

write, erase, or read function by adjusting the applied fields with varying distance to the sample surface.

A baseline in-plane magnetic field reduces the activation threshold for switching the spin state first, then the magnetic tip applies a small additional field to trigger the switch, causing a “write” action. Reversing the applied field “erases” the switch,

and turning off the applied field resembles the “read” mode.

“In principle, our artificial magnetic charge ice could benefit the investigations and applications in any two-dimensional materials systems that change properties in a magnetic field,” Wang says.

“The paper demonstrates a method of directly writing patterns into specific

moments of an artificial ice array of nanomagnets,” says Peter E. Schiffer, professor of physics and Vice Chancellor for Research at the University of Illinois at Urbana-Champaign. “Through the clever use of array geometry and external magnetic field, this microscopic control opens the door to new flexibility in the study of artificial spin ice.”

**YuHao Liu**

### Energy Focus

#### New process enables ultrathin, ultraflexible GaAs photovoltaics

By modifying a commonly used technique for printing solar cells on flexible materials, a team of South Korean scientists have created photovoltaics so flexible that they can bend around a pencil. As reported in a recent issue of *Applied Physics Letters* (doi:10.1063/1.4954039), the photovoltaics are based on ultrathin solar cells that are as efficient as similarly formed thicker cells, but can withstand extreme bending. These properties are ideal for powering wearable electronics like fitness trackers, as well as other devices that require mechanically flexible power sources.

The researchers created their ultrathin solar microcells out of gallium arsenide (GaAs). They stamped the cells directly onto a flexible substrate covered in gold using a modified version of a process called transfer-printing. Transfer-printing usually involves stamping solar cells onto an adhesive layer that lies on top of a substrate electrode. In this case, however, the team bypassed the adhesive layer altogether.

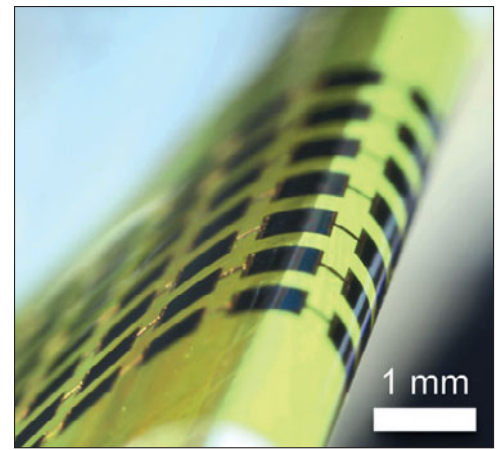
The researchers used heat and pressure to adhere the solar microcells directly to the gold-covered substrate. This process also melted a preexisting layer of photoresist over the microcells. The photoresist acted as a temporary adhesive and protected the microcells from damage when the stamp was peeled away. The photoresist was then removed, leaving behind a photovoltaic just 1  $\mu\text{m}$  thick and extremely flexible.

The key to their success is the adhesive process, according to Jongho Lee, a professor at Gwangju Institute of Science and Technology and the leader of this research group. “Others usually use an interlayer adhesive between the solar cells and substrate. The interlayer adhesive, even with a conductive adhesive, increases the electrical and thermal resistance, reducing electrical performance.” The interlayer adhesive, even with a conductive adhesive, increases the electrical and thermal resistance, reducing electrical performance.” By eliminating the interlayer, the researchers eliminated this loss and reduced the thickness of the photovoltaic.

Most photovoltaics created by transfer-printing solar cells onto a flexible substrate are 2–4 times thicker than those created by this research team. Traditional designs use laterally conducting solar cells that require a thick bottom contact layer. This layer absorbs light, but does not generate electricity. By using vertically conducting solar cells, the researchers were able to reduce the thickness of the bottom contact layer without reducing performance.

In addition, most designs feature a thick base layer in order to absorb more photons and generate more electricity. In the new design this isn’t necessary. The layer of gold in direct contact with the thin bottom contact layer acts as a reflector, rerouting photons back into the solar cell and giving them another chance to be absorbed.

John A. Rogers, an expert on flexible electronics from Northwestern University



An optical image of the solar microcells wrapped around the edge of a glass slide 1 mm thick. Credit: Photo by Juho Kim. Reproduced with permission from *Appl. Phys. Lett.* **208**, 253101 (2016); doi: 10.1063/1.4954039. © 2016 AIP Publishing.

who was not affiliated with the research, considers the work to demonstrate powerful approaches for releasing GaAs cells from a source wafer and printing them onto substrates. “The authors introduce some interesting means to control the interface mechanics in a way that allows transfer-printing without separate adhesive layers,” he says.

Looking to the future, Rogers continues, “An opportunity for the materials community is in the development of advanced release layers and associated epitaxial growth methods to enable this scheme to be used with multijunction solar cells that offer even higher performance.”

The team is now working to optimize and extend the technology and process they developed in order to produce more efficient large-area solar-cell arrays.

**Kendra Redmond**