Stretching the Point

New materials that get fatter—rather than thinner—when they're stretched may have some revolutionary implications

HIDDEN IN EVERY GORE-TEX PARKA is a most remarkable material: expanded polytetrafluoroethylene (PTFE, or Teflon). Everyone knows this stuff keeps liquid water out but lets water vapor through. Indeed, that property is the basis for an entire industry. What almost no one knows—yet—and what is even more remarkable is that when you pull on PTFE, it gets fatter. And that fact could have a powerful effect on several industries, including possibly even building construction.

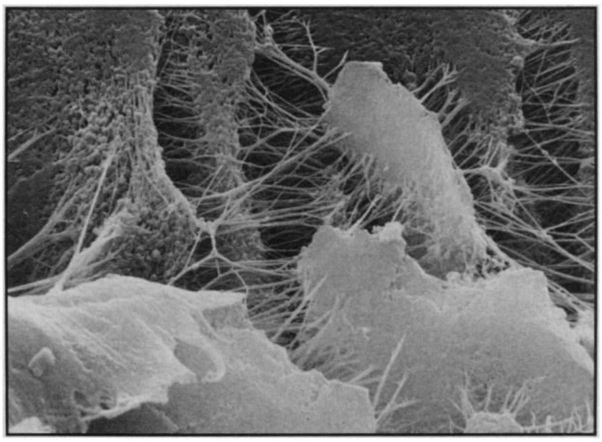
The reason this property is so striking is that it's so rare. Most materials tend roughly to maintain their volume when stretched or compressed. A rubber band, for example, gets thinner when you stretch it. But there is no "Law of Conservation of Volume." It just so happens most natural materials do get thinner when stretched and thicker when compressed.

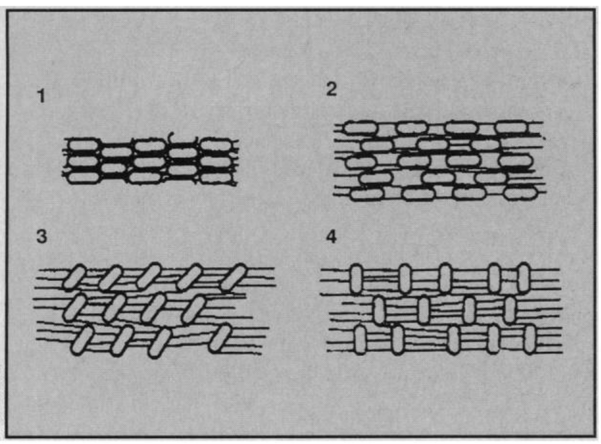
The recent history of things that don't follow this rule begins in 1987, when Roderic Lakes of the University of Iowa published an article about some unusual foams he had made. Lakes predicted that these foams might become very useful structural materials. The reason—and the most interesting thing about them—was that they had a negative Poisson ratio.

What, you might ask, is a Poisson ratio? The Poisson ratio is one of four numbers that define the elastic properties of a material; it relates stretching to thinning. Rubber has a Poisson ratio of almost 0.5, indicating that it very nearly does conserve its volume. Cork, on the other hand, doesn't change thickness when stretched or compressed. Because it doesn't conserve its volume, it has a Poisson ratio of 0.

Now, in theory isotropic materials (those whose properties are the same in all directions) could have Poisson ratios ranging from 0.5 to -1.0. In spite of the theory, until recently nobody thought negative Poisson ratios existed in practice. If materials with negative Poisson ratios did exist, they would be extremely useful—because of the implications of the negative Poisson ratio for the material's other properties.

Substances with a high positive Poisson ratio are difficult to compress in all directions at once but are easy to bend. In the language of the materials scientist, they have a large bulk modulus relative to their shear modulus. A negative Poisson ratio implies the opposite: substances that can be readily compressed but are difficult to bend. Such substances also are less brittle than inflexible materials with positive Poisson ratios. This stiffness without brittleness would be of great value in withstanding shear forces. Hence the excitement—in the world of materials science, at least—over Lakes' finding.





Ken Evans

Stretch marks. *PTFE (shown in the micrograph) gets fatter when you stretch it. The reason, as shown in the panels of the diagram below, is that the material consists of thin strands that connect larger disks. When the material is pulled, the strands tilt the disks upward, thereby increasing the material's bulk.*

The excitement would have been even greater had Lakes found solids rather than foams. Indeed, about the time Lakes published his paper, Ken Evans, senior lecturer in the Department of Materials Science at Liverpool University in England, was trying to get funding to look for solid materials with negative Poisson ratios. Evans knew about Lakes' foams, but he couldn't quite see how to make a solid with the same properties. And without a sample, funds were not forthcoming.

Then along came a colleague waving a piece of PTFE from W. L. Gore Ltd. The colleague, who knew of Evans' interest, had been at a plastics fair and idly picked up a piece of PTFE on the Gore stand. He stretched it, and, to his amazement, it grew fatter. "He said, 'This stuff's got a negative Poisson ratio,' " Evans recalled, "and they just looked at him blankly."

Evans decided to find out why PTFE expands when you stretch it. Looking at a piece of PTFE under the scanning electron microscope he could see disk-shaped particles connected by strands. In the compressed state, the particles lie flat and closely packed, connected by thin strands. As the ends of the piece are pulled, however, the disks tilt up, increasing the material's bulk (see diagram).

That preliminary investigation showed how materials with negative Poisson ratios could exist although expanded PTFE isn't much good for structural work, the combination of theory and a practical example flushed out some funds.

Funding in hand, Evans pushed forward quickly. He's already made negative Poisson ratio polymers that are much better suited to structural uses than expanded PTFE is. "I can't say too much about that because we are applying for a patent," he told *Science*. Evans foresees a wide range of uses for these materials: better artificial bones, improved sound and shock absorbers, even enhanced bulletproof vests. Gaskets and seals are another obvious area for applications.

Computer modeling has yielded molecules that should have negative Poisson ratios and, at a larger scale, honeycomb structures. Honeycombs are at the heart of the composite sandwich panels, beloved of the aerospace industry, that combine lightness and strength. Conventional sandwich panels cannot be curved, but a negative Poisson ratio allows one to make rounded panels. What is more, careful design of the honeycomb cells can create domes of any desired curvature, and it is not too far-fetched to imagine that negative Poisson ratios could revolutionize many types of construction work. ■ JEREMY CHERFAS