

rated into flexible materials in a shoe or a piece of clothing, for example, the mechanical forces of walking or tapping a foot would cause the negatively and positively charged surfaces to separate and create an electrical potential. Hook up a wire between the two surfaces and electrons will flow through the wire from the electron-rich Kapton to the electron-poor PMMA.

Initially they created a maximum potential of 5 volts. But at the meeting, Wang reported that by patterning the surface of the two materials to increase the amount of friction they could create a potential of up to 1000 volts and a current density of 128 milliwatts per cubic centimeter. A 6-centimeter-by-6-centimeter device powered by foot tapping was able to recharge a cell phone battery or power some 600 LED lights. “I was very impressed with the power output,” says Seung-Wuk Lee, a bioengineer and nanogenerator expert at the University of California, Berkeley. The Georgia Tech results are also reported in the 12 December 2012 issue of *Nano Letters*.

Wang says he is already considering making square meter-sized devices with up to 200 layers of nanogenerators stacked atop one another for use in harvesting ocean power. Such a device may be able to produce as much as 40 kilowatts of power per cubic meter, which could make nanogenerators a large-scale power source.

the small size of the particles allowed these changes without cracking.

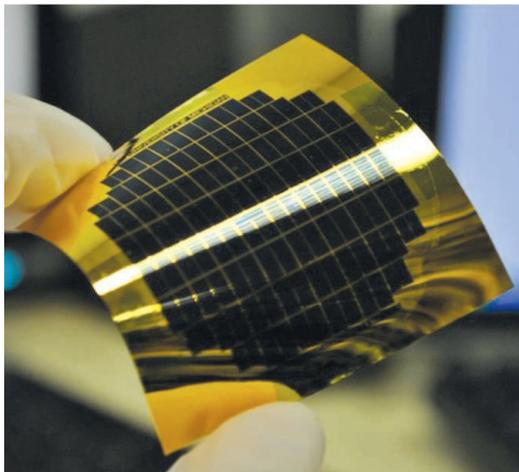
Finally, the TiO_2 also constrained the polysulfides, so these byproducts were unable to escape and poison the rest of the cell. At the meeting, Cui reported that the new batteries have a capacity of about 800 to 1000 milliamp-hours per gram, roughly six times that of the current devices on the market. And Cui said his team charged and discharged the battery more than 1000 times with negligible drop off in performance.

Pooi See Lee, a materials scientist at Nanyang Technological University in Singapore, says that Cui’s work represents “big progress” for lithium-sulfur batteries. In previous work, Cui’s team encapsulated silicon nanoparticles in either a carbon or polymer coating for use as a high capacity anode, which can potentially give lithium-ion batteries another 10-fold power boost. Now, Cui says, his group is working to put the two nanoparticle electrodes together to see if they can produce the battery Christmas presents have been waiting for.

Space Solar Cells With A Down-to-Earth Cost

The joke among electrical engineers is that gallium arsenide (GaAs) is the semiconductor of the future and always will be. Nowhere is that more true than with commercial solar cells that use semiconductors to convert sunlight to electricity—a market where profit margins are razor thin. GaAs has been used for decades to make ultrahigh-efficiency solar cells for spacecraft. But the out-of-this-world cost of GaAs itself makes these too expensive for mass-market uses. Now, researchers at the University of Michigan may have found a way not only to drop the cost of producing GaAs cells, but also to drop the cost of the power they produce to near that of grid power from fossil fuels.

Rao Tatavarti, a condensed matter physicist at MicroLink Devices in Niles,



Recycled. A new strategy for reusing gallium arsenide wafers may allow solar cells made from this top performer to be cheap and flexible.

Illinois, says the new work is “a good approach.” However, he cautions, the work remains an early proof-of-concept, and scaling up advances in GaAs solar cells has long proven challenging. “In principle it’s a good idea. But it can be a costly process to do it on a large scale,” Tatavarti cautions.

The idea for that process isn’t dramatically different from what others have been trying to do for a long time. Crystals of GaAs are typically grown in 200-millimeter-diameter cylinders that are then sliced into thin wafers. Other materials are then layered on the wafers and patterned to make electronic devices or solar cells. But this tends to use too much of the expensive GaAs.

More recently, groups around the world have used GaAs as a substrate on which to

grow other semiconductor alloys. These top layers are grown to perfectly match the atomic arrangement of atoms in the underlying GaAs, which gives them good electronic properties. Manufacturers then use a process known as epitaxial liftoff to remove the topping layers and recover the GaAs wafer so that it can be reused. Unfortunately, the epitaxial liftoff usually causes some minor damage to the GaAs wafer, so it can only be used a few times before engineers must replace it with a fresh wafer. As a result, costs for GaAs solar cells remain high.

Three years ago, Stephen Forrest, a materials scientist at the University of Michigan, Ann Arbor, came up with a way to solve this problem for a related semiconductor alloy called indium phosphide (InP). His team’s strategy was to add two additional very chemically different layers to the sandwich-like stack of materials. The added layers allowed the materials grown above to continue to match the exact lattice spacing of InP, but because they were chemically distinct, they could be etched away selectively without damaging the underlying InP wafer at all, enabling it to be reused again and again.

Still, Forrest says that interest in the approach was muted because InP is not as good of a solar cell material as GaAs. At the meeting, Forrest presented his group’s latest achievements in extending their epitaxial liftoff approach to GaAs. As before, the two extra chemically distinct sacrificial layers allowed Forrest’s student Kyusang Lee and electrical engineer Jeremy Zimmerman to grow thin layers of high-quality GaAs on top of a GaAs wafer and then remove the top layer while not damaging the underlying wafer at all. Moreover, additional steps also allowed them to bond the final GaAs layer to a clear plastic substrate, giving them a flexible solar cell with more than 22% efficiency.

If cheap solar concentrators are added to focus more light onto the cell, Forrest says he believes that they should be able to convert more than 30% of the energy in sunlight into electricity. If that’s the case, Forrest says his calculations show that they can reduce the cost of power from the cells to less than \$1 per watt, roughly the current cost for silicon-based solar cells. If they can muster further improvements, that price could drop close to grid parity—the holy grail for solar power.

—ROBERT F. SERVICE