whether the heart is at the systole (contraction) or diastole (relaxed) phase.

Recently, the research team led by Molly M. Stevens at the Imperial College London published an article in *Advanced Functional Materials* (doi:10.1002/adfm.201800618) on an auxetic conductive cardiac patch that stretches and contracts seamlessly with heart tissues. As the term "auxetic" suggests, the scaffold design has a negative Poisson's ratio, which allows it to expand in multiple directions when subject to forces to meet the large mechanical deformations during the beating of the heart (**Figure 2**).

The auxetic property was found to improve the shear and indentation resistance of the cardiac patch, and it also stretched and conformed to native rat heart tissues. The research team observed promising results at day 14 after surgery, as the cardiac patch remained adhered and well integrated with rat heart tissue without eliciting any adverse fibrotic activities *in vivo*.

Shaochen Chen from the University of California, San Diego, who was also not involved in this work, commented that he is "glad they made this [auxetic cardiac patch] happen and the work is excellent." He also added that with a 3D printing technique (see *Advanced Functional Materials*, doi.org/10.1002/adfm.201002022), the fabrication process could probably be faster and more precisely controlled. However, Stevens added that as their auxetic structure had a bilayer structure, their chosen fabrication technique was also appropriate.

Kella Kapnisi, who worked on auxetic biomaterials in Stevens's group, says that auxetic materials can more comfortably form around a curved sheet than a non-auxetic material. Stevens's group is excited to explore future applications, such as interfacing auxetic materials with tissues such as the "skin that stretches and curves in multiple directions, vascular tissues, and cavities such as the stomach."

Future

Cardiovascular diseases present a huge monetary cost to society due to treatments, loss of working abilities, and mortality. Heart models that better mimic physiology can provide more accurate assessments of drug toxicity and enhance tissue engineering efficacy. Patches with improved mechanical properties can meet the biomechanical demands simultaneously with the biochemical/electrical needs of the heart to improve treatment outcomes.

Materials innovations have significantly impacted diagnosis and clinical treatment of heart disease. Recently, the Japanese government has given the green light for clinical trials of cardiac patches loaded with stem cells for heart regeneration, as reported by David Cyranoski in *Nature* (doi:10.1038/d41586-018-05278-8). An exciting area in the future for materials researchers is to synergize their creativity in materials designs with patient-derived stem cells to improve (personalize) drug screening and cardiac regeneration.

Andy Tay, of Stanford University, is the inaugural MRS Bulletin *2017 Postdoctoral Publication Prize recipient.*

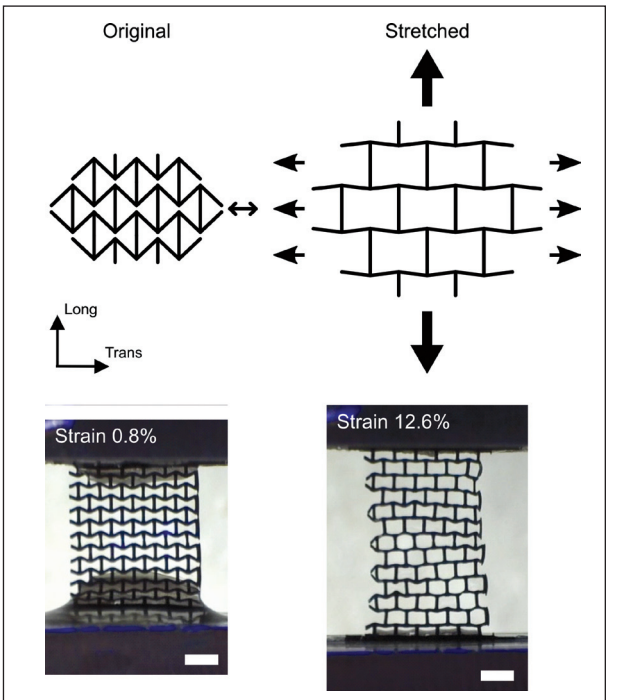


Figure 2. Most materials have a positive Poisson's ratio. This means that when they are stretched longitudinally, they contract transversally. However, auxetic materials are defined as having a negative Poisson's ratio, which allows them to expand in multiple directions. An example of stretching of the auxetic cardiac patch is shown where increasing strains result in expansion of the scaffold material. Scale bar is 1 mm. Credit: *Advanced Functional Materials*.

Energy Focus

Structural water plays key role in hybrid energy-storage device

Energy-storage devices that use layered electrodes are of great interest. Batteries are relied on for their high charge storage capability owing to ion intercalation into electrodes. Capacitors, on the other hand, output charge faster due to ion adsorption onto electrode surfaces. Hybrid energy-storage devices reap the benefits of both. Now Veronica Augustyn's research group from North Carolina State University has examined another important property of layered energy-storage electrodes: their mechanical behavior during charging and discharging. The researchers used this insight to show how water embedded into a structure can transform its energy-storage behavior from battery-like to capacitor-like.

Since ion intercalation significantly strains materials, outstanding battery electrode structures must bend and expand with relative ease to accommodate ions in order to offer high power densities and rate capabilities. While observing and quantifying local mechanical flexibility is tricky, an appropriate probe characterization technique, coupled with electrochemical cycling, can provide this information. The team has designed an *in operando* method using atomic force microscopy (AFM) to assess the charge mechanism and resulting strain-induced deformations in tungsten oxide (WO_3) electrodes, and compared their

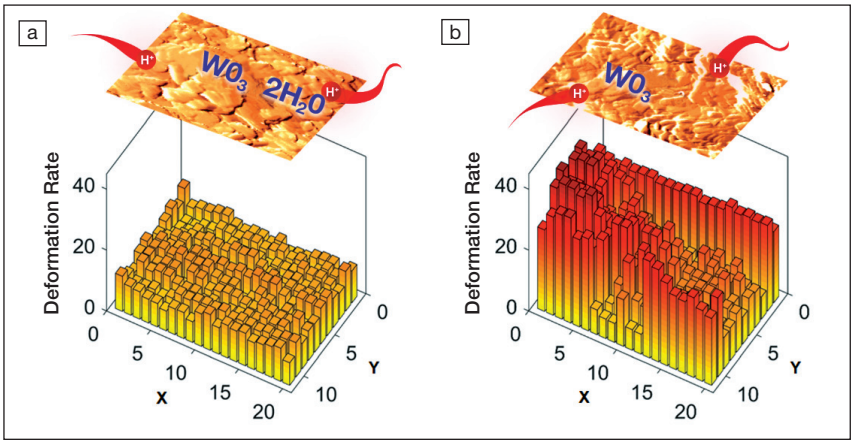
https://doi.org/10.1557/mrs.2018.183 Published online by Cambridge University Press

response to hydrated, two-dimensional tungsten oxide ($WO_3 \cdot 2H_2O$) electrodes that contain water. They reported their findings in a recent issue of *ACS Nano* (doi: 10.1021/acsnano.8b02273).

"The exciting aspect about the correlation between the electrochemical current and electrode deformation measured via AFM is that it allows us to probe electro-chemo-mechanics at the nanoscale," Augustyn says. "This was particularly helpful in elucidating the unexpected role of water incorporated into the structure of the hydrated form of tungsten oxide."

"We found that the water layers in hydrated tungsten oxide do two things," says Ruocun Wang, a doctoral student in Augustyn's laboratory and lead author of the article. "First, they minimize deformation and reduce expansion and contraction of the material as ions move in and out. Second, the water layers make the deformation more reversible, meaning that the material returns to its original dimensions more easily," he says.

The researchers used a platinum-coated AFM cantilever to measure deformations in tungsten oxide electrodes while they applied an electrochemical cycling experiment with a sulfuric acid electrolyte. The shapes of charge–discharge cyclic voltammetry curves corresponded with the mechanical deformation rate of the respective electrodes. Of note, electrochemical results contrasted the pseudocapacitive-like behavior of hydrated WO_3 (fast, reversible surface reactions) against the battery-like intercalation process in its anhydrous counterpart (slow, diffusion-limited process).



Scanning probe microscopy captures the flexibility of tungsten oxide electrodes during electrochemical cycling and highlights the relative ease with which ions enter and exit the hydrated electrode form (a) compared to the anhydrous electrode (b). Credit: Veronica Augustyn et al.

Anhydrous tungsten oxide experienced significant strain in order to intercalate the protons into its structure, and the asymmetrical profile of its charge–discharge cycling behavior mirrored its AFM-detected mechanical deformation rate. Structural analysis of the hydrated material showed that water molecules in the interlayer spacing separated the layers of corner-sharing $WO_5(OH_2)$ octahedra and confined the deformation to two dimensions. This, in turn, endowed the hydrated form with greater flexibility and allowed ions to easily move in and out of the electrodes during cycling.

Albert Davydov of the National Institute of Standards and Technology, who was not involved in this study, says, "*In situ* correlation of reversible redox activity with the mechanical deformation, together with high spatial and temporal resolution of the AFM dilatometry, has unambiguously inferred the proton exchange mechanism in hydrated versus anhydrous tungsten trioxide. I can envision how this methodology can be extended to gain an insight into the reaction mechanisms in other industrially relevant electrochemical processes, such as catalysis or corrosion."

Other members of the research team are affiliated with Oak Ridge National Laboratory and Texas A&M University.

Boris Dyatkin

Bio Focus

3D printed scaffolds developed from isomalt sweetener

Three-dimensional (3D) printing is one of the fastest-growing industrial technologies, but it still lacks versatility. Commercial 3D printers typically use brittle plastics that have limited biocompatibility and cannot print hollow or unsupported structures. Now, a group of researchers from the University of Illinois at Urbana-Champaign has developed a way to 3D-print open structures using an artificial sweetener called isomalt. This paves the way to more biocompatible 3D printed structures that can be used to grow artificial organs and veins.

In order to be used as a scaffold for growing organs and blood vessels, the printed objects need to be easily dissolved after cells have grown on them, while still being strong enough to hold a 3D structure. It is also important that the material, when solid, forms a glass rather than a crystal, so that it can cool into its desired shape without clogging the printer. The class of materials that fits this bill is the sugar alcohols, similar in chemical structure and used as sweeteners, which can form carbohydrate glasses when they solidify.

While several sugar alcohols were tested, the best candidate was isomalt, a sweetener used in sugar-free candy, because it is stable at room temperature and resists crystallization as compared to other sugar alcohols. "We especially focused on using isomalt as it is readily processed and has excellent biocompatibility," says Rohit Bhargava, who led the research team. "However, its use also needs a careful analysis and validation of the printing process," he says. As the research group reported in a recent issue of

https://doi.org/10.1557/mrs.2018.183 Published online by Cambridge University Press