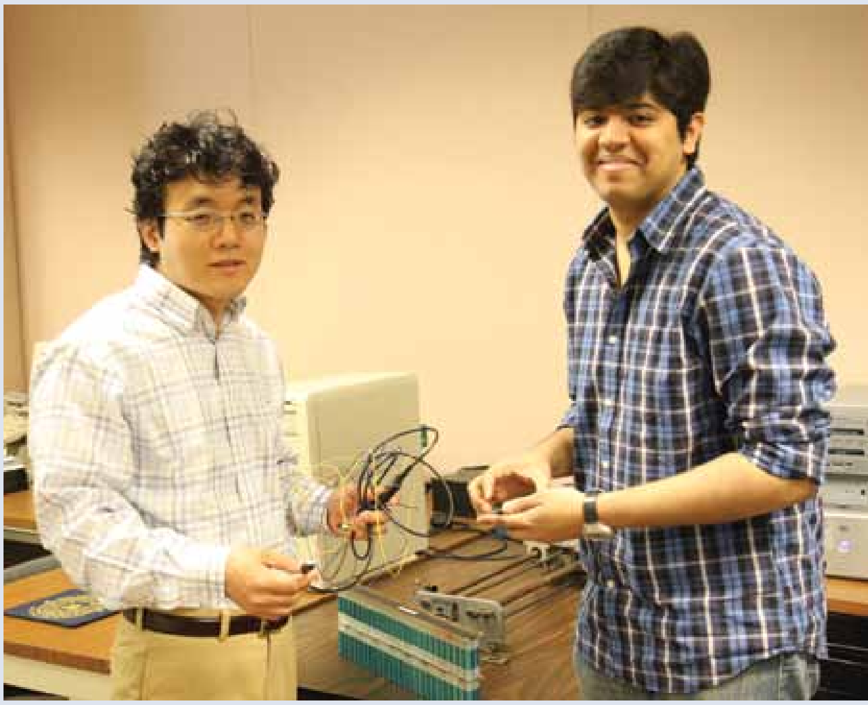
PRAVANSU MOHANTY, RAMESH GUDURU, RESEARCH SCIENTIST, AND NICK MOROZ, GRADUATE STUDENT, REVIEW BATTERY ASSEMBLY AND TESTING

Specifically, the liquid precursors used for spray deposition are prepared following the sol-gel approach. They are then fed to the plasma jet through a proprietary axial injector/atomizer. These films show the desired nanoparticulates embedded in a conductive matrix, which is required to enhance the electrodes' performance.

After further research focusing on the optimization of parameters, Mohanty concluded that "the charge/discharge characteristics of the $LiFePO_4$ film were observed to be comparable to that observed with conventional powder compact electrodes. These preliminary observations clearly demonstrate the feasibility of our concept. This direct fabrication scheme, if successful, can provide tremendous cost advantages."

"Our approach offers unique advantages in terms of process step elimination, and the method is scalable for large-area electrode manufacturing and hence viable for industrial-scale production," Mohanty says.

For more information, contact Pravansu Mohanty at pmohanty@umich.edu.



ASSISTANT PROFESSOR CHEOL LEE AND CHANDRAKANT GAVARA, GRADUATE STUDENT

Professor studies ways to reduce costs of fuel cells, extend battery life

When Cheol Lee worked for a company that manufactured materials for solid oxide fuel cells, he noted that many critical decisions were made mostly based on engineers' and technicians' intuition. Now, as faculty member in the College of Engineering and Computer Science, Lee has dedicated his research to producing an efficient process to take promising materials for fuel cells from early developmental stages to mass manufacturing.

Solid oxide fuel cells, or SOFCs, generate electricity from natural gas and gasoline after minimal fuel processing, resulting in high efficiency and lower emissions. Although these fuel cells could be used to power houses, ships, refrigeration trucks, or even small communities, they are expensive to produce. Strict requirements for various materials drive up costs and reduce manufacturing yields, Lee said.

That's why Lee is working with Samchun Pure Chemical Company, a South Korean business, to develop new experimental designs, data mining, technical cost modeling, optimization techniques, and quality control for determining relationships between the characteristics of three powders used to manufacture SOFC electrodes and the resulting fuel cells' performance.

"The quality of powder materials for solid oxide fuel cells is known to have a direct impact on cell performance," said Lee, an assistant professor of industrial and manufacturing systems engineering. "The long-term goal of my research is to produce a streamlined process for materials companies—from research and development of new materials to their manufacture in mass volume. We will aim to develop software that interactively guides users in this process based on data mining and mathematical optimization."

SOFCs' performance depends upon various characteristics of the powders, such as purity, crystal structure, surface area, particle size, and electrical characteristics, Lee said.

Samchun Pure Chemical Company has provided $36,659, which has allowed Lee to hire a graduate student to assist in programming and literature survey.

Lee is also working with Chandrakant Gavara, a graduate student in electrical and computer engineering, on a separate project. "Modeling and Estimation of Aging in Lithium-Ion Batteries," which is Gavara's directed study, seeks to solve aging problems in lithium-ion batteries.

Batteries' premature failure because of aging can significantly increase the cost of electrical vehicle upkeep, Lee said. Because the aging process occurs more slowly than real-time voltage-current characteristics of batteries, researchers require a model that operates in two different time scales.

Lee has developed a multi-rate observer that allows users to compare measurements made over varying time scales to understand the tool wear in manufacturing processes. Gavara and Lee will use this patent-pending tool to better model the aging process in lithium-ion batteries.

"We are adopting the insights and techniques that we have learned through manufacturing research," Lee said. "This multi-rate observer enables effective integration of measurements made over two different time scales so that we can figure out what is happening inside the machine, the manufacturing process, the battery, and so on."

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