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Energy storage: A nanowire spring surfaces

Calculations show that a metallic nanowire can store energy efficiently in the arrangement of its surface atoms.

Devices ranging from wrist watches to toys can all be powered by elastic springs. In a similar manner, nanoscale springs can store energy when bonds between atoms are stretched in response to an external mechanical force. When the spring relaxes, the bond lengths return to normal and so the stored energy is released. However, although ubiquitous, elastic springs are also limited in particular ways: they can withstand only so much strain, and can store only a relatively small amount of energy in a given volume.

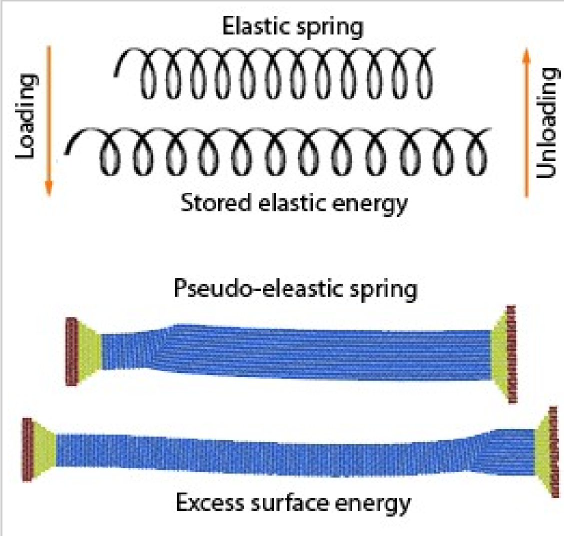

Fig. 1: Whereas a standard elastic spring stores energy in its atomic bonds (top), the proposed nanowire spring (bottom) stores energy in the arrangement of its surface atoms, in a phenomenon called 'pseudo-elasticity'.

Now, a team of Chinese and US scientists led by Xiangdong Ding at Xi'an Jiaotong University, Ju Li at the University of Pennsylvania and En Ma at Johns Hopkins University have proposed storing energy in a nanoscale spring not by changing its atomic bond lengths, but by reconfiguring its surface atoms[1] (Fig. 1). Their calculations predict that this would result in a 16,000-fold increase in energy volume density compared with a watch spring.

The researchers demonstrated this 'pseudo-elastic' behavior in a thin metallic nanowire. Applying a stretching force induces a defect that travels down the length of the nanowire. This in turn causes the atoms at the nanowire surface to assume a higher energy arrangement, thus storing the initial energy applied to the nanowire. Ding and his colleagues found that if the nanowire is made of tungsten and has a particular atomic configuration, the motion of the defect will encounter very low friction, allowing 98% of the stored energy to be recovered when the nanowire relaxes. Further calculations indicate that the nanowire can withstand a strain of 30% and a stress of over 3 GPa.

This performance compares well with existing energy storage materials such as piezoelectrics, which can withstand only small strains; electroactive polymers, which can withstand only low stresses and have low energy densities; and shape memory alloys, which are inefficient at releasing stored energy. Furthermore, the small scale of the nanowires presents interesting opportunities; they can, for example, be combined int dense arrays, allowing them to store a greater total energy.

In addition to introducing a new material for storing mechanical energy, the results contribute to the understanding of this important physical phenomenon for many potential applications, says Ding. "Surface-energy-driven transformations involving the ordered cooperative movements of many atoms may result in other novel functional properties of nanoscale materials, including information storage."

Reference

1. Li, S.,[1] Ding, X.,[1*] Li, J.,[1,2] Ren, X.,[1,3,4] Sun, J.[1] & Ma, E.[1] High-efficiency mechanical energy storage and retrieval using interfaces in nanowires. *Nano Lett.* **10**, 1774 (2010) | article

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