Engineer making rechargeable batteries with layered nanomaterials

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(Phys.org)—A Kansas State University researcher is developing more efficient ways to save costs, time and energy when creating nanomaterials and lithium-ion batteries.

Gurpreet Singh, assistant professor of mechanical and nuclear engineering, and his research team have published two recent articles on newer, cheaper and faster methods for creating nanomaterials that can be used for lithium-ion batteries. In the past year, Singh has published eight articles—five of which involve lithium-ion battery research.

"We are exploring new methods for quick and cost-effective synthesis of two-dimensional materials for rechargeable battery applications," Singh said. "We are interested in this research because understanding lithium interaction with single-, double- and multiple-layer-thick materials will eventually allow us to design battery electrodes for practical applications. This includes batteries that show improved capacity, efficiency and longer life."

For the latest research, Singh's team created graphene films that are between two and 10 layers thick. Graphene is an atom-thick sheet of carbon. The researchers grew the graphene films on copper and nickel foils by quickly heating them in a furnace in the presence of controlled amounts of argon, hydrogen and methane gases. The team has been able to create these films in less than 30 minutes. Their work appears in the January issue of ACS-Applied Materials and Interfaces in an article titled "Synthesis of graphene films by rapid heating and quenching at ambient pressures and their electrochemical characterization."

The research is significant because the researchers created these graphene sheets by quickly heating and cooling the copper and nickel substrates at atmospheric pressures, meaning that scientists no longer need a vacuum to create few-layer-thick graphene films and can save energy, time and cost, Singh said.

The researchers used these graphene films to create the negative electrode of a lithium-ion cell and then studied the charge and discharge characteristics of this rechargeable battery. They found the graphene films grown on copper did not cycle the lithium ions and the battery capacity was negligible. But graphene grown on nickel showed improved performance because it was able to store and release lithium ions more efficiently.

"We believe that this behavior occurs because sheets of graphene on nickel are relatively thick near the grain boundaries and stacked in a well-defined manner—called Bernal Stacking—which provides multiple sites for easy uptake and release of lithium ions as the battery is discharged and charged," Singh said.

In a second research project, the researchers created tungsten disulfide nanosheets that were approximately 10 layers thick. Starting with bulk tungsten disulfide powder—which is a type of dry lubricant used in the automotive industry—the team was able to separate atomic layer thick sheets of tungsten disulfide in a strong acid solution. This simple method made it possible to produce sheets in large quantities. Much like graphene, tungsten disulfide also has a layered atomic structure, but the individual layers are three atoms thick.

The researchers found that these acid-treated tungsten disulfide sheets could also store and release lithium ions but in a different way. The lithium is stored through a conversion reaction in which tungsten disulfide dissociates to form tungsten and lithium sulfide as the cell is discharged. Unlike graphene, this reaction involves the transfer of at least two electrons per tungsten atom. This is important because researchers have long disregarded such compounds as battery anodes because of the difficulty associated with adding lithium to these materials, Singh said. It is only recently that the conversion reaction-based battery anodes have gained popularity.

"We also realize that tungsten disulfideis a heavy compound compared to state-of-the-art graphite used in current lithium-ion batteries," Singh said. "Therefore tungsten disulfide may not be an ideal electrode material for portable batteries."

The research appeared in a recent issue of the *Journal of Physical Chemistry Letters* in an article titled "Synthesis of surface-functionalized WS2 nanosheets and performance as Li-ion battery anodes."

Both projects are important because they can help scientists create nanomaterials in a cost-effective way. While many studies have focused on making graphene using low-pressure chemical processes, little research has been tried using rapid heating and cooling at atmospheric pressures, Singh said. Similarly, large quantities of single-layer and multiple-layer thick sheets of tungsten disulfide are needed for other applications.

"Interestingly, for most applications that involve this kind of battery research and corrosion prevention, films that are a few atoms thick are usually sufficient," Singh said. "Very high quality large area single-atom-thick films are not a necessity."

Singh plans future research to study how these layered nanomaterials can create better electrodes in the form of heterostructures, which are essentially three-dimensional stacked structures involving alternating layers of graphene and tungsten or molybdenum disulfide.

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