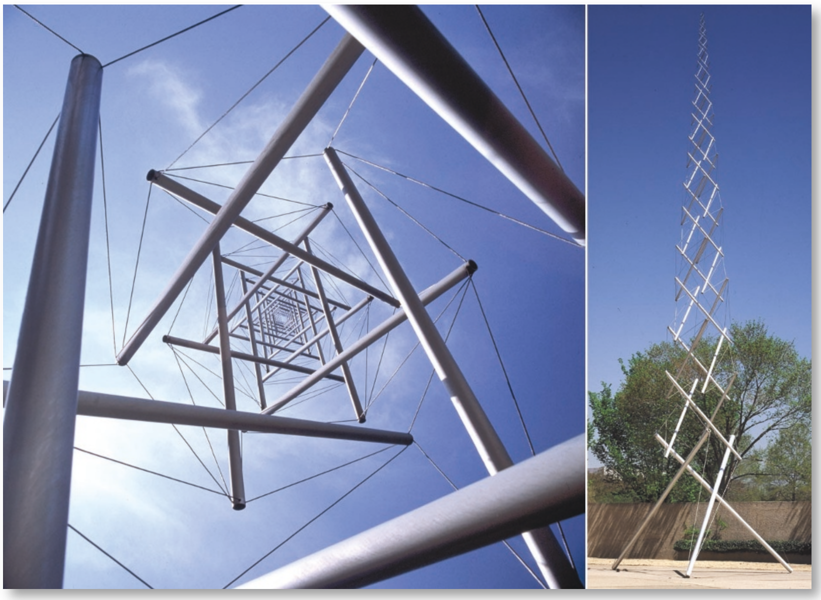

**Figure 2** Interplay between compression and tension can stabilize structures at all length scales. The Needle tower by Kenneth Snelson is a macroscopic example of a structure in equilibrium between compression (aluminum tubes) and tension (steel cables), that leaves us with the puzzling impression of tubes floating in space. It is a simliar construction principle that holds together some zeolitic frameworks.

Kenneth Snelson
Needle Tower, 1968
Aluminum & Stainless Steel
18.2 m x 6 m x 6 m
Collection: Hirshhorn Museum & Sculpture Garden, Washington, DC

Photos: Kenneth Snelson

opening of one oxygen bond angle T-O-T in the structure causes the closing of another oxygen bond angle, thus maintaining an approximately constant volume, despite drastic changes in the chemical composition of ions or molecules inside their pores.

Lee and collaborators[1] speculate that the pressure-induced hydration they have discovered might one day be used to immobilize tritiated water or other pollutant molecules within a zeolite. Alternatively, they suggest that the pressure-induced expansion of the rather dense natrolite framework might admit larger radioactive ions, which on pressure release would be trapped inside the zeolite, removing them from the environment. Time will tell if these applications are feasible. An even more far-fetched possibility is that somebody will take a hint from these versatile zeolitic frameworks and construct structures on the macroscopic scale making use of their strange properties (negative thermal expansion, resistance to chemical changes, or expansion with pressure). For example, the principles of architecture on our gravity-bound planetary surface are not appropriate in zero-gravity environments, but structures analogous to certain tetrahedral frameworks might be. Their structures would be stable in space without the aid of gravity and might be useful for space stations. I am not aware of any such attempts except those by the sculptor Kenneth Snelson who has employed similar principles in his art work[6]. In his sculptures, aluminium tubes held by steel cables seem to be floating in space in a manner reminiscent of the arrangement in zeolitic structures (Fig. 2).

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## MATERIAL WITNESS

# Lithium light

It seems that hardly a week goes by without some new material being proposed for use as electrodes of lithium batteries. One can't help wondering whether this incessant tweaking can have any real commercial benefits. But battery technology is at a point where potential new markets hinge on the minutiae of economics, which means that every little improvement counts. And never more so than in the case of electric vehicles (EVs).

In one sense, the future of battery-powered consumer cars looks bleaker now than it has done for some time. When Ford in the USA decided to drop its principal battery-run EV, the Th!nk city, last October, some people regarded it as the death knell for this technology. General Motors had already ditched their own model, the EV1, and Toyota is now about the only company to offer a fully electric vehicle to US customers.

But this is not because motor companies have given up on zero-emission vehicles. After all, the Californian legislation requiring 10 percent of all new cars to be emission-free makes it very difficult for them to do so. Rather, the industry seems to have decided that battery power alone is not the way forward.

Most research is now focused on two alternatives: hybrid EVs and fuel-cell vehicles. Hybrids (HEVs) have a combination of an internal combustion engine and a battery that recharges in transit to achieve very high fuel efficiency. The two main commercial HEVs—the Honda Insight and the Toyota Prius—average between 500 and 700 miles on a single tank.

Fuel cells provide electrochemical power from an onboard fuel supply: ideally hydrogen, although 'hydrogen carriers' such as methanol are also being used. The mainstay of fuel-cell vehicles has been the polymer electrolyte membrane cell developed by Ballard Power Systems in Vancouver.

Both these technologies are heavily materials-dependent. Hydrogen storage has been promoted as one of the first potential applications of carbon nanotubes, although it has proved difficult to reproduce the high storage densities achieved by researchers at the National Renewable Energy Laboratory in Colorado. An ongoing challenge is to make vehicles from lighter materials to improve their efficiency.

Battery power is not completely ruled out: Ford is still testing the lithium-battery-driven e-Ka, for example. But perhaps the largest obstacles to cleaner vehicles remain psychological and political: car culture still favours noisy, fuel-hungry beasts. The technology exists for a sports car capable of 40 miles per gallon, a recent article in *Technology Review* claims—but no one wants it. Instead, gas guzzlers have driven US fuel efficiency to a 20-year low of 20 miles per gallon. On a test drive for the e-Ka, a motor reviewer lamented the lack of the 'emotive' engine roar that makes him feel secure. And Bernard Robertson, Senior Vice President of Engineering Technologies at DaimlerChrysler, points out that the USA has simultaneously the only regulations calling for zero emissions and the lowest energy prices in the world, undermining any incentive towards fuel efficiency.

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