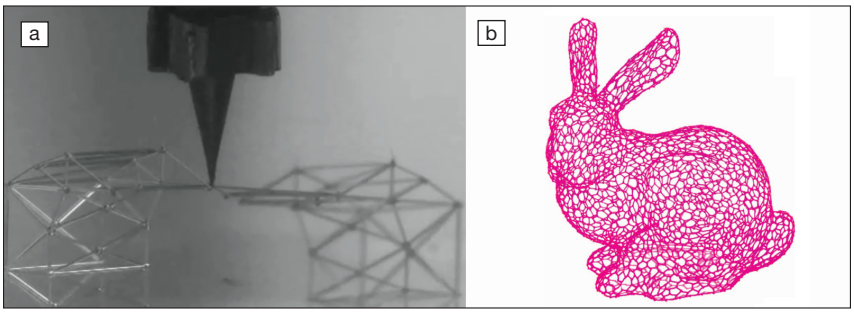
Additive Manufacturing (doi:10.1016/j.addma.2018.04.026), the two principal challenges that had to be overcome were the dehydration of the isomalt and its stability during the extruding process.

Isomalt forms crystals in the presence of water, but remains glassy when dehydrated. Dehydration was achieved by stirring the isomalt in a vacuum to eliminate any dissolved water. Debugging the extrusion process was more challenging. The material needs to quickly solidify as it cools, while maintaining its desired printed shape.

Most 3D printers operate by depositing horizontal layers on top of one another, making structures thick enough to support their own weight. In contrast, the objects the researchers printed were hollow and made entirely of thin rods. Furthermore, the research team faced challenges and structural issues that do not arise during traditional 3D printing, which include thermal contraction as the material cools, the sagging of the rods under gravity, the momentum imparted in the fluid by the moving nozzle, and the inherent viscosity of the rods. Through numerical models the researchers determined that the printed beams are stable if they are thinner than the extrusion nozzle. They then proved their concept by printing structures out of rods that would be impossible with traditional 3D printing methods, including truss bridges and hollow bunnies.



(a) The extruding nozzle in action, printing the scaffolds for a bridge. (b) A hollow 3D printed bunny with pink dye added. Credit: Images adapted from *Additive Manufacturing*.

The ultimate goal is to be able to use these 3D printed structures as scaffolds for cell culture to grow organs and blood vessels for transplantation. "The first step was to establish the scaffold printing process, which we report in this study," Bhargava says. "The next step is to deposit and grow cells in a supported manner on these scaffolds. The third major step is to remove scaffold materials such that biological activity is minimally affected and the fabricated tissue structure is structurally stable." If all goes well with the development of this technology, we can look forward to both lifesaving and delicious printed structures.

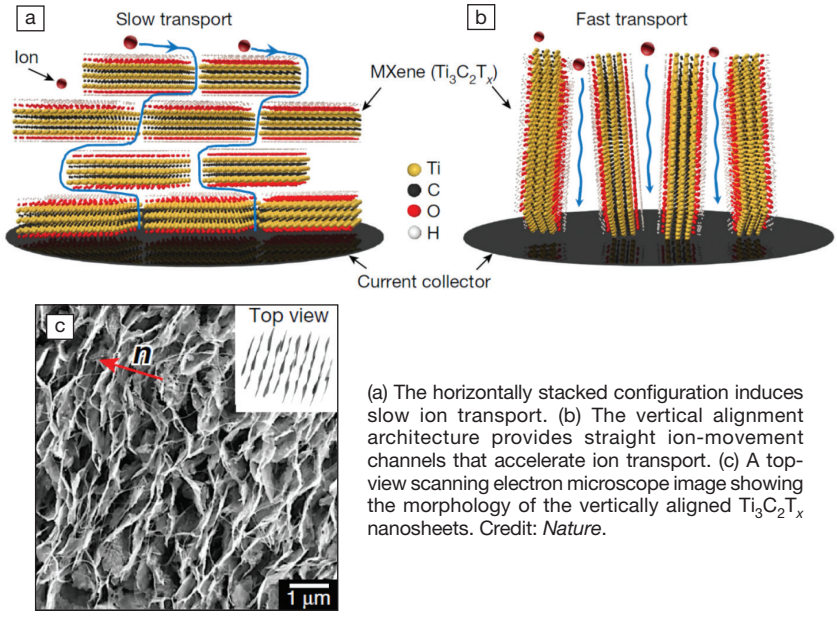
Alex Klotz

Nano Focus

Vertically aligned MXene nanosheets speed up supercapacitor

The practical potential of MXenes (two-dimensional, a few atoms thick layers of transition-metal carbides, nitrides, and carbonitrides) as supercapacitor electrodes has become more promising with the successful vertical alignment of MXene nanosheets on substrates. These electrodes exhibit ultrafast charging capabilities. This leap in energy storage, published recently in *Nature* (doi:10.1038/s41586-018-0109-z), was achieved by the collaboration between Shu Yang's group at the University of Pennsylvania and Yury Gogotsi's group at Drexel University.

The conventional configuration is composed of horizontally stacked MXene sheets that is undesirable for fast-rate charging as ion diffusion through the sheets is severely impeded by the compact-film configuration. The sluggish ion movement leads to deterioration of energy-storage capacity at elevated charging rates. This problem is exacerbated when the film thickness approaches or exceeds 10 μm, far less than the industrial thickness standard of 100 μm for active materials used in supercapacitors. To resolve this issue, developing electrodes with straight ion-movement channels extending from the electrode surface to the substrate is critical.



(a) The horizontally stacked configuration induces slow ion transport. (b) The vertical alignment architecture provides straight ion-movement channels that accelerate ion transport. (c) A top-view scanning electron microscope image showing the morphology of the vertically aligned $Ti_3C_2T_x$ nanosheets. Credit: *Nature*.

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Inspired by the anisotropy and self-assembly of liquid-crystalline materials, Yang and Gogotsi's groups converted $Ti_3C_2T_x$ (T_x: surface functional groups) nanosheets, the most widely studied MXene, into liquid-crystal phases. They hoped to vertically align $Ti_3C_2T_x$ in the specific liquid-crystal phase. However, this was not a trivial task, according to Yu Xia, first author of the article: "The biggest challenge is that very little is known in the field of two-dimensional materials-based liquid crystals.... Everything had to start from scratch."

A solution came soon. The researchers attached a surfactant, hexaethylene glycol monododecyl ether ($C_{12}E_6$), onto the surface of $Ti_3C_2T_x$ through hydrogen bonds, which turned the $Ti_3C_2T_x$ nanosheets into high-order liquid crystals, coined lamellar nematics. Upon applying a shear force, these surface-modified $Ti_3C_2T_x$ sheets "stand" straight on the substrate, forming orderly distributed arrays, as suggested by liquid-crystal theory. These vertical arrays were maintained after the $C_{12}E_6$ surfactants were removed. This structure contains abundant inter-sheet slits that serve as ion-movement "expressways" to allow quick ion diffusion.

Electrochemical testing revealed that the vertically aligned $Ti_3C_2T_x$ nanosheets are capable of being charged rapidly. Cyclic voltammetry tests showed that the 200-µm-thick film electrode lost little of its charge-storage capacity at a fast charging rate of 1000 mV s^{-1}. This behavior was observed in electrodes that were 40–320 µm thick. The control sample, the same $Ti_3C_2T_x$ nanosheets but stacked parallel to the substrate, abruptly lost its charge-storage capability starting at an intermediate rate of 10 mV s^{-1}, even though the thickness was only 35 µm. The results unambiguously highlight the advantage of the vertical arrangement in retaining the fast charge-storage characteristic of MXene-based supercapacitor electrodes.

"It is amazing that simply making MXenes 'stand up' leads to such a big difference," says Yat Li of the University of California, Santa Cruz. "This work shows an innovative method of controlling the alignment of electrochemically active materials to achieve ultrafast directional ion diffusion in thick electrodes," he says. Li was not involved in this study.

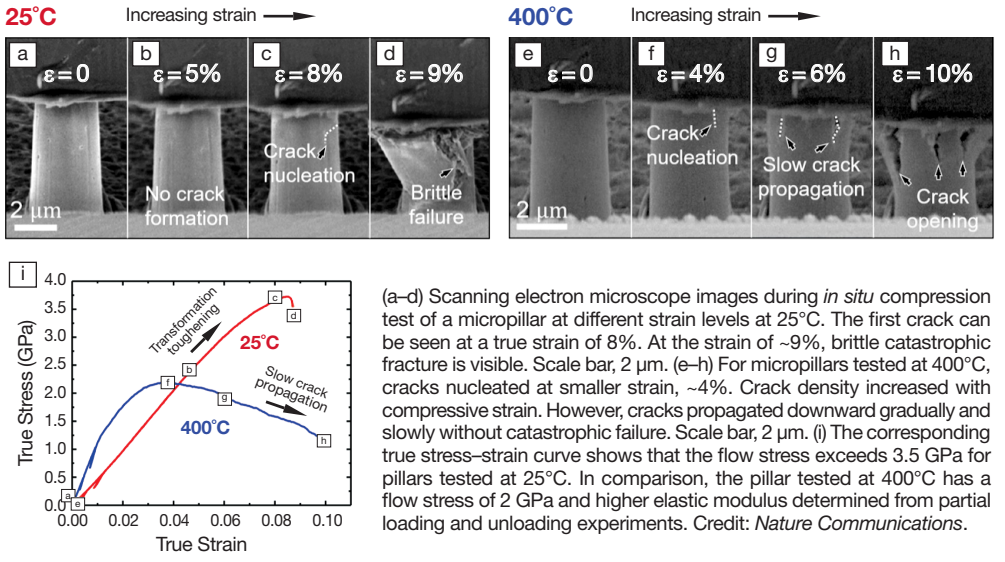
This method may encourage a plethora of future work. Gogotsi says, "Alignment of mechanically strong and electrically conductive MXene layers may lead to manufacturing of MXene fibers, membranes, coatings, and other forms with unique and anisotropic properties for various applications beyond energy storage."

Tianyu Liu

Ductility observed in flash-sintered yttria-stabilized zirconia

Ceramics have many important high-temperature industrial applications but are exemplars of brittle failure. Yttria-stabilized zirconia (YSZ) is a ceramic that undergoes a stress-induced phase transformation that grants it limited ductility as crack propagation is slowed. However, further increases in ductility remain elusive as ceramics lack the ability to support a high-enough dislocation density. In a recent issue of *Nature Communications* (doi:10.1038/s41467-018-04333-2), Jaehun Cho, Qiang Li, Haiyan Wang, and Xinghang Zhang of Purdue University and their colleagues detail their study of flash-sintered YSZ with improved ductility.

Flash sintering is a rapid densification process that results in nano-sized grains: heat is increasingly applied to a sample at a constant rate, under a moderate external electric field. When flash sintering was developed by Rishi Raj's group at the University of Colorado Boulder a few years ago, this process seemed promising as a way to limit the grain growth of ceramics upon sintering, which is one of the standard ways of increasing ductility in metals—following the well-known Hall–Petch relation (doi:10.1111/j.1551-2916.2010.04089.x). Above the flash temperature, nanoparticles undergo densification within a few seconds. Once completed, the sample exhibits a significant and sudden increase in density and electrical conductivity.



(a–d) Scanning electron microscope images during *in situ* compression test of a micropillar at different strain levels at 25°C. The first crack can be seen at a true strain of 8%. At the strain of ~9%, brittle catastrophic fracture is visible. Scale bar, 2 µm. (e–h) For micropillars tested at 400°C, cracks nucleated at smaller strain, ~4%. Crack density increased with compressive strain. However, cracks propagated downward gradually and slowly without catastrophic failure. Scale bar, 2 µm. (i) The corresponding true stress–strain curve shows that the flow stress exceeds 3.5 GPa for pillars tested at 25°C. In comparison, the pillar tested at 400°C has a flow stress of 2 GPa and higher elastic modulus determined from partial loading and unloading experiments. Credit: *Nature Communications*.

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