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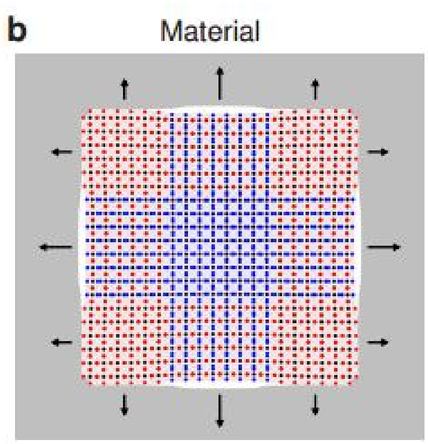
# How to Make a Metamaterial that Expands Under Pressure and Contracts In Tension

Treating materials like complex networks leads to substances with extraordinary counterintuitive properties, say physicists.




Compress a material and it will deform in the direction of the applied force: in other words, it becomes squashed. Similarly, a material under tension will stretch.

But what of the opposite idea, that a compressed material will stretch and substance under tension will become squashed?

That's impossible, right? Not according to Zachary Nicolaou and Adilson Motter at Northwestern University in Evanston Illinois, who say they've worked out how to create materials with "negative compressibility transitions" that contract when tensioned and expand under pressure.

The secret is based on network science and in particular how networks behave when they are changed in some way. The result is not always obvious or intuitive.

Back in the 1960s, the German mathematician Dietrich Braess noticed that opening extra roads in a city can increase travel time rather than reduce it. Similarly, traffic planners have often noticed that closing major roads can improve the flow of traffic through a city.

It turns out that this effect occurs in many networks. For example, removing a wire from a conducting network can increase the flow of current and the performance of a basketball team can improve when a key player is removed.

The explanation comes from the new discipline of network science. The optimal flow through a network is determined by its structure. But adding edges to the network can move the system away from this optimal state, while removing edges can move it closer.

Now Nicolaou and Motter have worked out how to use this idea to make materials that expand when compressed. The trick is to think of the substance as a network in which force is transmitted through the structure along a network of links between the material's basic building blocks.

A network with negative compressibility must be designed so that it there is an internal latent strain between the building blocks that constrains the overall shape.

With that in mind, it's not hard to imagine how an external force can change the internal dynamics in way that allows the material to expand. Similarly, it's easy to see how the internal strain can squash a material when it is placed in tension.

A substance that gets its properties from its structure rather than its component building blocks is called a metamaterial, something we've looked at many times on this blog.

Clearly, a metamaterial with negative compressibility would have some interesting applications. Nicolaou and Motter point to new kinds of actuators and protective armour.

But they also say that this network approach ought to work in other areas too, such as in electrical and microfluidic networks. Imagine negative resisters, for example.

However, the one thing missing from their paper is working example of a metamaterial with negative compressibility. Given that it ought to be possible to make one out of some old mattress springs and and few pieces of wire, it shouldn't be long before we see the first one in action.

Ref: arxiv.org/abs/1207.2185: Mechanical Metamaterials with Negative Compressibility Transitions

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