Applying a coat of fluoropolymer to the Ta_2O_5 dielectric ameliorates the problem, the researchers found, but cannot prevent it.

Nonetheless, Krupenkin and Taylor remain sanguine about embedding their circuits in a pair of shoes to drive mobile electronics such as a cell phone, music player, or emergency flashlight. Fortunately, mercury isn't the only metal that is liquid at room temperature; galinstan, a nontoxic, liquid-metal alloy of gallium, indium, and tin, has proven equally effective when sealed off in closed channels to avoid oxidation. The two researchers don't expect the shoes to replace batteries, only to keep them charged and to dramatically extend their lifetime. (For more on the challenges associated with rechargeable batteries, see the article by Héctor Abruña, Yasuyuki Kiya, and Jay Henderson in PHYSICS TODAY, December 2008, page 43.)

So far, they have patented the idea, talked with the US military, and founded a company (InStep NanoPower) but have not yet commercialized the technology.

Mark Wilson

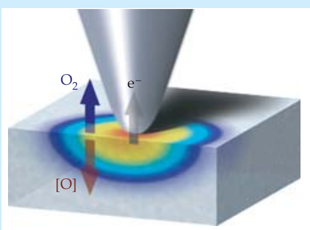
References

1. For a review, see F. Mugele, J.-C. Baret, *J. Phys. Cond. Mat.* **17**, R705 (2005).
2. T. Krupenkin, J. A. Taylor, *Nat. Commun.* **2**, 448 (2011).
3. T. M. Squires, S. R. Quake, *Rev. Mod. Phys.* **77**, 977 (2005).

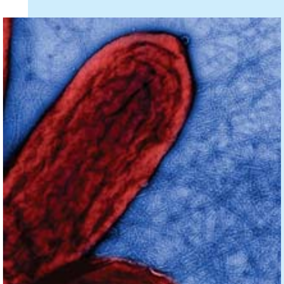
physics update

These items, with supplementary material, first appeared at http://www.physicstoday.org.

Nanoscale electrochemistry. Although rechargeable batteries and fuel cells have been increasingly considered for or used in mobile electronic devices and electric vehicles, they have not been adopted for large-scale energy-storage and power generation primarily because their energy and power densities are still orders of magnitude below hydrocarbon fuels. Those densities can be greatly improved in metal–air batteries and fuel cells that tap an unlimited supply of environmental oxygen. Studies have shown that the reduction and formation of molecular oxygen in an electrochemical process play a significant role in limiting the efficiencies of those technologies, but insight into the dynamics of those reactions has been hindered by an inability to probe and model them on the nanoscale. Now, researchers from the US, Germany, and Ukraine, led by Sergei Kalinin at Oak Ridge National Laboratory, have employed a scanning probe microscope to map local electrochemical activity on a surface by tracing the appearance, disappearance, and diffusion of oxygen vacancies. As shown in the sketch, a platinum-coated cantilever tip (which doubles as a catalyst) applies a voltage bias to the surface and generates or annihilates oxygen vacancies; the false colors represent the concentration of reduced oxygen. The associated volume change produces an electrochemical strain that is detected by the microscope. Information from the resulting maps may lead to batteries and fuel cells whose mesoscopic architecture is designed to optimize the oxygen-reaction processes. (A. Kumar et al., *Nat. Chem.* **3**, 707, 2011.) —JNAM



Metal-like microbial nanowires. Although most bacteria are electrical insulators, some do support electric currents. Debates remain, however, over the nature of that transport (see PHYSICS TODAY, December 2010, page 18). New work by microbiologist Derek Lovley, physicist Mark Tuominen, and colleagues at the University of Massachusetts Amherst shows that the anaerobic bacterium *Geobacter sulfurreducens* can conduct along filaments attached to the cell membrane. Composed of the protein pilin, the filaments—only 3–5 nm wide and up to tens of microns long—have metal-like properties akin to those of synthetic organic conductors. Furthermore, the filaments form extended networks, like the one seen here in dark blue surrounding a bacterium 0.5 µm wide, that can conduct over centimeter distances. The researchers studied the nanowire networks by growing films of living *G. sulfurreducens* on top of two electrodes separated by a 50-µm gap. The biofilms had a conductivity of 5 mS cm^{-1}, comparable to that of manmade polymer nanostructures, and exhibited many hallmarks of metallic behavior. In a transistor configuration, a nearby gate electrode could modulate the film's conductivity by a factor of 100. At moderate temperatures, the conductivity showed an exponential temperature dependence reminiscent of quasi-one-dimensional organic metals. Disorder effects began to dominate at low temperatures, which suggests that appropriate processing to remove network defects could improve the conductivity for potential applications. Microbial nanowires, say the researchers, could open the door to a range of conducting nanomaterials that are naturally occurring, nontoxic, and inexpensive to produce, for such uses as environmental cleanup, biosensors, and power applications. (N. S. Malvankar et al., *Nat. Nano.*, in press, doi:10.103/nnano.2011.119.) —RJF



Network analysis diagnoses kidney disease. Obstructive nephropathy (ON) is the most common kidney disease among children. Sufferers have a blockage of the urinary tract, which forces urine back into the kidney. If unrecognized and unchecked, the ensuing damage shuts down the organ. In principle, kidney function and malfunction are reflected in the metabolites that pass through the kidney and the regulators that control the metabolites' consumption and production. But of the myriad species of metabolites and regulators, which ones presage ON? To answer that question, Massimiliano Zanin and Stefano Boccaletti of the Technical University of Madrid turned to network theory. Their starting point was a database of 852 metabolites and 834 regulators (microRNAs) drawn from 10 ON patients and a 10-member control group. Levels of metabolites and regulators varied within each group. Still, it proved possible to construct for each metabolite (or regulator) a network that embodied how far every other metabolite (or regulator) deviated from its statistically expected correlation. As the examples in the figure show, control group networks had amorphous topologies, whereas ON networks had star-like topologies centered on the most abnormal metabolite or regulator. Thanks to their simplicity, ON networks are more "efficient" than control networks—that is, the paths between all their node pairs are shorter on average. That difference, Zanin and Boccaletti propose, could underlie an early ON diagnostic. (M. Zanin, S. Boccaletti, *Chaos* **21**, 033103, 2011.) —CD ■