Glowing soft colloids give their structure away

Soft colloids such as polymer brushes and polymer-coated particles have a wide range of applications and could be used as biomimetic lubricants, for example in artificial implants. "Even though the microscopic properties of these colloids are widely recognized to play a key role in tailoring their macroscopic properties, they so far are poorly addressed in a variety of physically distinct soft and penetrable colloidal systems," said researcher E. Stiakakis. With colleagues from the Institute of Complex Systems at Forschungszentrum Jülich, he combined smart material preparation and confocal fluorescent microscopy to visualize the microscopic behavior of two-dimensional (2D) lattices of polymer-coated particles.

In the December 2014 issue of *Physical Review Letters* (DOI: 10.1103/PhysRevLett.113268303), the researchers report grafting fluorescent markers onto the DNA arms of charged DNA-coated particles. By modifying the position of the markers along the arm, the arm extension and the particle shape could be quantified. Furthermore, the researchers can image the way soft colloids deform when they are compressed by the action of a magnetic field – using superparamagnetic particles to control the density of the 2D arrays of particles.

It turns out that the DNA arms get compacted without much entanglement with the arms of the neighboring particles, under pressures approaching the MPa range. This confirms that the low friction between particles comes from the lack of arm entanglement, hence the well-known lubrication properties. The researchers finally tested the defect tolerance of the 2D arrays and found that these accommodate large and small particles alike through particle shrinking and anisotropic deformations of the corona.

E. Eiser, an expert in soft materials at the University of Cambridge working on self-assembly of DNA-functionalized colloids, said that this confirms work done in the 1990s with neutral polymer brushes, whose remarkable lubrication properties are due to the fact that the brushes are being compacted rather than interpenetrating each other. She underlines that one of the challenges facing the field is the highly interdisciplinary nature of the work, where knowledge of synthesis, biology, and physics is required if these new findings are to be applied to real-world problems.

The DNA brushes have wide functionalization possibilities and could be used in new electronic or photonic applications: "The DNA brushes can be end-functionalized with many different types of markers. This could be employed in multiplex detection applications in sensors. The mechanical strength of their corona could be used in materials science to design large-area photonic or plasmonic arrays," the researchers report.

Elsa Couderc

Energy Focus

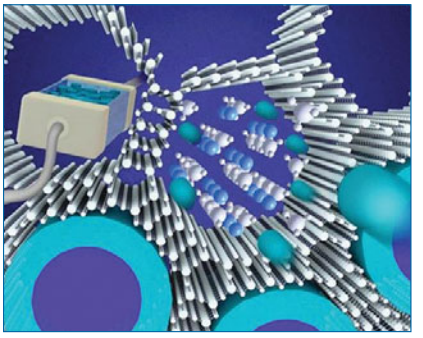
Confining $LiBH_4$ in mesoporous silica yields solid electrolyte for Li-ion batteries

Lithium-ion batteries are all around us; they are in our phones, our laptops, and even our cars. However, these batteries have not yet reached their potential and properties such as lifetimes and energy densities remain to be optimized. One of the major challenges is reducing the weight of these batteries. Lithium-ion batteries are currently filled with liquid or gel electrolytes, where the weight of these cannot easily be altered. In addition, the liquid is often flammable, which can be dangerous, especially during the fabrication process. A study published in the January 14 issue of *Advanced Functional Materials* (DOI: 10.1002/adfm.201402538; p. 184) shows promise for a new, all-solid lithium-ion battery that could potentially cut down the weight of the batteries.

"This would be a big deal for cars," said Petra E. de Jongh, a materials scientist at Utrecht University in The Netherlands and a co-author of the study. With lighter batteries in place, cars can achieve better gas mileage—this is particularly important to environmentally friendly vehicles such as hybrids.

Lithium-ion batteries rely on liquid or gel electrolytes for ion transport, where these typically comprise lithium salts. Positive lithium ions shuttle between the anode and cathode of the battery upon charging and discharging, where this drives the flow of current in the external circuit. Liquids and gels have been the go-to for battery electrolytes because ion transport is fast and reliable, said de Jongh. But beyond weight and safety issues, liquids and gels don't make for long-lived batteries. Lithium dendrites can form, stretching between the electrodes and resulting in short-circuits.

To create longer-lived and lighter batteries, de Jongh turned to her work with hydrogen-storage materials. Replacing the liquid and gel electrolytes with a solid electrolyte would be ideal, but the electrolyte would have to have high ion-transport properties. For de Jongh, a metal hybrid family known as borohydrides, such as $Mg(BH_4)_2$ and $LiBH_4$, became of interest. When used for hydrogen storage, this material had shown high efficiency in transporting ions. In collaboration with



This drawing depicts lithium ions (blue balls) moving fast through $LiBH_4$ near the interface with a silica nanoscaffold. Graphic: Christopher Ege.

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Didier Blanchard, a materials scientist at the Technical University of Denmark, de Jongh decided to trial the ability of this material to transport lithium ions in batteries.

The researchers encased the $LiBH_4$ in a nanoporous silica, which has a low ionic and electronic transport efficiency, and pores with tunable shapes. By creating pores of different shapes and sizes, the researchers aimed to gain a better understanding of the effects confinement had on the ion-transport efficiency of $LiBH_4$.

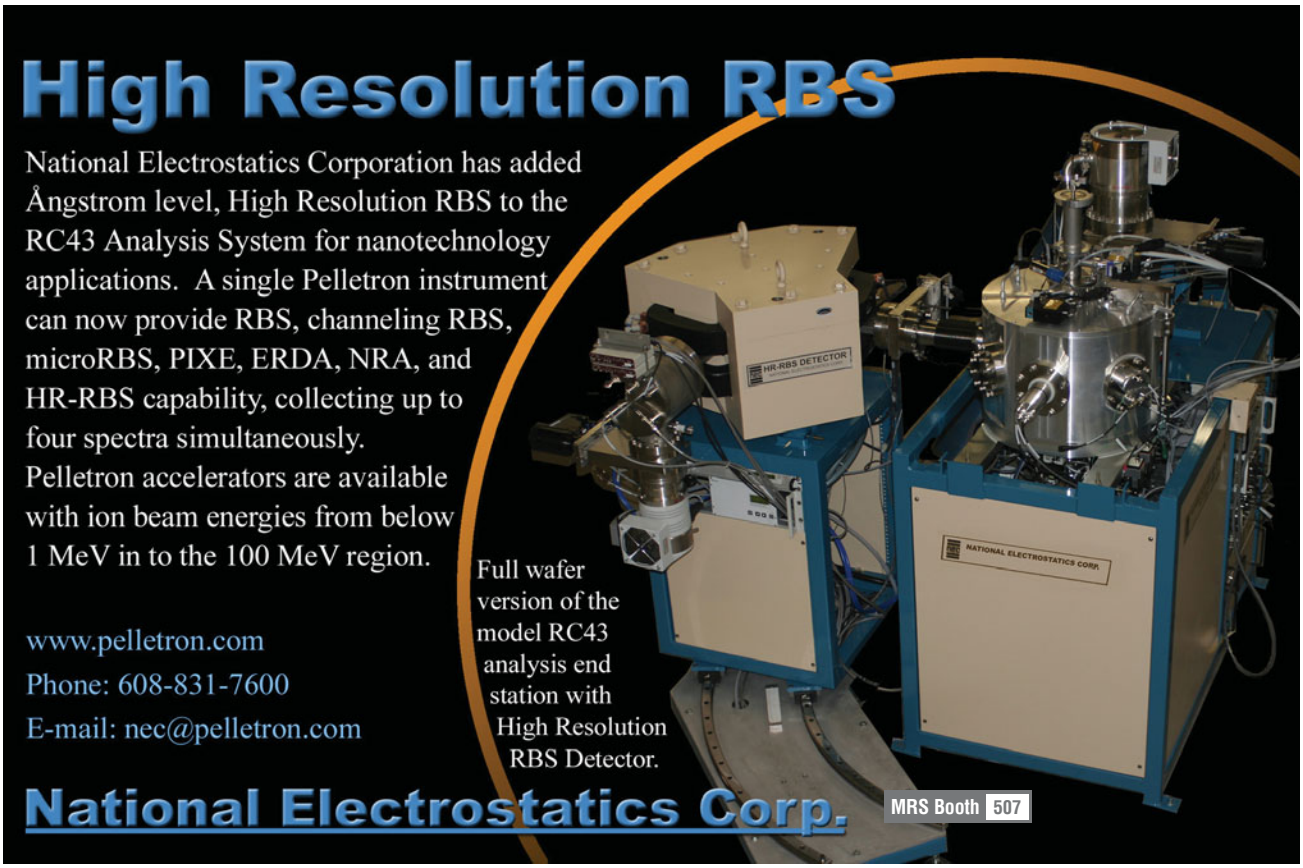
They created scaffolds of silica dioxide that had cylindrical pores with a volume of 0.88–0.97 cm^3/g. The pores were filled with $LiBH_4$ through melt infiltration, where the scaffold and samples of $LiBH_4$ were autoclaved at 295°C, allowing the $LiBH_4$ to infiltrate the scaffold. It became clear that the lithium ions were still highly mobile even at room temperature.

"[The speed] wasn't much different than what happens in a liquid," said de Jongh. The mechanism behind the fast conductance remains a bit of a mystery, she said, though it is clear that it is related to the interface between the scaffold and the $LiBH_4$.

John B. Goodenough, a mechanical engineer at the The University of Texas at Austin, who also studies lithium batteries, has a theory however. He said that it's been known for some time that the introduction of oxides, such as the dioxide in the silica scaffold, allows for faster conductance of lithium ions. "The morphology of the cylindrical pores in the porous SiO_2 creates connected interfacial regions for a better bulk Li^+ conduction," said Goodenough, who was not affiliated with the current research.

But while the increased conductance of lithium ions in a solid electrolyte is interesting, said Goodenough, a major hurdle remains in putting it into practice. So far, all-solid batteries haven't achieved a stable interface where the solid electrolyte and the electrodes meet, he said. "This problem has so far restricted all-solid Li-ion batteries to those with thin electrodes," said Goodenough, "and, therefore, a reduced capacity of stored electrical energy."

Meg Marquardt



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