Haiyan Wang's group began looking at flash-sintered ceramics and the fundamental sintering mechanisms.

The researchers studied the microstructure of flash-sintered YSZ using a transmission electron microscope. They observed dislocations (as multiple arrays of lines in the sample), which are only seen in metallic materials or ceramics deformed under extremely high temperatures. From there, the researchers began investigating the fundamental mechanism behind the ductility of flash-sintered YSZ: why does flash sintering result in high dislocation densities? They also measured the mechanical properties of flash-sintered YSZ using an *in situ* nanomechanical testing tool inside a scanning electron microscope. They found that while transformation toughening was the primary deformation mechanism at room temperature—with strains of 8% that led to brittle failure—at 400°C the mechanism changes and dislocations become the primary carriers of deformation—with strains of up to 10% leading to ductile failure.

B. Reeja Jayan of Carnegie Mellon University, not associated with this study, was impressed to see the high density of dislocations in flash-sintered YSZ. "Understanding such processing–structure–property relationships under external fields is exciting and will be an active area of research," she says.

In future work, the research team hopes to generalize the results to other ceramic systems by understanding which are key in enabling the ceramics' plastic deformation. This could lead to advances in engineering ceramics for many industrial applications.

Other members of the research team are affiliated with Oak Ridge National Laboratory, Colorado State University, and the University of California, Davis.

Antonio Cruz

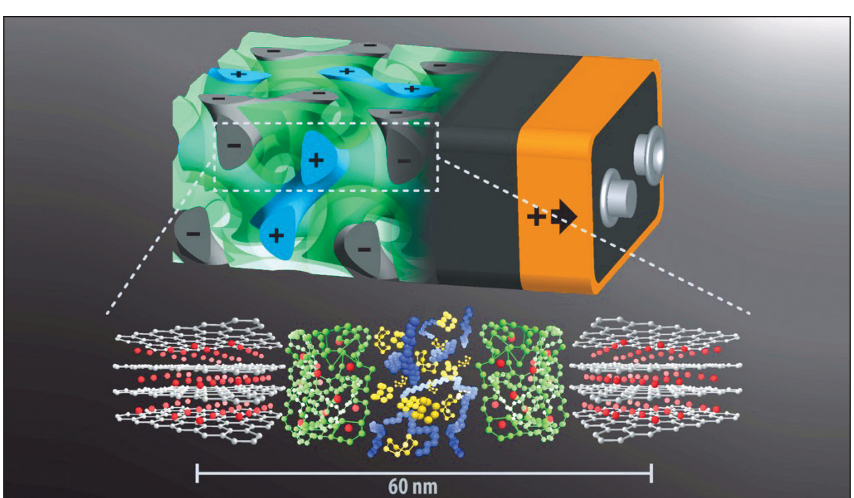
Energy Focus

Fast-charging 3D battery developed by bottom-up nanofabrication

Traditionally, battery architectures include a layered assembly of anodes, cathodes, and a separator. In Li-ion batteries, the thickness of each component, which is typically ~10 μm, dictates the charging rate of the battery governed by the diffusion of lithium ions. Now researchers have designed a so-called three-dimensional (3D) battery fabricated through a novel bottom-up approach, where all of these components interpenetrate and in which the thickness of each layer is just 10 nm. This makes it three orders of magnitude thinner than the mainstream batteries currently on the market. Since diffusion time significantly depends on the size of each component, this design results in orders of magnitude faster charging times. The 3D battery design is a radical deviation from mainstream battery design concepts. The concept sounds straightforward, but was complicated to achieve in practice.

According to U.B. Wiesner of Cornell University, lead researcher in this study that was published in a recent issue of *Energy & Environmental Science* (doi:10.1039/c7ee03571c), thinner batteries have been demonstrated previously that have increased power density but reduced energy density. With the 3D design, the thinner components promote fast ion transport while also offering increasing charge storage.

In this bottom-up nanofabrication, approach the porous carbon anode is deposited first. The porous structure of the layer was confirmed through a scanning electron microscope. The polymer electrolyte poly(phenylene oxide) is coated afterward. The last layer (cathode) of two interpenetrating network mesopore channels is deposited, which is a composite of sulfur and poly(3,4-ethylenedioxythiophene)(PEDOT). The redox-active functionality with a discharge voltage of 2–2.5 V versus lithium and infiltration at moderate temperatures (155°C) made the selection of sulfur an easy choice in comparison with the standard lithium cobalt oxide cathode. PEDOT is employed because of its high electronic conductivity. With these components in place and in the interpenetrating configuration, the battery could operate at a stable open-circuit voltage and a well-defined discharge plateau at 2.7 V with a reversible capacity of 0.2 mA h cm^{-2}. As an illustrative comparison, a conventional battery design with a similar capacity would occupy an area that is 4700 times larger.



Rendering of the 3D battery design with anode (gray) and cathode (blue) interpenetrating each other separated by the separator layer (green). Bottom: Molecular structures of anode, separator, and cathode (same color code) materials with lithium ions (red) shuttling back and forth. Scale bar indicates that the entire sandwich has a thickness of only about 60 nm. Credit: U. Wiesner.

https://doi.org/10.1557/mrs.2018.187 Published online by Cambridge University Press

Étienne Knipping, a senior researcher at Leitat Technological Center in Barcelona, says, "The expansion of small electronics encourages the development of smaller batteries [with greater performance]. This requires a different way of designing a battery such as the 3D architecture that [maximizes] the material's capacity in a limited volume. In this work, the authors found an elegant bottom-up, self-assembly process to fabricate a 3D carbon/sulfur battery with encouraging performance. Their results provide essential insights for the improvement of microbattery development."

Rahim Munir

Bio Focus

GaN thin films encode cell regulatory response for biological communication

Bioelectronics-based computing uses communication between cells through ion exchange to encode and decode information. Brain-machine interfaces establishing a connection between the human brain and an external device are expected to be the future of communication as they would provide accelerated information channeling, long-term data storage, and enable the handling of a large amount of data. Similar to neural networks, the ultimate bioelectronics interface will employ artificial intelligence with biology to continuously sense and process information at discrete locations.

To this aim, the first requirement is to develop suitable interfaces that receive and transmit signals between biological entities and synthetic materials. To allow for efficient bridging, these materials should be good conductors, biocompatible, and applicable to many functions. Thin III-nitride electrodes based on GaN, AlN, or AlGaN are promising options as they are inert, scalable to mass production, and can be functionalized.

In work published in a recent issue of *Nanoscale* (doi:10.1039/c8nr03684e), the research group of Albena Ivanisevic at North Carolina State University has explored how nanostructured GaN thin films can encode the regulatory response of a model organism, the yeast *Saccharomyces cerevisiae*. Yeast cells are particularly suitable for this preliminary work as they are robust and can be cultured in a matter of hours.

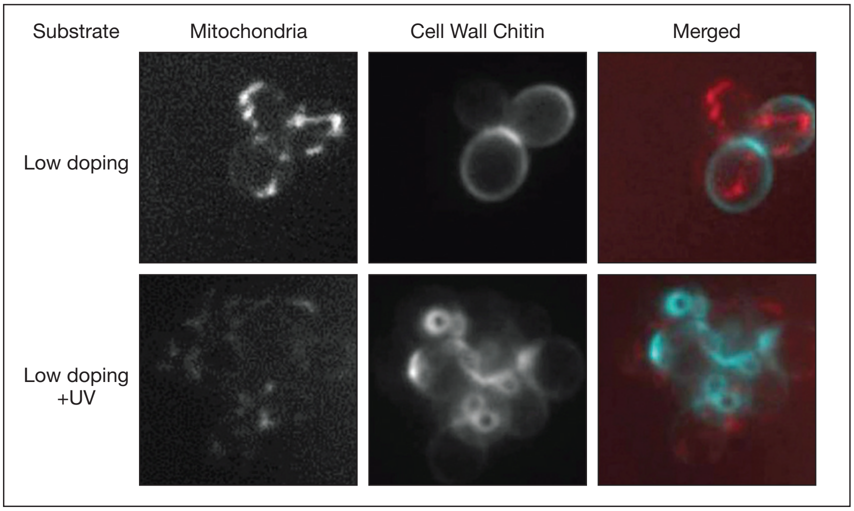
The first key parameter measured is adhesion of the cells, achieved by coating the GaN films with molecules from the growth medium. Then, the films are functionalized using a UV treatment in a controlled atmosphere and the cell response is assessed again. In the presence of oxygen, a large number of negative species such as free electrons, OH^- and O_2^- ions increase the surface charge. As a result, the cells tend to cluster into groups of 6–8 cells, which is twice more than in the absence of functionalization.

In addition to this macroscopic behavior, the yeast cells exhibit hyperoxia (a state when they are exposed to very high levels of oxygen) after the UV treatment in the presence of O_2. This state corresponds to changes in cell gene expression and cell polarization. The surface functionalization therefore directly influences the flux of ions across the cell's membrane. The impact of the substrate topography and surface charge and chemistry on the response of the yeast could then be used to encode information at the molecular level.

"This is our initial report and we are exploring a number of parameters we can change, both in terms of materials properties as well as experimental *in vitro* design. We plan to carry out further analysis to understand genetic changes as a result of our interfacial interactions," Ivanisevic says.

Ciro Chiappini from the Nanomaterials and Biointerfaces Laboratory of King's College London, UK, who did not take part in the study, is excited by the possible follow-up studies. He is expecting the development of useful ways of controlling the response of excitable cells if a similar strategy is applied to mammalian cells. Chiappini says that "a similar approach has been recently shown by Bozhi Tian's group at The University of Chicago … to be extremely versatile to stimulate activity in neurons. Also, coupling these strategies with substrate topography such as nanoneedle arrays could be a sophisticated means for combined intracellular stimulation and sensing." But to fulfill this potential, he says, "it would be important to first evaluate the toxicity of the photoinduced reactive oxygen species to primary mammalian cells."

Hortense Le Ferrand



Response of *Saccharomyces cerevisiae* before and after increase in surface charges by UV treatment, showing decreased mitochondrial activity and increased chitin expression by the cells. Credit: *Nanoscale*.

https://doi.org/10.1557/mrs.2018.187 Published online by Cambridge University Press